BOOK OF ABSTRACTS

THE 3RD INTERNATIONAL SCIENTIFIC CONFERENCE ON MATERIAL CYCLES AND WASTE MANAGEMENT (3RINCs)

Hanoi, 9 - 11 March 2016

FOREWORD

At the present time, as the amount, variety, and toxic levels of waste continue to increase, many countries around the world are seeking to further reduce, reuse and recycle waste (3Rs). In 2013, as the coordinating organization in Viet Nam, the Institute of Strategy and Policy on Natural Resources and Environment (ISPONRE) successfully hosted the Fourth Regional 3R Forum in Asia. Under the theme "3Rs in the Context of Rio+20 Outcomes - The Future We Want", all delegates unanimously approved the Hanoi 3R Declaration - Sustainable 3R Goals for Asia and the Pacific for 2013-2023.

Following on from the last Conference, with the cooperation and support from various agencies such as the Japan Society of Material Cycles and Waste Management (JSMCWM), the Korean Society of Waste Management (KSWM), the Society for Solid Waste, Chinese Society for Environmental Sciences (SSW-CSES), the United Nations Centre for Regional Development (UNCRD), the International Solid Waste Association (ISWA), the Institute for Global Environmental Strategies (IGES), the United Nations Environment Programme - International Environmental Technology Centre (UNEP-IETC), the Japan International Cooperation Agency (JICA), the Ministry of the Environment of the Government of Japan (MOEJ), the Viet Nam Environment Administration (VEA), the Department of Science and Technology under Ministry of Natural Resources and Environment (MONRE), the Department of Technical Infrastructure, and the Ministry of Construction (MOC), the Institute of Strategy and Policy on Natural Resources and Environment is organizing the 3R International Scientific Conference on Material Cycles and Waste Management (3RINCs).

The 3RINCs Conference is an opportunity for researchers, experts, managers, businesses, non-governmental organizations and related private organizations to exchange, discuss, and disseminate information on science and technology regarding 3R in order to promote the 3Rs Program, as well as to implement the Hanoi 3R Declaration.

On behalf of the Institute of Strategy and Policy on Natural Resources and Environment, and on behalf of all organizers, I respectfully introduce the Book of Abstracts which contains all abstracts submitted by participants in the 3RINCs Conference 2016. There are many initiatives and solutions unveiled in this Book to promote 3Rs' activities and positively contribute to the cause of environmental protection in general and to waste management in particular.

I would also like to take this opportunity to express my thanks to all authors and participants for their participation and contributions in the Conference. Their active participation plays a very important role in the success of Conference.

Assoc. Prof. Dr. Nguyen The Chinh
Director General of Institute of Strategy and Policy
on Natural Resources and Environment

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GHGs Emission

Analysis of Life Cycle Carbon Emissions from Road Infrastructure Sector in China

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ABSTRACT

This study aims to develop a comprehensive and feasible life cycle assessment (LCA) method during different phases in a road project, and to evaluate the lifecycle carbon dioxide (CO_2) emissions from road infrastructure in China. An LCA analyzing model for the road construction lifecycle was proposed in this paper including four stages of material production, to-site and on-site transportation, vehicle and machine production and vehicle operation. Then inventory analysis on sub-process of each stages were structured specifically and comprehensively. Hybrid LCA method were raised for data collection and statistics from different phases of a road construction project during carbon emissions calculation based on the availability of data. Exampled as two cases of road projects in Zhejiang province, China, life cycle carbon emissions of road project before being constructed and life cycle carbon emissions of road project after being constructed were both evaluated. The results showed that the stage of materials production produce the most of the carbon emissions (for more than 80%), thus, using recycled material or green material will be effective way to reduce road carbon emissions. Bridge is a large carbon contributor compared to the road segments, as the cement and steel account for large quantities of carbon emissions. It is recommended that evaluation on lifecycle emission from road infrastructure sector could offer decision makers a more comprehensive approach to realize the green transportation and sustainable transportation.

Keywords: life cycle assessment, carbon dioxide emissions, road infrastructure

INTRODUCTION

As the largest contributor to the global warming, most of the countries have reached a consensus on reducing the CO_2 emission, some developed countries even make their low-carbon development strategies to reduce their domestic carbon emissions. It is reported that human activities is the primary carbon emissions source (about 90% of all carbon emission), and the emissions from transportation sector contributes to 27% of energy-related CO_2 emissions (IEA, 2012) and is responsible for about 13% of greenhouse gas (GHG) emissions. Apart from the tailpipe CO_2 emissions during vehicle operation, road infrastructure sector, a part less being considered in previous researches, also show great potential to migrate carbon emission, especially in developing countries. Associated with the annual increased automobile population, the most CO_2 emissions are released during operation, the total mileage of highway in developing countries has grew up gradually. The emissions from road materials extraction, production, to-site transportation, on-site construction machine and other phases during road life cycle in terms of road construction, maintenance, recycling of road even make up 5%~25% of total CO_2 emissions from transport, according to several researches from different countries(Häkkinen and Mäkelä,1996; Wang et al.,2007; While Jullien et al.,2014).

To evaluate the lifecycle carbon emission from the road infrastructure, this study developed a calculate model through the whole process of road project, according to the principle of LCA ISO14040,and calibrated the model with the data sheet from engineering projects in China. After emissions from each stages being obtained, comparison between the amount of emissions from each phase and sub-process to gain the largest contributor in the whole lifecycle and effective measures to realize the low carbon goal in road infrastructure sector. Also, taking cases in China, the calculating results can be used to compare with results in foreign countries. In this way, the study provide an access to seek for the gap between China and other countries and further examine the possible cause. To be extended, evaluation on lifecycle emission from road infrastructure sector could offer decision makers a more comprehensive approach to realize the green transportation and sustainable transportation.

MATERIALS AND METHODS

Life Cycle Assessment

Lifecycle assessment (LCA) is a widely used method tool to demonstrate an entire picture consists of all the subtasks in road project and evaluate their impact towards the environment. Considering the special features of the road infrastructure sectors, emphasize should be put to the inventory analyses part, specific process and included subtask should be listed and analyzed. The road infrastructure is a streamlined process and the interrelations between each stage in the technical system are comparatively simple, whereas the relationships between the lifecycle systems are more complex, for the facts that there are various kinds of resources occupied in the research target and each of the resource has its own lifecycle. Comprehensive analysis (Hybrid LCA) will be done in the valuation stage, several valuation methods may be put forward according to the statistics resources. The improvement assessment will be determined by the calculating results in the valuation part. Thus, the modified lifecycle assessment framework in this paper may include four stages: goal definition and scoping, inventory analysis, impact valuation and improvement assessment.

Data source

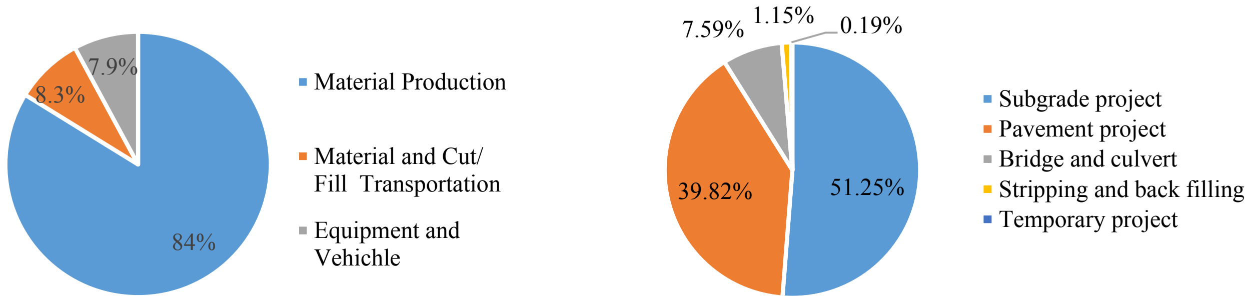
Data before construction in the design period and after construction are collected in this study. The amounts of resources have been calculated according to the specific design plan of the project. In China, the expected project quantity, resources consumed and vehicle/equipment occupied can be obtained by looking up the estimate and budget documents issued by the Chinese authorities, the referenced value in this study is keeping updated to the construction reality in China.

RESULTS AND DISCUSSION

Calculation and Analysis: Statistics from Design Period before Construction

It can be seen clearly from Figure 1 that throughout the whole construction process, the carbon emissions from the production of material make up the most proportion, about 84% of the total amount. The emissions from the transportation and the equipment/ vehicle are nearly of the same amount, which are 8.3% and 7.9%

respectively. Within these five sub-projects, the subgrade project is the largest contributor to the carbon emissions: it takes more than half of the total emission. Pavement project is the second largest resource in total carbon emission from the road construction period, constitutes about 40% of the total emission. Only 7.5% of the carbon emission is from the construction of bridge and culvert, the result may be caused by the special property of this road construction project: it is a road extension project, and the overall design part has defined that the existing bridge and culvert will not be broaden within this construction sector. The calculated results show that during this road construction project, the amount of emission per km per lane is 702.66 t/km (Table 1). The existing researches toward the lifecycle emissions from the road construction project shows that most of the results vary from about 150 t per km per lane to 980 t per km per lane. The calculated result in this research paper is within this range, which can partly prove that there are no fatal error during the modeling, analyzing and calculating parts.



(a) Main stages (b) Main sub-projects

Figure 1 CO_2 Emissions Proportion of Total Project

Table 1 Summarization of carbon emission from each part of road project（t per km per lane）

Sub-projects	Material Production		material and cut/ fill Transportation		Equipment and vehicle		Total amount (t)
	Total emission(t)	%	Total emission(t)	%	Total emission(t)	%	
Subgrade project	281.87	78.3	50.78	14.1	27.43	7.60	360.07
Pavement project	255.71	91.4	7.39	2.6	16.71	6.00	279.83
Bridge and culvert	51.53	96.6	0.09	0.2	1.70	3.2	53.31
Stripping and backfill					8.10	0.00	8.10
Temporary project					1.35		1.35
Sum							702.66

Calculation and Analysis: Statistics after Construction

The calculated results in table 2 are much bigger than that in table 1, though the highway classes, geological and climate condition are much alike. Through long periods analyzing and conclusion, the possible causes are listed as below. Emissions from operation, related emissions from vehicles and equipment and emissions from labor are not included in the first case study. Through specific analyzing towards the original data, it is found out that the amount of cement and steel occupied in this case are quite large, which might be the sources of huge amount of carbon emissions. Most of the existing research towards carbon emissions of the road construction have not include bridge and culvert into their analyze scope, also, as an extension project, the emissions calculation in case 1 have not involve in bigger bridge and culvert project, this may be one of the causes.

Table 2 LCA emissions Summarized Results after Construction (t per km per lane)

Project NO.	Vehicle Production (t)	Operation (t)	Labor (t)	Fuel Consumed (t)	Ground material (t)	Quick Lime (t)	Cement (t)	Asphalt (t)	Steel (t)	Total (t)
A	7.69	147.80	2.98	81.90	5.19	0.00	1684.91	13.49	1067.72	3011.68
B	23.38	141.82	0.54	157.79	2.56	0.00	1330.33	15.32	333.45	2005.18
C	20.62	149.52	6.67	141.17	7.48	4.25	1995.36	19.43	2306.25	4650.76
D	18.46	76.12	1.58	76.07	0.91	0.00	406.26	10.76	88.55	678.71
E	63.19	171.52	8.10	414.56	11.91	0.00	2200.87	13.63	1667.84	4551.63
F	40.57	137.94	11.32	262.65	8.55	0.00	1531.45	12.93	447.45	2452.86
G	46.39	187.63	10.22	279.51	10.43	12.31	2290.66	15.88	2040.45	4893.47

CONCLUSION

This study proposed a specific streamlined analysis on life-cycle emissions from road infrastructure sector and developed a comprehensive and detailed Hybrid LCA calculated model covering most of the common construction stages, based on the characteristics of statistics in different phases in a road project. Lifecycle emissions from the construction of the target projects are obtained, and the calculated results have been evaluated and compared to the other existing studies. According to the calculated results, it is concluded that the production of materials produce the most of the carbon emissions (for more than 80%), thus, using recycled material or green material will be an effective way to reduce the carbon emissions. Through the analysis towards cases, bridge is a large carbon contributor compared to the road segments, as the production of cement and steel produce large quantities of carbon emissions, based on this fact, asphalt road maybe the better choose to control the amount of carbon emission, however, the further study should be done by added the emission from the maintenance and demolishing period.

ACKNOWLEDGEMENT

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CO_2 transfer from air to water enhanced by alkaline property: comparative study using CO_2 and O_2

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ABSTRACT

The rate of CO_2 transfer from air to aqueous phase is of interest from the viewpoint of heavy metal immobilization and carbon capture and storage（CCS）. The transfer is accelerated by alkalinity of aqueous phase. In order to estimate the degree of the acceleration, flux across the air-water interface was measured using CO_2 with alkaline-adjusted water. Same examination was conducted using O_2 as a reference. No transfer enhancement was observed for pH 7 and 9; however, 13 ~ 15 times of enhancement occurred with water of pH 11.

Keywords: carbonation, CO_2, CCS

INTRODUCTION

Carbonation has considered to be an important process for neutralization of ash and immobilization of heavy metals（Arickx et al. 2006; Gerven et al. 2009）. The technique is recently applied to carbon capture and storage（CCS）（Mazzoti et al. 2005）. However, historically, CO_2 flux between air-sea interface has been investigated in the geological field for several decades（Hoover and Berkshire 1969; Liss and Slater 1974; Wanninkhof et al. 2009）.

Reviewing those works, a question arises about the acceleration of CO_2 transfer from air to water by alkalinity of water, i.e. chemical enhancement. Carbonation and CCS make use of alkalinity of materials to promote CO_2 capture, while the geological study indicated that pH value of sea water would not significantly affect the transfer of CO_2 from air to sea. It is supposed that the chemical enhancement is very sensitive to pH and coexisting substances.

Film transfer model is a representative method to express mass transfer across air-water interface quantitatively（Wannikhof et al. 2009）. The basic equation is

$$(\text{flux}) = \varepsilon\, k_L\, (C_L^{eq} - C_L) \qquad (1a)$$

$$H = \frac{C_G}{C_L^{eq}} \qquad (1b)$$

where,（flux）:［mol m^{-2} s^{-1}］; ε: chemical enhancement factor［-］; k_L: mass transfer coefficient［m s^{-1}］; C_L^{eq}: imaginary concentration in water which is calculated by Eq（1b）［mol m^{-3}］; C_L: concentration in water［mol m^{-3}］; H: non-dimensional Henry's constant［-］; and C_G: concentration in air［mol m^{-3}］.

The mass transfer coefficient, k_L, is not a velocity, but it could be thought as "imaginary exchange-depth per the unit time". To give an actual sample, if k_L［cm h^{-1}］is 10% of the depth of water column, the exchange rate between water and air is 10% an hour, which is equivalent to half life of 6.93 h in water column. The comprehensive study about CO_2 transfer between air-sea interface, correlation of k_L and wind velocity at 10 m above sea has been obtained, in which k_L ranged ca 1 to 20 cm h^{-1} (Wanninkhof et al. 2009).

The chemical enhance is expressed by the factor, ε, which is higher than one, if CO_2 transfer is enhanced by alkaline property and other coexisting substances.

The purpose the present study is, first, to measure εk_L using CO_2 and non-ionic reference substances; secondly, to observe variation of εk_L according to pH value of the water; and in the final stage, to obtain the correlation of ε to pH.

MATERIALS AND METHODS

Air-water contactor

A stainless steel bottle（5 L or 10 L）with a sealed lid was utilized as an air-water contactor. The lid was devised to have a gas-inlet and a gas-outlet. The water in the bottle was kept homogeneous mildly by a 30 mm stirring bar rotating with 130 revolution per minutes. The surface was observed to be smooth with no wave.

Deionized water or alkaline-adjusted water was placed in the bottle. For pH 7 and pH 9 conditions, buffer solutions for pH measurement were used. Alkaline water was prepared as follows: 21.04 g of NaCl, 17.6 g of NaOH and 27.02 g of glycine were dissolved in 8 litre of deionized water（Bunseki Kagaku Binran, 2001）. The initial pH value was 11.7 ~11.8; however, the value decreased to 10.3~10.4 after uptake of CO_2. (Volume of the water)/(area of the air-water interface) were 4 L / 204 cm^2 and 8 L / 348 cm^2, respectively.

Supplied gas was Ar of 300 mL min^{-1} for "O_2 transfer from water to air", air of 300 mL min^{-1} for "O_2 transfer from air to water", and air containing 5% CO_2 of 240 mL min^{-1} for "CO_2 transfer from air to water". The water sample was periodically taken from the gas-outlet using a tube connected to a syringe.

Measurement

Concentration of O_2 in water（dissolved oxygen, DO）was determined by Winkler method. Fifty mL of water was carefully taken by a syringe to which reagents were injected without air invasion.

Total CO_2 in the water was determined as follows（Figure 1）. Ten mL of sample was placed in a gas impinger, which was connected to a gas bag containing Ar. After the air in the gas impinger was replaced by Ar, 2 mL of sulfuric acid（1+1）was injected quickly followed by introducing the inner gas to CO_2-quantitative detecting tube（Gastec, Japan）. Since the detecting tube is scaled to indicate concentration of CO_2 with sampling of 100 mL gas（at 20 ℃）, the amount of CO_2 is calculated to be 0.0416 ×（CO_2%）mmolCO_2.

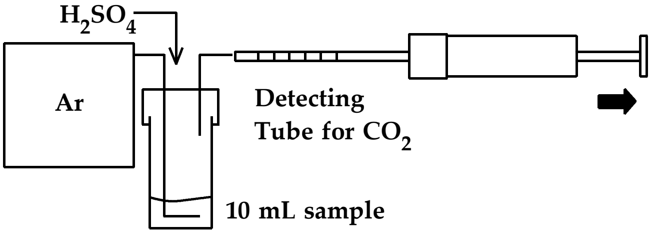

Figure 1 Measurement of total CO_2 in water

Regressed equation

Time change of the relevant substance enables to calculate the product of ε and k_L as follows:

$$\varepsilon\, k_L = \frac{1}{C_L^{eq} - C_L} \frac{dC_L}{dt} \frac{V_L}{A} \tag{2}$$

where, V_L: volume of the water（= 4000 or 8000 cm^3）; and A: area of the air-water interface（= 204 or 348 cm^2）. For the experiment of CO_2, measured value is total CO_2 including CO_2(aq), HCO_3^-, and CO_3^{2-}. Time change of total CO_2 is equal to（flux）A; therefore, dC_L/dt could be replaced by d（total CO_2）/dt.

RESULTS AND DISCUSSION

The change of DO in 4 L of water supplied with Ar followed by air is plotted and regressed in Figure 2. In the front half, the deceasing rate of DO was － 0.273 mg L^{-1} h^{-1} with $C_L^{eq}=0$ and $C_L=5.96$（center of regressed range）; hence, k_L was calculated to be 0.898 cm h^{-1}. Note ε was assumed to be one due to non-ionic property of O_2. If the k_L is divided by the depth of water column （=V/A）, a first-order decreasing rate 4.58% h^{-1} is derived. The k_L value for the reverse transfer was 1.31 cm h^{-1}. The difference of k_L of both directions was considered to be within an experimental error. Since the turbulence of the water body was minimized, obtained k_L was the lowest level compared to that estimated in oceanic science （Wanninkhof et al. 2009）.

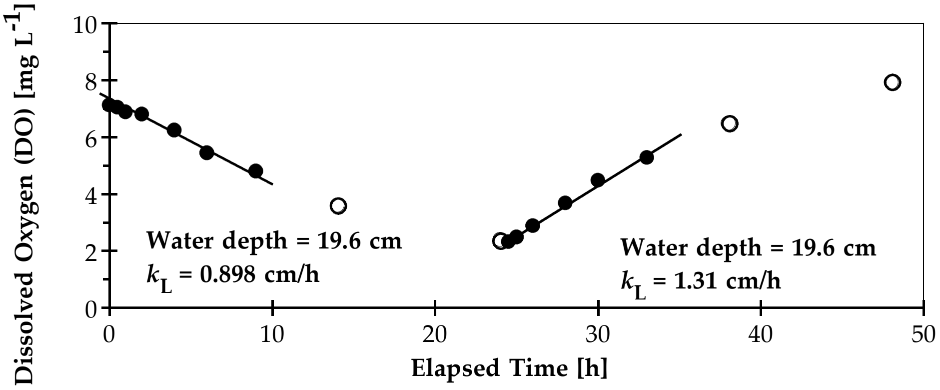

Figure 2 Time change of dissolved oxygen in water. Filled circles were used to calculate flux.

The experiments on CO_2 transfer from air to water gave different increasing rates of total CO_2 in 4 L of water depending on pH（Figure 3）. The value of εk_L ranged from 0.726 to 0.824 cm h^{-1} with pH value of 7 to 9; on the other hand, εk_L with weak alkaline water was 10.8 cm h^{-1}. The pH of the prepared water changed from 11.7 to 10.4 because of CO_2 uptake. Hence, no chemical enhancement of CO_2 transfer was observed at pH ＜ 9 (ε = 1); however, ε increased to 13.1 ~ 14.9 if pH was elevated to ca 11. The present result agrees well with Wanninkhof et al. （2009） who claimed that chemical enhancement would not occur in oceanic water（pH is less than 9）. At the same time, CO_2 absorption in CCS technology using alkaline solution （possibly pH ＞ 11） could be consistently evaluated.

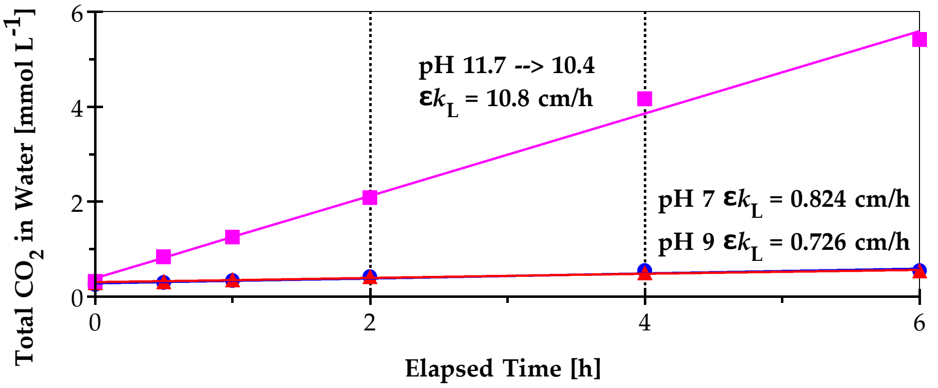

Figure 3 Time change of total CO_2 in 4 L-experiment

The bar plot of k_L in Figure 4 shows k_L of O_2 and CO_2 for both directions in 4 L and 8 L experiments, which denoted the volume of water did not affect k_L and ε. The small difference between O_2 and CO_2 may be due to diffusion coefficients of those two substances.

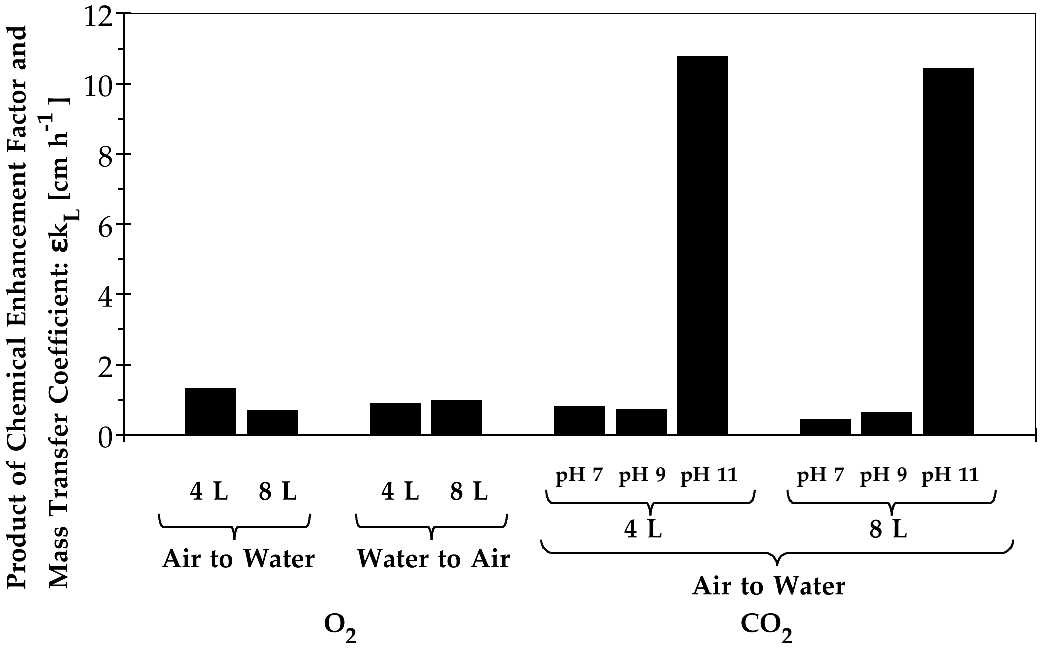

Figure 4 Product of chemical enhancement factor and mass transfer coefficient

CONCLUSION

Transfer rate of CO_2 from air to water was studied using a film model, whose parameter was εk_L, a product of chemical enhancement factor (ε) and mass transfer coefficient (k_L). k_L of O_2 and CO_2 was identical. ε was 1 for O_2 and CO_2 in pH range of 7 ~ 9. If the pH was increased to ca 11, ε increased to 13 ~15.

At the present stage, reference gas used was only O_2. Any other gas is favored to be examined as a reference. Moreover, quantitative relation of pH to ε are going to be further studied.

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Greenhouse Gas Emission from Municipal Solid Waste Disposal Sites in the Target Cities in Vietnam and Potential of Emission Reduction

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ABSTRACT

Landfill sites are widely considered as one of the significant contributors to global greenhouse gas (GHG) emissions through their long life-cycle of organic decomposition. This paper aims to figure out the amount of GHG emissions from landfills and evaluate the potential of emission reduction with three possible scenarios in four target cities in Vietnam, namely Hanoi, Hai Phong, Hue, and Ho Chi Minh. The IPCC method was employed for the estimation. The results show that emissions from landfills amount to 2,016; 1,148; 301; and 58 thousand tons carbon dioxide equivalent (CO_2eq) for Ho Chi Minh, Hanoi, Hai Phong and Hue cities respectively based on the waste data collected in 2009. The results also highlight contribution of landfills in terms of emission unit that is calculated by amount of GHG emission per ton of waste collected. Depending on the local conditions, emission unit is ranged from 0.79 to 0.87 tons CO_2eq/ton of waste. The study reveals that waste composting and methane gas recovery could have a high potential of GHG emission reduction in all of the studied landfills.

Keywords: greenhouse gas emission, municipal solid waste, scenario, potential

INTRODUCTION

It is widely recognized that waste disposal sites have contributes a significant amount of greenhouse gas (GHG) emission to global anthropogenic sources (IPCC, 2007). Considering this concern in the era of climate change, international communities, nations have struggled with numerous efforts to reduce emission from this source, however landfills seems to be a "chronic" contributor of GHG, in particular in developing countries, since emissions certainly last a long period even after its closure (Lou and Nair, 2009).

In Vietnam, the government has recently announced to strive for a low-carbon economy, accordingly, GHG emission reduction associated with the municipal solid waste (MSW) management system is one of the crucial concerns in this regard. On the other hand, GHG emission estimations were conducted in previous studies in individual landfill and province in Vietnam (Thanh et al. 2015, Giang et al. 2013; Thanh et al. 2012), however emissions were calculated by different methods such as IPCC guideline, first order decay, LCA approach and so on. Therefore the results among these studies are not comprehensively comparable. To overcome this obstacle this study primary aims to apply the widely accepted method (IPCC) to estimate emissions from landfills and evaluate potential of emission reduction through three possible proposed scenarios in the four target cities in Vietnam.

MATERIALS AND METHODS

Materials

This study uses municipal solid waste data in four target cities reported in several official reports and research articles (MONRE, 2011; URENCO, 2011, JICA, 2011). Currently, landfilling is the most popular practice, and organic waste is the dominant component in four cities studied. Waste generation and compositions are presented inTables 1 and 2.

Table 1. Waste generation in target cities

No	Item	Unit	Hanoi	Hai Phong	Hue	Ho Chi Minh
1	Collection amount	Tons/year	1,449,415	373,760	73,730	2,315,195
2	Collection rate	%	83.2	80	90	90
3	Generation amount	Tons/year	1,742,085.3	467,200	81,922	2,572,439

4	Population	Person	6,451,909	1,837,173	337,169	7,162,864
5	Waste per capita	Kg/person/year	0.74	0.7	0.67	0.98

(JICA, 2011)

Table 2. Waste composition in target cities (%)

No	Waste category	Hanoi	Hai Phong	Hue	Ho Chi Minh
1	Organic waste	70.9	55.5	77.2	65.4
2	Paper	3.8	3.5	2.3	6.8
3	Textile	1.6	1.0	1.2	1.8
4	Wood	1.3	12.8	1.7	4
5	Plastic	9.0	6.1	14	16
6	Leather and rubber	0.7	0.3	0.4	0.8
7	Metal	0.4	0.5	0.5	0.7
8	Glass	1.3	0.3	0.5	0.5
9	Others	11.0	20.0	12.2	4
Total		100	100	100	100

(JICA, 2011)

Methods

Scenario proposal

Considering the current waste technologies and management practice, and national strategy on solid waste management (PMD 2009), we suggest a gradual improvement approach for solid waste management system by composting organic matters for agricultural needs, and by applying landfill gas (LFG) recovery system for greenhouse gas emission reduction purpose. Besides, the organic waste rate set for compost in each scenario is referred to other previous studies (Mohared et al. 2008; Zhao et al. 2009).

- Baseline scenario: reflect current practice in four case studies
- Policy scenario 1 (PS1):commercial organic waste is sent for compost, the rest of waste is sent to landfills
- Policy scenario 2 (PS2): 30% of total collected organic waste is sent for compost, the rest of waste is sent to landfills
- Policy scenario 3 (PS3): landfill gas recovery system installed in landfills with recovery efficiency 50%

The scenarios assume that municipal organic waste is separated into two categories: households and commercial waste (waste generated in institutions, offices, schools, hotels and restaurants).

Greenhouse gas emission estimation

Landfill generates mainly carbon dioxide (CO_2) and methane (CH_4). However, CO_2 component is a result of the natural biogenic process so that it is not considered as GHG in this study. Therefore, GHG emission from landfills is calculated for methane (CH_4) basing on the IPCC guideline (IPCC, 1996):

$$CH_{4\text{emitted}} = (MSW_{\text{input}} \times MSW_f \times MCF \times DOC \times DOC_f \times F \times 16/12 - R) \times (1 - OX)$$

where: $CH_{4\text{emitted}}$ is the total CH_4 emitted from landfill (tons/yr); MSW_{input} is the total MSW collected (tons/yr); MSW_f is the fraction of MSW disposed in landfill; MCF is the methane correction factor; DOC is the degradable organic carbon; DOC_f is the fraction of DOC decomposing under anaerobic condition; F is the fraction of methane in landfill gas; R is the methane recovered (tons/yr)

Table 3. The required factors and default values of application of IPCC model

Factor	Method of deriving	Default value	Applied value
MCF	The IPCC recommended that default MCF values for different types of landfill including managed (landfill has cover and liner), unmanaged-deep (> 5m waste), unmanaged-shallow (< 5m waste) and uncategorized are 1.0, 0.8, 0.4 and 0.6, respectively.	0.4 - 1	**1**
DOC	DOC_{MSW} = % of food waste x 0.15 + % of garden waste x 0.43	Not specified	**0.13[1]; 0.14[2];**

Factor	Method of deriving	Default value	Applied value
	+ % of paper waste x 0.4 + % of textile x 0.24		**0.15**[3]
DOC_f	IPCC recommended value	0.5	**0.5**
F	IPCC recommended value	0.1 - 1	**0.5**
R	This value will be changed based on methane recovery technology applied in landfill	0	**0**
OX	IPCC recommended value for sanitary landfill with cover is 0.1; and for open dumpsite is 0.	0/0.1	**0.1**
GWP_{CH4}	IPCC recommended value	21	**21**

[1]:Hanoi; [2]:Hue; [3]:Hai Phong, and Ho Chi Minh

RESULTS AND DICUSSION

Estimation of GHG emission from disposal sites

The current GHG emissions from disposal sites in four cities studied are displayed in Fig. 1. Methane emission from landfills calculated by IPCC model is converted to carbon dioxide equivalent emission by multiplying with its global warming potential. As shown in Fig. 1, Ho Chi Minh city ranks the biggest among emitters with 2,016 thousand tons, followed by Hanoi capital (1,148). The two other cities' emissions are considerably lower compared to Ho Chi Minh and Hanoi city, in which the figures are 301 and 58 for Hai Phong and Hue city respectively.

Looking at the emission unit figure (Fig.2), it is noticed that Ho Chi Minh city presents the highest value while the three others show approximately the same.

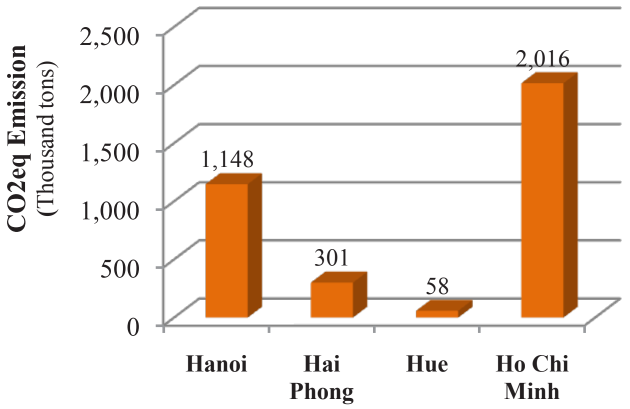

Fig. 1. Emission from disposal sites in four cities

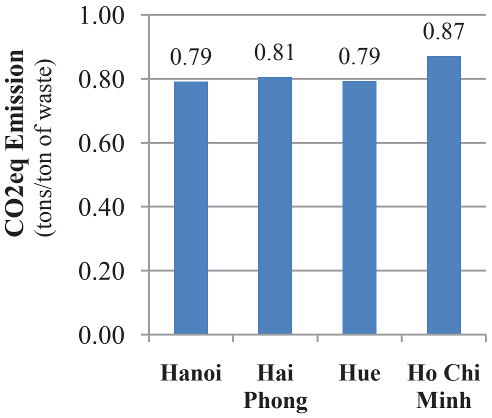

Fig. 2. Emission unit

Potential of GHG emission reduction

Emissions from proposed scenarios comparing to baseline are presented in Fig. 3. The results indicate a significant potential of reduction for each case study by enhancing composting amount of organic waste and installing LFG recovery system. Accordingly, the figures for PS1, PS2 and PS3 are 7%, 21% and 43% lower than baseline emission for every case but the amount of reduction is different.

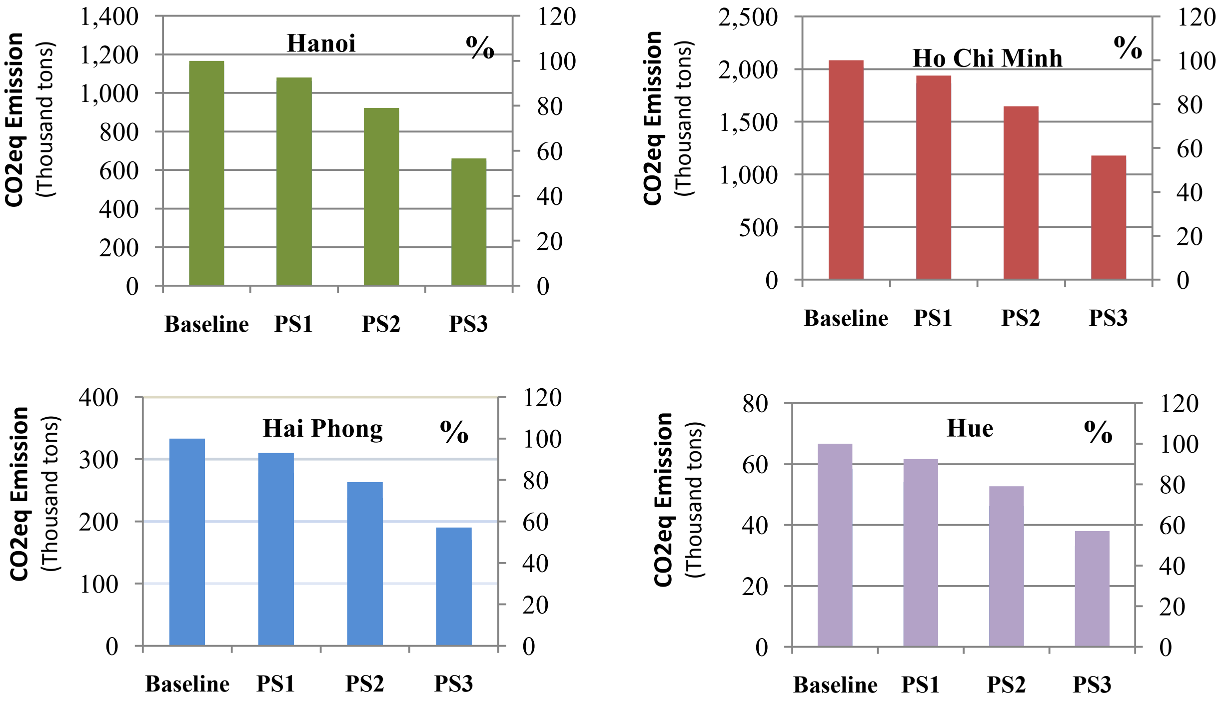

Fig.3. Potential of emission reduction in cities studied

CONCLUSION

Depending on the local conditions in terms of waste generation, compositions, GHG emissions from disposal sites in metropolitan cities (Hanoi and Ho Chi Minh) are far higher than regular cities (Hai Phong and Hue).

The scenarios analysed in this study indicate that GHG emissions are reduced the most through applying LFG recovery system. In addition, diverting organic waste from landfills to composting facilities also brings the positive effect of emission reduction. Findings from this study therefore significantly complement previous studies on the same topic to support a better MSW management system for the cities studied towards GHG reduction perspective.

ACKNOWLEDGEMENT

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Greenhouse Gas Mitigation Potential of Municipal Solid Waste Sector in Viet Nam for Developing Nationally Appropriate Mitigation Actions

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ABSTRACT

National Appropriate Mitigation Action (NAMA) is an opportunity for developing countries, like Vietnam, to cope with (or response to) climate change and to promote sustainable development. This study aims to determine the reduction potential of greenhouse gas (GHG) emissions that come from the field of Solid Waste Management during 2020-2030. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories is applied to develop Business as Usual (BAU) scenario.Strategies and policies for solid waste management in Vietnam has used as assumptions. According to the base emission scenario, the amount of GHG emissions from solid waste disposal sites will reach over 21.3 million tons of CO_2e *in 2020.This figure can climb to 58,2 million tons of* CO_2e *in 2030. Mitigation scenario is calculated by applying simplified Clean Development Mechanism (CDM) methodologies. Results show that, in 2030, Viet Nam can reduce 41.4 million tons of* CO_2e *from solid waste disposal compared to BAU by implementing alternative mulnicipal solid waste treatment measures. These results will be reference sources to build a NAMA in waste sector in Vietnam.*

Keywords: NAMAs, greenhouse gas, mitigation, mulnicipal solid waste, waste to resources

INTRODUCTION

Vietnamese socio – economy has developed rapidly in recent years that lead to an increase in the amount of mulnicipal solid waste in both mass and composition. According to the national report on environmental status that was released by MONRE in 2011, more than 10 million tons of milnicipal solid waste is generated every year. This report also shows that the components of solid waste include organic waste (54-77,1%), plastic waste (8-16%), metal waste (2%) and hazardous solid waste (less than 1%). In Vietnam, about 8-12% of solid waste, which is mostly paper, plastic, and metal, were recycled (MONRE, 2011).

In Vietnam, big cities (such as Hanoi, Ho Chi Minh City, Danang) have piloted solid waste segregation at source program. This program has achieved some initial results. However, there are still certain difficulties and restrictions, so it has not been widely applied in the whole country. According to MONRE (2011), in urban areas, the average percentage of mulnicipal solid waste collection rose from 72% in 2004 to 80-82% in 2008 and to 83-85% in 2010. This means that about 15-17% of the amount of mulnicipal solid waste had not been collected and processed. Until 2011, only 8-12% of the amount of collected mulnicipal solid waste was recycled. Some projects that used organic waste to produce fertilizer but they was still limited in capacity. However, paper,plastic and metal has been collected and recycled significantly by private sector, which is mainly small-scale. Another solid waste treatment measure that is applying in Vietnam is waste incineration. Modern incineration technologies have been implemented in big cities such as Hanoi, Ho Chi Minh City or Danang. Besides, technologies that recover waste heat from burning solid waste have been also planned.

In Vietnam, solid waste management is considered to have potential to reduce the GHG emission because domestic solid waste is mainly being disposed at landfills. Therefore, the potential to reduce the GHG emission from this sector needs to be calculated and assessed to support the development of nationally appropriate mitigation actions (NAMAs).

MATERIALS AND METHODS

Baseline emission scenario:

Baseline emission scenario does not consider climate change policies or strategies related to GHG emission reduction. In this study, basline emission scenario is defined that "*Given the case without specific and strong support from both domestic and foreign resources, mulnicipal solid waste treatment will be treated mainly by diposing at landfills*". The annual amount of GHG emissions from landfill sites is calculatedin accordance with Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. In particular, the FOD – First Order Decay is applied.

Table1. Data and assumptions for baseline emission scenario

Data and Assumption	Value	Nguồn
Population data and projection		Vietnam 1999-2049 population projection report (GSO, 2009)
Annually increasing in mulnicipal solid waste generation	10%	Environmental Status Report (MONRE, 2011)
Mulnicipal solid waste in urban area in period 2004-1010		Annual environment report(DONRE 2004 – 2010)
The rate of urban solid waste generation per capita (kg/person/day)	0.7	Environmental development report2004 (MONRE, 2004)
The rate of urban solid waste collection in the period 2015 - 2030	2020: 90% 2030:100%	Decision No. 2149/QĐ-TTg in 2009
The rate of rural solid waste generation per capita before 2010 (kg/person/day)	0.3	Environmental Status Report (MONRE, 2011)
The rate of rural solid waste generation per capita in the period 2011 - 2030 (kg/person/day)	0.34	Environmental Status Report (MONRE, 2011)

The component of mulnicipal solid waste is synthesized from the Annual Environmental Report published provinces. The figures can change in the future because of the urbanisation and the increase in population. However, the component of domestic solid waste is assumed to remain unchanged until 2030 due to lack of forecast data.

Table2. Average mulnicipal solid waste component

	Components	%
1	Food waste	59,24
2	Garden waste	2,76
3	Paper waste	2,7
4	Wood waste	1,05
5	Textile waste	3,30
6	Nappies	0,01
7	Plastic and other inert	30,94

(Source: Vietnam Environment Administration)

Mitigation scenario:

Mitigation scenario considers alternative measures for treating solid waste to reduce the amount of organic waste dumped in landfills. To assess these alternative measures, CDM methodologies for waste sector have been simplified so that they are suitable to apply in Vietnam.

Table3. Methodologies to assess GHG emission reduction in solid waste sector

Measure	Methodologies
W_1. Composting	AM0022: Reducing emissions by treating organic waste
W_2. Recycling	AMS-III.AJ:Recover and recycle materials from solid waste

W_3. RDF production	AM0025/Version 05: Avoided emissions from organic waste through alternative waste treatment processes
W_4. Anaerobic digestion with methane recovery and use	AMS-III.AO: Recovering and using methane released from anaerobic treatment system

These four measures will be implemented 63 provinces and cities in Vietnam. The amount of mulnicipal solid waste is determined based on Decision No. 2149/QDD-TTg on National Strategy for integrated management of solid waste to 2025, vision to 2050.

Table4. Data and Assumptions for mitigation scenario

Stt	Assumption	Valua	Source
1	Mulnicipal solid waste treatment objectives	2020: 85%; 2025: 90%;	Decision No. 2149/QĐ-TTg in 2009
2	Emission factor	Default	Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

RESULTS AND DISCUSSION

Based on the IPCC Guidelines for National GHG Inventories, data and assumptions, baseline emission scenario are calculated as follow:

Table5. Estimating GHG emissions from mulnicipal solid waste disposal

Year	CO_2eemission (million tons)
2010	7.7
2015	12.6
2020	21.3
2025	36.4
2030	58.2

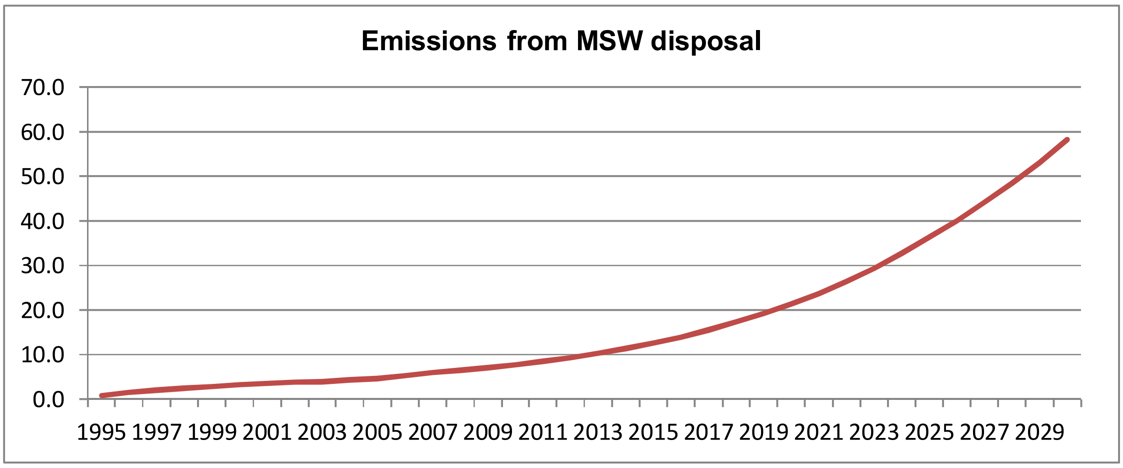

Figure1. Baseline emission scenario of mulnicipal solid waste management

In 2030, by applying alternative solid waste treatment measures, Vietnam can reduce about 41.4 million tons of CO_2e. In general, W_1 is the method that has the highest potential to reduce the GHG emissions and could be the most cost-effective measure. W_2 and W_3 are also appropriate current situation and policies on solid waste management; therefore, they should be recommended to be implemented apart by domestic resources. W_4 has high investment costs and is not cost-effective at present; however, it is also has a high potential in GHG reduction that should be recommended to implement with the international support.

Table6. Potential for GHG reduction

Year	BE_y (10^6 tCO_2e)	$ER_{comp,y}$ (10^6 tCO_2e)	$ER_{paperrecycling,y}$ (10^6 tCO_2e)	$ER_{RDF,y}$ (10^6 tCO_2e)	$ER_{AD,y}$ (10^6 tCO_2e)	ER_y (10^6 tCO_2e)
2016	14.0	0.49	0.02	0.13	0.04	0.68
2020	21.3	4.53	0.22	0.82	0.35	5.92
2025	36.4	15.07	0.81	2.55	1.15	19.58
2030	58.2	28.49	1.44	7.91	3.57	41.41

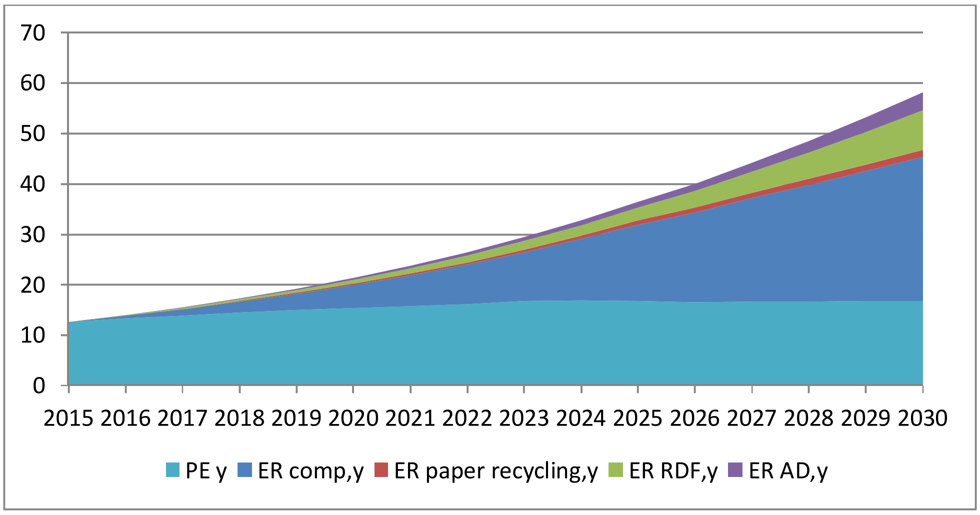

Figure2.Total emission reductions from the Waste-to-Resource NAMA

CONLUSION

In conclusion, the application of IPCC Guidelines for National GHG Inventories and methodologies of CDM in assessing the potential of GHG emission reductions in solid waste sector have shown initial results. Waste sector is not responsible for the largest amount of GHG emissions, but it has high potential to reduce emissions (over 71% comparing to BAU, approximately 41.4 million tons of CO_2 in 2030). In the future, IPCC guidelines can be applied to adjust the baseline emission scenario with new assumptions. Besides, CDM methodologies could be still suitable for assessing the emission reduction potential of alternative solid waste treatment measures.

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Bioremediation of Landfill Methane towards Reduction in Greenhouse Gas Emission.

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ABSTRACT

This paper aims to quantify CH_4 emission from a selected landfill in Malaysia using the IPCC Waste model and to compare it with real time field data, and to investigate the potential of bioremediation of landfill CH_4 in tropical climate via methane oxidation technique. Landfills accounted for 1,255 Gg or approximately 47% of total CH_4 emission in Malaysia. Nevertheless, the calculations based on the IPCC Waste model showed 7-60% higher than the actual landfill emission. The model estimated nearly twice the flux emitted from the surface of the study area. Methane oxidation was found to record the best performance using compost, when 100% CH_4 was removed within 5 days. It can be concluded that the estimation using IPCC Waste model can be misleading in certain areas such as that in tropical region. CH_4 oxidation using several waste organic products namely compost mixture can be a suitable solution to bio-remedy landfill gases (LFG) to ensure that impacts from emission GHG can be sustainably implemented.

Keywords: methane oxidation, greenhouse gas, mitigation, biocover, bio-window

INTRODUCTION

Waste management sector in Malaysia has been reported to contribute 47% of the total CH_4 emission and 24% of the total GHG emission in the country (NC2-Malaysia, 2010). To worsen the situation, most of the disposal sites in Malaysia lack proper lining system to prevent 'free migration' of CH_4 vertically or/and horizontally to the atmosphere. Thus, it is necessary to implement strategic mitigating measures to prevent CH_4 emission to the atmosphere. It is very crucial since CH_4 has been reported to be 34 times more detrimental in the global warming context than CO_2 across a 100 years period (IPCC, 2014).

During methanogenesis phase, hydrogen and acetic acids are converted into CH_4 which lasted for several years where 45-60% CH_4 will be generated profusely until it reaches the oxidation phase when acids have totally depleted from the landfill system. Migration of LFG can happen according to the gradient where low barometric pressure exists. Thus, gas migration may be influenced by the diffusion factor, the existing pressure and the permeability characteristics of the waste cell system, normally in an upward movement. Moisture and temperature too have been reported to affect the migration of these gases (Agamuthu et al, 2014; Resurs et al, 2011). It is imperative that the gases are not allowed to escape without a minimum treatment especially the conversion of CH_4 to less harmful GHG such as CO_2. The objectives of this paper are to quantify CH_4 emission from a selected sanitary landfill in Malaysia using the IPCC Waste model, and to compare it with the actual emission from the waste cells. Additionally, the research is aimed to investigate the potential of bioremediation of landfill CH_4 using several agro-waste as a supplement to promote methane oxidation under tropical conditions.

MATERIALS AND METHODS

A sanitary landfill namely Jeram Sanitary Landfill was selected for the purpose of the study. It covers 160 acres of land to cater the disposal of approximately 2,000 tonnes of waste daily. The landfill is established with HDPE liners and geomembrane, with gas and leachate collection system in place.

Estimation of CH_4 generated from the landfill site

Data on the municipal solid waste received was collected from 2007 to 2013 to calculate the estimated CH_4 generation based on the IPCC Waste model formula.

$$CH_4 \text{ Emission} = [\textstyle\sum_X CH_4 \text{ generated}_{X,T} - Rt].\ (1\text{-}OX_T) \quad \text{……..Eq 1}$$

Where: CH_4 Emission = CH_4 emitted in year T in Gg
X = waste category or types/material
T = Inventory year
R_T= recovered CH_4 in year T, Gg
OX_T= oxidation factor in year T, (fraction)

The amount of CH_4 generated was calculated by multiplying the decomposable degradable organic carbon (DDOC) found in MSW with the fraction of CH_4 in LFG and CH_4/C molecular weight ratio, and the mass of DDOC was calculated using Eq 2.

$$DDOC_m = W.\ DOC.\ DOC_f.\ MCF \quad \text{……Eq 2}$$

Where $DDOC_m$ = mass of DDOC deposited, Gg
W = mas of waste deposited, Gg
DOC = degradable organic carbon, Gg C/Gg waste
DOC_f= fraction of decomposed DOC
MCF = CH_4 correction factor for aerobic decomposition

Monitoring of the Actual CH_4 Emitted from the landfill site (Model Validation)

Actual LFG emission from landfill was obtained by analyzing the samples collected from, the gas well of the landfill. Memograph M Graphic Data Manager RSG40 was used to determine the LFG flow rate and the actual emission was calculated.

Field measurements were carried out in a temporarily closed waste cell which has been filled with MSW from 2008 to 2009 and covered with clay in 2010. The monitoring was recorded over six months to determine the CH_4 flux emission from landfill surface. The data obtained was compared with the calculated data (using IPCC Waste model).

Biocover window Experiment

Biocover windows (50cm X 50cm) were constructed in plots where cover soil material has been removed. Selected biocover materials were used namely, compost and black soil, to replace the removed cover materials. Monitoring was conducted for five days to establish the methane oxidation rate.

RESULTS AND DISCUSSION

Comparison of calculated methane from IPCC Model and the actual emission of CH_4

Table 1 gives the key parameters established to calculate the relevant factors in estimating CH_4 using the IPCC Waste model.

Table 1 Values used to calculate the influencing factor for IPCC Waste Model

Parameters	Minimum	Site-specific	Maximum
Fraction of Degradable Organic Carbon (DOC)	0.12	0.14	0.28
Fraction of DOC decomposed (DOC_f)	0.56	0.77	0.91
Decay rate (k), y^{-1}	0.15	0.09	0.20
Faction of CH_4 in LFG (F)	0.5	0.6	0.7
CH_4 correction factor (MCF)	0.5	0.6	0.8

Comparative results of CH_4 calculated using IPCC Waste model and the measured field CH_4 is shown in Figure 1.

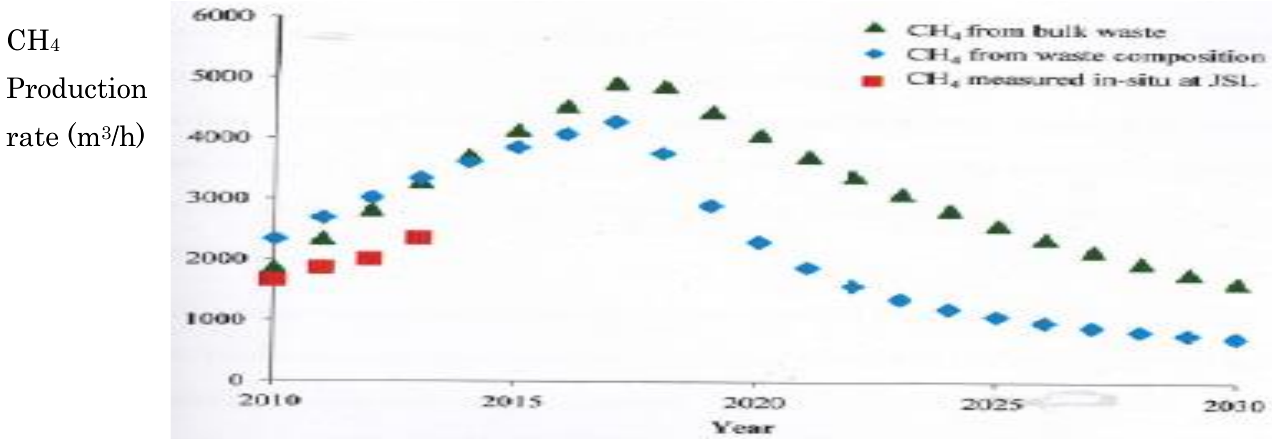

Figure 1 Measured and calculated CH_4 production

The results indicated that CH_4 generation by the IPCC model overestimated the actual emission by 13% to 58%. This is agreeable to findings by Penteaso et al (2012) and Abushammala et al (2011) who also reported the overestimation in their studies. A one-way ANOVA test concluded that there is significant difference between the estimated and actual CH_4 emission in this study. Therefore, it is important to note that estimates based on the model alone are insufficient to provide accurate data for planning of treatment facilities and such.

Methane Oxidation Experiment

Among the two biocover materials tested in this bio window experiment, compost was found to demonstrate the best rate in CH_4 oxidation. Second day of the experiment saw the drop in CH_4 from 9,400gm^{-1} to approximately 1,000 gm^{-1}, with average CH_4 flow of 1,000 $gm^{-1}day^{-1}$. However, no further drop was significant after Day 3 onwards. This probably was due to the limited atmospheric pressure created by the loose system of the compost which allowed the restricted emission of CH_4. It was also noted that higher rates of CH_4 oxidation were achieved with the height of the compost applied within the bio-window. On the other hand, black soil showed rapid reduction in CH_4 flow only after the 2.5 days. This was probably due to the need of organism within the black soil to acclimatize to the system since black soil has very limited supply of nutrient as compared to that of compost. Percentage of CH_4 removal by black soil ranged from 79% to 87% only as compared to that of compost (90% - 94%). Figure 2 illustrates the average CH_4 removal for compost and black soil at different biocover height.

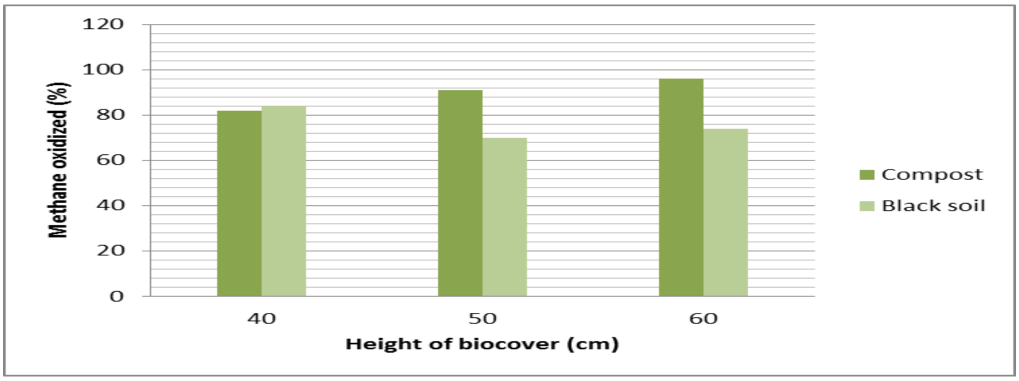

Figure 2 Average methane removals according to height of biocover materials.

This implies that compost showed better performance in removing CH_4 from the landfill bio-windows as compared to black soil.

CONCLUSION

This study concludes that calculation using IPCC Waste Model is not sufficient to provide comprehensive and accurate data in extrapolating CH_4 emission from landfill since it may be overestimated, particularly due to the variation in climatic factors as that observed in tropical region. Therefore, it is also important that data on the actual emission from landfill is also considered to plan any mitigation facilities. To enhance CH_4 oxidation process, bio-window is applicable to tropical climate where compost can be utilized to promote rapid conversion of CH_4 into CO_2. This is practical since bio-window can be easily set-up in disposal sites to prevent 'free emission' or passive release of LFG to the atmosphere. It is also a more practical bioremediation technique to mitigate CH_4 emission and to reduce global warming.

ACKNOWLEDGEMENT

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Methane Emission from MBT Technology at Phitsanulok Landfill

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ABSTRACT

The investigation of methane emission was conducted at Phitsanulok landfill, Thailand. At this site, the measurements were done at 3 different zones including at the Mechanical Biological Treatment (MBT) waste piles, landfill, and rejected waste zone. In MBT process, the waste was mixed by homogenizer then piled above pallet about 5 meters in height. The ventilation pipes were installed for promoting the aerobic condition to the waste body. To measure the methane emission, the static chamber technique and geo-statistics were used to assess the total gas emission at each study zone. The results shown that the methane emission rate at the MBT zone was just only half when compared to the methane emission rate at the landfill zone. It illustrated that some parts in the MBT waste pile were degraded under the aerobic condition. Moreover, the rejected waste emitted methane at the very low emission rate. Most degradable substances in waste were already stabilized. From this preliminary result, the MBT can be one of the promising greenhouse gas mitigation options for the developing Asian country.

Keywords: methane emission, landfill gas, MBT, landfill

INTRODUCTION

Landfill gas (LFG) is generated as a result of physical, chemical, and microbial processes occurring within the refuse. Due to the organic nature of most waste, it is the microbial processes that govern the gas generation process (Christensen et al., 1989). The composition of the LFG depend on the microbial system, the substrate (waste) being decomposed, and the site-specific variables such as oxygen access to the waste and moisture content (Ham and Morton, 1989). LFG is typically described as consisting of approximately 50 percent methane (CH_4) and 50 percent carbon dioxide (CO_2) with the less than 1 percent other gas constituents, including hydrogen sulfide and mercaptans (World Bank, 2004). Methane released from landfills has also been identified as a significant contributor to greenhouse gas emissions, in comparison with carbon dioxide, methane is considered to be 25 times more efficient at trapping heat within the atmosphere (Forster et al., 2007). The total global methane emissions have been estimated at 500 Tg/year and landfill contribute 40 Tg/year, 8% of the total (Mosher and Yardley, 1996). The Intergovernmental Panel on Climate Change (IPCC) estimates that landfill emissions are 7% of the total global methane emissions (IPCC, 2001).

In the developing Asian countries, the changes in consumption patterns with alterations in the waste characteristics have resulted in a quantum jump in solid waste generation. Inadequate waste management and disposal practices combined with the tropical climatic influence results in increasing environmental problems in region (Visvanathan et al 2004). In Thailand, the volume of municipal solid waste (MSW) generated in 2013 was about 26.774 million tons, or about 73,355 tons a day. 7.421 million tons was delivered to suitable waste management facilities. However, 6.938 million tons were unsuitably disposed of by open burning and open dumping (PCD, 2015). Phitsanulok municipality, one of local administrative authority in Thailand where promotes the MBT technology. The treated waste from MBT waste pile is separated for the refuse derived fuel (RDF) and utilized in the cement factory. However, at the present, there is no information about the methane emission from this waste treatment technology. The objective of this study is to investigate the landfill methane emission characteristics from MBT process which operates under the tropical condition and compare it to the landfill methane which emitted from the conventional landfill.

MATERIALS AND METHODS

Configuration of study site

Measurement was performed at Phitsanulok landfill site. This study site locates in northern region far from Bangkok about 370 km. The site received the MSW about 80 tons/day and operated by the Phitsanulok municipality. The main activities in this landfill are MBT and sanitary landfill. The components in this landfill site are similar to the traditional landfill. However, the resource recovery facility was added for the RDF production from local private sector called SCI ECO Co., Ltd. This landfill operates with 2 main processes. MBT is the first process; the waste is mixed by homogenizer then pile above pallet plate about 5 meters in height. The ventilation pipes are inserted for promoting the aerobic condition to the waste pile. Moreover, there is no daily cover operation for this waste pile so the waste is degraded under the aerobic condition which can be expected that the low methane emission should occur. In each waste pile, the waste is placed for 9-12 months. After that, this treated waste is transported to separation facility for producing the RDF. In the other hand, rejected and small organic fractions are utilized as soil amendment material. From waste composition investigation in this study, it was found that the waste comprised of 53.90% of food waste, 19.20 of plastic, 18.20% of paper and 2.3% of textiles. The second process is the landfilling for a portion of MSW.

Methane emission measurement

Methane emission rates from the landfill site surface in this study were determined by using the static chamber technique. The size of plastic chambers that used in this study was 0.40 m in diameter and 0.30 m in height. To protect against air intrusion, the chambers were sealed to the ground by placing wet soil around the outside rim. The gas in the chamber was sampling every 5 minutes interval started from 5 to 30 minutes. The gas samples were analyzed by GC-FID clarus580 PerkinElmer. The Surfer software (Golden Software, Inc.) was used to analyze the geospatial distribution with the Kriging model. The methane emission measurement was conducted in April 2015 at 3 disposal zones (MBT, landfill, and rejected waste zones).

RESULTS AND DISCUSSION

The summary results from field investigation at Phitsanulok landfill are shown in Table 1. Methane fluxes were measured at 54 points. These results indicated that high spatial heterogeneity of methane emission can be found only at MBT and Landfill zones. The methane flux fluctuated within the range of N.D. (Not Detected) to 155.27 g/m^2/d. The arithmetic mean ranged from 0.0018 to 18.86 g/m^2/d. The average spatial varied from N.D. to 21.36 g/m^2/d. The results as shown in Table 1 also showed that the rate of methane emission from landfill zone was greater than that in MBT zone for double. It indicated that MBT technique can promote aerobic degradation condition and reduce the methane emission when compared to the landfill zone which represented as anaerobic degradation. At the final stage of separation process, the rejected waste contained small fraction of organic and inorganic waste. These were utilized as soil amendment. Methane emission from rejected waste zone emitted at very low emission rate to N.D. It prefers that degradable substances in waste already stabilized. However, from these methane emission rates, there are only 3 data sets which are not enough to create the methane emission trend. It should be better to continue the investigation again in order to create the methane emission trend.

Table 1 Summary of methane emission from field investigation

Study zones	No. of measured points	Min. (g/m^2/d)	Max. (g/m^2/d)	Mean (g/m^2/d)	Avg. spatial (g/m^2/d)
MBT	30	N.D.	155.27	8.73	11.53
landfill	18	N.D.	78.82	18.86	21.36
Rejected waste	16	N.D.	0.16	0.0018	N.D.

From this preliminary result, the methane emission rate in MBT zone is very low when compares to the previous study at the tropical final disposal sites (Wangyao et al., 2010). This may imply that most of degradable organic carbon in waste at the M.B.T zone were degraded under the aerobic condition due to the air can penetrated to the waste body by the ventilation pipes and pallet as well as from the waste surface. However, this investigation was conducted in the dry season. The water blocking from rainfall to the void in waste body and create anaerobic condition may not occur in this dry season. It should be better to investigate the methane emission again in the wet season and evaluate the methane emission rate at these three study zones again as the seasonal variation of methane emission study.

CONCLUSION

This study aimed to investigate the methane emission from 3 different operated zones including MBT, landfill, and rejected waste zones. It was shown that MBT zone emitted methane half amount when compared to the landfill zone. MBT operation could refer for a good practice of methane emission reduction. After the MBT process, the waste was sorted in the separation facility. The investigated methane emission confirmed that most organic fractions were already stabilized. It also indicated that MBT implementation in 9-12 months can accelerate the degradation of organic carbon that faster than traditional landfill. However, for more information, the author should investigate in longer period in order to study the characteristics and seasonal variation of the methane emission.

ACKNOWLEDGEMENT

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Session 2

Waste to Energy 1

Demonstration test to reduce environmental loads of fluidized bed incinerator

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ABSTRCT

Demonstration test to develop an improved fluidized bed incinerator has carried out in an existing commercial plant with applying technical experience and knowledge through development of gasification and melting furnaces. Operation at a low air ratio of 1.3 is conducted in condition with high waste load of sand bed leading to low sand temperature and making combustion rate low. Improvements of secondary air injection technology and the control technology by using a laser oxygen analyzer achieve higher combustion performance. NOx is reduced to around 40ppm only by improvement of combustion, and selective non-catalytic reduction (SNCR) method leads to further low NOx operation as low as 20ppm.

Keywords: Fluidized bed incinerator, Low air ratio operation, NOx, Selective non catalytic reduction (SNCR)

INTRODUCTION

Currently in Japan, gasification and melting process, which allows melting of ash by combusting of synthesis gas from a gasifier, is one of the common process of municipal solid waste (MSW), and 97 plants(1) are operated using this process. Advantages of the process are to decompose dioxins and to prolong a life of landfill site by reducing residual ashes by melting mineral components at high temperature around 1200-1300 degree-C. Slag from melting facilities complied with JIS, Japanese Industrial Standard, has been used for road and/or cement material. Melting facility was mandatory to obtain subsidy to build a MSW plant in the past to reduce the amount of ashes to landfill site. However, after 2004, local governments who plan to build a MSW plant can choose either a melting facility or an incinerator, in case their landfill life remains more than 15 years. In particular, after The Great East Japan Earthquake, a MSW plant is greatly expected as electricity supplier in each community, increasing efficiency of electric power generation is becoming one of the most urgent.

KOBELCO ECO-SOLUTIONS has delivered 17 plants of gasification and melting furnaces in Japan and foreign country after the first plant built in 2000. Fluidized bed and combustion technology has been improved through development of gasification and melting process, the subject of this report is to show improvement of the fluidized bed incinerator in demonstration test in the commercial plant with applying technical experience and knowledge.

DEMONSTRATION TEST

The demonstration test was carried out in the commercial plant. The outline of the plant is shown in Table 1 and the process flow diagram shown in Fig.1. Concept of secondary air injection process is shown in Fig. 2. Combustion in a low air ratio condition is effective to achieve high efficiency of electric power generation due to reduction of heat loss that exhaust gas carries away. Low NOx combustion is also effective to make electric efficiency high because of eliminating the need of a De-NOx catalysis reactor which consumes steam. In demonstration test of the fluidized bed incinerator, following improvements were implemented in the commercial plant.

(1) Low air ratio combustion

+Additional installation of a crusher, which improves MSW feeding.

+High waste load of sand bed to achieve low sand bed temperature and low combustion rate.

+Control of secondary air injection by a laser oxygen analyzer[2)] and exhaust gas recirculation (EGR).

(2) Low NOx generation

+Low air ratio combustion leading to low NOx generation.

+ Low NOx emission by SNCR (Selective non-catalytic reduction)

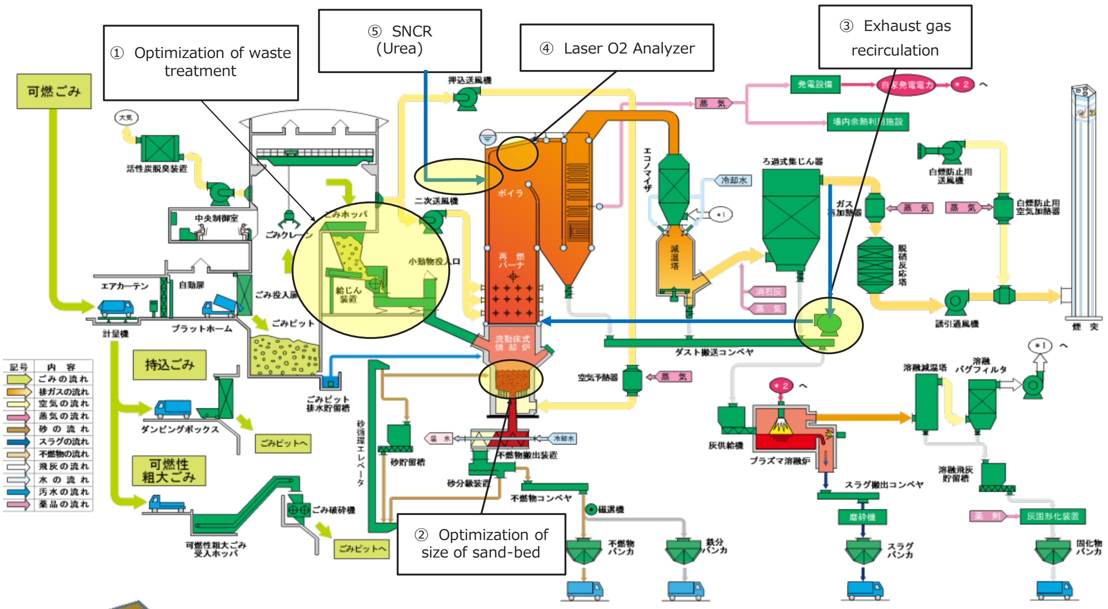


Fig. 1 Process diagram and improvement

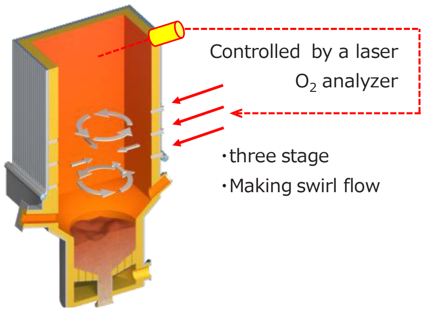


Fig. 2 Secondary air injection process

Table 1 Outline of the commercial plant

Furnace	Fluidzed-bed incinerator、46t/d×3furnace
Gas cooler	Waste heat boiler、Gas cooler
Flue gas treatment	Bag Filter、De-NOx catalyst
Generator	Steam Turbine 1,470kW

RESULTS AND DISCUSSION

1) Stable combustion at a low air ratio operation

Trend curves of O_2 and CO concentration at outlet of the furnace at an air ratio 1.3 are shown in Fig. 3. By controlling secondary air injection using the laser oxygen analyzer, O_2 concentration was maintained as low as 4 vol% (wet), and peaks of CO concentration were rarely occurred. Fig.4 shows that coefficient of variance of 30 minute moving average of boiler steam flow rate is within ±3%. In addition, operation at a low air ratio was able to lead to 10% increase in steam generation because of reduction of heat loss from the process as shown in Table 2.

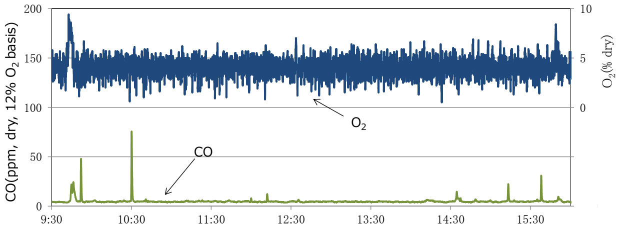


Fig. 3 Trend curves of CO/O_2 (Air ratio 1.3)

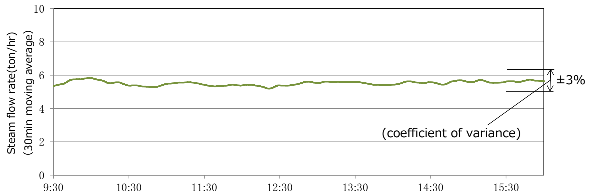


Fig. 4 Trend curve of steam generation (Air ratio 1.3)

Table.2 Comparison of steam flow rate

	Improved	Conventional
Steam generation	3.1	2.7～2.9

(Steam-ton/waste-ton)

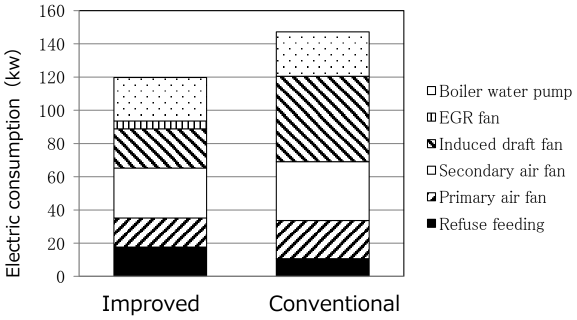


Fig. 5 Breakdown of Electric consumption

2）Reduction of electricity consumption

Electricity consumption of main equipment shown in Fig. 5 was reduced more than 10% in comparison with a conventional process. This was because of reduction of each fan power in a low air ratio operation, even though increasing electricity consumption by adding installation of crushers in order to improve feeding system and an EGR fan. As the results, not only gross efficiency but also net efficiency was increased.

3）Low NOx operation[3)]

NOx formation characteristic was investigated by changing O_2 concentration at furnace outlet. Fig. 6 shows relationship of O_2 concentration and generation of NOx volume/waste-ton. Fig. 7 shows relationship of air ratio and NOx concentration as converted by O_2=12%. These results show that low air ratio combustion results in not only low NOx concentration but also low NOx generation. The author reduced NOx concentration to 40ppm (O_2=12% cal) by operating at a low air ratio 1.3.

Numerical simulation using “ANSYS Fluent” was carried out for two conditions, conventional and improved operations, to understand behavior of NOx generation in the furnace. The results of the simulation were in good agreement with measurement values of temperature and NOx concentration in the furnace as shown in Fig. 8 and Fig. 9.

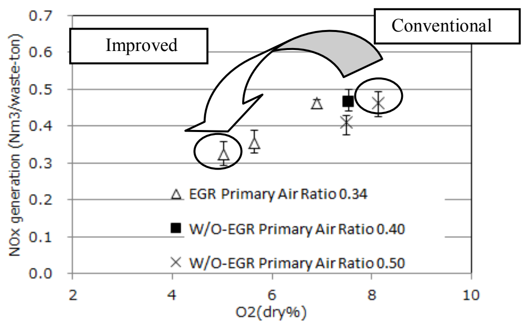


Fig. 6 O_2 - NOx generation

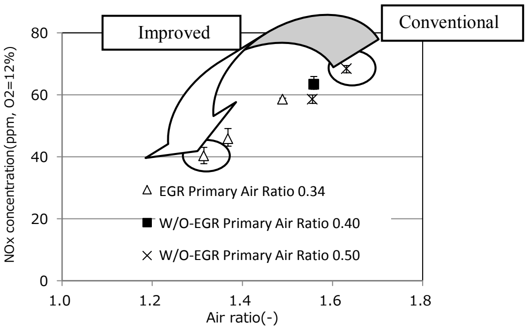
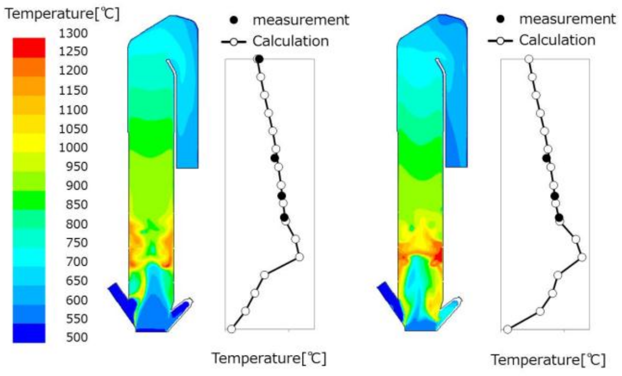
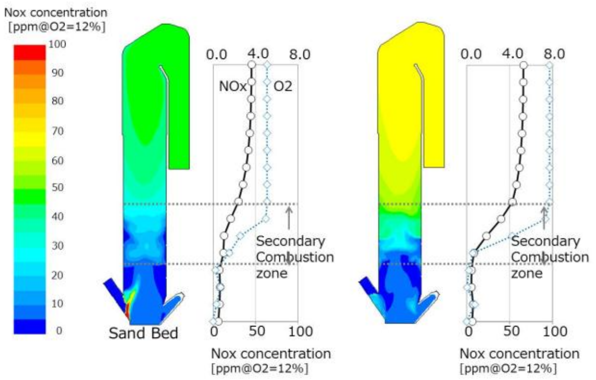


Fig. 7 Air ratio - NOx concentration



(a) Improved (Air ratio=1.3) (b) Conventional (Air ratio=1.6)

Fig.8 Temperature of measurement and calculation



(a) Improved (Air ratio=1.3) (b) Conventional (Air ratio=1.6)

Fig. 9 NOx and O_2 of measurement and calculation

4） SNCR operation

SNCR operation supplying urea into the furnace was carried out for further NOx reduction. In this test operation, flow rate of urea to the furnace was controlled to set variable of NOx concentration at the outlet of bag-filter with feedback control. Fig.10 shows trend curve of one hour moving average of NOx concentration and slip NH_3 concentration at the outlet of bag-filter for two conditions, NOx=30ppm and 20ppm. As a result of the test operation, good controllability of NOx concentration was confirmed with urea feedback control. Slip NH_3 concentration was below 1.7ppm, lower than 10ppm of concentration which caused visible NH_4Cl smoke at stack.

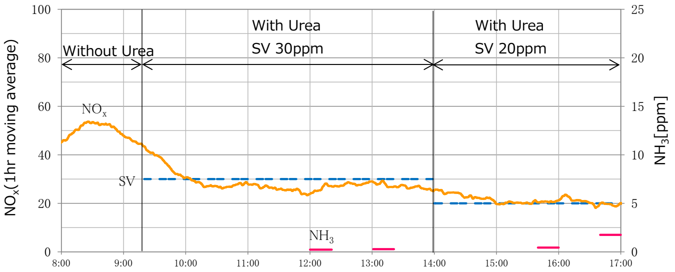


Fig. 10 Results of SNCR operation

CONCLUTIONS

Improving MSW feeding system and combustion control in the existing commercial plant, a low air ratio operation is demonstrated, in a relatively small plant with a capacity of 46tons/days. The operation is expected to increase gross electric output due to reduction of electric consumption and increase of steam flow rate to steam turbine. A low air ratio operation can reduce to NOx generation to 40ppm by improvement of combustion only, in addition, NOx emission can be lowered to 20ppm with SNCR method.

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Innovation of Waste-to-Energy Plants for High-Efficiency Power Generation

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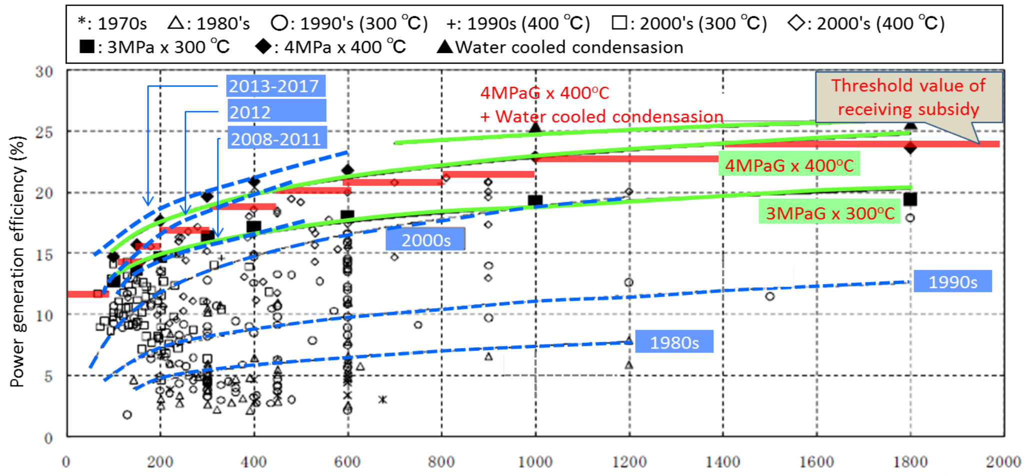
ABSTRACT

We would like to introduce the innovation on flue gas treatment systems with low energy consumption and high removal efficiency in order to secure high-efficiency power generation of the Waste-to-Energy (WtE) plants. By combining *low excess air ratio combustion* and *advanced SNCR*, NO_X is removed with high efficiency (54 – 63%) with low NOx emission concentration of 61.6 mg/m^3N or less without using SCR system. For SO_X and HCl removal, *high-efficiency dry flue gas treatment* is very high removal efficiency (99%). In addition, Dioxins and Mercury are also removed with high efficiency. The results also showed that higher efficiency power generation by applying these innovations was achieved and guaranteed.

Keywords: Waste-to-Energy (WtE), Low excess air ratio combustion, SNCR, Dry flue gas treatment

INTRODUCTION

In Japan, the waste incineration power generation (waste-to-Energy, WtE) plants for high efficiency power generation receive financially policy incentives: (1) subsidizing up to half of the project's capital expenditure (by "Recycling Society Formation Promotion Grant" started since 2009) and (2) subsidizing higher energy selling price (according to "feed-in tariffs for renewable energy") started since 2012). The threshold values (based on plant's capacity and power generation efficiency) of receiving subsidy are shown in Figure 1. This figure also presents the increasing trend of power generation efficiency by time (since 1980s) and by technology development (by improving steam condition: higher temperature and higher pressure); the efficiency has been increased gradually since 1980s and expected to increase in the near future. High-efficiency power generation of WtE has been identified as the strategic target of innovation. In this paper, we introduce the innovation on high-efficiency flue gas treatment systems with low energy consumption and high removal efficiency as one of the most important means to secure high-efficiency power generation of the WtE plants.



Source: JEFMA's survey

Figure 1. Power generation efficiency (%) of WtE plants by time and technology development

ADVANCED INNOVATION ON FLUE GAS TREATMENT FOR HIGH-EFFICIENCY WTE PLANTS

1. NOx reduction technology

Regarding to NOx reduction technology for WtE plants, there are three major techniques: Low Excess Air Ratio Combustion, Selective Catalytic Reduction (SCR), and Selective Non-Catalytic Reduction (SNCR). Among them, SCR achieves the best NO_X removal efficiency (60% or more) and NO_X emission concentration can reach

※ *In this paper, the concentration values of gaseous pollutants in flue gas have been known as standard condition (Dry, 0^oC, 11% O_2)*

to 45mg/m^{3}N. For applying SCR systems, there are two options: high temperature catalyst and low temperature catalyst. (1) High temperature catalyst: SCR requests that flue gas must be re-heated to a suitable temperature for catalyst reaction by flue gas re-heater utilizing steam; therefore, the power generation efficiency is reduced. (2) Low temperature catalyst (with operation temperature of approximately 180-190^{o}C): It has been developed recently, although steam consumption to re-heat the flue gas is not applied, the SO_X and HCl removal system is requested as high operational temperature system (e.g., Sodium bicarbonate dry flue gas treatment system), which is higher energy consumption and more expensive cost of reductant consumption comparing to common hydrated lime dry flue gas treatment system (as presented section 2.1). In addition, structural measures as SCR reactor/tower and its facilities are installed for both options; costs of construction, operation, and maintenance are raised.

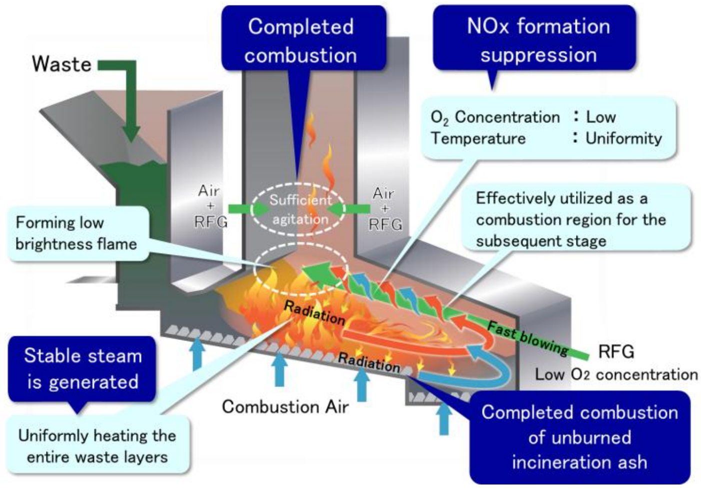


Figure 2. Concepts of our Low Excess Air Ratio Combustion system

The SNCR technique is additionally non-structural measures without steam consumption to re-heat flue gas, although NOx removal efficiency just achieves around 30%. In order to secure high-efficiency power generation of the WtE plant, we have developed an innovation on combining low excess air ratio combustion and advanced SNCR to remove NOx with high efficiency (approximately 60%) and low energy consumption without using SCR system. The details are presented below.

1.1. Low Excess Air Ratio Combustion Technology

The concept of our *low excess air ratio combustion* technology is displayed in Figure 2 and its features are shown as follows:

① Low excess air ratio and low NOx combustion: By blowing high speed Recirculated Flue Gas (RFG) in the primary combustion chamber from the rear wall, combustion air supplied from under the grates and combustible gas with high temperature generated from the main combustion zone of the waste layers are attracted to the rear wall side. Then, the combustion air and the combustible gas are inverted by the rear wall forward and diluted by RFG as well as begun mutual mixing. By above action, Oxygen (O_2) concentration in this region is low; therefore, combustion speed is decreased. Since, the flame temperature is reduced and temperature is distributed uniform, the generation of NOx is suppressed.

②Stabilization of generated steam amount: Generally, by increasing or decreasing the combustion airflow rate supplied from under the grates, the stabilization of the generated steam amount is achieved. In this system, by supplying RFG from the rear wall, the hot combustion gases spread throughout the primary combustion chamber. Thus, the entire waste layers are heated and less combustion airflow is supplied. Since, combustion is stabilized, the stable steam amount is generated.

③Reduction of unburned bottom ash: By receiving radiation from the hot combustible gases attracted to the rear wall side of ash deposited on the post-combustion grate top, unburned bottom ash is completely burned.

1.2. Advanced SNCR

SNCR is a technique for reducing NO_X by blowing reductant into high temperature flue gas without using catalyst. Ammonia (NH_3) is a harmless nitrogen compound used as the reductant. To achieve high performance in a SNCR, it is important to blow the reductant in a proper flue gas temperature range (800 ~ 900℃). On the other hand, the furnace temperature and NOx concentration formed of waste incinerator are changed by waste quality and waste amount, the optimum supply amount and supply position of reductant are constantly changed.

Our SNCR technology known as *advanced SNCR* combines the following three techniques to achieve high performance of NOx removal and its concepts are shown in Figure 3.

① Optimization of proper flue gas temperature range for ammonia supply: Multi-stage ammonia injection nozzles are installed into the combustion chamber at different height-based positions along the bottom-up direction of flue gas flow. Each nozzle is switched automatically in response to changes of furnace temperature.

② Optimization of ammonia supply amount:

③ Sufficient dispersive mixing: Steam or compressed air are combined to supply with ammonia into the combustion chamber, ammonia is dispersed and mixed instantaneously into flue gas.

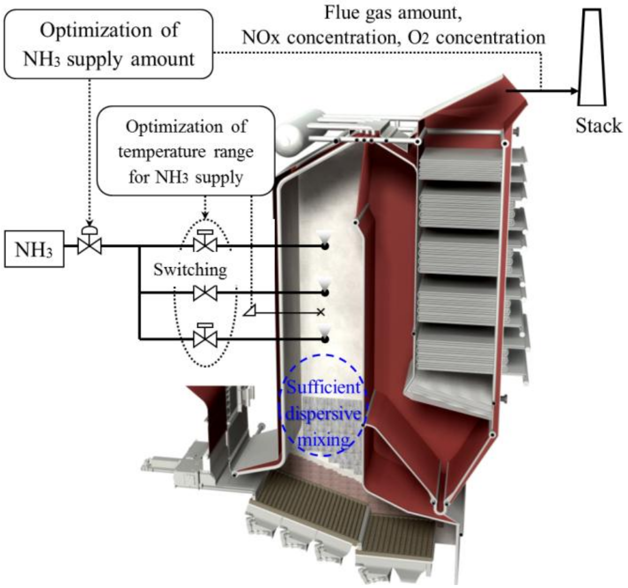


Figure 3. Concepts of our advanced SNCR technology system

1.3. Combined operation of Low Excess Air Ratio Combustion and Advanced SNCR

A case study of combined operation of low excess air ratio combustion and advanced SNCR was carried out in order to check the practically operational efficiency. Table 1 presents the overview of the experimental plant, operation conditions, as well as value of key parameters.

Table 1. Experimental operation conditions and results*

Experimental time	[date]	2014.12.1 – 2015.2.6
Plant capacity	[t/day]	101 (91 – 118)
Calorific value of input waste	[MJ/kg]	9.6 (8.8 – 10.7)
Steam generation amount	[t/h]	13.0 (11.7 – 14.7)
Internal furnace temperature	[°C]	963 (942 – 978)
NO_X at SNCR inlet	[mg/m^{3}N]	131.4 (92.4 – 215.6)
NO_X at Bag filter outlet**	[mg/m^{3}N]	53.4 (43.1 – 61.6)
NH_3 at Bag filter outlet***	[mg/m^{3}N]	2.1 (1.7 – 2.4)
Equivalent ratio (NH_3/NO_X)	[-]	1.17 (0.88 – 1.50)
NO_X removal efficiency	[%]	59 (54 – 63)
Combustion air ratio	[-]	1.23 (1.21 – 1.27)

* *Values of parameters: average value (minimum – maximum value)*
** *NO_X concentration: hourly measurement*
*** *NH_3 concentration: only 3 times of measurement*

The experiment was carried out in approximately 2 months (2014.12.1 ~ 2015.2.6); in which, the plant was shut down in 8 days for periodic maintenance and the plant ran with 80% rated-load. The result showed that NOx removal efficiency was in a range of 54% – 63%, the NOx emission concentration of less than 61.6 mg/m^{3}N was guaranteed during testing period. Besides, low combustion air ratio was maintained in a narrow range of 1.21 – 1.27 and low equivalence ratio (NH_3/NO_X) and low residual NH_3 concentration were achieved. Regarding to power generation efficiency, another experiment (facility capacity: 150t/dx2, calorific value: 8,800KJ/kg, SCR operation temperature: 210°C) showed that by applying our advanced SNCR, power generation efficiency was improved 300 kW comparing to SCR system (Usutani et al., 2013).

2. SOx, HCl reduction technology

Regarding to SOx and HCl reduction technology for WtE plants, there are three conventional techniques: dry-type (known as semi-dry-type in Europe), wet-type, and semi-wet-type. Among them, Wet-type technique is the highest removal efficiency, followed by Semi-wet-type and dry-type, respectively. However, by using the wet-type technique, flue gas temperature is dropped rapidly and significantly (50 – 60°C), if the SCR is requested to install in the downstream, more steam energy is utilized as above-mentioned. Therefore, power generation efficiency is low. In addition, since the equipment is large-scale, construction costs as well as maintenance costs are expensive. For semi-wet-type technique, handling of lime slurry (preparing lime slurry and spraying this slurry into the reactor by rotary atomizer) is very complicated. It has not been almost adopted in Japan.

Although dry-type technique is easy and convenient operation and management as well as very low steam consumption, its removal efficiency is low. In order to avoid the limitations and difficulties of wet-type technique and semi-wet-type technique, we have developed an innovation on high-efficiency dry flue gas treatment with low energy consumption, easy operation, and high removal efficiency. The details are presented below.

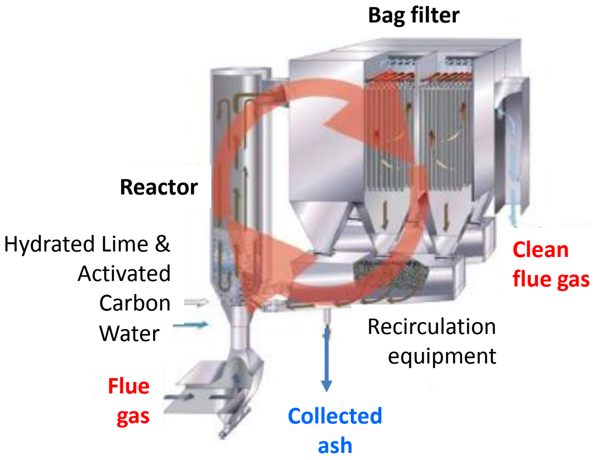


Figure 4. Concepts of our high-efficiency dry flue gas treatment system

2.1. High-efficiency dry flue gas treatment

Acid gases (SOx, HCl, HF) are removed by spraying hydrated lime powder ($Ca(OH)_2$), while Dioxins (DXNs) and Mercury (Hg) are removed by spraying activated carbon. Both hydrated lime powder and activated carbon are sprayed into the upstream of the bag filter (Figure 4). The innovation of the dry-type technique is that fly ash including unreacted hydrated lime and activated carbon collected at the bag filter's bottom is recirculated and recycled. By this approach, removal efficiency is really improved and chemical use and energy consumption are also saved at the same time. This advanced technology known as *High-efficiency dry flue gas treatment* has been applied widely in Europe with more than 30 facilities and started to be adopted in Japan.

2.2. Practically operational efficiency

Table 2. Experimental operation results

		Inlet	Outlet	Efficiency (%)
SOx	[mg/m^{3}N]	94.3	0.3	99%
HCl	[mg/m^{3}N]	392.7	5.5	99%
HF	[mg/m^{3}N]	–	0.04	–
DXNs	[ng-TEQ/m^{3}N]	–	0.00036	–
Hg	[mg/m^{3}N]	–	0.003	–

Facility capacity: 348t/d x 2, Operation temperature: 150°C, Equivalent ratio: 1.9

A case study was carried out in order to check the practically operational efficiency. Table 2 presents the overview of the experimental results. The results showed that SOx and HCl were removed with very high efficiency (99%) and low emission concentration (SOx = 0.3 mg/m^{3}N, HCl = 5.5 mg/m^{3}N) was guaranteed. In addition, DXNs and Hg were also removed as well with high efficiency. Regarding to power generation efficiency, another experiment (facility capacity: 250t/dx2, calorific value: 10,300KJ/kg) showed that by applying our high-efficiency dry flue gas treatment system, power generation efficiency was improved from 16.1MW to 17.0 MW (from 22.1% to 23.3%) comparing to wet flue gas treatment system (Usutani et al., 2013)

CONCLUSION

This paper introduced the innovation on high-efficiency flue gas treatment systems with low energy consumption and high removal efficiency. By combining low excess air ratio combustion and advanced SNCR, NOx was removed with high efficiency (54% – 63%) with low NOx emission concentration of 61.6 mg/m^{3}N or less without using SCR system. Regarding to SOx and HCl removal, our high-efficiency dry flue gas treatment was very high removal efficiency (99%) and low emission concentration. In addition, Dioxins and Mercury were also removed as well with high efficiency in order to meet almost strict regulations. Especially, power generation efficiency has been increased significantly when high-efficiency flue gas treatment alternatives (advanced SNCR, high-efficiency dry flue gas treatment systems) were adopted. These approaches are proven as not only high-performance flue gas treatment systems but also high-efficiency power generation solutions.

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The Characteristics of Air Gasification for Fluff SRF in a Bench Schale Advanced Down-draft Fixed Bed Reactor

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ABSTRACT

Air blown gasification causes tar emission and high percent of loss on ignition. To enhance stability of gasifier, an effective reduction of tar emissions from a gasifier is necessary. In this study we have studied the multistage oxidizing agent gasification and in bed tar reforming with calcium oxide. In the case of multistage oxidizing agent gasification(Run 2-1-2), H_2, CH_4, CO concentration increased and C_2-C_6 concentration decreased, resulting in high cold gas efficiency(CGE) and high carbon conversion ratio(CCR) due to the tar cracking with 3rd stage oxidizing agent and the conversion of carbon and hydrogen in bottom ash to gas. In the case of gasification with calcium oxide (Run 2-2), H_2, CH_4, CO concentration dramatically increased and CO_2 and C_2-C_6 concentration decreased, resulting in very high CGE and CCR due to the adsorption of CO_2 and the steam reforming of tar by calcium oxide.

Keywords: MSW, fluff SRF, gasification, advanced down-draft fixed bed

INTRODUCTION

In the gasification process, the composition of the syngas and its heating value are influenced by the oxidizing agents. The oxidizing agent can be air, oxygen, oxygen enriched air or steam. Using air dilutes the syngas with nitrogen, which adds to the cost of downstream processing, particularly compress process. However using oxygen avoids this, but oxygen production cost is expensive, and so oxygen enriched air can also be used. Air blown gasification causes tar emission and high percent of loss on ignition. To enhance stability of gasifier, an effective reduction of tar emissions from a gasifier is necessary. In this study we have studied the multistage oxidizing agent gasification and in bed tar reforming with calcium oxide.

MATERIALS AND METHODS

Bench scale gasification system concept

The advanced down-draft fixed bed gasification system conceptual design is shown in Figure 1. The advanced down-draft fixed bed gasifier is consisted of a fluff SRF feeder, a catalyst feeder, a double tube down-draft fixed bed reactor, a multistage oxidizing agent nozzle and a bottom ash drain.

The syngas of gasifier flows from top of the inner reactor to bottom of the outer reactor, and finally exits from top of the outer reactor. Fluff SRF is fed in the inner reactor by a paddle type screw feeder. Tar catalyst, desulfurizing agent and CO_2 adsorbent such as quicklime and steel slag are fed in the outer reactor to reform tar and/or to adsorb H_2S and HCl.

The advanced gasifier has designed 1st-, 2nd-, and 3rd-stage oxidizing agent nozzles for the high efficient gasification. A first stage oxidizing agent nozzle has been the object of a partial oxidization of a fluff SRF in the inner reactor. The first stage nozzle is located on a middle of the gasifier. A second stage oxidizing agent nozzle has been the purpose of a control of loss on ignition in the inner reactor. The second stage nozzle is located on a bottom of the inner reactor. A third stage oxidizing agent nozzle has been the aim of a reforming of a tar in the outer reactor. The third stage nozzle is located on an inlet of the outer reactor.

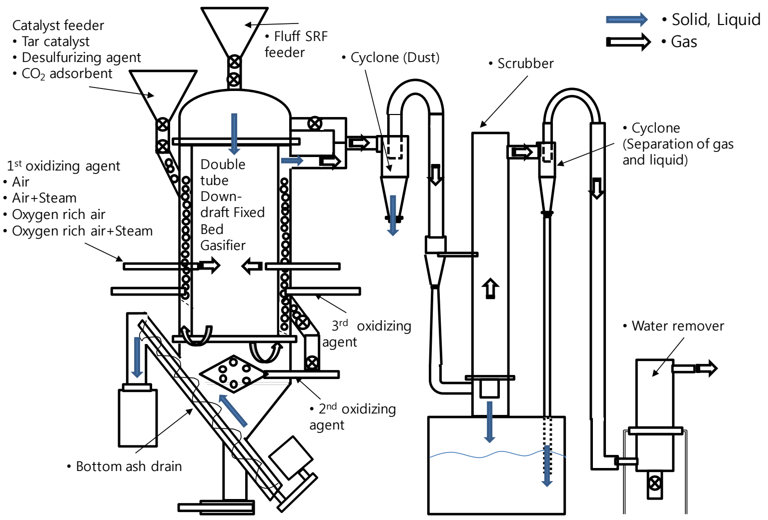


Figure 1. Advanced down-draft fixed bed gasification system conceptual design

Bench scale gasifier specification

The capacity of the advanced gasification system is 3kg/h of fluff SRF. The advanced fluff SRF gasification system includes a paddle type screw feeder, a catalyst feeder, a down-draft fixed bed gasifier, a cyclone, a wet scrubber, a water remover, and a flare stack.

The multistage oxidizing agent is quantitatively fed with mass flow controller(Line Tech M3100V). The double tube gasifier is made stainless steel 304 tubes of 100A(In diameter 108.2mm, thickness 3mm) and 150A(In diameter 162.5mm, thickness 3mm). The total height of the gasifier is 2,216mm.

The tar produced from the inner reactor is reformed with calcium oxide filled in the outer reactor. After then, tar, dust and water of syngas are removed through the cyclone, wet scrubber and water remover. The syngas purified is combusted in the flare stack and then exhausted in the air. The purified gas is analyzed using gas chromatography(Inficon Micro GC 3000) at an interval of 3 minutes.

Sample and chemical composition

Municipal Solid Waste(MSW) used in this study is obtained Y city of Republic of Korea. The non-combustible components such as steel and aluminum in MSW are separated and the combustible components such as plastics and paper are crushed less than 30mm with pre-treatment facilities, and fluff SRF is finally produced to use in the bench scale gasifier. The fluff SRF used in this study shows Figure 2.

Figure 2. Fluff SRF used

The results of proximate analysis, ultimate analysis and calorific value of fluff SRF are conducted. Moisture, combustible component and ash of fluff SRF are 22.1%, 67.3% and 10.6%, respectively. Nitrogen, sulfur and chlorine, which produce pollutant matter such NH_3, H_2S and HCl are 0.1%, 0.1% and 0.3%, respectively. Calorific value of the fluff SRF shows 3,561kcal/kg(14.91MJ/kg) as a low heating value. It indicates that the fluff SRF is available to use for air blown gasification.

Experimental conditions

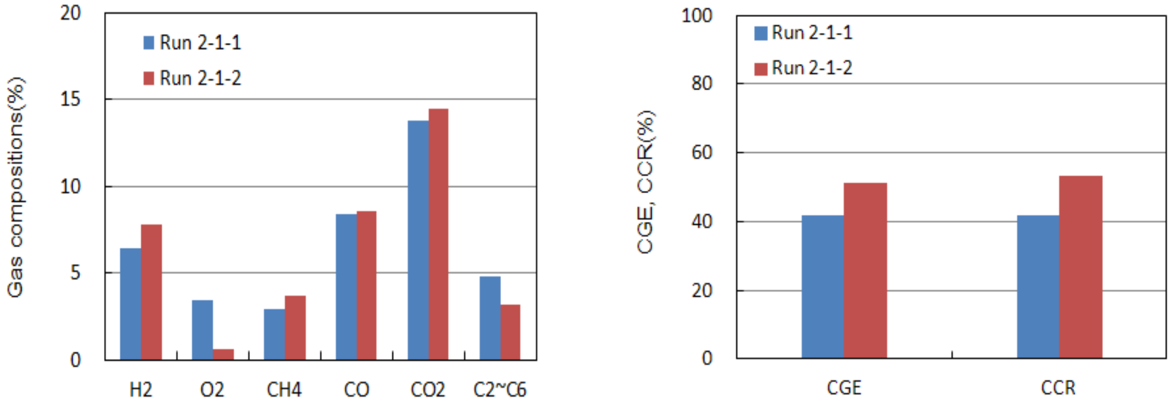
Table 1 shows the experimental conditions for multistage oxidizing agent and calcium oxide. Feeding rates of Run1, Run 2 and Run 3 are 2.87kg/h, 2.87kg/h and 2.78kg/h, respectively. Run 2 is multistage oxidizing agent gasification. Run 3 is used calcium oxide in the outer reactor to reform tar.

Table 1. Experimental conditions and results

		Unit	Run 2-1-1	Run 2-1-2	Run 2
Feeding rate		kg/h	2.87	2.87	2.78
Temperature	Top	℃	810	817	787
	Middle	℃	692	702	740
	Bottom	℃	400	564	468
Total Air/Fuel ratio(AFR)		-(%)	0.137(100)	0.190(100)	0.141(100)
1st stage oxidizing agent AFR		-(%)	0.137(100)	0.149(78.4)	0.141(100)
2nd stage oxidizing agent AFR		-(%)	-	0.011(6.0)	-
3rd stage oxidizing agent AFR		-(%)	-	0.030(15.6)	-
Calcium oxide		kg	-	-	8.83

RESULTS AND DISCUSSION

Effect on gasification characteristics by a multistage oxidizing agent



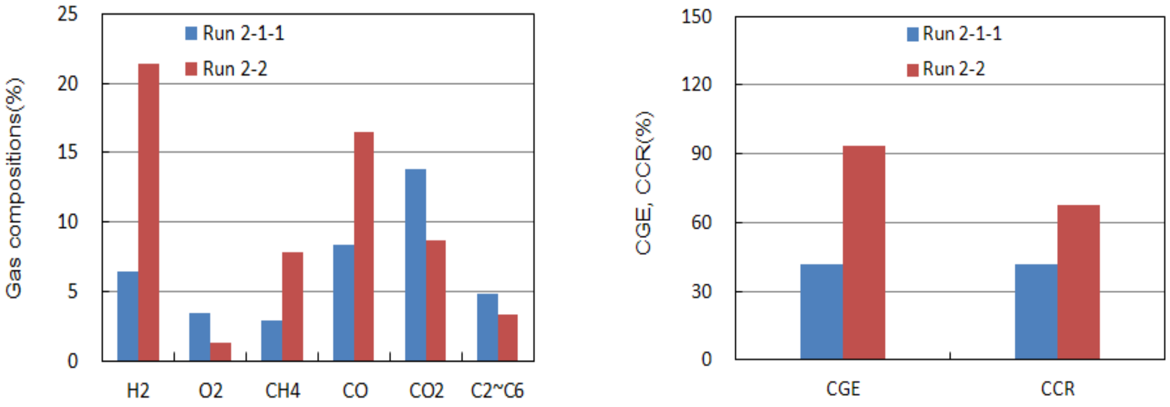
(a) Syngas composition (b) CGE and CCR

Figure 3. Effect on gasification characteristics by a multistage oxidizing agent

Figure 3 shows the effect on the gasification characteristics by a multistage oxidizing agent. In the case of multistage oxidizing agent gasification(Run 2-1-2), H_2, CH_4, CO concentration increased and C_2-C_6 concentration decreased, resulting in high cold gas efficiency(CGE) and high carbon conversion ratio(CCR) due to the tar cracking with 3rd stage oxidizing agent and the conversion of carbon and hydrogen in bottom ash to gas.

Effect on gasification characteristics by calcium oxide

Figure 4 shows the effect on the gasification characteristics by calcium oxide. In the case of gasification with calcium oxide (Run 2-2), H_2, CH_4, CO concentration dramatically increased and CO_2 and C_2-C_6 concentration decreased, resulting in very high CGE and CCR due to the adsorption of CO_2 and the steam reforming of tar by calcium oxide.



(a) Syngas composition (b) CGE and CCR

Figure 4. Effect on gasification characteristics by a calcium oxide

CONCLUSION

This study aimed to evaluate the multistage oxidizing agent gasification and the tar reforming with calcium oxide to increase cold gas efficiency and carbon conversion ratio and to reduce tar emission. In the case of multistage oxidizing agent gasification(Run 2-1-2), H_2, CH_4, CO concentration increased and C_2-C_6 concentration decreased, resulting in high cold gas efficiency(CGE) and high carbon conversion ratio(CCR) due to the tar cracking with 3rd stage oxidizing agent and the conversion of carbon and hydrogen in bottom ash to gas. In the case of gasification with calcium oxide (Run 2-2), H_2, CH_4, CO concentration dramatically increased and CO_2 and C_2-C_6 concentration decreased, resulting in very high CGE and CCR due to the adsorption of CO_2 and the steam reforming of tar by calcium oxide.

ACKNOWLEDGEMENT

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Electric Power Generation from Municipal Solid Waste in Yangon City, the Republic of the Union of Myanmar

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ABSTRACT

In Yangon City today, about 1,600 tons of municipal solid waste is generated daily, and the amount has been growing due to the rapid economic growth and population increase. Along with it, the search for new landfill sites is becoming more and more difficult. The city's governmental unit, Yangon City Development Committee (YCDC), well aware of the necessity of alternative solution to landfilling, decided to construct a model incineration plant. The bilateral greenhouse gas emission reduction cooperation scheme, Joint Credit Mechanism, between Myanmar and Japan is applied to this project.

Keywords: waste to energy, municipal solid waste, Joint Credit Mechanism, Yangon

INTRODUCTION

Since establishing its branch in Yangon City in 1995, JFE Engineering Corporation has been working in Myanmar with a state-owned enterprise in bridge construction and provided technical assistance in seven bridge construction projects.

From 2012 to 2014, we conducted a series of feasibility studies on waste incineration in Yangon city. During the studies, we investigated the city's waste management situation, from collection to final disposal, explained to the city officials the both financial and regulatory framework issues, and conducted workshops for both the YCDC officials and residents. After successfully getting the officials to understand the waste to energy technology and its reliability, we proposed a pilot project.

In Yangon City today, about 1,600 tons of municipal solid waste is generated daily, and the amount has been growing due to the rapid economic growth and population increase. Along with it, the search for the land for landfill is becoming more and more difficult.

While JFE was conducting the study, the city made its own efforts to solve the waste issue. The city implemented a tender of waste to energy project with an 800 ton/day capacity. A consortium was awarded first refusal right and negotiated, but the project has not been realized until today perhaps because of incomplete framework of the tender scheme, meaning that some critical conditions for project implementation might be missing, and the parties could not come to agreement. YCDC tried to separate waste into two kinds, wet and dry, distributed two types of garbage bags, and held educational programs. However, even though waste was collected separately, it ended up in the same place (i.e. landfill), so their effort needed more effective, schematic structure to be successful.

JFE'S PROPOSAL

While JFE was conducting the study, YCDC was facing urgent issue: two temporary landfills were about to become full. JFE's proposal was to construct a waste to energy plant to treat the 60 tons/day waste coming in to those two landfills. YCDC was very eager to realize our proposal, but the Pollution Control and Cleansing Department, the department to be responsible for the construction and operation of waste to energy plant, could not prepare necessary budget for the project. JFE's next proposal was for Myanmar to join the Joint Credit Mechanism (JCM), a bilateral cooperation scheme for greenhouse gas emission reduction initiated by Japanese government. The aim of our proposal was to obtain JCM subsidy from the Ministry of Environment, Japan that would cover up to 50% of construction cost. YCDC and the Ministry of Environmental Conservation and Forestry, Myanmar decided to start the talk with Japanese government.

After the talk started between two countries, Japanese government added Myanmar to the list of JCM subsidy applicable countries, and our application for the subsidy was granted. As a result, about a half of the construction cost would be covered by the subsidy, and YCDC would bear the rest.

PLANT SPECIFICATION AND PROCESS FLOW

Table 1: Plant Summary

Technology	Grate Furnace
Input	Municipal Solid Waste
Treatment Volume	60 tons/day
Electric Power Generation	700 kW
Operation	24 hours/day, 310 days/year
LHV	6,100 kJ/kg

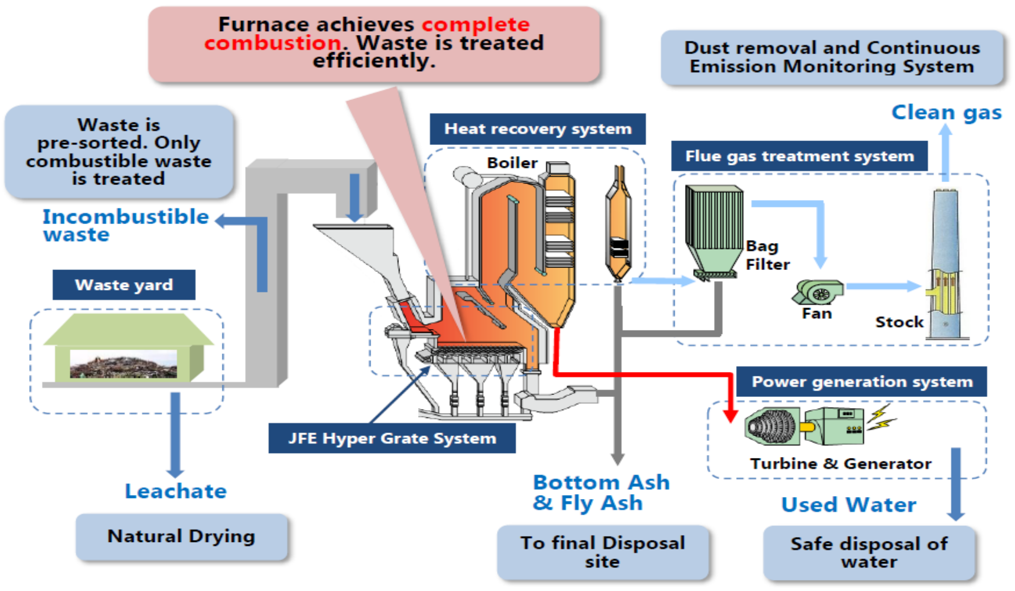

Figure 1: Process Flow

PROJECT CONCEPTS AND TOPICS

The project started in September 2015 and scheduled to finish construction in March 2017.

This project is a symbolic project in many aspects. It is the first waste to energy plant in Myanmar, the first JCM project in Myanmar, and the first waste to energy project in the JCM scheme.

Our concepts for this project are to make it best fit to the waste composition of Yangon City, to maximize efficiency and environmental friendliness, and to employ local contractor as much as possible.

GREENHOUSE GAS EMISSION REDUCTIONS

Greenhouse emission reductions of this project are expected to be 4,732 ton-CO_2e/year. Details of this amount are summarized in the table below.

Table 2: Emission Reductions Summary

Total GHG Emission Reductions	**4,732**
Reference Emissions	**12,198**
CH_4 Emissions from Landfill Site	8,032
CO_2 Emissions from Electricity Generation to be Replaced	4,166
Project Emissions	**7,466**
CO_2 Emissions from Waste Incineration	5,263
N_2O Emissions from Waste Incineration	395
CO_2 Emissions from Electricity Generation	1,786
CO_2 Emissions from Fossil Fuel Consumption	22

Unit: tCO_2e/year

CONCLUSION

This project is the first waste to energy project in Myanmar with treating 18,600 tons of MSW annually and the first JCM project in the Myanmar-Japan Joint Credit Mechanism with GHG emission reductions of 4,372 ton-CO_2e/year.

This is a first step for the improvement of waste management in Myanmar. This step may be small, but it is definitely a step that leads to next bigger steps. We, JFE Engineering Corporation, hope that waste to energy practice will spread throughout Myanmar.

ACKNOWLEDGEMENT

This project is partially subsidized by Ministry of the Environment, Japan.

Effects of torrefaction on fast pyrolysis characteristics of waste biomass

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ABSTRACT

In this work, the influence of torrefaction on the characteristics of bio-oil from fast pyrolysis is investigated. Torrefaction of Larix kaempferi sawdust was conducted in an auger type reactor. The torrefaction was performed varying reaction temperature such as 200, 220, 240, 260, 280, 300˚C. Also, the residence time was changed as 10, 30, 60 min. Then, the solid products produced by torrefaction were pyrolyzed to obtain bio-oil. The fast pyrolysis experiments were performed in a bubbling fluidized bed reactor at a temperature of 500˚C. To assess the effect of torrefaction on the quality of bio-oil, pyrolysis experiment was also conducted for raw Larix sawdust (untorrefied) at 500˚C. It was found that raw sawdust (54.6 wt. %) showed more oil yield than that of torrefied sawdust (53.5 wt. % for torrefied sawdust obtained at 220˚C). However, the torrefied sawdust showed high quality bio-oil such as increased HHV (4724 kcal/kg for torrefied sawdust obtained at 300˚C and 4329 kcal/kg for raw sawdust, respectively) and lower moisture content (19.86 wt.% for torrefied sawdust obtained at 300˚C and 28.06 wt. % for raw sawdust, respectively). This indicates that pretreatment of biomass by torrefaction significantly improves the quality of bio-oil.

Keywords: Bio-oil, Fast pyrolysis, Larix Sawdust, Torrefaction, Waste biomass

INTRODUCTION

The energy demand of the world is increasing but, the major energy sources such as fossil fuels make big problems such as air pollution and global warming. Hence, the world is focusing on renewable energy resources. There are various sources of renewable energy. Biomass is one of renewable energy sources. Biomass is considered as less influential in environment especially for global warming because it is carbon neutral fuel. However, the heating value of biomass is low and the moisture content of biomass is high. Hence, biomass needs some pretreatment process to increase its heating value and to decrease its moisture content. Biomass properties can be changed by torrefaction so that it can show better solid fuel qualities. Torrefaction reduces moisture and light volatile content of biomass; thereby increasing its fixed carbon content and HHV. Until now, the studies of torrefaction have mainly focused on the improvement of solid fuel quality. Hence, the torrefaction of biomass has carried out before combustion process. However, torrefied biomass can be converted to liquid or gas fuels through pyrolysis or gasification, respectively. But, the studies for fast pyrolysis of torrefied biomass are very rare. Hence, in this study, Larix sawdust was torrefied with various temperatures and residence time. Then, the torrefied sawdust was fast pyrolyzed to study the effects of torrefaction on the characteristics of bio-oil.

EXPERIMANTAL METHOD

Larix kaempferi sawdust was used for this study. Larix tree is the main tree species in South Korea. Sawdust of size 1-2mm was chosen for this study. Before torrefaction, samples were dried in a hot oven at 105℃ for 24 hr. An Auger type reactor was used for the torrefaction experiments. The schematic diagram of the torrefaction system is shown in Fig. 1. Experiments were done with varying temperatures such as 200, 220, 240, 260, 280 and 300℃. And the residence time was changed as 10, 30 and 60min.

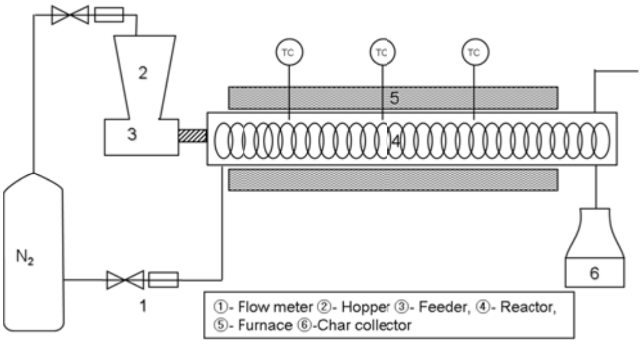

Fig 1. Schematic diagram of torrefaction apparatus

After torrefaction, torrefied sawdusts were fast pyrolyzed in a bubbling fluidized bed reactor. Fig.2 shows the schematic diagram of the fast pyrolysis system.

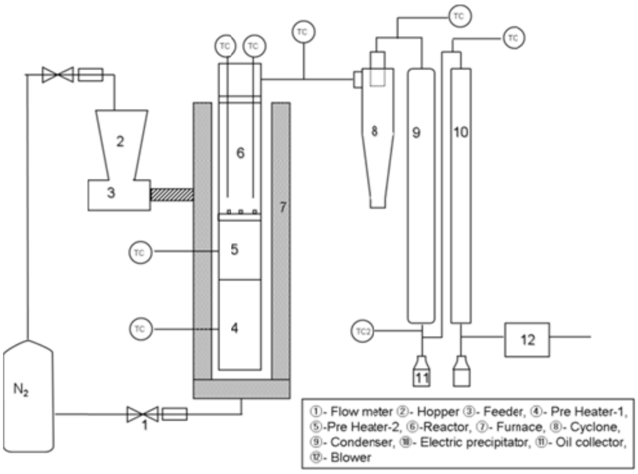

Fig 2. Schematic diagram of fast pyrolysis system

The pyrolysis experiments were performed at 500˚C. In torrefaction results, 30 minutes was the optimal residence time. Because the residence time of 10 minutes was not effective to fully torrefy sawdust. The residence time of 60 minutes reduced solid yield too much. In hence, the sample which torrefied with 30 minutes was selected for the pyrolysis samples.

RESULTS AND DISCUSSION

Properties (wt.%)					
Residence time	Temperature	Moisture	Volatile	Fixed carbon	Ash
30 minutes	200	1	85.41	12.91	0.71
	220	1.35	82.90	14.98	0.86
	240	1.48	82.34	15.78	0.83
	260	1.69	82.57	16.48	0.25
	280	1.93	76.83	21.08	0.76
	300	2.63	62.76	33.79	0.75
*Raw sawdust		3.19	78.58	17.09	1.15

Table 1. Proximate analysis of torrefied at 30 min sawdust

Table 1 showed proximate analysis of torrefied sawdust. Moisture content of torrefied sawdust was decreased less than 3 wt. %. Volatile content of torrefied sawdust decreased with increasing temperature. Especially, above 280℃, volatile content decreased significantly. The fixed carbon content of torrefied sawdust increased with increasing temperature. Especially, the maximum fixed carbon content was 33.79 wt. % at 300℃. This amount is almost twice as large as raw sawdust (3.19 wt. %). In case of ash, all of torrefied sawdust had less than ash content of raw sawdust (1.15 wt.%).

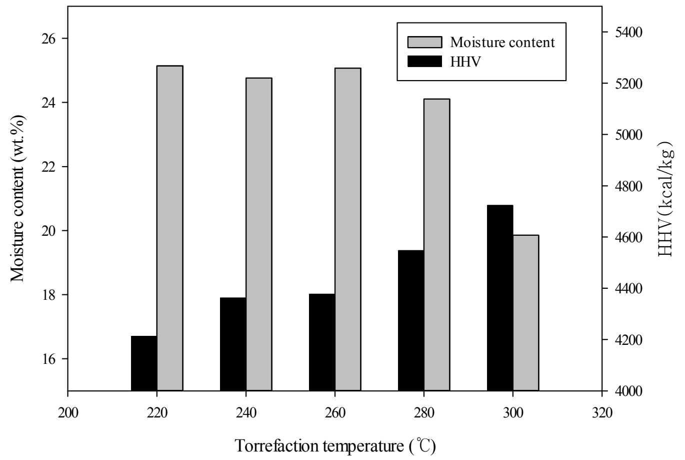

Fig 3. High heating value and moisture content of bio-oil

Fig. 3 shows HHV and moisture content of the bio-oil. In the pyrolysis experiments, the raw sawdust showed the lowest HHV bio-oil (4329.35kcal/kg). The highest HHV of bio-oil was obtained for torrefied sawdust obtained at 300˚C (4724.31kcal/kg). Similarly, the raw sawdust produced bio-oil that had the highest moisture content of 28.06 wt. %. On the other hand, torrefied sawdust obtained at

300˚C produced bio-oil with lowest moisture content (19.86wt. %). Considering fuel quality, high heating value and lower moisture content are important. From the results the fuel characteristics of bio-oil can be greatly improved by pretreatment of biomass using torrefaction.

CONCLUSION

In this work, the influence of torrefaction on the characteristics of bio-oil from fast pyrolysis was investigated. Prior to fast pyrolysis, torrefaction experiments were performed varying temperatures of from 200 to 300˚C and residence time of 10, 30 and 60 min. After then, torrefied samples were pyrolyzed at 500˚C.

- From the fast pyrolysis results, the raw sawdust (54.6 wt. %) showed more oil yield than all of torrefied sawdust bio-oil. Torrefaction decreased bio-oil yield on pyrolysis process. Minimum bio-oil yield was 42.17 wt. % for torrefied sawdust obtained at 300 ˚C.
- The HHV of bio-oil is greatly improved with increasing torrefaction temperature. (4724 kcal/kg for torrefied sawdust obtained at 300˚C compared with 4329 kcal/kg for raw sawdust)
- Also, bio-oil of torrefied sawdust had low moisture content (19.86 wt. % for torrefied sawdust obtained at 300˚C compared with 28.06 wt. % for raw sawdust).
- Hence, torrefied sawdust at 300˚C generated the highest quality bio-oil (HHV 4,724 kcal/kg and moisture content 19.86 wt. %). It can be concluded that pretreatment of biomass by torrefaction considerably improves the quality of bio-oil obtained through fast pyrolysis.

ACKNOWLEDGEMENT

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Session 3

3R Policy

Economic Conditions for Recycling of Waste

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ABSTRACT

If individuals or establishments make a decision in favor of recycling, it only happens if it is beneficial for them. A strict ban on landfill of organic waste promotes recycling. We need smart regulations for end-of-life products ensuring individual economic benefits.

Keywords: Recovery paths, recycling quotas, economic actions, decision-making autonomy

INTRODUCTION

In the lecture, the economic conditions for the recycling of waste should be worked out. It shows that recycling is an optional choice among various alternatives. A regulatory framework (whether law or ordinance) can indeed limit the possible alternatives, but ultimately not prevent the pursuit of economic benefit. Thus the further development of recycling requires a smart regulation so that increasing opportunities to make a profit with recycling activities can be linked to the general social desire for more recycling.

STATEMENTS AND EMPIRICAL DATA

First of all, the term "Economies" will be presented. Shortage-induced decisions are subject to an economic benefit – for an individual or an establishment) in accordance with the opportunity principle. It appears essential to note that shortage is not equated with lack of or even poverty, but its aim is to think about alternatives when making decisions. Any real action has simultaneously the effect that other possible alternatives will not be implemented. The benefit, (qualitatively or quantitatively), is crucial for the decision made by the economies.

The effective regulation of alternative actions is the market, which coordinates the individual plans of business entities. The benefits of market coordination only unfold if certain requirements are met. These considerations can be summarized by asking the question, whether the market conditions relating to pricing and liability promote or hinder recycling.

The second part shows that recycling is not an objective, but an instrument - so to speak an alternative among several options for action -. This is explained by using linked production as an example. Overall, six possible alternatives are derived and evaluated as to its importance for the individual benefit. The alternatives are derived by deduction (from general to particular) and show all theoretical possibilities.

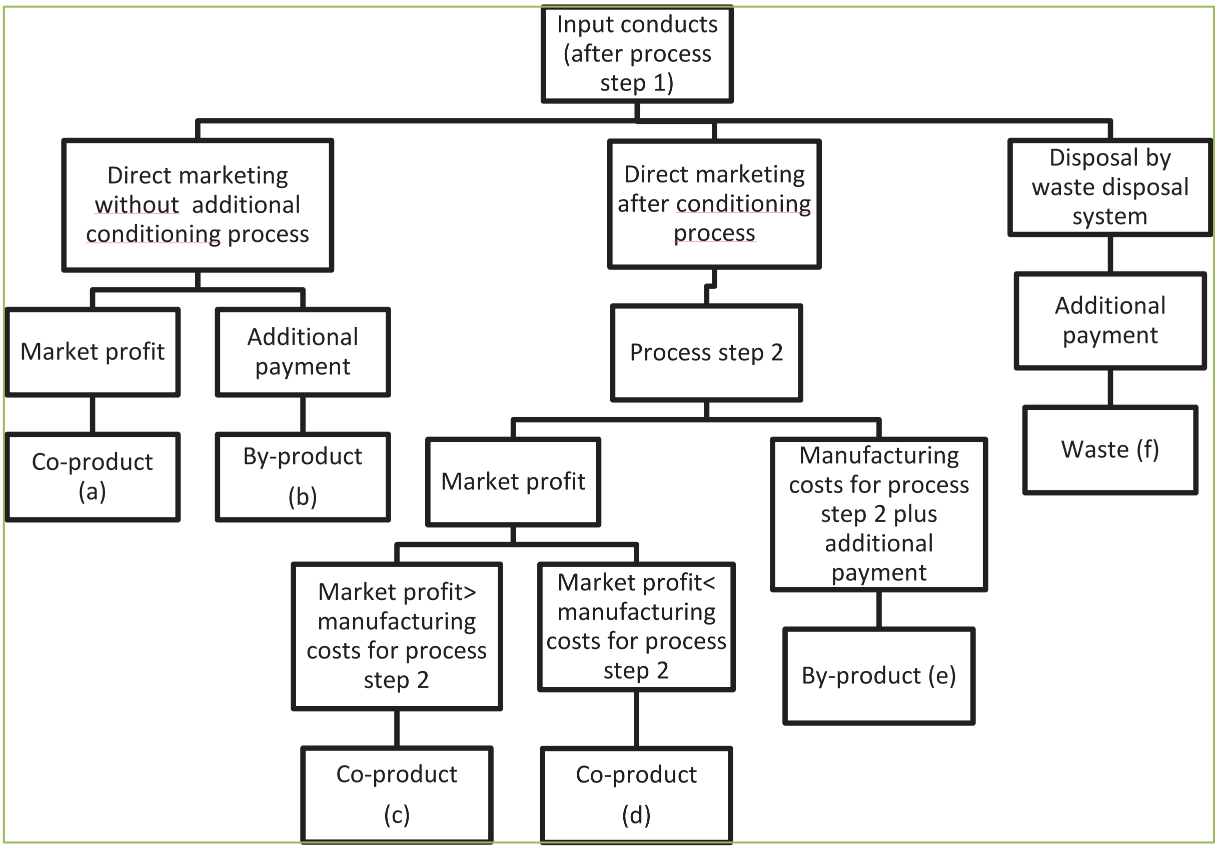


Figure 1 Possibilities for use of residues of a linked production

The results obtained are confronted with the real waste disposal practices in the EU countries. As a result, there is the empirical confirmation of the theoretically derived relationship. Thus, just about all those EU countries with a high proportion of dumping their waste show the lowest recycling rates.

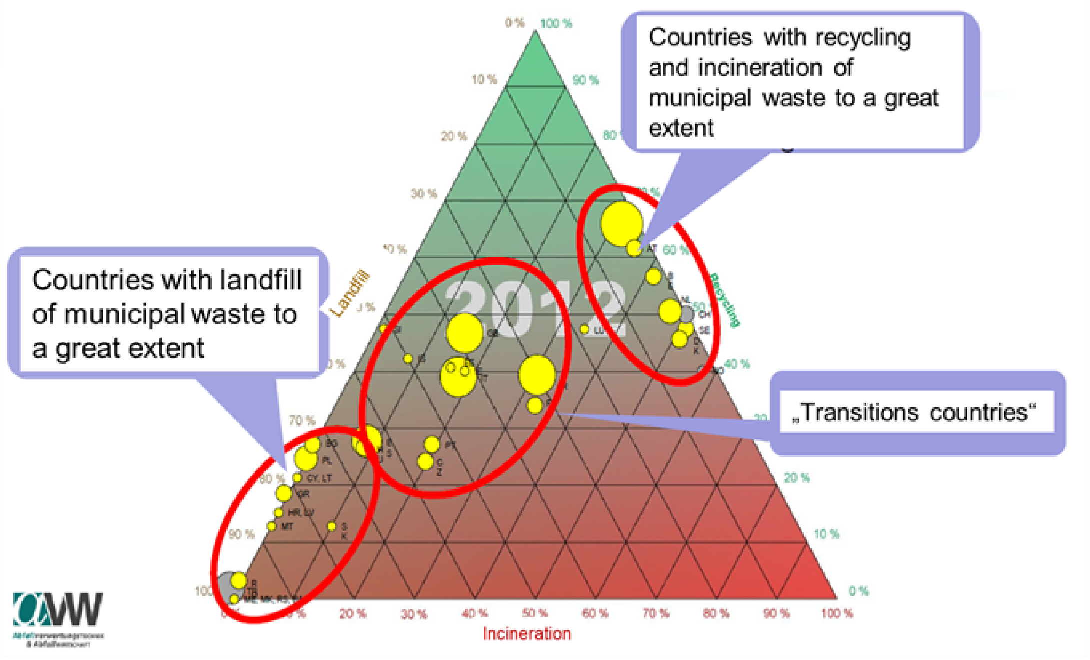


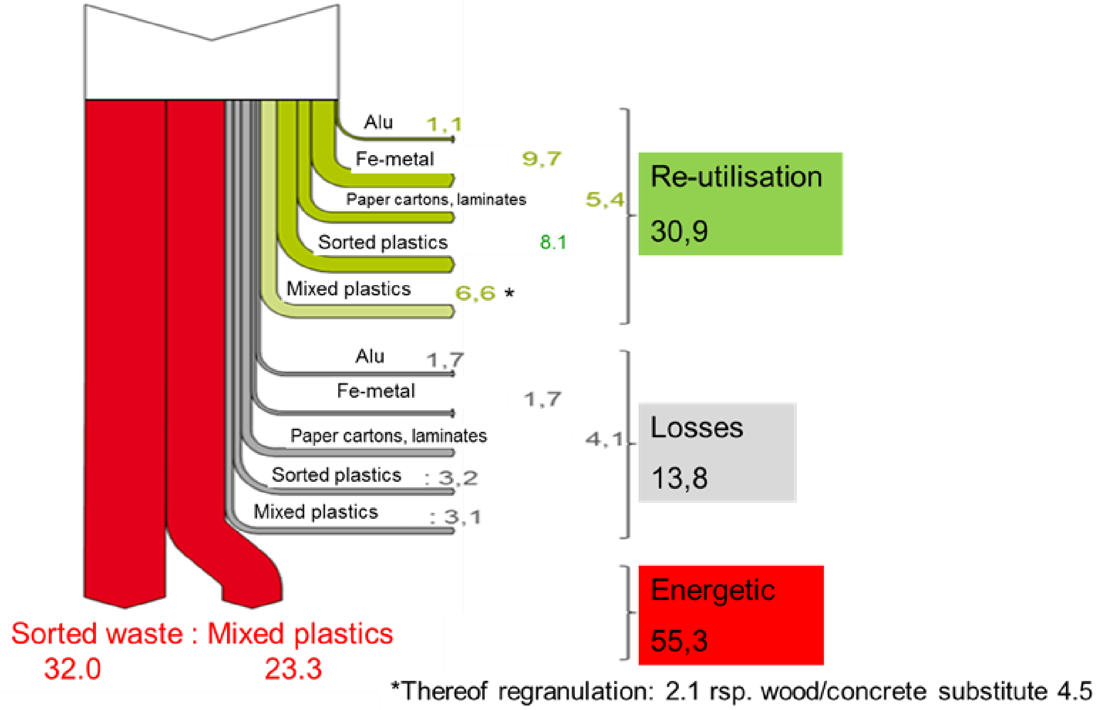
Figure 2 Triangle of Incineration, Landfill and Recycling in EU-Countries (Pomberger, 2014)

In this respect the planned EU recycling management package must work towards a mandatory landfill ban.

On the other hand, the waste management tending to sinking prices impedes the recycling option. Possible solutions are presented in order to further promote recycling.

In the last part, the focus will be on "end of life products". Particular emphasis is laid on the disposal of packaging waste. The escalation taking place with this trend is particularly based on the fact that here it is demonstrated in an impressive exemplary manner that a wrong incentive structure due to a legal framework will cause exactly the opposite of what was actually intended.

Contrary to artificially high recycling rates, the material reuse quotas are "manageable".



*Thereof regranulation: 2.1 rsp. wood/concrete substitute 4.5

Figure 3 Real re-utilisation rate of light packaging (%) in Germany (Baum et al., 2014)

The fixation of quotas, however, does not consider the necessary qualitative aspects. Reuse options, which cause a demand for a surcharge on behalf of the buyer, are considered as recovered. To set up a sustainable waste management, secondary raw materials must at least partially substitute the primary raw materials. This requires, however, that secondary raw materials must have a positive market value. The empirical data presented reflect the situation in Austria and Germany.

CONCLUSION

Recycling is an option but not an objective. The official recycling quotas of lightweight packaging are quantitatively – especially considering the official determination method - correct, but factually incorrect. The real rate of re-utilisation is by far lower. If you wish to increase the extent of recycling, the social requirement and the economic benefit have to be balanced.

The summary also takes a look at a possible future by mentioning innovative recycling instruments.

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Recycling of Plastic Packaging Waste: Lessons for Indonesia from Japanese Knowledge and Practice

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ABSTRACT

To create a better packaging waste management system, Indonesia established several regulations that require producers to manage their post-consumer packaging waste. However, to date there is no established formal packaging waste management system to support these regulations. We analyzed the experiences in Japan, which has practiced packaging waste recycling since 1997, to draw lessons for improvement in Indonesia. We also discuss the experiences of several other countries for reference. Based on lessons from these countries, Indonesia first needs to define specific criteria under which businesses must conduct their recycling. Second, it needs to enforce the practice of waste sorting by consumers rather than relying on the existing sorting that occurs in informal sectors. Finally, the country needs to fuse the existing informal sector with formal recycling initiatives and establish a national strategy for recycling management.

Keywords: Recycling, plastic packaging, Indonesia, Japan

INTRODUCTION

Plastic, a commonly used packaging material, makes up 11% of all waste in Jakarta (Jakarta Sanitation Department, 2011). This amount is predicted to increase due to changes in lifestyles, and living standards that tend to consume more packaged products (Dhokhikah and Trihadiningrum, 2012). Facing this challenge, Indonesia has initiated efforts towards better management of plastic packaging waste (PPW). The requirements for producers to manage post-consumer PPW are mentioned in Law No. 18/2008 and Government Regulation No. 81/2012. Indonesia has also set a target of zero waste by 2020. However, to date there is no established formal system regarding management of PPW. In contrast, Japan implemented a container and packaging recycling law in 1997. Currently, 75.3% of municipalities in Japan conduct PPW sorting (MOE, 2015). Managed by the Japan Containers and Packaging Recycling Association (JCPRA), the system involves consumers, municipalities, recyclers, and business entities. To help Indonesia move forward in this domain, we discuss the lessons that can be learned from the Japanese experience and suggest possible improvements for Indonesia's waste management system.

MATERIALS AND METHODS

Definition of 'plastic packaging waste' used in this study refers to Japan Containers and Packaging Law, which is 'containers or wrapping made mainly of plastic excluding PET bottles'. We conducted our study of the Japanese experience by reviewing the literature, visiting recycling plants, and interviewing stakeholders. Site visits took place at the Ukishima waste recovery facility in Kawasaki, at a mechanical recycling plant in

Saitama, at a gasification plant in Kawasaki, and at a coke oven plant in Chiba. We conducted our study of Indonesia's existing conditions by reviewing the literature published in both English and in Bahasa. We did not explicitly compare the recycling conditions in Japan and Indonesia, but rather we discuss several Japanese practices that can be used to improve PPW management in Indonesia. To support this goal, we also review and discuss several practices from other countries.

RESULTS AND DISCUSSION

Basic Legal System

The Containers and Packaging Recycling Law is the basic law for packaging recycling in Japan. It was established in 1995 and enacted in 1997, targeting four types of packaging waste including PET bottles, glass bottles, paper packaging, and plastic packaging. Based on guidelines drafted by the Ministry of the Economy, Trade, and Industry (METI) (2003), subjects that are obligated to recycle include business entities that: (1) use containers, packaging, or wrapping in the manufacture of merchandise; (2) manufacture containers or packaging; (3) sell containers, packaging, or wrapping through retail or wholesale businesses; and (4) import and sell containers or merchandise in containers or packaging or wrapping. Exceptions apply to small-scale manufacturing businesses with fewer than 20 employees and sales less than 240 million Yen and to small-scale retailers with fewer than 5 employees and sales less than 70 million Yen. Business entities must pay JCPRA a recycling fee or obtain a permit to create contracts with recyclers independently.

Indonesia, on the other hand, has not yet established specific packaging recycling laws. However, there are several laws that mention the intention to manage packaging waste. For example, Law No. 18/2008 notes that producers should be responsible for the packaging of products that do not easily decompose through natural processes. In the Ministry of Environment Regulation No. 13 Year 2012, the law notes an expectation that the 3R effort through Waste Bank, a place for a community to sort and collect recyclable waste that have economic values, will be integrated with extended producer responsibility practice. Furthermore, in Government Regulation No. 81/2012, producers are required to carry out waste reduction and waste recycling. Producers required to recycle include those that: (1) produce goods with packaging; (2) distribute goods with packaging as well as import packaging; or (3) sell goods with containers that will either never degrade or will take an extended period of time to degrade by natural processes.

Experience from the Japanese legal system suggests there is a need for Indonesia to: (1) define packaging and which types of packaging must be recycled; (2) specify the scale of businesses required to recycle; and (3) establish a system for business entities to recycle with financial and technical guidelines.

Waste Handling and Recycling

In Japan, municipalities are responsible for municipal solid waste management at their jurisdiction based on the national regulatory framework, and they generally have local rule for citizens how to sort municipal solid waste including PPW. Currently, 75.3% of Japan municipalities sort PPW (MOE, 2015). The Japan Ministry of the Environment established three schemes to manage PPW: a self-collection scheme, a designated corporate scheme, and an independent scheme (Tasaki, 2008). In Kawasaki, under the designated corporate scheme, PPW is sorted by consumers and collected every Wednesday by municipalities. Then the PPW is picked up by recyclers from recovery facilities and transported to recycling plants.

As for recycling technologies, the Recycling Act has only approved mechanical and chemical recycling. Energy recovery is only approved for refuse-derived fuels or for PPW recycling in special cases, such as when the amount of PPW collected exceeds the recycling capacity (Tasaki, 2008). In Chiba, some companies use PPW as feedstock to supplement coal in coke ovens, with a plastic to coal ratio of 1:4. In Kawasaki, one chemical company gasifies 195 tons/day of PPW to produce 175 tons/day of ammonia. One particular mechanical recycler in Saitama converts 50% of the PPW into pellets of polyethylene (30%), polystyrene (5%), and polypropylene (15%), while the remaining 50% is sent to another recycler to be used as refuse plastic and paper fuel.

In contrast, Indonesia has no requirements to sort PPW specifically. Waste sorting for recyclable waste is required by Government Regulation No. 81/2012, yet in practice most wastes are mixed. However, there is an informal sector in Indonesia that plays an important role in waste sorting and waste recycling. Scavengers and junkmen collect valuable PPW at sources, collection points, transfer depots, or final disposal sites. Then they sell the PPW to intermediates who sort, clean, and resell it to dealers who crush it into small pieces and/or pelletize it before selling the material to recycling facilities (Chaerul et al., 2013).

The most common technology used to recycle plastic in Indonesia is mechanical recycling, which consists of shredding, washing, drying, and pelletizing (Sahwan et al., 2005). To the best of our knowledge, there is currently no plastic chemical recycling for household waste in Indonesia. This is most likely because, while technically feasible, chemical or feedstock recycling is generally economically unfeasible without significant subsidies. This is because of the low price of petrochemical feedstock compared to the plant and process costs incurred when producing monomers from waste plastic (Patel et al., 2000). Chemical recycling is economically challenging even in developed countries such as Japan and Germany, and some companies have been forced to withdraw from the practice while other plants have closed down (PWMI, 2013; Aguado et al., 2007).

Another significant reason why mechanical recycling dominates is because the plastic pelletizing industry, which involves informal sectors, has very strong networks. In fact, in many cases, this industry has not only survived but grown during weak economic circumstances (Damanhuri and Padmi, 2012). A study in Cambodia, India, and the Philippines noted that in developing countries that have informal sectors, calorie-rich waste such as plastic is the basis for the informal recycling sector's livelihood. For this reason, the sector stands to lose its livelihood if countries promote technologies such as incineration and gasification that require calorie-rich waste (Chintan, 2005).

Based on the lessons learned from PPW handling in Japan as well as the experiences of other countries, we have three main suggestions for Indonesia: (1) legal enforcement of waste sorting for consumers; (2) an evaluation of current and future potential recycling schemes (collection, transportation, and technology), which takes into account economic, environmental, and social aspects; and (3) the establishment of a national strategy for waste management where the informal sector and formal recycling initiatives are fused.

CONCLUSION

To establish an improved PPW management system, Indonesia first needs to define specific criteria and system for business entities to conduct recycling. Second, the country needs to enforce the practice of waste sorting by consumers, and to end its reliance on sorting done by informal sectors. Third, unlike Japan (which has no informal sector), Indonesia needs to take into account the existing informal sector in its recycling practices. It is necessary to evaluate recycling schemes and ensure that they consider economic, environmental, and social aspects to create a national strategy where formal recycling initiatives are fused with the informal sector.

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The Effect of Trash Bin Design and Trash Bin Setting Condition on Cap Removal and Other Waste Incorporation

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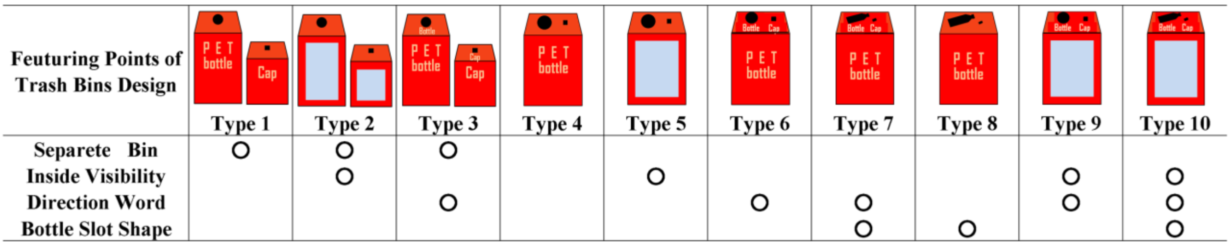
ABSTRACT

PET bottle recycling industry in Japan faces a difficulty to collect enough amounts of PET bottles for their activity. Half of collected PET bottles are exported to other countries because the quality of collected PET bottles is bad and usually requires further manual purification. It is necessary to improve the quality of collected PET bottles for domestic circulation of PET bottles as recyclable resource. Cap removal is helpful to improve PET bottle collection efficiency and wash bottles after collection process. In this context, we focused on the design of trash bin which encouraged people to do recycle-friendly actions like cap removal. It was investigated whether trash bin design could promote cap removal action and reduce the mixed contaminants. 10 types of trash bin designs featuring 4 design points were investigated; 1) separate type bin vs. single type bin, 2) inside visible vs. inside invisible, 3) direction word vs. no word, 4) round shape slot vs. bottle shape slot. In addition, trash bin setting condition, which was stand-alone or stand with other trash bins, was also considered when the impact on cap removal and other waste incorporation was analyzed. Designed trash bins were made and set in the Suzukakedai-Campus in Tokyo Institute of Technology. Experimental results suggest that setting trash bins with other trash bins is effective to encourage cap removal action and reduce mixed contaminants. It was also found that single type bin and direction word also seem to be helpful.

Keywords: PET bottle, Cap Removal Action, Trash Bin Design, Contaminants

INTRODUCTION

Many municipalities in Japan started to collect recyclable wastes since 1980’s due to the tight capacity of landfill sites. The low regarding the recycle of plastic containers and packaging was legislated. Among those plastic containers and packaging, this study focused on PET bottle. Because PET bottle is widely available in significant quantity, and made from single material which helps material recycle. Recently, however, there are difficulties to collect enough amounts of PET bottles for recycle and keep good quality of collected PET bottles. If cap is removed from PET bottles, it makes PET bottles compactable and thus helpful to increase PET bottle collection efficiency. In addition, it makes washing process easy after PET bottle collection process. Although many PET bottles are collected by trash bin in home and public spaces, the design of trash bin and its impact on PET bottle collection has been uncertain. Therefore, this study aims to investigate the effect of trash bin design and trash bin setting conditions on cap removal action and other waste incorporation.



Feuturing Points of Trash Bins Design	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10
Separete Bin	○	○	○							
Inside Visibility		○			○				○	○
Direction Word			○			○	○		○	○
Bottle Slot Shape							○	○		○

Figure 1. 4 featuring points of trash bins design

MATERIALS AND METHODS

Trash Bins design evaluated in this study

10 types of trash bins were designed to find the relation between trash bin design and cap removal action. Each design can be categorized to 4 featuring points; 1) single trash bin for bottle and cap collection or separate trash bin only for caps or bottles, 2) inside visibility, 3) direction word near disposal slot, and 4) disposal slot shape (see Figure 1).

Setting conditions of trash bins

On-site experiment was conducted in Suzukakedai-campus, Tokyo Institute of Technology over 36-month period since June 2013. 2 high-traffic sites in two major buildings were chosen as the experimental site. Designed trash bins were placed beside other trash bins for combustible waste, incombustible waste and can/bin/glass in Site 1 (“stand-with-others” condition). There were also a vending machines and a bench near trash bins. On the other hand, designed trash bins were placed alone in Site 2 (“stand-alone” condition).

Collection experiment

The number of PET bottles with/without caps disposed into trash bins was counted and recorded. In addition, the number of contaminants other than PET bottle was also counted. This data collection was conducted by first author on the day of small hours of the morning when trash bin is full of its contents, to minimize interaction between campus users and the data collector. Cap removal ratio and contaminants ratio were calculated to evaluate the impact of each featuring design point. The number of collected PET bottles without cap divided by the total number of collected PET bottles was defined as the cap removal ratio. In addition, the number of mixed contaminants into trash bins divided by the total number of collected PET bottles was defined as the contaminants ratio.

Analysis methods

Paired t-test was used to investigate the effect of each featuring design point on cap removal ratio and contaminants ratio. In addition, chi-square test was used to confirm a statistically significant relation between trash bin types and cap removal action. Furthermore, cluster analysis was also conducted to classify the results from a view point of both cap removal ratio and contaminants ratio. The Ward method determined a distance as an index of similarity for cluster analysis. Each test considered setting conditions of trash bin.

RESULTS AND DISCUSSION

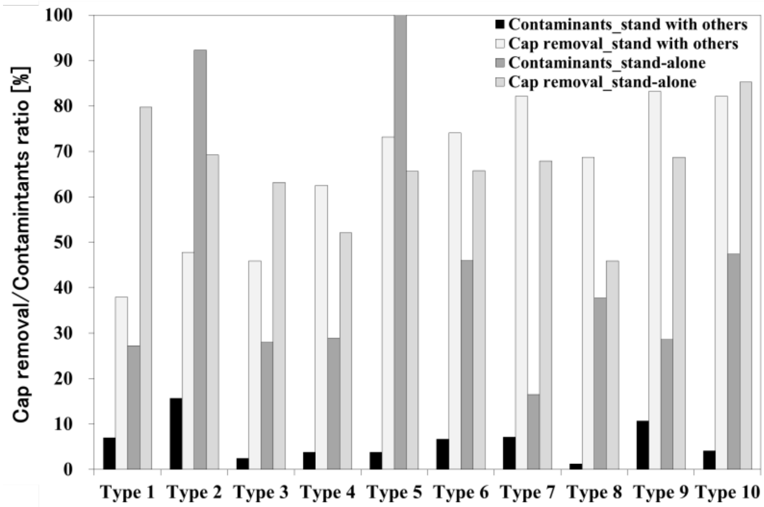


Figure 2. Cap removal ratios and contaminants ratios of 10 designed trash bins under two types of trash bin setting conditions

Cap removal ratio and contaminants ratio of all design types under both “stand-with-others” and “stand-alone” conditions are summarized in Figure 2. In regard to the cap removal ratio, separate trash bin (type 1, 2 and 3) showed higher ratio than single trash bin (type 4 to 9) under the “stand-alone” condition except for Type 10. In contrast, under the “stand-with-others” condition, cap removal ratio of separate trash bin was lower than that of single type bin. Figure 2 indicates obvious differences of cap removal ratio and contaminants ratio between “stand-alone” and “stand-with-others” condition. All design types have very small values of contaminant ratio under the “stand-with-others” condition. This dramatic decrease of mixed contaminants was readily confirmed during collection experiment.

Single type trash bin increased the average of cap removal ratio by 26% and paired t-test suggested this increase as significant at 1% significance level (t = 23.4, 2 degrees of freedom, p < .01). Direction word also increase cap removal ratio by 11% (t = 9.2, 3 degrees of freedom, p < .01) under the “stand-with-others” condition. On the other hand, inside visibility increased cap removal ratio slightly but the difference was not regarded as significant even at 10 % significance level. The difference of disposal slot shape also showed no significant difference of cap removal ratio. As for the contaminants ratio, only the difference of setting conditions indicated significant increase (41%) at 1% significant level (t = 3.9, 9 degrees of freedom, p < .01).

Chi-square test suggests non-negligible impact of trash bin designs on cap removal ratio under both the “stand-with-others” condition ($\chi^2 = 140.9$, 9 degrees of freedom, p < .01) and “stand-alone” condition ($\chi^2 = 74.5$, 9 degrees of freedom, p < .01). Chi-square test suggests that cap removal ratio cannot be regarded as independent from trash bin designs. More or less, cap removal action of people is affected by trash bin design. In order to compare impacts of trash bin design and setting conditions on cap removal ratio and contaminants ratio, cluster analysis was conducted.

Figure 3 shows the results of cluster analysis. 4 clusters were formed. Cluster 4 was classified the most different from other clusters (average cap removal ratio: 67.4%, average contaminants ratio: 102.8%). Trash bins of cluster 4 collected so much contaminants due to their inside visibility under the “stand-alone” setting condition. Trash bins with inside visibility illustrated in figure 2, especially Type 2 and 5, also showed high contaminants ratio. Once other wastes are disposed to trash bins for PET bottles, it seems to discourage people to pay attentions to separate PET bottles and other wastes. It promotes other waste incorporation and negative spiral to invite more contaminants might start. These findings are consistent with those of Cialdini

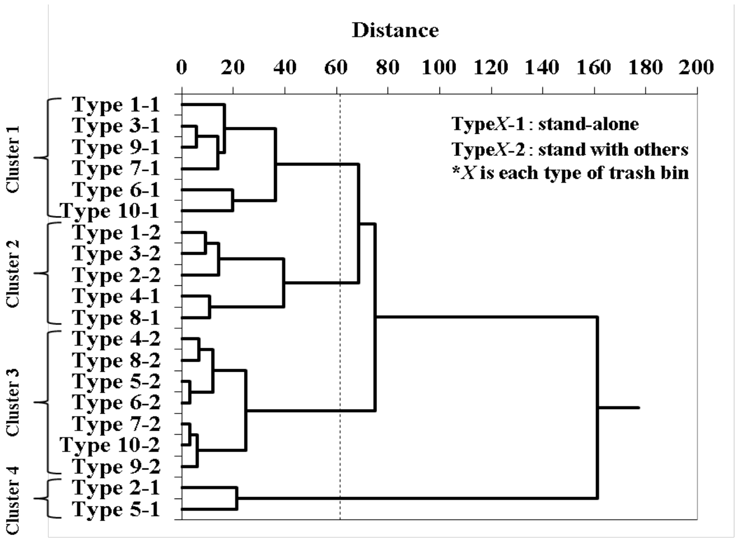


Figure 3. Dendrogram of trash bin design

et al. (1990). Cluster 3 consisted of single trash bins under the "stand-with-others" setting condition. Trash bins of cluster 3 indicated preferable results from a viewpoint of both cap removal ratio and contaminants ratio (cap removal: 75.1%, contaminants: 5.3%). This result was consistent to the results of paired t-test. This consistency indicated that installing recycling bins with other trash bins likely increased awareness of people to segregate waste. Cluster 2 consisted of trash bins showing low cap removal ratio (cap removal: 45.9%, contaminants: 18.4%). It seemed that separate-type bin and no direction word affected forming cluster 2. An importance of information like trash bin location and segregation rule, known as direction word in this paper, was reported in previous work (Austin J., Hatfield, B D. et al., 1993). Cluster 1, composed from trash bins set under the "stand-alone" condition, indicated lower indices compared to cluster 3 (cap removal: 71.8%, contaminants: 32.3%). A comparison of indices between cluster 1 and 3 emphasized that the difference of setting condition particularly contributed to a great impact on waste disposal behaviors of people.

CONCLUSION

To investigate the effect of trash bin design and its setting condition, 10 types of trash bins were designed and tested. Experimental results suggest that setting with other trash bins has the great impact on PET bottle disposal with increasing cap removal action and reducing mixed contaminants. It was also found that single type bin and direction word might be helpful, but disposal slot shape is not effective. Inside visibility activated other waste incorporation.

ACKNOWLEDGEMENT

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Organic solvents waste management priority substance and contents characteristics in S.Korea

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ABSTRACT

This study was carried out to improve the management scheme of spent solvents generated in the industrial facilities. In the first year, the research was focused on the generation processes of spent solvents, generation amounts and treatment methods of spent solvents in the industry facilities. According to the Allbaro System of specific wastes in 2013, Total amounts of solvent was 1,028,139 ton which was the 21.8% of generation amount of specific wastes. Among them, the amount of non-halogenated spent solvents was 1,010,285 ton(98.2%) and that of halogenated spent solvents was 17,854 ton(1.8%).

Spent solvents were mainly generated in nineteen manufacture industries. Generation amounts of spent solvents in manufacturing industry were charged such as electronic components, radio, television and communication equipment (28.3%), chemicals and chemical products(27.8%), textiles(9.6%), rubber and plastic products(7.5%). Seventeen halogenated spent solvents such as dichloromethane are prescribed in the Waste Management Act of Korea.

Keywords: waste solvent, non-halogen organic solvent, waste management, hazardous characteristics

INTRODUCTION

Many types of chemicals used in the current Earth. In an organic solvent dyes, pigments, agrochemicals, drugs, petrochemicals. A chemical substance such as a basic raw material or an intermediate for preparing Food and Drug Use or manufacturing, electronic components and audio-visual barrel Height ratio manufacturers, other machinery and equipment manufacturing, etc.[1] The Cleaning Solvent at various sites, extract the active ingredient, in the production process. It has been used for cleaning of degreasing, devices and components.

Thus an organic solvent is kept increasing amount of waste organic solvents, since large amounts for various purposes in various industrial fields. For the treatment and management of waste oil problem in developed countries appointed agent. One interest is increasing significantly.[2]

Total amount of waste organic solvents have appointed my country, accounting for 21.8% of the total waste volume, specify one thousand tons in 2013. And this amount increases each year.

Waste organic solvents are toxic, flammable, explosive, high reactivity when directly exposed to the environment, to give a serious human health and even greater impact on the ecosystem. Especially halogen spent solvent so that when the low temperature incineration is highly toxic organic chlorine compounds such as dioxin is generated in the "Waste Management Law" stipulates that a high-temperature incineration

this study rational management and a source to raise the processing method used in the waste organic solvents centered status and emissions of waste organic solvents were investigated with respect to the processing type of source, identify sources with a focus on emissions establishments sampling and surveys were conducted for 80 sites for the 19 industries. By analyzing the survey results derive any problems and can be clearly distinguished than the waste organic solvents from waste organic solvent emissions establishments and processing companies the revised plan by management system and process technology and comparative analysis of foreign hence, environmentally safe studies were reviewed to focus on matters need to improve the criteria for classification so that it can be processed understanding the mechanisms.[3,4]

MATERIALS AND METHODS

- **The organic solvent usage in domestic**

To understand the domestic waste organic solvent usage PRTR (Pollutant Release and Transfer Registers) Information System data were used.

- **Emission and Treatment of spent solvents**

Review the "generation 2012 designated waste and Treatment" statistical data created in each local Environment Agency and ensure a 2013 waste organic solvents discharged business data to assess the status of process of waste organic solvents, classified according to the Korea Standard Industrial Classification Code one sector was the amount of waste organic solvents to clean.

- **Other than domestic waste organic solvents Management**

Including the country the United States, Japan and European Union (EU), Related to the waste management of waste-related provisions of the first machine, such as OECD. The regulations and the cleanup was collected.

- **Other domestic waste organic solvents analysis**

Test method of waste processing in Korea, the US EPA 8260B And an organic solvent such as Japan JIS method of analysis were summarized.[5]

- **Waste organic solvents in the workplace Emission Survey**

By the Korea Industrial Classification Code in 36 of the classification by sector using organic solvents ‘13 Year Status emissions by businesses as a reference, this amount was used in an organic solvent selected 29 industries in many order and amount of waste organic solvents these sectors accounted for 99.9% of the total emissions.

RESULTS AND DISCUSSION

Select the managed priority substance entry(First consideration when selecting a managed entity)

Table 2 shows considerations for preference managed entries. 1) Check whether to include management of domestic laws and other items, and 2) the domestic industry handling materials, measuring, amount rank 3) Domestic Substances by discharge, transfer amount rank 4) domestic organic solvents production Rank 5) in August 1999 closing amendment management items of around 43 kinds of non-halogenated organic solvents by first considering a managed entries, etc.

Table 1. Domestic and foreign spent solvents management system

Division	S.Korea	Japan	USA	EU
Law	Waste Management Act	Act on the treatment and cleaning of waste	Resource conservation and reproduction Law(RCRA)	Waste framework directive (Directive 2008/98/EC)
Designation	Designated Waste	Special management industrial waste	Hazardous waste	Hazardous waste
Classification and Type	17 halogen by weight more than 5% impurities and substances	Waste Oil (Waste organic solvents, 12 substances)	11 substances of halogen	EWC code 14(waste organic solvents)
	Other waste organic solvents		19 substances of non-halogenated	

<Table 2> Considerations for preference managed entries

번호	Considerations	Resources
1	Modified in accordance with domestic law revision Manage list	Waste Management Act and Act amendment
2	Foreign regulations Managed	Foreign laws
3	Organic solvents into the lungs caused by substances	Chemical emissions disclosure system
4	Waste material-specific recycling machine first and Treatment	Specify waste and Treatment
5	Waste organic solvents substance-specific Hazard status	Occupational Health and Safety Act, TCCA
6	Organic solvents sector into marketable	Material handling, handling capacity, utilization, production, etc. Statistical Office data
7	Exhaust establishments site survey	Waste emissions establishment survey items

Analysis of the waste organic solvents

Selected by industry and field investigation using in the manufacturing process or process, unprocessed organic solvent and used, processed according to the other of the plants that discharge waste oil machine first waste appoint discharging operations to 80 locations KSIC (Korea Standard Industrial Classification) 139 samples were collected after the gun against my being appointed discharge waste into designated waste sites. Largely survey-site waste discharge characteristic was appointed first can be divided into two types. Other waste organic solvent used for the washing, and the cleaning process in the goods production process such as an electronic component manufacturing is acetone, isopropyl alcohol, toluene, benzene, methyl ethyl ketone, DMF (dimethylformamide), etc.

The content analysis of priority management items detected in the target Item 21 species of samples taken at the plant to discharge the waste and other organic solvents, 18 species have been detected. The content analysis of dimethylformamide (2.62 to 98.94%), toluene (from 0.93 to 32.80%), xylene (0.29 to 57.48%), n-hexane (3.18 ~ 8.98%), methyl ethyl ketone (1.90%), tetrahydrofuran (2.39 ~ 19.56%),

1-propanol (2.27 to 16.64%), ethyl phenol (1.77 ~ 3.90%), ethyl benzene (0.30 to 21.62%), benzene (0.90 to 57.68%), phenol (1.66 - 40.88%), nitro-benzene (1.71 ~ 3.57%), pyridine (1.90 ~ 16.41%), methyl isobutyl ketone (1.80 ~ 18.81%), cyclohexanone (1.84 ~ 21.83%), butanol (2.39 ~ 3.61%), butyl acetate (1.79 ~ 5.93%), methyl acetate (from 4.15 to 40.01%) were detected.

CONCLUSION

This study derived the first substance administration to 21 selected by using the seven kinds of factors. And this facilitates analysis and management in developed countries, toxic and hazard other media, domestic (water, soil, drinking water, air quality, workplace health and environment) that manages the item, PRTR (chemical emissions · travel distance information taking into account the emissions and the amount of movement, and the 1999 law amendment before closing 43 kinds of items, such as non-halogen management system)

We have 80 of the 19 sectors 3211 workplaces workplaces (45 manufacturing locations, 10 locations sewage and waste disposal, transportation 10 points) visits were sampled for other waste my 139 machine gun in liquid form. That of the 42 samples, or foreign substances such as oil, earth and sand is contained excessively, not soluble in the solvent excluded from the analysis target, and counts the sample 97 by using the GC / FID analysis, the content of the organic solvent.

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Toward a policy for promoting eco industrial park as a strategy for waste minimization in Vietnam

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ABSTRACT

Vietnamese government has committed to green growth by issuing a national strategy in 2012. The strategy considers the important of natural resources as it is unlimited and has been explored severely for a long time and is likely unrecoverable. Green production and consumption are also requested to be implemented to achieve the green growth targets.

Eco industrial park is an approach to minimize waste and has been introduced in many countries in the world as well as in Asian region. In Vietnam, the economic restructuring is priority of government with the increasing of industries contributions in the national gross domestic products. As a consequence, the industrial wastes have become serious problem in many provinces. A properly strategy to deal with the situation has become urgent and needed studies in a large scale of industrial production. Eco industrial park has a great potential to meet this requirement, but the existing policies are not clear and lack of coordination amongst industrial sectors to make the model become effectively implementing.

The paper will review international experience in implementing eco industrial park, particularly in countries that are similar with Vietnam. It also reviews the current policies that the country has been implementing to promote eco industrial park (EIP) approach. To conclude, the paper will come up with suggestions for further enable policies to promote the EIP effectively in Vietnam.

Keyword: Eco industrial park (EIP), waste minimization, 3R, recycle

INTRODUCTION

Vietnamese government has committed to green growth by issuing a national strategy in 2012. The strategy considers the important of natural resources as it is unlimited and has been explored severely for a long time and is likely unrecoverable. Green production and consumption are also requested to be implemented to achieve the green growth targets.

A properly strategy to deal with the situation has become urgent and needed studies in a large scale of industrial production. Eco industrial park has a great potential to meet this requirement, but the existing policies are not clear and lack of coordination amongst industrial sectors to make the model become effectively implementing.

MATERIALS AND METHODS

This paper reviews the existing literature on the international experience of eco industrial park models. This aims to clarify the main philosophy of the approach, with its strengths and weakness. It also to brings the potential challenges to successfully implementing the model in less developed countries like Vietnam. Besides that, the requirements to establish or improve the legal framework are critical to enable the implementation of eco industrial park models.

The paper reviews existing policy framework in Vietnam that support to establish eco industrial park. It looks into the coordination amongst sectors to support the implementation and encourage the participation from different stakeholders, particularly private sector. On the other hand, the paper evaluate the market potential that plays as a catalyst factor to promote the waste recycling as a key of eco industrial park approach.

RESULTS AND DISCUSSION

The review of existing policies on 3R in Vietnam has identified as follows:

3R activities in Vietnam

At-source solid waste sorting

It is clear that the central and local governments are aware of at-source sorting's benefit. The recycling activities are implementing at a small scale and recently there are large investment projects by private companies in this field. -Pilot projects have been implemented in several cities but only few are sustainable. And most of the project are individual, without a linkage. The infrastructure for collecting, transferring and treating solid waste is unsynchronized, even at the large industrial parks.

Cleaner production

The clearer production program has been implementing in Vietnam quite long time. Being aware of the importance and urgent needs for Cleaner Production in Industry, the Ministry of Industry and Trade has promptly developed a Strategy for Cleaner Production in Industry of Vietnam to 2020. This Strategy was endorsed by the Prime Minister and issued at the Decision no. 1419/QD-TTg dated 07th September 2009. The strategy aims to encourage industries to minimize their wastes from production processes. Following the strategy, at provinces, the Provincial Departments of Industry and Trade have implemented a series of trainings to disseminate the benefits and technical knowledge on cleaner production. In fact, the cleaner production is mostly applied in the field of energy saving with improvement of production process by input reduction. Unfortunately, cleaner production is still not widely implemented in nationwide

Reuse, Recycle activities

The operation of domestic waste treatment facilities in Vietnam is still low. It is estimated that there are about : 22 facilities operate in the field of waste treatment, including composting, but not effective in the North. In fact, recyclable waste is collected and sold by waste pickers.

Most industrial waste is collected for recycling, but limited to small-scale craft village. They apply low recycling technologies cause pollution in craft villages.

Legal framework on 3R:

The Vietnamese government has issued several policies regarding solid waste management, the following are some key policies:

- Law on Environment Protection 2015

- Decree No. 59/2007/ND-CP dated 9th April 2007 of the Government on solid waste management
- Decision No. 2149/QD-TTg of December 17, 2009, approving the national strategy for integrated
- management of solid waste up to 2025, with a vision to 2050
- The Viet Nam National Green Growth Strategy (VNGGS)

The strategy has been inspired by green growth core principles, but also encompassing a cultural dimension. Implementation priorities focus on integrating Green Growth within the planning process and strengthening the legal and institutional framework. VNGGS is structured around 3 strategic tasks:

Reducing greenhouse gas emissions and promoting the use of clean and renewable energy. After 2020, it targets an absolute disconnection of greenhouse gas emissions from economic growth, i.e. a decrease of damage linked to emissions.

Greening production based on i) Implementation of a clean industrialization strategy via adjusting sector master plans; ii) Development of green industry, agriculture, technologies and equipment; iii) Investment in natural capital; iv) Prevention and treatment of pollution. VNGGS aims to reduce external costs, but it is based on marginal carbon cost-abatement studies, which do not integrate externalities.

Greening lifestyle where traditional lifestyle is combined with means to create quality and traditionally rooted living standards, including the creation of green jobs. New consumption modes should prevent that environmental benefits are counterbalanced by increased consumption.

The findings on existing legal framework show that there are gap amongst them to make effectively coordination of eco industrial systems. It requests a master plan to develop an industrial park at provinces that take into account the wastes flows, and identify the role of private sectors to participate in the industrial park as simulators of waste minimization process. They needed to be treated equally, with supports from local government in terms of financial or enabling policies. These are all lack to make the implementation of eco industrial park be successfully.

ACKNOWLEDGEMENT

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REFERENCE

Law on Environment Protection 2015

Decree No. 59/2007/ND-CP dated 9th April 2007 of the Government on solid waste management

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Decision No. 2149/QD-TTg of December 17, 2009 of national strategy for integrated

management of solid waste up to 2025, with a vision to 2050

Decision No. 1339/QD-TTg on December 2012 of the Viet Nam National Green Growth Strategy

Zero Waste Solution: Solid Waste Management in Nepal

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ABSTRACT

Sustainable solutions for solid waste management and treatment are needed due to the challenges of resource depletion, climate change, and rising consumer awareness. Solid waste management is a challenging environmental issue especially for under-developing countries. The aim of this paper is to identify problems and challenges in Nepal's solid waste management and the recommendation potential of applying zero waste solution in Nepal's solid waste management. At present, Nepal has 58 municipalities with a population of approximately 26.5 million as at 2011. The total municipal solid waste generation of the 58 municipalities was estimated at about 1,435 tons/day and 524,000 tons/year. The problems faced by the Nepal municipality are rapid and uncontrolled urbanization, lack of public awareness, cost of waste management, and poor management by municipalities. Hence, zero waste solution should be implemented in each community to reduce the cost of waste management and poor management by municipalities. This is because zero waste solution is a holistic approach to tackling waste problems in the twenty-first century. The solution is a cost effective and efficient approach to sustainable waste management, which has been implemented in South Africa, England, Taiwan, India, Sweden, China, Japan, Thailand, and Brazil.

Keywords: Zero waste solution, Nepal, Municipal Solid Waste

INTRODUCTION

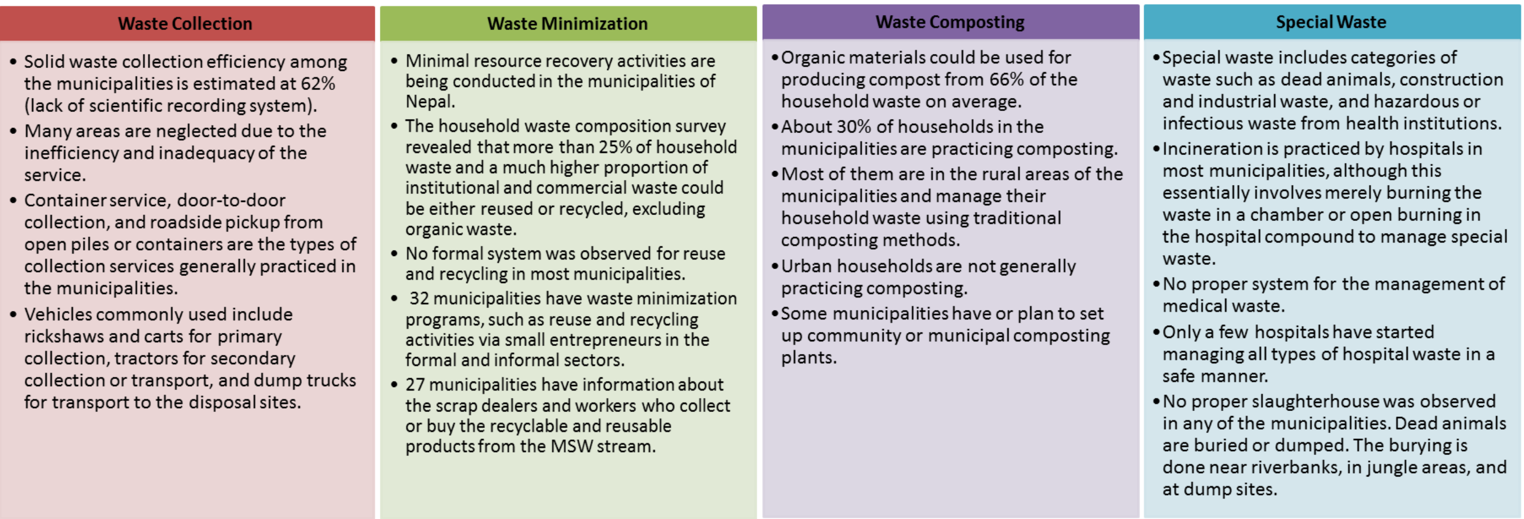
Sustainable solutions for solid waste management and treatment are needed due to the challenges of resource depletion, climate change, and rising consumer awareness (Cole et al., 2014). Solid waste management is a challenging environmental issue especially for under-developing countries. Improper solid waste management will lead to health problems and environmental pollution (Practical Action Nepal, 2008). Solid waste management is one of the major environmental issues in Nepal. In Nepal, urban population growth and economic development has led to an increased generation of municipal solid waste. In particular, Nepal experienced two massive earthquakes on 25th April and 12th May 2015 and has been facing a fuel crisis since November 2015 (Saif, 2015; Oxfam International, 2015). The crises have caused greater impacts on Nepal's solid waste management. Zero waste solution could be one of the solutions in overcoming Nepal's solid waste management crisis. The aim of this paper is to identify the problems and challenges of Nepal's solid waste management and the recommendation potential of applying zero waste solution in Nepal.

SOLID WASTE MANAGEMENT PRACTICES IN NEPAL

Background

At present, Nepal has 58 municipalities with a population of approximately 26.5 million as at 2011 (Central Bureau of Statistics, 2014). In 2001, the total amount of solid waste generated by all of the municipalities was estimated to be 427 tons/day (UNEP, 2001). In a report by the Asian Development Bank (2013), average municipal solid waste generation was found to be 317 g/capita/day. Using these per capita waste generation rates and the population in 2011, the total municipal solid waste generation of the 58 municipalities was estimated to be about 1,435 tons/day and 524,000 tons/year. The daily waste generation in 2013 increased by 336% compared to the daily waste generation in 2001.

Furthermore, none of the municipalities outside of the Kathmandu valley uses sanitary landfills or other means of sanitary disposal facilities for waste management. Municipalities located in Pokhara, Biratnagar, Birgunj, and Nepalgunj have been experiencing the stress of solid waste management in recent years. The traditional practice of managing solid waste in most of the municipalities includes open dumps in abandoned fields or on the bank of the rivers or streams (65–100% of the MSW depending on the municipalities) and open burning. Figure 1 summarized current solid waste management practices in Nepal.



Waste Collection

- Solid waste collection efficiency among the municipalities is estimated at 62% (lack of scientific recording system).
- Many areas are neglected due to the inefficiency and inadequacy of the service.
- Container service, door-to-door collection, and roadside pickup from open piles or containers are the types of collection services generally practiced in the municipalities.
- Vehicles commonly used include rickshaws and carts for primary collection, tractors for secondary collection or transport, and dump trucks for transport to the disposal sites.

Waste Minimization

- Minimal resource recovery activities are being conducted in the municipalities of Nepal.
- The household waste composition survey revealed that more than 25% of household waste and a much higher proportion of institutional and commercial waste could be either reused or recycled, excluding organic waste.
- No formal system was observed for reuse and recycling in most municipalities.
- 32 municipalities have waste minimization programs, such as reuse and recycling activities via small entrepreneurs in the formal and informal sectors.
- 27 municipalities have information about the scrap dealers and workers who collect or buy the recyclable and reusable products from the MSW stream.

Waste Composting

- Organic materials could be used for producing compost from 66% of the household waste on average.
- About 30% of households in the municipalities are practicing composting.
- Most of them are in the rural areas of the municipalities and manage their household waste using traditional composting methods.
- Urban households are not generally practicing composting.
- Some municipalities have or plan to set up community or municipal composting plants.

Special Waste

- Special waste includes categories of waste such as dead animals, construction and industrial waste, and hazardous or infectious waste from health institutions.
- Incineration is practiced by hospitals in most municipalities, although this essentially involves merely burning the waste in a chamber or open burning in the hospital compound to manage special waste.
- No proper system for the management of medical waste.
- Only a few hospitals have started managing all types of hospital waste in a safe manner.
- No proper slaughterhouse was observed in any of the municipalities. Dead animals are buried or dumped. The burying is done near riverbanks, in jungle areas, and at dump sites.

Figure 1. Solid waste management practices in Nepal

Source: Asian Development Bank, 2013.

Problems and Challenges in Nepal

Rapid and uncontrolled urbanization, lack of public awareness, lack of budget, and poor management by the municipalities have intensified the environmental problems in towns in Nepal, including unsanitary waste management and disposal (Asian Development Bank, 2013). While solid waste management has become a major concern for municipalities and the country as a whole, the status of solid waste management is not fully understood due to the lack of solid waste management baseline data, which are essential for effective planning. Additionally, physical factors, such as altitude, temperature, rainfall, and humidity, as well as socioeconomic factors, such as population, economic status, and consumption patterns, vary from one region to another. These factors affect the municipal waste management planning and waste collection system, especially given the two massive earthquakes and the fuel crisis in 2015.

RECOMMENDATION OF ZERO WASTE SOLUTION

Zero Waste is one of the most visionary concepts for addressing waste problems and encompasses many different strategies developed for the sustainable management of waste; these include waste reduction, repair, reuse, and recycling (Welsh Assembly Govt., 2010). The concept of Zero Waste goes beyond maximising recycling and focuses on the Waste Hierarchy by targeting recovery of all resources, and aims to reduce the amount of waste collected, whilst reusing and recycling progressively higher proportions and designing and managing production processes to eliminate waste and encouraging the recovery of all resources to mitigate the impact of waste (Scottish Government, 2010). Many cities such as Adelaide, San Francisco, and Vancouver have adopted zero waste goals as a part of their waste management strategies (Connett, 2006; SF-Environment, 2013). Additionally, the zero solution or concept has been implemented in South Africa, England, Taiwan, India, Sweden, China, Japan, Thailand, and Brazil (Zaman, 2015).

Zero waste management concepts are holistic approaches of zero waste society (Bartl, 2011; Whitlock et al., 2007), zero waste community (Dileep, 2007), zero waste city (Lehmann, 2012; Premalatha et al., 2013; Zaman & Lehmann, 2011), zero waste living (Khan et al., 2007), zero waste campus (Mason et al., 2003), zero waste places (Phillips et al., 2011), zero waste practices, programmes, and strategies (Cole et al., 2014; Connett & Sheehan, 2001; Johnston, 2014). Therefore, the zero waste solution could be a solution for Nepal's solid waste management crisis. This is because the zero waste solution includes high involvement by the community to establish the zero waste vision together. Figure 2 shows the phases of implementation in the zero waste strategy guidelines.

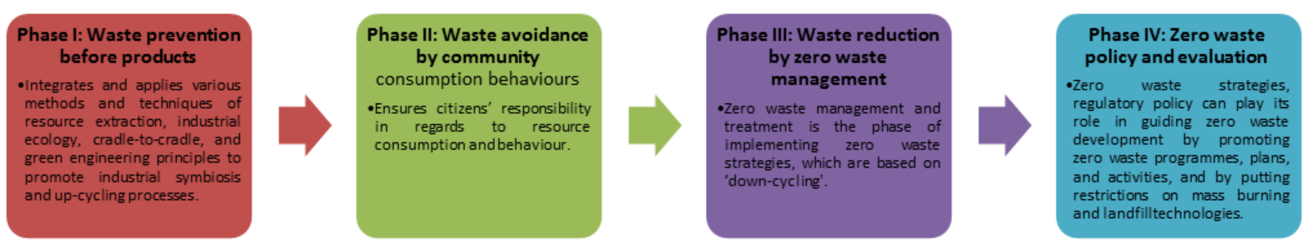


Figure 2. Phases of implementing zero waste guidelines

CONCLUSION

Municipalities are wholly responsible for the collection, transport, treatment, and final disposal of solid waste. However, the municipalities are not well equipped to manage solid waste problems. Municipalities are unable to manage municipal solid waste effectively and efficiently because of the lack of technical and human resources, statistical records, and proper planning, as well as insufficient budget and a lack of political leadership. The municipalities spend an average of 10% of their total budget on solid waste management, of which about 60–70% is used for street sweeping and collection, 20–30% for transport, and the rest for final disposal. Therefore, zero waste solution could be one of the options for Nepal's solid waste management. This is because zero waste solution is a holistic approach to tackling waste problems in the twenty-first century. In addition, zero waste solution requires a high involvement and participation from the community. The solution is a cost effective and efficient approach to sustainable waste management, which has been implemented in South Africa, England, Taiwan, India, Sweden, China, Japan, Thailand, and Brazil.

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Session 4

Biomass waste

Scenario Analysis of Waste Biomass Utilization in Yangon, Myanmar

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ABSTRACT

This study estimated greenhouse gas (GHG) emissions from the organic fractions of municipal solid waste (MSW; i.e., food, wood, and paper), agricultural waste (i.e., rice straw and rice husk), and livestock (pig) sludge produced in Yangon, Myanmar, using Life Cycle Assessment (LCA). GHG emissions were evaluated based on five different scenarios of integrated waste disposal techniques, including; landfill, composting, wet and dry anaerobic digestion (AD), and incineration. A modeled waste management plan provided data on multiple aspects on energy recovery, biomass resource management, and sanitation. The results showed AD to be the most effective approach, resulting in a negative impact of -0.34 ton CO_2 eq. per ton for pig sludge with emissions reduction benefits. In comparison with the control scenario (all waste to landfill), the greatest emission offset was shown to be 2.30 million tons CO_2 eq. per year (for the AD of food and pig sludge, composting of wood and agricultural waste, and disposal of paper in landfill).

Keywords: greenhouse gas, municipal solid waste (MSW), anaerobic digestion, rice husk, pig sludge

INTRODUCTION

Myanmar produces 265 million tons CO_2 eq. of greenhouse gas (GHG) emissions per year with significant inputs from agriculture. Waste in the domestic sector, (e.g., small household livestock units), the industrial sector, and municipalities, are most often left unutilized (UNEP 2013), despite organic waste representing the dominant waste stream in developing Asian countries. The agricultural sector, including fisheries and livestock, represents 32.8% of Myanmar's gross domestic product (GDP; MOAI 2014). However, few studies have quantified the use of wastes for energy production and other purposes, while no studies have presented data on GHG emissions from waste biomass. While numerous studies have investigated the co-digestion of livestock sludge, organic municipal solid waste (MSW), and agricultural residues (Jabeen et al., 2015), none have focused on Myanmar. However, as a rapidly growing city, Yangon requires the development of a waste management strategy. With Yangon as a focus, this study quantified GHG emissions for different waste disposal scenarios, and assessed the GHG reduction performance of several types of waste biomass using the Life Cycle Assessment (LCA) method.

METHODOLOGY OF ENVIRONMENTAL EMISSIONS ESTIMATION

Functional unit

In this study, we estimated the GHG emissions from 1.83 million tons of integrated waste produced in the Yangon region between April 2012 and March 2013. The waste sources included MSW (i.e., food, wood, and paper), agricultural waste (i.e., rice husk and rice straw), and livestock (pig) sludge, (Table 1). The generation of food, paper, and wood waste was estimated by multiplying the MSW composition by the amount of MSW generation. Rice straw was estimated using the mean yield of paddy and its cultivation area (ARF 2014). Rice husk generation was estimated using the ratio of rice husk to rice straw. Paddy rice husk is traditionally used as a fuel, while straw is widely used for animal feed; however, surplus quantities generate GHG emissions. It was assumed that 25% of rice husk was utilized for energy (UNEP 2013). From 2002 to 2003, the minimum straw utilization ratio for feeding animals in Myanmar was 40% (FAO), and on this basis it was assumed that 50% of the waste utilization was agricultural in this study. Pig sludge was estimated based on pig population, daily manure sludge generation per pig, and the solid fraction of mixed waste manure (FAO 2011).

Table 1 Estimated waste availability and targets

Waste types	Food	Paper	Wood	Rice straw	Rice husk	Pig sludge	Total
Potential(million tons/year)	0.20	0.09	0.07	1.68	0.40	0.43	2.87
Targeted(million tons/year)	0.20	0.09	0.07	0.84	0.20	0.43	1.83

System boundary and scenarios flow

The system boundary included the treatment of waste from households, agricultural and livestock sectors, and the utilization and production of energy and materials. Collection of waste was excluded from our estimations owing to a lack of data. The Yangon City Development Committee (YCDC) defines food waste as wet waste, and paper and wood, as dry waste. GHG emission quantification and comparative assessment for integrated waste biomass was estimated using five different scenarios (Figure 1). Scenario 1 (the control scenario) considered all waste types to be disposed on in landfill. In scenario 2, food, wood, and agricultural waste products were treated by composting, while other waste types were disposed of in landfill. In scenario 3, the anaerobic digestion (AD) of food and pig sludge was considered, while wood and agriculture waste were composted and paper was disposed of in landfill. In scenario 4, all waste was treated using AD, except for pig sludge, which was disposed of in landfill. Scenario 5 considered the incineration of organic MSW and the composting of agricultural waste and pig sludge.

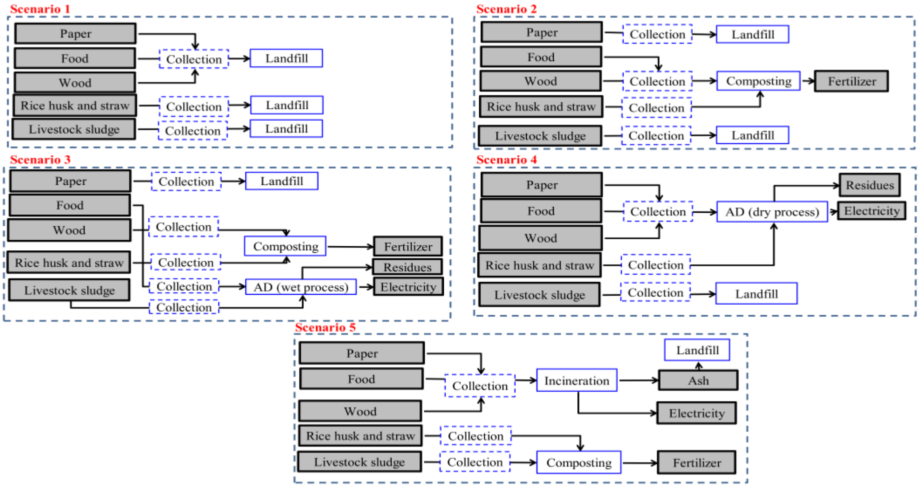

Figure 1 Flow diagram of current and future scenarios in Yangon, Myanmar

Process setting

Default values of biodegradability were set to 84%, 66%, and 60% for food, paper, and wood. Calculated biodegradation rates, for rice straw, rice husk and pig sludge, which were based on methane yield, were 84%, 13% and 95%, respectively. Calculations also considered fossil fuel consumption at landfill sites, utilization of fossil fuels, grid electricity, and diesel consumption during composting, incineration plant operation, and blower and other operations in the AD process. In addition to calculating GHG emissions from operation, and waste management, avoided GHG emissions from waste treatment processes were also calculated. For composting, avoided GHG emissions were calculated based on the replacement of chemical fertilizer utilization. For AD and incineration, avoided GHG emissions were calculated based on the replacement of commercial electricity production. Furthermore, fermentation residues from the AD process (scenarios 3 and 4) were treated as fertilizer compost replacing emissions from chemical fertilizer production. Power plant and engine efficiencies were crucial for compensation in energy conversion from AD and incineration, for which 37% electricity production efficiency was assumed for AD and 15% for incineration. The estimation of the lower heating value (LHV) was based on the Bento's model equation:

$$\mathrm{LHV} = (44.75 \times C_{combustion} - 5.85 \times C_{moisture} + 21.2) \times 4.19$$

where LHV is the lower heating value (GJ/Gg), $C_{\mathrm{combustion}}$ is the combustible content (%-wet) and C_{moisture} is the moisture content (%-wet).

RESULTS AND DISCUSSION

GHG emission profiles for different waste management processes and waste fractions

Analysis showed that landfill (scenario 1) results in the highest emissions (Figure 2), with wood waste contributing the highest proportion of emissions and food waste the lowest, reflecting its low degradable organic carbon content. In organic waste incineration, CO_2 emissions were considered to have a biogenic origin, with CH_4 and N_2O emission factors affecting waste emissions. Pig sludge produced the highest N_2O emissions (up to 0.14 ton CO_2 eq. per ton of waste treated). Emissions from composting were influenced by the organic dry matter contents of the waste, with food waste having the lowest organic dry matter and producing the lowest emissions (0.11 ton CO_2 eq. per ton of waste treated). AD was the most effective method for offsetting GHG emissions through energy recovery and residues treatment. In particular, the high biodegradability of pig sludge during AD resulted in negative emissions of about −0.34 ton CO_2 eq. per ton of waste treated.

Emission profiles for different scenario settings

Scenario 1 (all waste to landfill) had the worst impact on GHG emissions (Figure 3), with emission levels of up to 2.51 million tons CO_2 eq. per year, consistent with the current situation in Yangon. In comparison, emission levels for scenario 2 (combining combustion and landfill) were less than half, confirming the benefits of diverting organic waste to composting instead of landfill. Scenario 3 resulted in the lowest environmental emissions (0.21 million tons CO_2 eq. per year), some 2.30 million tons less than in scenario 1. The AD process (scenario 4) also resulted in negative emissions that were 2.23 million tons CO_2 eq. per year lower than those in scenario 1. In scenarios 3 and 4, rice straw and pig sludge treatment played a more significant role than the treatment of other waste types. Changing pig sludge AD treatment (scenario 3) to landfill disposal (scenario 4) significantly increased GHG emissions. Total emissions in scenario 5 were

2.24 million tons CO_2 eq. per year lower than in scenario 1. This mainly reflects the diversion of organic MSW from landfill (scenario 1) to incineration (scenario 5), which reduced emissions to 0.38 million tons CO_2 eq. per year. Moving agricultural and pig sludge from landfill (scenario 1) to composting (scenario 5) reduced emissions by 1.86 million tons CO_2 eq. per year.

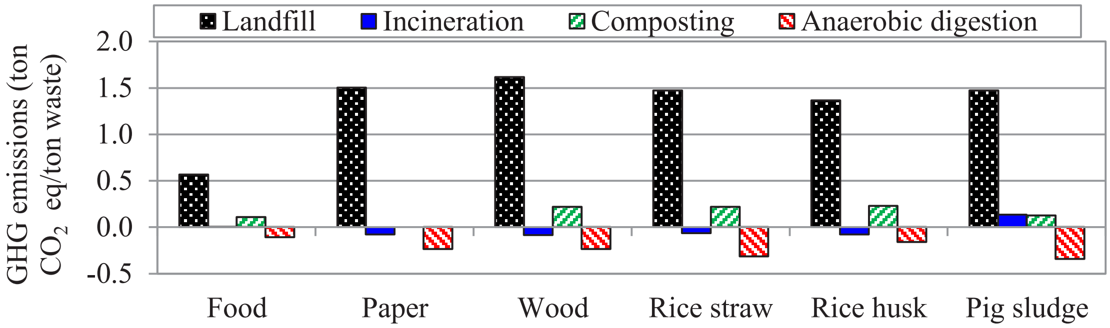

Figure 2 Greenhouse gas (GHG) emissions per ton of each waste biomass for each process

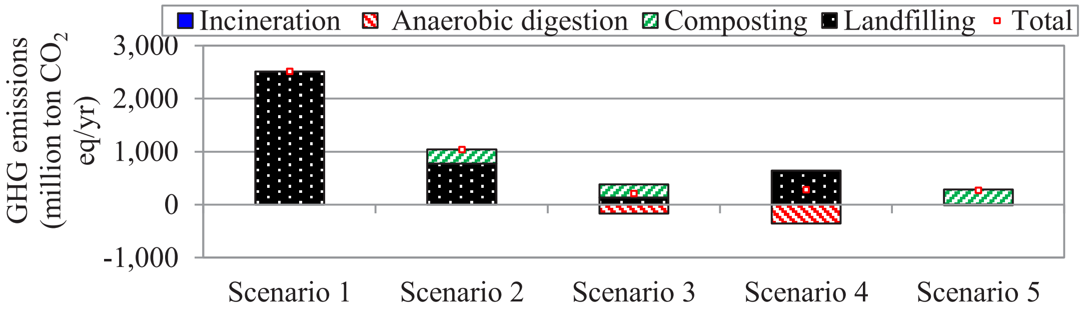

Figure 3 Greenhouse gas (GHG) emission profiles for five scenarios

CONCLUSIONS

For most waste biomass, AD and incineration provide the most significant environmental benefits by offsetting GHG emissions, the only exception being the incineration of pig sludge, reflecting its lower heating value (LHV). The results of this study highlighted the importance of integrating different types of wastes biomass in emissions estimations. In Myanmar, rice husk utilization for heat generation is commonplace, reportedly accounting for up to 25% of rice husk disposal. The results of this study showed that, along with other organic waste, surplus rice husk has a high potential as an energy resources. However, uncertainty analysis is needed to identify the key parameters and assumptions that may affect the results of this study. Future work should also consider other livestock sludge; for example, that of cattle or fish (pond).

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A Case Study about the Development Barriers of Municipal Solid Waste Composting in China

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ABSTRACT

Composting was an extremely popular treatment method in 1980s and 1990s, but is gradually abandoned by most Chinese cities. Five obstacles are noted in the municipal solid waste (MSW) compost plants in China. 1) The collection of most MSW is mixed, leading to low-quality compost products, which are not welcomed by farmers. 2) Odor is produced during composting. 3) Composting requires an extended period, whereas incineration can be employed at any time. 4) Composting only reduces the MSW volume by one-third. 5) Most of the young labor force from rural areas shifts to the cities, and the old people who remain in rural areas are more willing to apply chemical fertilizers than compost in their farmland.

An analysis of the MSW compost plants in Beijing and Guilin with the same technology and devices determines that the plant in Beijing operates well, whereas the one in Guilin faces possible closure. Moreover, the treatment capacity of the Beijing plant is enhanced from 400 to 2,000 t/d. The Guilin government regards the compost plant only as a means of producing compost; thus, they consider the sales revenue before they provide the disposal costs. However, compost products usually do not have a good market, leading to the imminent closure of the plant. In Beijing, the MSW compost plant reduces the waste volume and extends the service life of the landfill site. The Beijing government is not concerned with possible income gain from the product; hence, the government offers sufficient funds for waste disposal. Therefore, apart from addressing the five obstacles, adequate operation cost from the government is crucial for the development of MSW composting.

Keywords: municipal solid waste, compost, reduce, barrier

INTRODUCTION

With the dramatic growth of urban population and the development of economies in China, the quantity of the municipal solid waste (MSW) increases rapidly (Agamuthu and Masaru, 2014). The Ministry of Environmental Protection of China (2014) reported that more than 1.6×10^8 t/a MSW were produced in 2014. Landfill and compost are the most popular methods for MSW treatment and disposal over the past decades in China. However, a growing number of cities including Beijing, Shanghai, and Shenzhen have difficulties in finding new landfill sites, and they have banned the disposal of untreated waste in landfills. In recent years, an increasing number of cities have begun to set up waste incineration power plants for MSW treatment.

Composting, which is an extremely popular treatment method between the 1980s and 1990s, is gradually abandoned. By investigating the compost plants in China, we intend to analyze the reasons for the decline of compost technology and determine the difference between the successful compost projects and the failed ones. Then, we can provide suggestions to promote the MSW compost development in China.

MATERIALS AND METHODS

Data collection of MSW composition and tendency of MSW treatment

The composition of MSW in China was collected according to a review of the literature. The tendency of MSW treatment was obtained from several annual reports by China Association of Urban Environmental Sanitation.

Reasons why people are reluctant to accept MSW composting

This survey included the current willingness toward MSW composting, the reasons why people are reluctant to accept MSW composting, and the motives for the selection of the current and proposed treatment and disposal methods.

Case analysis of the parameters of successful and failed compost plants

We analyze the key differences between the successful and unsuccessful compost projects by investigating the MSW compost plants' facilities, treatment process, operation, compost quality, cost, and financial support from government.

RESULTS AND DISCUSSION

MSW composition and its trends in China

The MSW composition is related to the composition of fuel, lifestyle of people, and the level of city development. Table 1 shows the MSW composition for the past few years (i.e., 2002, 2005, and 2011).

Table 1 MSW composition for year 2002, 2005, and 2011.

Time	Paper	Plastic	Fabric	Glass	Metals	Kitchen waste	Wood and grass	Dust
2011	28.79	17.27	4.34	5.19	4.25	34.28		5.88
2005	9.75	11.76	1.69	1.70	0.33	63.80	1.26	9.71
2002	4.56	7.3	1.83	1.36	0.63	47.78	—	36.54

In general, the MSW composition has four characteristics. 1) It has high water content. The water content of most MSW is over 30% and even 50% in certain areas and seasons. 2) Organic matters (e.g., kitchen waste such as vegetable, bones, etc.) and package waste account for over 50% of the total dry matters. 3) Dust accounting for the total dry matters has decreased. 4) The recovery material has no apparent increase for most wastes; papers, metals, and beverage containers are sold to waste recovery workers.

Now, the collection of most MSW is mixed, and the quantity of heavy metals and dust is high in the compost. The nutritious and the organic matters are low, whereas the pollutants are high.

Tendency of MSW treatment and disposal

Landfill, composting, incineration, and recovery are the four main means to treat MSW in China. The four methods can be used either exclusively or together. The different cities or areas select the various combination patterns depending on the situation (Kodwo M., Kwasi O. et al., 2015). The recovery methods have a few small-scale experiments in certain cities, and they have extremely limited application.

By the end of 2014, the number of MSW treatment, landfill, incineration, and compost facilities was 819, 605, 187, and 11, respectively. In particular, the treatment capacity of landfill, incineration, and compost was 33.5×10^4, 18.5×10^4, and 1.2×10^4 t/d, respectively.. The MSW treated by composting remained in a standstill.

Reasons why people are reluctant to accept MSW compost

Now, most people are reluctant to use composting for MSW treatment, and most of the MSW plants founded in the 1980s are closed. By interviewing the proprietors and farmers, five reasons for the failure of these MSW compost plants are noted. 1) The quality of the MSW compost cannot meet the requirements of the farmland and cannot be applied to the land because of dirt and other impurities. 2) Now, the farmers prefer chemical fertilizers to organic ones. Before the 1980s, China could not produce sufficient chemical fertilizers to meet the farmer’s demands and the farmers need organic waste to improve the fertility of their farmland. Now, the increased rural labor costs for most young rural labor have expedited their transfer to the cities and chemical fertilizers become more convenient to use than organic ones. 3) Odor is inevitably produced in the MSW composting, which has become the bottleneck of promoting compost technology in MSW treatment to the surrounding people (Yuan J., Yang Q. et al., 2015). 4) Compost treatment needs a long time (more than one month) to meet the requirements of the sanitary and organic matter stabilization, which is different from incineration that can be immediately harmless. 5) Composting can reduce approximately one-third of the MSW volume, whereas incineration can reduce 90% of the MSW volume.

Case analysis of successful and failed compost plants

Two MSW compost plants have different fates during the past years. Both the Nangong MSW compost plant in Beijing (Nangong plant) and Pingshan MSW compost plant (Pingshan plant) in Guilin were built with a 400 t/d production capacity in 1998. With the demand of MSW treatment, the production capacity of Nangong plant was expanded to 2000 t/d in 2014. However, Pingshan plant’s actual processing ability decrease to 200 t/d, and the plant will be closed.

All equipment of the Nangong and Pingshan plants was purchased from Germany, and the land for the plants was provided by the government. The two plants use tunnel composting systems with forced aeration. During the pond, the organic matters undergo a biological decomposition. The largest function of the Nangong and Pingshan plants is minimizing the MSW. After the fermentation treatment, they screen the separation and the rest of the waste (approximately 35% and 40% in Nangong and Pingshan, respectively) goes to landfill sites as the landfill cover soil.

The operation costs of the Nangong plant is shouldered by the Beijing government, including the fees for the health of the staff, safety measures, and troubleshooting. The Pingshan plant is a privately owned enterprise, and the cost is shouldered by the Guilin government depending on the handling capacity. The fees for the staff’s health and safety measures and troubleshooting come from the company.

In China, the government is responsible for the MSW treatment. Thus, the tipping fee should be shouldered by the government, and the land can be obtained from the government for free. The treatment plants cannot operate normally if the local government does not provide adequate tipping fee for the MSW treatment. No special law states that the government should pay the tipping fee to compost plant; it depends on the economic ability and the intent for environmental protection of the local government (China Association of Urban Environmental Sanitation, 2011). The attitude of the local government is crucial for the MSW composting plant operation. Even the creation and implementation of the policy on sorting the collection of MSW depends on the government to overcome the barriers of the MSW composting treatment.

CONCLUSION

The most important barrier of MSW composting is the sorting of the collection cannot meet the requirement, leading to the poor quality of the compost. In the present circumstances in China, the compost treatment method is extremely difficult if the treatment companies depend on the compost products for marketing. The shortage of funds for a plant's daily operation depends on the subsidy from city government. The development of MSW composting can be promoted only with sufficient subsidy from the government.

ACKNOWLEDGEMENT

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Assessment of the potential to use biomass pellets in household scale in Vietnam

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ABSTRACT

Biomass pellets derived from cellulosic wastes are increasingly used worldwide because this is a teeming source of energy and may contribute to the reduction of fossil fuel demand. In Vietnam cellulosic wastes are abundant and are causing pollution such as emission from field open burning. Hence, using them as input materials for biomass pellets production is a multi-benefitial way of treatment. Although biomass pellets are preffered to be used in industrial scale, its usage in household scale should be considered in Vietnam beause there are still many people using hive-shaped coal for daily cooking. This study investigated physico-chemical properties of different biomass pellets produced from sawdust, rice straw, rice husk, peanut hull, and coconut coir. Their combustion propertiess were also investigated and then compared to those of hive-shaped coal using a household stove. The results showed that studied pellets have many properties which meet european standard EN 14961. However, some have water content higher than 15%, ash content higher than 10%, gross heating value lower than 13,2 MJ/kg and bulk density lower than 600 kg/m^3, which don't meet this standard. In comparison to hive-shaped coal, biomass pellets have shorter ignition time, mostly higher burning rate and similar water vaporizing capacity. Clearly, replacement of hive-shaped coal by biomass pellets in household scale could not only improve the convinience and health of the users but also mitigate green house gas emission and protect the environment.

Keywords: Biomass pellets, physical and chemical properties, combustion properties, hive-shaped coal

INTRODUCTION

Biomass pellets are densified biomass which have homogenious form and structure in order to ease the storage, transportation and load into combustion system (Stelte et al., 2012). In fact, biomass pellets is a renewable energy form which could contribute to the reduction of green house emission and the dependance of human being on fossil fuel.

Up to now, biomass pellets are mainly produced from wood residue because wood is advantageous over agricultural wastes in ash and slag formation and corrosive characteristics (Stelte et al., 2012). Many countries with developed pellet industry like in Scandinavia, wood material has becoming shortage and need to be suplement by new materials (Obernberger and Thek, 2010). The similar situation happening in Vietnam meanwhile, agricultural wastes are abundant and need to be treated properly.

On the other hand, hive-shaped coal are using by many peole, especially the poors in Vietnam in their daily life (Phuc Anh, 2013). This coal is produced from mixture of low quality powder coal and sludge or soil. This kind of coal cause environmental pollution due to the emission of SO_2, CO, CO_2 and NO_x. In order to protect the health of the user and the environment, this coal could be replaced by biomass pellets. The question is whether biomass pellets meet the requirements of houshold users?

Quality of biomass pellets play a very important role in heat recovery, operation of incinerator as well as their emissions to the environment. Hence, in order to be effectively applied in houshold scale, biomass pellets should have acceptable quality. Regarding this item, european commission has issued EN 14961 standard series for solid biofuel. The series includes 6 different standards, of which 3 are directly related to biomass pellets: EN 14961-1 on general requirements, EN 14961-2 on wood pellets for non-industrial use and EN 14961-6 on non-wood pellets for non-industrial use.

This study aimed to compare combustion properties of biomass pellets and hive-shaped coal in order to provide evidences for the potential use of biomass pellets in household scale. The quality of studied pellets reflected by physicochemical properties had been analyzed as a prerequisite for the comparison.

MATERIALS AND METHODS

Materials

Cellulosic wastes were collected from different places in Vietnam randomly. Rice straw, rice husk, peanut hull and coconut coir were collected from crop areas in Nam Dinh provincee; Bagasse from Hoa Binh sugar company; Sawdust mixture from different saw mills in Thai Nguyen province. Hive-shaped coals are collected from a manufacturing company in Thanh Xuan, Hanoi.

Pellets production

Collected cellulosic wastes were air-dried and cut to the size of 1-2 cm prior to peletization by a flat die pelletizer in Binh Minh clean kitchen company in Thai Nguyen. The designed diameter of pellets was 8 mm.

Determination of physico-chemical and combustion properties

Some physico-chemical properties of biomass pellets were analyzed according to european standards as listed in Table 1. Combustion properties (ignition time, burning rate, water vaporizing capacity) were analalized according to Islam et al. (2014). These properties were evaluated using EN 14961-1, EN 14961-2 and EN 14961-6. The properties of hive-shaped coal were determined according to TCVN 4600:1994.

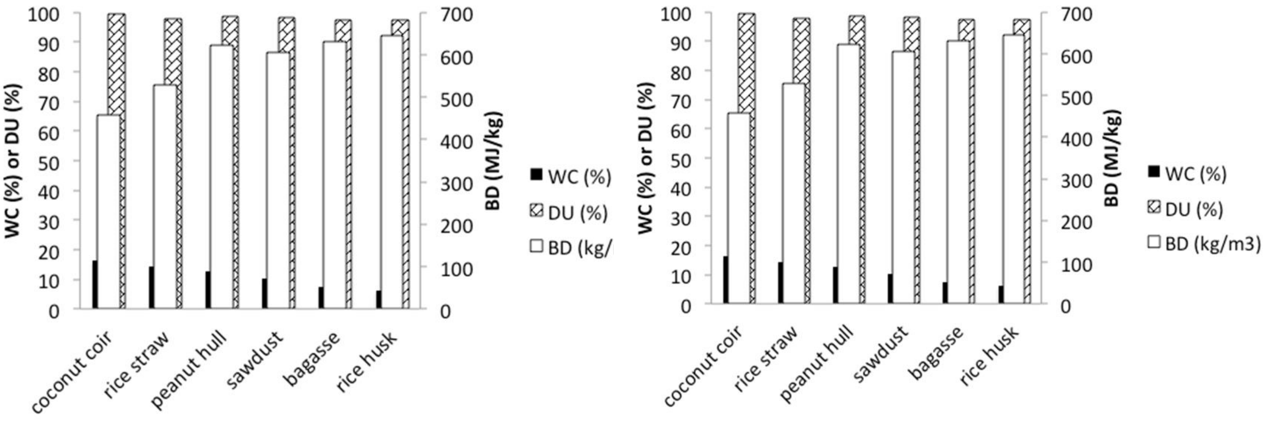
Table 1. Methods for analyzing some physico-chemical properties of biomass pellets

Properties	Methods	Properties	Methods
Moisture content (M)	EN 14774-1	**Bulk density (BD)**	EN 15103
Fines (F)	EN 15149-1	**Heating value (Q)**	ASTM D5865-04
Mechanical durability (DU)	EN 15210-1	**Ash content (A)**	EN 14775

RESULTS AND DISCUSSION

Physico-chemical properties of different biomass pellets

Figure 1a and b shows some physico-chemical properties of produced biomass pellets. According to EN 1496-6, mosture content of non-woody pellets must not exceed 15%, hence coconut coir with moisture content of 16.10% did not meet the requirement. Although all other biomass pellets met the requirement, their moisture contents were relatively high. This is explained by the high moisture content of input materials and the drying efficiency of pelletizing system. According to Stelte et al. (2012), moisture content of mateirals for woody pellets and non-woody pellets should lie in range of 5-10% and 10-20%, respectively. High moisture content could lead to the decrease of mechanical durability and the decrease of bulk density. Nevertheless, the durability of all biomass pellets still have a highest ranking based on EN 1496-1. However, bulk density of coconut coir and rice straw did not meet EN 1496-6 standard, which in turn reduces the energy carrying capacity of those pellets. In addition to characteristics of input materials (moisture content, size, material composition), bulk density is also dependent on pelletizing pressure and temperature, etc. (Stelte et al., 2012). Meanwhile, bulk density has a significant value in reducing pellets transportation and storage cost (Stelte et al., 2012). In order to increase the quality of biomass pellets, material characteristics and pelletizing conditions could be improved.



(a) (b)

Figure 1: Some physico-chemical characteristics of studied biomass pellets

As can be seen in Figure 1b, all produced biomass pellets have fines lower than 3% which were classified and the highest ranking – F1.0 in EN 14961. Low fines were due to high lignin content in input materials. Under temperature of 65-70°C during pelletizing process lidnin is glassified and act as binding factor in biomass pellets (Islam et al, 2014; Obernberger and Thek, 2010).

Ash contents of sawdust, peanut hull pellets were lowest of all. Rice straw and rice husk pellets have highest ash contents (> 10%) which did not meet EN 1496-6 due to higher silicon content. High ash content leads to increase of ash emission both in fly ash and bottom ash forms; hence ash have to be remove from the stove more regularily (Caroll and Finnan, 2012). Meanwhile ash content of hive-shaped coal was analyzed at 41.19%. Besides emission it also cause trouble with disposal area.

Table 2 shows that gross heating value of produced biomass pellets decreased in order of sawdust, peanut hull, rice husk, coconut coir and rice straw pellets. Accoridng to EN 14961-2 and EN 14961-6, only rice straw pellets did not meet the requirement. This is the result of high moisture content and low bulk density of sproduced rice straw pellets.

Comparison of combustion properties of biomass pellets and hive-shaped coal

Table 2 compares combustion properites of produced biomass pellets and hive-shaped coal. The values show that hive-shaped coal had higher heating value than all biomass pellets, except sawdust pellets. Nevertheless, its burning rate was lower than all kind of studied pellets, except sawdust and rice husk pellets. In addition, water evaporizing capacity of hive-shaped coal was just similar to studied biomass pellets. Low burning rate lead to time consuming during cooking at household scale. Furthermore, ignition time of hive-shaped coal was 3-4 times longer than that of studied biomass pellets (13 min. vs. 3-5 min., at 30°C), which in turn challenges the patience of users and might increase input materials for ignition.

Table 2. Comparison of some combustion properties of biomass pellets and hive-shaped coal

Form of fuel	**Unit**	**Coconut coir**	**Rice straw**	**Peanut hull**	**Sawdust**	**Bagasse**	**Rice husk**	**Hive-shaped coal**
Gross heating value	**(MJ/kg)**	14.47	12.96	16.24	18.78	16.25	14.7	18.21
Burning rate	**(g/min.)**	7.81	7.58	7.69	6.1	7.69	6.25	7.05
Water evaporizing capactity	**(L/kg)**	0.68	0.89	1	1.16	1.52	0.85	To be redetermined (1.00)

CONCLUSION

This study aimed to provide evidences on the potential use of biomass pellets in household scale. Biomass pellets produced from different cellulosic wastes were shown to have physico-chemical properties in line with european standard EN 1946, although there are still some improvement to be obtained for a complete fit. In comparison with hive-shaped coal, studied biomass pellets showed a number of advantages such as shorter ignition time, relative higher burning rate, relatively same range of water evaporation capacity and especially they are renewable source. In this sense, it is recommended that hive-shaped coal should be completely replaced by biomass pellets in houshold scale. Furthermore, extention of biomass material for pellets production should be investigated.

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Feasibility Study on Reuse of Water Treatment Sludge, and Coagulant Recovery – A Case Study in Tan Hiep Water Treatment Plant

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ABSTRACT

Sludge generated from water treatment process is considered as an industrial waste, water treatment sludge (WTS) contains a large volume of coagulant was used, therefore, the reuse and recovery of sludge are effective solutions to reduce the sludge volume, sludge disposal cost and save the chemical using costs in the wastewater treatment plant. The study was conducted to investigate the possibility of reusing water treatment sludge as a coagulant in wastewater treatment process and determine the feasibility of recovering the Alum in the sludge. The optimum conditions of the acidification method for Alum recovery were determined at pH = 1, stirring velocity = 200 rpm, stirring time = 30 mins and the Alum recovery rate reaches highest level 91%. The application of recovered coagulant in wastewater treatment showed efficiency of color removal is 74,54%, turbidity is 89,81%, TSS and COD are 89,23% and 75% respectively. An other investigation of reusing water treatment sludge as a coagulant in wastewater treatment gave the following optimum conditions: sludge dose 400 ml/L, pH = 5, fresh Polyaluminum Chloride (PAC) 1% = 2ml/L. The result showed that the combination of water treatment sludge with fresh coagulant (PAC) would give a substantially higher contaminant removal compared to the Alum recovery from sludge. The study verified that water treatment sludge could be reused in wastewater treatment or recover the coagulant then recycled to the chemical treatment process with high efficiency.

Keywords: Alum recovery, acidification, sludge reuse, water treatment sludge.

INTRODUCTION

In recent years, Viet Nam's population increased rapidly, along with the population growth is the demand of water supply to the people, so water plants are required to increase the capacity, the result of expansion is a large quantities of water treatment sludge are produced. Chemical treatment processes produce about 1.5 – 2.0 times more sludge than that produced by conventional primary treatment. Aluminum salts hydrolyse to form precipitates of aluminum hydroxides when add to the water, the impurities in water are removed by charge neutralization, sweep floc mechanism and absorption on the precipitates. Water treatment sludge contains elevated concentration of chemical precipitates derived from the coagulants were used. The proper diposal, regeneration or reuse of waste residual sludge has become a significant environmental issue.

Reuse of water treatment sludge as a coagulant has been reported by many researchers. Chu (2001) assessed the feasibility of using recycled alum sludge for dye removal from textile dye wastewater. Chu (1999) reported the recycled alum sludge can be used to remove heavy metal in wastewater. Guan et al. (2005) studied the reused water treatment sludge for treating sewage water.

Coagulant recovery method has been offered many benefits to wastewater treatment by reducing chemical demand and waste production. Acidification is a high efficiency and low cost method for the recovery of coagulants. The acidification involves neutralizing the flocs of hydroxide to release aluminum salt back in the solution. According to Panswad et al (1992), the aluminum recovery by acid extraction (pH between 1.0 – 3.0) can reach 70 – 90%. Xu et al (2008) has reported that the highest efficiency of aluminum recovery is 84,5% and sludge volume reduced 35,5%. The treatment ability of aluminum recovered solution to wastewater is 96% turbidity, UV_{254} and COD respectively are 46% and 53%.

Thus the objective of this research work is to study the possibility of reusing water treatment sludge as a coagulant for wastewater treatment and determine the feasibility of recovering the alum in the sludge. The optimal conditions for applying the sludge as a coagulant (sludge dose, pH, fresh PAC dose) and aluminum recovery (stirring time, stirring velocity and pH) are also investigated.

MATERIALS AND METHODS

Sample collection and characterization

Water treatment sludge (WTS) was collected from the sedimentation tank of the Tan Hiep Water Treatment Plant at Hooc Mon District, Ho Chi Minh City, which treats water from the Sai Gon River. The plant uses polyaluminum chloride (PAC) as the coagulant. The same batch of sludge was used in all the test. The wastewater was collected from the textile wastewater treatment plant at Chyang Sheng Limited Co., Thuan An Town, Binh Duong Province. The characteristics of WTS was determined pH = 7.1, 96,79% moisture, Al = 578 mg/L, Fe = 253,9 mg/L; Characteristic of wastewater pH = 7.3, color = 180 Pt-Co, turbidity = 180 NTU, TSS = 130 mg/L, COD = 928 mg/L. Fresh PAC was purchased from market and has an aluminum content of 30%.

Experimental methodology

Coagulation experiments were carried out to determine the optimal conditions of reusing WTS as a coagulant, six beakers were used to simulate a conventional coagulation-flocculation process. Each beaker contained 500 ml wastewater. The coagulation – flocculation procedure consisted 1 minute of rapid mixing at 100 rpm, followed by slow mixing at 30 rpm for 30 minutes and 30 minutes of settling. A number of jartests were conducted to determine the optimum parameters. In different tests, WTS dose, initial pH value and fresh PAC dose were varied. The initial pH of samples were adjusted by using 1N H_2SO_4 and 1N NaOH solutions before adding the other reagents. The WTS was added in liquid form after settling time of 2 hours. After each test, about 100 ml supernatant was withdrawn from each beaker for analysis of different parameters.

500 ml WTS was added 1000 ml beaker, the effect on Al extraction rate of pH, stirring time and stirring speed were investigated. The pH was adjusted by using 6N H_2SO_4 to solubilize Al as Al3+. Stirring time was selected as 30, 60, 90 and 120 minutes and stirring speed as 100, 150, 200 rpm. After obtained the recovery aluminum solution in optimal conditions as determined, carried out the jartest to evaluate the efficicency of recovery aluminum solution for wastewater treatment. The effect of pH and recovery aluminum solution dose are also investigated.

RESULTS AND DISCUSSION

Aluminum recovery

Figure 1 presents Aluminum extraction results in different tests to optimize the conditions for coagulant recovery. In the acidified condition (pH between 1.0 and 3.0) the maximum extraction yield was 91,02% at pH = 1.0, stirring time = 30 minutes, stirring speed = 200 rpm. The difference in pH is the major factor affecting on the recovery efficiency of Aluminum. The recovery Aluminum solution (RAS) has concentration of Al = 526,11 mg/L and Fe = 168,6 mg/L. The optimum conditions for application of recovered solution in wastewater treatment were identified at pH = 5 and recovery Aluminum dose = 60 ml/L. Figure 2 showed the treatment efficiency of recovered solution in optimum conditions, color, turbidity, TSS and COD removal were 74,54%, 89,81%, 89,23% and 75%, respectively. Wastewater after treatment almost reach the standard of textile wastewater treatment QCVN 13:2008/BTNMT.

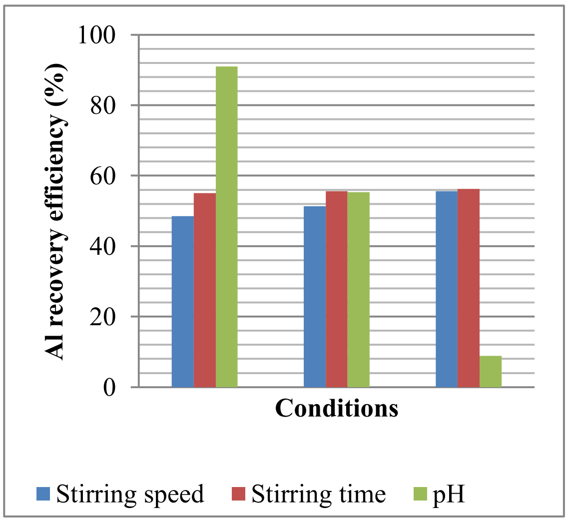
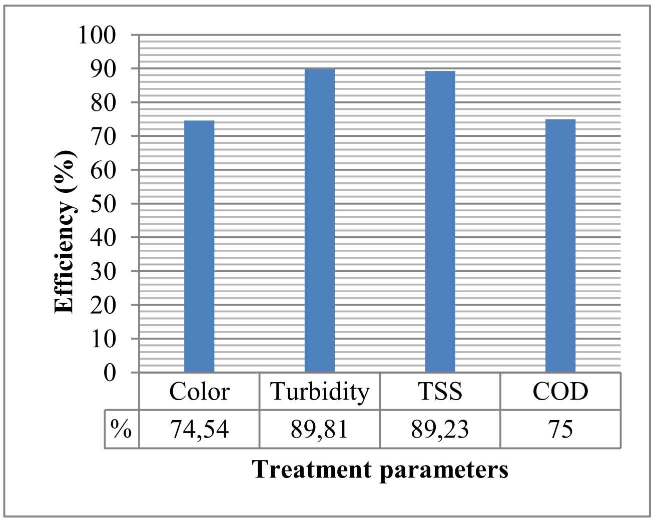


Figure 1. Aluminum recovery efficiency



	Color	Turbidity	TSS	COD
%	74,54	89,81	89,23	75

Figure 2. Wastewater treatment efficiency of RAS

Water treatment sludge reuse

Experimental results to determine the optimal conditions for reusing WTS in wastewater treatment is presented in Table 1. The color, turbidity, TSS and COD removal efficiency in difference conditions shown the effect of pH, WTS dose and fresh PAC dose. The appropriate conditions selected are pH = 5, water treatment sludge dose is 400 ml/L and fresh PAC dose is 2 ml/L which are suitable for the process and chemical saving.

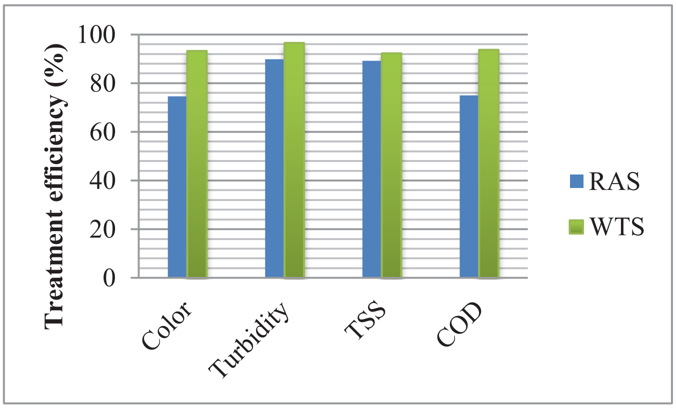


Figure 3. Comparision of RAS and WTS application in wastewater treatment at optimum conditions.

Figure 3 showed the comparision of the treatment effectiveness of RAS and WTS reusing applied in wastewater treatment at optimum conditions were determined. The results present that the combination of water treatment sludge with fresh coagulant (PAC) would give a substantially higher contaminant removal compared to the Aluminum recovery from sludge.

Table 1. Wastewater treatment efficiency of WTS

Conditions		**Parameters**				**Conditions**		**Parameters**			
pH	**WTS dose (ml/L)**	**Color %**	**Turbidity %**	**TSS %**	**COD %**	**WTS dose (ml/L)**	**PAC dose (ml/L)**	**Color %**	**Turbidity %**	**TSS %**	**COD %**
4		87.96	86.24	86.15	75.00	400		89.49	87.48	83.08	68.75
5		87.11	85.38	84.62	75.00	500		90.97	90.09	85.38	68.75
6		83.43	32.26	76.92	75.00		1	90.04	93.86	87.69	75.00
7		69.93	14.35	65.38	56.25		2	93.29	96.59	92.31	93.75
8		58.88	14.26	51.54	56.25		4	94.68	97.02	93.85	93.75
9		44.15	4.00	26.15	18.75		8	94.68	97.12	93.85	93.75
	100	38.66	23.56	7.69	18.75		12	94.68	97.27	93.85	93.75
	200	64.12	56.52	25.38	31.25		16	95.14	97.37	95.38	93.75
	300	83.10	74.71	42.31	37.50		20	95.14	97.70	95.38	93.75

CONCLUSION

The study verified that water treatment sludge could be reused in wastewater treatment or recover the coagulant then recycled to the chemical treatment process with high efficiency. Acidification can effectively recover the Aluminum from sludge with highest level at pH = 1. The quality of treated wastewater by RAS and WTS almost reach the standard, the tests show that it could be a good way to recover/reuse resource and reduce the sludge volume from the water treatment plant. More importantly, the recycling of WTS could make the wastewater treatment process more cost-effective.

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Review of composting activities in Vietnam

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ABSTRACT

This paper was carried out by ISPONRE in cooperation with IGES, in order to show the real picture on the current situation of the manufacture and consumption of compost in Viet Nam. Field trips to the state management agencies and 4 compost facilities and questionnaires sent to 63 provinces and 20 composting plants were carrying out over all three regions of Vietnam (the North, the Centre and the South). The results show that currently waste composting activities in Viet Nam has been young with both limited number of organizations involved and quality of operation activities. The lack of at-source separation of waste materials leads to the quality of compost products not meeting local requirements and production costs being high while product price remains low. Meanwhile, Viet Nam does not have separate policies for waste recycling activities, including composting, causing difficulties for both domestic and foreign composting technologies. Despite the many difficulties, certain opportunities still exit for composting activities as amounts of domestic waste increase and become plentiful input materials for composting activities.

Keywords: composting activities, recycling waste, composting technology.

Introduction

The amount of waste generated as a result of socio-economic development in Viet Nam has increased significantly in the last few years. According to the National State of Environment Report 2011, the total amount of generated waste has been rising appreciably, at quite a high rate (10% per annum), in which 46% is from urban areas, 17% from industrial activities and the rest is from rural areas, craft villages and medical areas.

One of the main directions of the National Strategy on Integrated Solid Waste Management to 2025 and vision to 2050 is to promote 3R solutions, focusing on waste recycling using the composting method. Composting is biodegradation process based on micro-organisms. Through the degradation of organic matter in mud, industrial and agricultural wastes, generated biomass provide nutrition for plants and soil as well as making soil porous.

In order to have a foundation to assess composting activities in Viet Nam, under the supports of IGES, ISPONRE carries out the research on “Review of Composting Activities in Viet Nam”.

Research Objectives include:

- To review policies and legislation on environment protection and fertilizer management.
- To investigate, survey, assess situation of compost production and consumption.
- To provide recommendations for promotion of composting activities in the coming time.

METHODS

Investigation and field survey: Visits and interviews were carried out at the Department of Cultivation, Ministry of Agriculture and Rural Development (MARD) and 4 composting plants representative of the Northern, Central and Southern regions of Viet Nam. Telephone interview were also used to collect information from 24 remaining Departments.

83 questionnaires sent to Departments of Natural Resources and Environment (DONRE) in 63 provinces and 20 composting plants. Result: 39 DONREs and 14 composting plants responded.

Desk study: relevant secondary data from research documents and studies were collected

Receiving comments from Workshops: ISPONRE in collaboration with IGES organized a seminar on the review of composting activities in Viet Nam at ISPONRE, January 17th, 2013. Seminar participants included representatives of 11 composting plants in the North, Centre and South of Viet Nam.

RESULTS AND DISCUSSIONS

- **Legal framework on recycling waste for composting**.

Viet Nam's policy and legislation system concerning waste recycling was formed under the Party's guidelines and the State's policies and legislation. These documents emphasize the importance of waste recycling, encouraging waste recycling and reuse in Vietnam in the period of industrialization and modernization promotion. They also set the goals for the proportion of waste reused and recycled or energy recovered and composted at 55% in 2015 and 85% in 2020

Principally, the Environmental Protection Law 2015 created the legal framework for waste management including recycling activities. The Law has specific articles related to waste recycling in general and for solid waste in particular.

Under the laws, there are a number of bylaw documents issued by the government and ministries regarding incentives and encouragement of compost production and use such as Decree 59/2007/ND-CP and Decree 04/2009/ND-CP. Some provinces have promulgated guidelines, policies and propaganda programs for composting activities. However, the result of the composting plants survey has shown that producers only have received incentives for land use, land rent, taxes and site clearance (see Table 3) but have not received other incentives, such as support for sorting waste at-source, consumption, advertising products, and subsidizing product price.

Table 1. Incentives received by the composting plants

Incentive	Land	Loan	Tax	Others
Number of the plants	11/13	6/13	6/13	1/13
Ratio	84,6	46,2	46,2	7,6

Regarding to regulations on standards of composting fertilizer, there are several national standard on specific type of fertilizer such as TCVN 6169:1996 for Microbial Fertilizer, TCVN 6167-1996 for phosphate soluble microbial fertilizer, TCVN 6166-2002 for Nitrogen fixing microbial fertilizer... On 16 May 2002, MARD promulgated sector standard 10/TCN/526-2002 on technical parameters and testing methods for Organic-Biofertilizer from domestic waste (attached with the Decision No.38/2002/QD-BNN-KHCN). However, currently, the standard is no longer applied, replaced by Circular 36/2010/TT-BNNPTNT dated 24 June 2010 of MARD on regulation of fertilizer production, trade and use.

Beside the efforts as mentioned, it is not difficult to recognise number of challenges relating legal framework for waste composting activities in Vietnam. In fact, there are no legal documents which specifically regulate for composting activities; the documents only mention waste recycling generally. Although Decree 59/2007/ND-CP has concretized the Law on Environmental Protection by regulating the implementation of at-source solid waste classification, the classification has not yet been implemented in practice, as people remain unaware of it, and still combines their organic waste with other waste.

- **Current status of composting activities in Vietnam**

The findings are included into 4 main parts:

- **Number of composting plants and production capacity**

There are 41 composting plants in Viet Nam, of which 28 composting plants in operation, 10 composting plants under construction, 3 composting plants stopped operation. Most plants are not working with their full capacity. As this researchsurvey, out of the 13 plants that provided information, there are 9 operating plants (69%) working with over 50% of designed capacity, 3 plants below 50% designed capacity.

- **Composting technologies**

Regarding to composting technologies in use, due to poor input waste quality, most composting plants use a method of mechanical screening combined with manual screening and separating metal by magnet. Out of the 14 plants having feedback, there is 50:50% (7:7) plants are usingforeign and domestic technologies, respectively.

Compared to foreign technologies, domestic composting technologies have some advantages such as simple and easy in operation, not highly qualified worker requirement, low investment cost, low treatment costs and saving land use. Besides, the disadvantages can be counted included: waste classification is fully manual with low efficiency which results in poor quality input materials; High humidity of waste easily damages waste classification floor and conveyor systems; Due to incomplete waste mixing, compost quality is uneven.

- **Compost Quality**

To control product quality, some plants have registered Vietnam standard TCVN 6168:1996 for fertilizer quality in general. Some others try undertake regular analysis of compost quality for every 3 months. However, in general, quality of compost Vietnamese productis likely uncontrolled due to registration and certification procedures remain complicated and discouraged.

- **Consumption Market**

The compost market is mainly in districts in the same province or the region of the plants (Table 2). However, there are also a number of plants expanding their market to neighbouring provinces or even for export.

Table 2. Market of compost

Survey results	Consumers			
	Plant site	Same provinces	Different provinces	others
Answers	6/13	11/13	7/13	2/13
Ratio (%)	46,1	84,6	53,8	15,4

The compost price ranges relatively high from 150,000 VND per ton to 3,500,000 VND per ton due to the high variation of product quality.

CONCLUSION

In conclusion, although waste composting is a relatively new issue, Viet Nam is trying to develop an initial legal framework for composting policymaking and implementation. Most importantly, there is a Law on Environmental Protection which emphasises waste management and provides a basis for further progressing composting activities. However, there is a lack of policies on encouraging and supporting waste recycling, and science and technology research and development to deal with entrenched obsolete and inefficient domestic recycling technologies, low quality products and environment pollution, while foreign advanced technologies are not suited or applicable to Viet Nam's conditions.

Despite the many difficulties, certain opportunities still exit for composting activities as amounts of domestic waste increase and become plentiful input materials for composting activities. In the immediate future, in order to promote compost manufacture in Viet Nam that meets the potential and actual needs of agriculture, the following actions shall be prioritized: (i) completion of mechanisms and policies on at-source waste separation, (ii) completion of national technical regulations and standards for compost, (iii) completion of preferential financial mechanisms for compost manufacture; and (iv) encouraging the private sector to become more involved in this field.

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Session 5

Waste to Energy 2

Facts study of biodiesel production processes with sewage sludge as raw material

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ABSTRACT

The potential of sewage sludge as lipid feedstock for biodiesel production was investigated. In the study, biodiesel production from sewage sludge is done by three common methods: traditional transesterification process, in-situ transesterification process and a two-step process. The effect of factors influencing the yield of biodiesel, such as methanol-to-sludge mass ratio, acid concentration, and temperature, was examined. The yield of biodiesel (16.6%) obtained from sludge by in situ transesterification is the highest of the three methods tried at methanol-to-sludge mass ratio of 10:1, temperature of 60°C, and acid concentration of 5% H_2SO_4 (v/v).Furthermore, the characterization of sludge residue collected after the biodiesel production process was carried out in order to study the whole process.

Keywords: Biodiesel, Sewage sludge, three methods

INTRODUCTION

Wastewater treatment plants (WWTPs) in China produce over 3×10^7t of sludge (moisture content 80%) every year (Dai, 2012), which is still on rise and it will reach 6×10^7t by 2020 due to increasingly strict wastewater effluent regulation together with the growing number of WWTPs. As the cost of sludge management (handling, storage, transportation and disposal) accounts for 50%～60% of the total wastewater treatment costs (Pastore C, Lopez A, et al., 2013). Besides that, sewage sludge contains substances, such as pathogens, heavy metals, and even some persistent organic pollutants (POPs), which may cause secondary pollution if it cannot be suitably treated. Recycling is now strongly suggested for waste treatment, therefore, a new method is proposed, which is to produce biodiesel by sewage sludge.

Research has indicated that sewage sludge contained approximately 20% of lipids (Dufreche S, Hernandez R, et al., 2007), which could be converted into biodiesel. Lipid is a mixture of triglycerides, diglycerides, monoglycerides, cholesterols, free fatty acids (FFA), phospholipids, sphingo-lipid, etc (Atadashi I M, Aroua M K, et al., 2013). Biodiesel, a mixture of fatty acid methyl esters or ethyl esters (FAMEs), is commonly produced via base- and/or acid-catalyzed transesterification or esterification of lipid (Liu and Zhao, 2007).

Biodiesel production from sewage sludge is generally done by three common methods (Mondala et al., 2009; David et al., 2010; Revellame et al., 2010; Wang et al., 2015). The first is the traditional transesterification process in which lipid is extracted from sludge using organic solvents and then transesterification reaction is performed with an alcohol (usually methanol) by a catalyst (usually an acid). The second method is the in-situ acid-catalyzed transesterification process in which sludge contacts with methanol directly instead of reacting with pre-extracted lipid. The third method is a two-step process—the acid-catalyzed pre-esterification of the FFA followed by the alkaline-catalyzed triglyceride transesterification.

Each method has innate advantages and disadvantages. The purpose of this study is to discuss the three common methods to produce biodiesel from sewage sludge. Furthermore, the characterization of sludge residue collected after the biodiesel production process was carried out in order to evaluate the whole process.

MATERIALS AND METHODS

Reagents and materials

Methanol (>99% purity), sulfuric acid (>98% purity), n-hexane (>95% purity), Sodium chloride (>99% purity), Potassium bicarbonate (>99% purity) and anhydrous sodium sulfate (>99%) were used in this work without further purification. Sludge samples were collected from a municipal WWTP in Beijing, China. The sludge was dried at 105 °C for 12h. Then it was milled into fine powder by vibration mill and stored in sealed plastic vials at 4 °C. The main characteristics of the sludge were shown in Table 1.

Table 1 Basic characteristics of sludge

Items	Water content	VSS	Crude Fats	Crude Protein	Acid value (mg KOH/g)	TOC
Contents	83 ± 0.5 %	65.3%	16.1%	26.2%	102.8	32.7%
Items	Ca	Fe	Si	Al	P	S
Contents	6.6%	5.4%	3.8%	3.7%	3.2%	2.2%
Items	Mg	K	Ti	Zn	Ba	Sr
Contents	0.6%	0.4%	0.3%	0.2%	0.1%	0.1%

Biodiesel production methods

Traditional transesterification. The traditional process in which lipid is extracted from sludge by using organic solvents and then transesterification converted into FAMEs. A 500mL extraction flask, a condenser pipe, and an automatic siphon, was used to extract lipids. 10g of sludge samples were placed into a tube using filter paper and transferred to the automatic siphon. Ethanol and hexane were used as extraction solvents in this experiment. The extraction was performed at 80°C for 10～12 h. Then the extracted lipids were placed in a 500 mL rounded-bottomed flask with a reflux condenser. 5% H_2SO_4 concentration (v/v) in methanol was added to the flask. The mixture was heated at 60°C for 8 hours. Afterwards, 10 mL of saturated NaCl solution was added. The FAMEs was extracted 3 times with 20ml of hexane. The hexane phase was washed with 10 mL of 2 % sodium bicarbonate solution and dried over anhydrous sodium sulfate. The hexane was subjected to solvent removal using a vacuum rotary evaporator at 40 °C. After hexane was evaporated, the flask was flushed with nitrogen to remove any remaining hexane in the gas phase and then weighed to determine the weight of the residue (FAMEs).

In situ transesterification. Dried sludge (10 g) was dissolved in 50 mL volume of hexane and transferred to the previously described rounded-bottomed flask with a solution of H_2SO_4 (5%) in 100 mL volume of methanol. In the same way above, the mixture was heated at 60°C for 8 hours. The subsequent steps were similar to those employed in the production of biodiesel from extracted lipids.

A two-step process. In the same way that above, the sludge (10 g) was heated to reaction temperature and under mechanical stirring (300 rpm) a solution of H_2SO_4 (5%) in methanol was added for pre-esterification. After 4 h, a solution of KOH (1.0%) in methanol was added and the reaction was carried out for 4h. Finally, the reaction mixture was filtered, washed as described above.

Analytical methods

The elements of sludge were tested by XRF-1800 instrument (Shimadzu, Kyoto, Japan). We adopted method HJ 557-2010 (solid waste extraction procedure for leaching toxicity—horizontal vibration method) to test the leaching behavior of the heavy metals in the sludge residue collected at the subsequent steps of biodiesel production process. The leaching solutions were then filtered for detection through flame atomic absorption spectroscopy (FAAS) (HITACHI, Z-2000).

RESULTS AND DISCUSSION

FAMEs production

Traditional, in situ transesterification, and the two step process of sludge resulted in FAMEs yield of 12.3%, 16.6%， and 13.8%， respectively. The yield of biodiesel (16.6%) obtained from sludge by in situ transesterification is the highest of the three methods tried as the reagents have access to all lipids in the sludge (Dufreche et al., 2007). Thus, the in situ process reduces the reaction time, cost, and amount of solvent associated with the pre-extracted lipid process, and maximizes the yield of the ester. The results revealed that the in situ process is the best method to produce biodiesel.

Characterization of sludge residue

Table 2 shows the main characteristics of the sludge residue collected after biodiesel production process. The main composition of original sludge and sludge residue indicated that no substantial differences except that the content of crude fats is substantially reduced. According to transesterification and esterification reaction theory, FAMEs results were directly related with the original lipid content.

Table 2 basic characteristics of sludge residue left

Items	Weight reduction	VSS	Crude Fats	Crude Protein	Acid value (mg KOH/g)	TOC
Contents	27.0%	52.3%	1.1%	20.4%	---	17.0%
Items	Ca	Fe	Si	Al	P	S
Contents	6.5%	2.4%	4.9%	2.1%	0.8%	9.9%
Items	Mg	K	Ti	Zn	Ba	Sr
Contents	0.4%	0.5%	0.4%	0.1%	0.2%	0.1%

The concentration of leaching solutions of the heavy metals in the sludge and sludge residue was shown in Table 3. The leaching toxicity of the heavy metals in the sludge and sludge residue is less than the regulation values of the identification standard for hazardous wastes in China (GB5085.3-2007) and European Union (EN12457.2-2002).

Table 3 concentration of leaching solutions

	concentration (mg/L)		GB5085.3-2007	EN12457.2-2002
	Sludge	Sludge residue		
Zn	0.60	7.26	100	20

Pb	--	--	5	5
Cd	0.03	0.39	1	0.5
Cu	0.18	2.82	100	10
Cr^{6+}	0.08	1.22	5	7

CONCLUSION

Production of biodiesel from sewage sludge is feasible by traditional, in situ transesterification, and two step process. The yield of biodiesel (16.6%) obtained from sludge by in situ transesterification is the highest of the three methods tried at methanol-to-sludge mass ratio of 10:1, temperature of 60°C, and acid concentration of 5% H_2SO_4 (v/v). The leaching toxicity of the heavy metals in the sludge residue is less than the regulation values of the identification standard for hazardous wastes.

ACKNOWLEDGEMENT

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Production of Ethanol from Wood Waste

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ABSTRACT

Preserved, treated wood is commonly found in construction waste. Preserved wood with chromated copper arsenate (CCA) has received a great deal of attention in North America in particular as it can have a significant role in soil and water contamination after disposal. In addition, as the ash of CCA treated wood is hazardous, the best available disposal method is thus landfilling. However, leaching of the metals (copper, chromium and arsenic) from disposed preserved wood in landfills can pollute the soil, water and the environment. To reduce the contamination of CCA treated wood after disposal, treatment should be performed before landfilling. As ethanol is alternate form of energy to oil, gas or gasoline, production was evaluated from the lignocellulosic material, waste wood. The objective of this paper is to evaluate the feasibility of producing ethanol from CCA treated wood. CCA treated wood was hydrolysed and fermented to ethanol. Results showed that the metals were taken up by the yeast. In the first step, the hydrolysis of the treated wood by sulfuric acid (4.4%) removed almost all chromium and 80% of copper and arsenic. In the second step, the remaining amount of the copper and more than 75% of the arsenic were removed by sulfuric acid (85%) hydrolysis after 10 minutes. The toxicity characteristic leaching procedure (TCLP) tests of the hydrolyzed wood showed that less than 4 mg/L of arsenic while minimal amounts of chromium and copper leaching from the remaining hydrolyzed wood. This indicates that landfilling of hydrolyzed wood is acceptable. Only a slightly lower amount of ethanol was produced from the CCA treated than the untreated wood (6 g/L and 7 g/L, respectively). Thus the production of ethanol, a source of energy, from a hazardous waste (CCA treated wood) was feasible.

Keywords: ethanol, CCA treated wood waste, leaching, arsenic, yeast

INTRODUCTION

A problematic preserved wood in North America is chromated copper arsenate (CCA) treated wood that has been used in outdoor decks, playgrounds, and fences. CCA was used as it is inexpensive, presents a dry, paintable surface, and binds to become relatively leach-resistant. However, concern increased due to leaching of Cu, Cr and As from treated wood in service and from wood removed from service and placed in landfills in North America (Shalat et al., 2006). In Florida, it has been found that up to 30% of the construction and demolition (C&D) wood was CCA-treated wood (Solo-Gabriele et al., 2003). The quantity of wood removed from service is estimated to be 16 million cubic meters by the year 2020 in the U.S. (Cooper, 1993).

Landfilling is the best existing disposal method for used treated wood. However, water penetrates into landfills and can leach preservatives (copper, chromium and arsenic) from the disposed treated wood and pollute ground water (Moghaddam and Mulligan, 2008). The leachate is genotoxic and carcinogenic, and is hazardous for human beings and animals. Therefore, a method of disposal of treated wood other than landfilling and incineration could decrease damage to the environment. As ethanol is a source of energy and valuable substitute for gas, oil or a gasoline complement, there is the potential for wood as a substrate for ethanol production. The main objective is to determine the feasibility of producing ethanol from CCA treated wood.

MATERIALS AND METHODS

Treated Wood

CCA treated wood was the most frequently used wood, for exterior applications, in Canada. This greenish wood, usually of Gray Pine species, was obtained from Rona, a renovation store. The pieces of 2.5 cm x 15 cm x 12.5 cm and chips were produced during cutting and rasping by RONA.

Analytical procedures

A Beckman Coulter High Performance Liquid Chromatograph (HPLC), System Gold with Model 508 Auto sampler and Jasco Refractive Index (RI) detector, model RI1530 was used to measure ethanol, and sugars. Arsenic (III and V) analyses were based on modified Shodex Company recommendations and copper analysis was based on the Hamilton website without EDTA and using a 192 nm wavelength for absorbance instead of 254 nm. Copper, chromium and arsenic in the liquid were measured by an Agilent 7500 Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The amount of arsenic, chromium and copper in the solid CCA treated wood was measured with the X-ray fluorescence (XRF) analyzer (Niton XLp 700 series Environmental Analyzer) according to the EPA Method 6200.

Experimental procedures

For the hydrolysis process wood samples were chopped into 2 cm x 1 cm x 0.5 cm cubes and a two step acid hydrolysis was performed by sulfuric acid (4.4% at 100°C for 60 minutes and 85% at 100 °C for 10 minutes), followed by addition of NaOH to increase pH to 4 to 6. Following the hydrolysis, hydrolysates were fermented (aerobically) using 250 ml flasks placed on a Thermolyne adjustable reciprocating orbital shaker adjusted at 170 rpm in a Fisher Scientific incubator model 304, at 30 ºC. The addition of nutrients was according to the Palmqvist et al. (1996) fermentation procedure. Two grams of active dry Fleischmann's Baker's yeast were added to all flasks except for the controls. Samples were taken and centrifuged (3500 rpm, 10 min), filtered (using a 0.45 μm syringe filter) and analyzed by HPLC and ICP-MS after digestion and filtering. The TCLP test (EPA Method 1311) was performed for the remaining solids of wood after the hydrolysis to determine if the values were less than 5 mg/L (the maximum acceptable limit) for chromium and arsenic.

RESULTS AND DISCUSSION

Wood hydrolysis

Figure 1 shows the metal contents of hydrolyzed and non- hydrolyzed treated wood. During the 1-hour hydrolysis of treated wood by sulfuric acid (4.4%), almost all the chromium and 80% of copper and arsenic were removed from the wood. The rest of the copper and more than 75% of the remaining arsenic were removed in the second step of hydrolysis by sulfuric acid (85%) after 10 minutes. The strong ability of sulfuric acid to leach almost all the chromium from the CCA wood was also observed during the leaching tests using different types of acids by Moghaddam and Mulligan (2008).

To determine if the hydrolyzed wood can be landfilled, TCLP tests for both 4.4% and 85% hydrolyzed wood were performed. During the TCLP test, the arsenic leached from 4.4% hydrolyzed wood, was about 4% and for 85% hydrolyzed wood, which is less than 4 mg/L. This is less than the acceptable maximum arsenic of 5 mg/L is allowed according to the EPA (http://ehso.com/cssepa/TCLP.htm). Therefore the two-step hydrolysis of CCA wood is an effective pretreatment method prior to landfilling.

Ethanol production

To compare the amount of produced ethanol from treated and untreated wood, 10 g of treated and untreated wood were hydrolysed and fermented. Yeast starts to produce ethanol 4 hours after inoculation and after 6 hours, the maximum amount of ethanol is produced. Existence of chromium, copper and arsenic in hydrolysate of CCA treated wood did not have any negative effect during the fermentation of untreated and CCA treated wood. The maximum yield of ethanol from both woods was almost 0.2 g of ethanol per g of wood. According to Taherzadeh (1999), the maximum theoretical yield of ethanol production is 0.32 g of ethanol per g wood based on an average of 42% cellulose and 21% hemicellulose in the wood. Using a dilute sulfuric acid hydrolyzation in appropriate vessels under pressure will improve the yield of ethanol production.

Hydrolysate metal removal

Figure 2 shows the results of monitoring the amount of chromium (VI) and (III), and arsenic (V) and(III) in the hydrolysate liquid phase (using sulfuric acid, 4.4%) during the fermentation by 2 g of bakers' yeast,

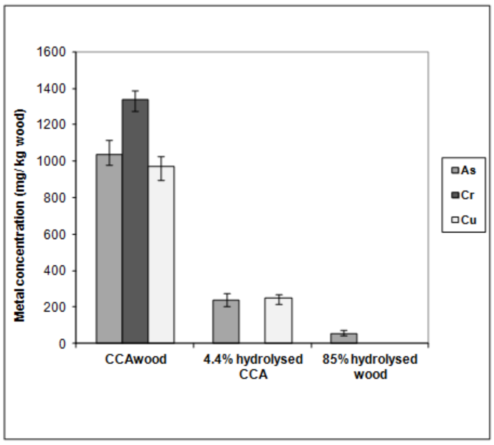

Figure 1 Metal contents of CCA wood before and after hydrolysis

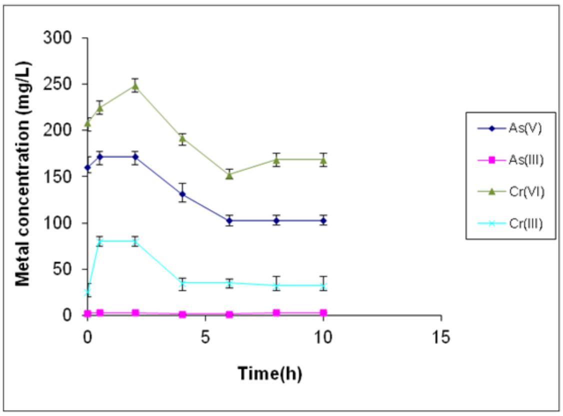

Figure 2 Metal concentrations during fermentation of CCA wood hydrolysate (4.4%)

Although the Cr(VI), As(V) and Cu(II) are the main species of metals used to treat the wood, the fixation step chromium (VI) could change to chromium (III) (Lebow, 1996). As chromium (VI) and arsenic (V) are the more soluble forms than the high levels of chromium (VI) and arsenic (V) in comparison to chromium (III) and arsenic (III) in the leached hydrolysate is logical (Figure 2). During fermentation the amounts of arsenic (III) and also chromium (III) does not change which means that yeast uptakes mainly chromium (VI) and arsenic (V). Copper was not detected by HPLC probably because of precipitation of copper compounds resulted from reactions of sulfuric acid and sodium hydroxide with copper during hydrolysis and pH adjustments.

CONCLUSIONS

The experiments showed that the presence of copper, chromium and arsenic in wood did not have a negative effect on ethanol production process. Removal of chromium, copper and arsenic from CCA treated wood was a substantial part of the pre-treatment process. As the hydrolysis of wood by sulfuric acid is the first step of ethanol production from wood, disposed wood could be the feed of an ethanol production factory. During the two step hydrolysation most of the metals leached out of the wood and the landfilling of residue would be acceptable according to the results of the TCLP tests. Almost 50% chromium (VI) and 60% arsenic (V) were removed from hydrolysate during the fermentation process while copper was removed at the hydrolyzation step. Using the disposed CCA wood as a source of ethanol production would be more sustainable as a source of energy from a hazardous waste than landfilling.

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Feasibility Study of Polyurethane SRF (Solid Refuse Fuel) for Combustion and Gasification: Characteristics of Flue gas and Nitrogen pollutants

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ABSTRACT

Polyurethane, one of WEEE(waste from electric and electronic equipment), are mainly generated from refrigerator. Recently, generation of WEEE has increased due to rapid changes in materials and shorter replacement of consumer products. For separating valuable and recyclable material, this WEEEs are collected and treated by recycling centers in Korea. Polyurethane used in this products becomes waste and is treated by proper methods like landfill and combustion.

In this study, polyurethane SRF(Solid Refuse Fuel) was fabricated to feed into the furnace. For applying thermal process, TG(Thermogravimetric) analysis, proximate analysis and HHV(higher heating value analysis) was conducted. Because of high nitrogen contents in polyurethane, NH_3 and HCN were analyzed by IC(Ion Chromatography) analysis.

Combustion and gasification of polyurethane were conducted for finding optimum condition with changing ER(Equivalent Ratio). Also, characteristics of flue gas and nitrogen pollutants were analyzed.

Keywords: Polyurethane, SRF, Gasification, Combustion, Nitrogen pollutant

INTRODUCTION

As development speed of culture and economy has accelerated, it also accelerated the generation of WEEE. Specially, following tendency of lightening and gentrification, amount of used polyurethane has increased, because polyurethane had chemical resistance, thermal insulation, variety of manufacturing and other advantages. But, polyurethane waste is a macromolecule and takes long time for natural decomposition. This feature causes environmental pollution. Usually, polyurethane waste are disposed of by landfill or incineration.

In this study, polyurethane generated from refrigerator were used for combustion and gasification. But, due to large bulk polyurethane in refrigerator, polyurethane waste had not only low economic feasibility but also low energy density. Consequently, for overcoming this weakness, polyurethane SRF has been fabricated.

For assessing the applicability to conduct thermal process, we conducted various thermal characteristics analyses like TG analysis, proximate analysis, HHV analysis. Elemental analysis was analyzed for ER setting and TG analysis, proximate analysis and HHV analysis were conducted to set reaction temperature and feeding rate. From these results, we found that polyurethane is good feeding material for thermal process.

Flue gas and syngas from thermal process were analyzed by flue gas monitoring analyzer (Hymeth plus, KINSCO) and Micro-GC(Agillant 3000A, Agillant). We analyzed contents of O_2, CO_2, CO for combustion and contents of H_2, CO, CH_4, CO2, C_2H_6 and C_3H_8 for gasification.

MATERIALS AND METHODS

First, we conducted basic characteristics analysis. For that we crushed fabricated polyurethane SRF, because we had to use small amount of samples in those instruments. Figure 1 shows raw polyurethane, polyurethane SRF and crushed polyurethane SRF. Using crushed SRF, we conducted basic characteristics analysis for assessing the applicability for thermal process. Table 1 and Table 2 show the basic characteristics of the sample.

[Raw polyurethane] [Polyurethane SRF] [Crushed SRF]

Figure 1. Figure of feedstock

Table 1. Element analysis result of feedstock

Elemental	C	H	O	N	S	Cl	LHV [kcal/kg]
[wt. %]	67.96	6.75	16.18	7.01	ND	0.15	6,945

Table 2. Proximate analysis result of feedstock

Composition	Moisture	Volatile	Fixed-Carbon	Ash
[wt. %]	1.83	82.78	10.28	5.11

Table 3 shows sampling methods of nitrogen gaseous pollutants in Korea, air pollutant official test. Figure 2 shows a diagram of gasification and combustion reactor (fixed bed). This reactor is composed of main reactor (heating zone, inconel column and max temperature : 1350 ℃), semi-batch feeder, cyclone, scrubber and others.

Gas analysis was performed by Micro-GC (Agilent 3000A) and Gas analyzer (KINSCO). Gas flow rate was analyzed by a dry gas meter (Shinagawa DC-5C-M), temperature was measured by thermocouple (K type)

Table 3. Sampling methods of gaseous pollutant

Gaseous pollutant	Analysis method	Reference
NH_3	Indophenol method	Air pollutant official test in Korea : inorganic method analysis in exhaust gas
HCl	Thiocyan and mercury second method	

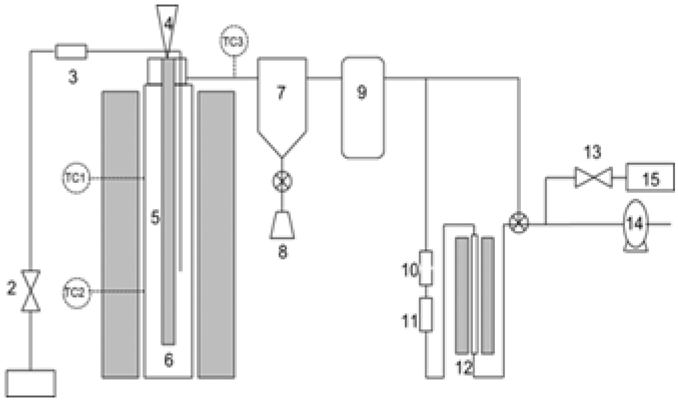

Figure 2. Diagram of reactor process

① Oxygen supply, ② Oxygen controller, ③ MFC, ④ Feeder, ⑤ Pipe of feeding, ⑥ Furnace, ⑦ Cyclone, ⑧ Residue collector, ⑨ Filter, ⑩ Filtering system(1), ⑪ Filtering system(2), ⑫ Clean-up reactor, ⑬ Syngas controller, ⑭ Gas pump, ⑮ Micro-GC/Gas analyzer

RESULTS AND DISCUSSION

Representatively, flue gas composition from combustion is shown in Figure 3. We analyzed flue gas composition after stabilization of combustion, and stabilization of combustion was judged by continuous flue gas monitoring.

In overall results, concentration of CO was about 0.0%, CO_2 was about 7.0% and O_2 was about 10%. Also, with increasing ER, concentration of O_2 and CO_2 was increased. But, there was no big difference at ER 1.5 and 1.8.

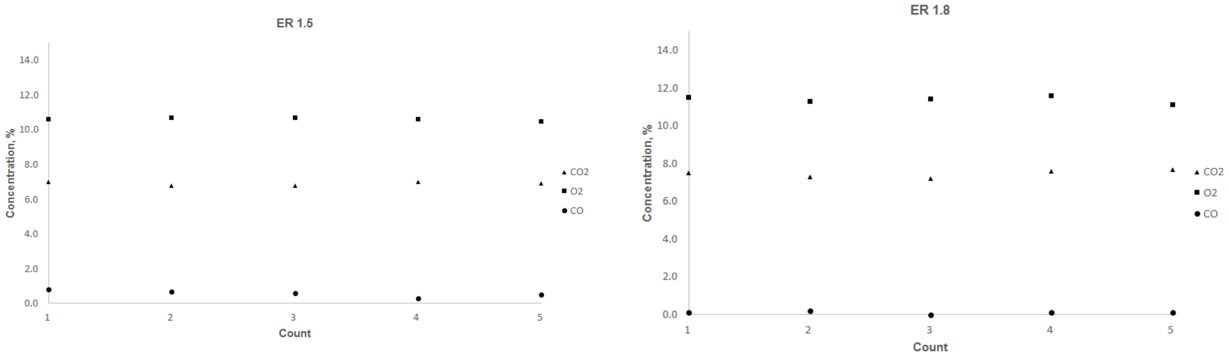

Figure. 3 Composition of flue gas by combustion

In case of gaseous pollutant, we could see clear difference between combustion and gasification. Concentration of HCN and NH_3 in gasification was higher than combustion. In case of HCN, the concentration was about 150ppm in gasification and about 20ppm in combustion. Concentration of NH_3 was about 50 ppm in gasification and about 20ppm in combustion.

But, low concentration of nitrogen gaseous pollutants were emitted from combustion and gasification and we can predict the reason behind this was using of wet scrubber in this study.

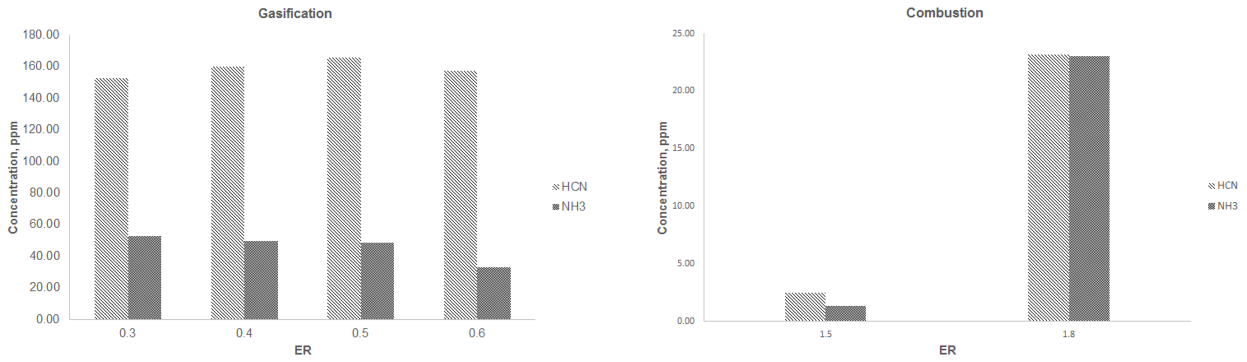

Fig. 5 Concentration of gaseous pollutant

CONCLUSION

From the result of basic characteristics analysis, polyurethane had high concentration of volatile matter and high heating value. Following these advantages, for applying thermal process, we could judge that feasibility of polyurethane was enough.

Also, composition of polyurethane SRF is different from waste SRF, composition of polyurethane SRF is uniform, and this uniformity was added advantage for applying waste to energy. But, to overcome low density problem of polyurethane, we had to fabricate polyurethane SRF.

Finally, for conducting thermal process on polyurethane and we need to control nitrogen gaseous pollutants, because of high nitrogen contents in polyurethane. Following these results, if we install nitrogen pollutants removal system, polyurethane is very good form of alternative fuel using thermal process.

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Pyrolytic route for the production of hydrocarbons from lignocellulosic biomass and waste plastics

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Progress towards a sustainable energy supply is without doubt one of the biggest challenges that mankind has ever faced. Long-term economic and environmental concerns have resulted in a great amount of research in the past couple of decades on renewable sources of liquid fuels to replace fossil fuels/chemicals from fossil resources. Biomass is a renewable and sustainable source of energy. There are several methods of lignocellulosic biomass conversion among which thermo-chemical methods of conversion are gaining limelight in the past few decades. The various processes that fall under the umbrella of thermo-chemical conversion methods are combustion, gasification, pyrolysis, liquefaction and carbonisation.

Biomass is the only renewable source of organic carbon which is required for the production of liquid fuels, petrochemical feedstocks and chemicals. Among the various thermo-chemical methods of conversion, pyrolysis seems to have the highest potential for commercialisation. It is a flexible process as the operating parameters can be tuned for the desired combination of bio-oil, bio-char and non-condensable gases. There are several types of pyrolysis depending on the heating rate, environment used, reactor, residence time etc. Fast and slow pyrolysis bio-oil can be used as a substitute for heating oil and also be upgraded to fuels. Biomass being a natural polymer, pyrolysis can be used to selectively cleave the bonds to produce high value chemicals which are now produced from crude oil after several steps of functionalisation. The integrated hydropyrolysis and hydroconversion of lignocellulosic biomass can provide directly usable transportation fuels/ petrochemical feedstocks in a self-sustainable manner. In addition, the valorization of waste plastics through pyrolysis approach for the production of liquid hydrocarbons and associated process has been successfully demonstrated. Pyrolysis, can hence be carried out in decentralised or centralised units depending upon the quality and quantity of biomass available end user requirement.

Biodry of Municipal Solid Waste to Utilize as Solid Recovered Fuel

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ABSTRACT

Thailand produces approximately 40,000 tons of municipal solid waste (MSW) per day and will increase due to the increasing of population and urbanization. In the normal practice, most waste is disposed only at the open dump sites and landfills. Waste to Energy (WtE) is an alternative option for the better MSW management. The production of Solid Recovered Fuel (SRF) by using the biodrying technology is a promising technology which can be applied to treat the waste in Thailand. However, there is no available data of the appropriate aeration rate for biodrying process which can be applied to the moist and mixed waste in tropical developing countries. In this study, the appropriate aeration rate was evaluated by the lysimeter study. The study investigated the effect of airflow rate in biodrying treatment with MSW. The results showed that at the rate of 0.006 m^3/kg/h, the heat from microbial activity could reduce the moisture content to 30% within 7 days and 19% within 14 days corresponding to 13.31 Mj/kg of heating value. The higher aeration rate of 0.042 m^3/kg/h, the waste dry by the physical evaporation although the moisture content could reduce to 30% within 5 days and 14.02 Mj/kg of heating value was obtained from 14 days.

Keywords: Biodry, Mechanical Biological Treatment, Municipal Solid Waste, Solid Recovered Fuel

INTRODUCTION

Thailand produces approximately 73,355 tons of MSW per day in 2013 (PCD, 2013) and will increase due to the urbanization, rapid economic growth and rise in community living standard. The most of waste generated in Thailand is MSW. Wastes have high moisture content and low calorific value due to water and inorganic components which are derived from food waste; the main component of MSW in Thailand. The correct methods of waste management in Thailand that often found are composting, landfill, incineration, dumping and anaerobic digestion. Bio-drying is a treatment of aerobic bioconversion applied to MSW with aims at removing water from bio wastes with high water content (Zhao, L., et al. 2010) using by self-generated heat from microbial biochemical processes to evaporate water. Biodrying process generate of heat, evaporate of waste as well as stabilize of volatile solid (Naylor, L., et al. 2009). The water evaporation and mass transfer conditions are improved through the aeration. Aeration rate is the main variable for controlling process in bio-drying, both in the laboratory and commercial applications. Using low aeration rate results in a decomposition without significant of moisture lose while too high aeration rate, the waste dries only by physical phenomena because of the lack of microbial activities (Sadaka S., et al. 2010).The improvement of air flow rate enhance the volatile solid degradation and energy utilization efficiency for water evaporation (Zhao L., et al. 2010). The aeration rate is the key factor for this success. However, there is no available data of the appropriate aeration rate for biodrying process with moist and mixed waste in tropical developing countries. In this study, the appropriate aeration rate was be evaluated by the lysimeter study. The objective of this study is to evaluate the optimum aeration rate in biodrying process by using the lysimeter study.

MATERIALS AND METHODS

Reactor and simulated waste preparation

The experiments were conducted in lysimeter and filled with simulated waste. A biodrying experiments were performed in lysimeter with 0.6 m in height and 0.2 m in diameters which was constructed by using the acrylic and covered with thermal insulation (Figure 1). The composition of simulated waste was based on the composition of MSW in Thailand, it comprised of 45% food waste, 12% paper, 25% plastic, 6% yard waste, 5% textile and 7% others. The waste was loaded to the lysimeter about 2.88 kg with density of approximately 340 kg/m^3.

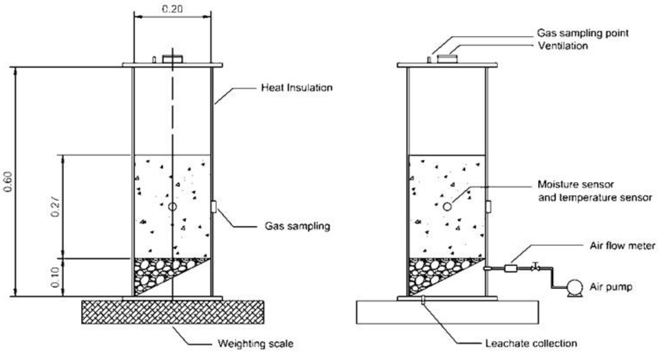

Figure 1 Configuration and cross sections of simulated lysimeters

Effect of different airflow rate on simulated waste

The experiments were operated for 14 days with six different airflow rates provided from the bottom to the top of each lysimeter as show in Table 1. During the experiment, the waste was sampled for measures: (1) moisture content which was directly related to the heating value (2) waste temperature and (3) the quantity and characteristics of leachate.

Table 1 The difference airflow rate provided to biodry lysimeters

Lysimeter	1	2	3	4	5	6	control
Airflow rate (m^3/kg/h)	0.002	0.006	0.010	0.015	0.021	0.042	-

RESULTS AND DISCUSSION

The summary results of moisture content and heating value in each lysimeter of day 14 are persented in Table 2. The reduction of moisture content occurred by the metabolic heat produced by microorganism in waste at 0.002 to 0.021 m^3/kg h aeration supplied. The moisture content could be reduced from 61.92% to 15.34-24.51% in the lysimeters in 14 days. There no leachate observed in this experiment, it could be concluded that the moisture content in lysimeter evapulated and released into the atmosphere or the condensation was occurred and the water drop into the surface of waste in lysimeter. The increasing of LHV of biodried waste reached 144.46% which coresponded to 13.41 Mj/kg. In the lysimeter with aeration rate of 0.006 m^3/kg/h, the results of moisture content was 19.19% with 142.69% increasing in LHV (13.31 Mj/kg) which was coresponding to the RDF value from the study of Silvapalan (2003) that varies from 13 to 18 Mj/kg. Although the increasing of LHV in lysimeter with 0.042 m^3/kg h aeration supplied rate was reached 155.51%, the loss in moisture content was mainly due to physical dry phenomena. In control lysimeter, the moisture content could be reduced to 30% within 7 days. The experiment was done in the small lysimeter with passive aeration. Due to it small size and open hole from bottom and top of this configuration, the air was flow within the reactor and removed the moisture content with its organic degradation activity in combination with passive aeration. Therefore, the reduction of moisture content from 62% to 30% was found within 14 days. On the other hand, the lysimeter with force airflow rate (active aeration) can reduce moisture content better than control lysimeter. Gas analysis in control particularly CO_2 was increase which indicated activity of biodegradation within the lysimeter.

Table 2 Summary of the moisture content and heating value

Aeration (m^3/kg h)	Initial MC (%)	Final MC (%)	Decreasing of MC (%)	Initial Weight (kg)	Final Weight (kg)	Weight loss (%)	Initial LHV (Mj/kg)	Final LHV (Mj/kg)	Increasing of LHV (%)
control	61.92	29.53	52.31	2.88	2.26	21.56	5.49	11.42	108.16
0.002		24.51	60.42		2.20	23.51		12.34	124.92
0.006		19.19	69.01		2.01	30.07		13.31	142.69
0.010		19.01	69.30		2.10	27.01		13.35	143.29
0.015		18.85	69.56		2.09	27.40		13.38	143.82
0.021		18.66	69.86		2.09	27.57		13.41	144.46
0.042		15.34	75.23		2.03	29.51		14.02	155.54

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CONCLUSION

The biodrying can be recommended as one of the promising technology for MSW treatment which is short process time and the final product could be used as SRF. The biodrying of MSW could be successfully developed in the lysimeters operated at aeration rates of 0.006 m^3/kg/h and 0.010 m^3/kg/h. The basic biodry phenomena was promoted by the degradation of microorganism to product a heat through the aerobic decomposition and could reduce moisture content from 61.91% to 19.19% within 14 days with heating value 13.31 Mj/kg.

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APPLICATION OF MECHANICAL BIOLOGICAL TREATMENT ON MUNICIPAL SOLID WASTE FOR UPRAITING OF HEAT VALUE

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Abstract

Cities of Vietnam are facing the inefficient handling of domestic waste. Currently waste is mostly landfilled (accounting for 76-82%). Only a small percentage (8-12%) is recycled or composted. In countries around the world, the production of energy from waste (Waste to Energy) is an effective solution. However, due to the high humidity of the solid waste in Vietnam, the direct incineration technology is not feasible. The research using mechanical and biological (MBT) treatment process is conducted at the plant in Binh Duong province to reduce humidity of wastes. The humidity and calorific values of input wastes are 65.9% and 2,186 kJ/kg, respectively. After 20-day aerobic fermentation in static boxs, the humidity and calorific values of the waste reached 45.7% and 9,540 kJ/kg, respectively. After 42-day, the humidity and calorific values of the waste reached 26.3% and 15,750 kJ/kg, respectively. Then the dried waste is compressed into briquette at factory. The products have the calorific value of 16.650 kJ/kg. MBT method shows the potential to reduce moisture of municipal solid wastes in Vietnam for higher calorific value in an efficient way, opening up the possibility of RDF and a significant reduction of solid waste to be landfilled.

Key words: Domestic Solid Waste, Mechanical Biological Treatment, Refused Derived Fuel, Calorific value.

1. INTRODUCTION

The effective and sustainable management of urban waste has needed care and attention of the government and community of Vietnam. According to the National Environment Report in 2011, the Southeast municipal solid waste (MSW) quantities were 2,450,245 tons / year, accounting for 37.94% of the grade III cities of the country. In Ho Chi Minh City the average (MSW) quantities were 6792.18 tons / day [2]. While in Binh Duong province in 2012, the average quantities were 900-1000 tons [3].

However, waste treatment in Vietnam today is mainly by land filling (accounting for 76-82%) and a number of measures such as recycling, composting of only 8-12% of collected (MSW) [1] .The composting or direct burning of garbage showed the inconsistence as Vietnam's urban garbage particulars are the non-separation of wastes at source and very high humidity. The research on the use of aerobic biological processes to reduce water content of wastes and producing high heat value RDF materials.

2. MATERIALS AND METHODS

2.1. Location for research and input materials

Research was conducted at the solid waste treatment complex of Binh Duong province. Input materials are household wastes from Thu Dau Mot city. The experiments were conducted from January to July 2015.

2.2. Determining the composition of waste

Waste composition (% by weight) is determined by means of a quarter. The classified components include: food waste (p1), packaging (p2), paper (p3), plastic (p4), fabrics (p5), stone / gravel / shells (p6), glass / porcelain (p7), metals (p8).

2.3. Determination of moisture, volatile matter, fixed carbon

Samples were analyzed at (MSW) lab in Industrial University of Ho Chi Minh City under the standard method for determining moisture (W), volatile matter (V) and fixed carbon (F) of solid wastes.

Moisture of trash generally is determined from the moisture of garbage as to the following formula:

$W (\%) = (w1.p1 + w2.p2+ w3.p3+ w4.p4+ w5.p5+ w6.p6+ w7.p7+ w8.p8):100$

2.4. Determining the heat value of waste

The calorific value of the sample was determined as to the formula: *(Source: [1])*

$HHV = 276{,}04V + 289{,}70F – 51{,}45W – 2.847{,}53$ (KJ/kg)

2.5. Biological processes to reduce humidity

Household waste is collected and transported to the plant. Rubbish bags were shredded and metal components are removed through a magnetic band. Then the garbage is transported into fixed fermentation boxs (length: 12,0m, width: 6,0m, height: 4.5m). The forced air supplied by fans from tank bottom along to the groove. After 20 days of aging in the tank, garbage is transferred to the composting section to make beds (Length: 12,0m; bottom width: 2.0m, height: 1.5m). Each day the beds are turned once by specialized turning equipment.

During fermentation, no additional water is allowed into the garbage. The temperature in aging tank is ranging from 50-65^{o}C. Temperature of annealing beds ranging from 70-80^{o}C.

3. RESULTS AND DISCUSSION

The composition and moisture of the ingredients of waste are shown in Table 1.

Table 1 Composition of the collected (MSW) at the treatment plant

Composition	Foods	Packaging	Paper	Plastic	Fabric	Metal	Rocks, stones, shells	Glass, porcelain
Mass (%)	77.54	6.90	5.97	1.27	2.23	0.27	3.67	2.15
Humidity (%)	74.98	45.79	45.19	11.25	57.85	5.29	9.95	2.20

Foods account for the largest percentage (77.54%) and the highest humidity (74.98%). Recyclables such as metal, plastic, paper etc are at a low rate. They are collected by individuals (junkmen) from the waste sources to the treatment plant.

Table 2 shows a decrease in moisture and volatile matter content of waste in 20 days of biological drying process in the static boxs and the next 22 days of fermentation in piles.

Table 2 Variability of moisture and volatile matter content of the waste in the biological drying process

	Input wastes	Fermentation in boxs				Fermentation in piles			
Fermentation time (days)	0	3	7	16	20	26	35	39	42
Moisture content (%)	65.91	63.93	55.47	49.94	45.72	37.85	33.34	28.25	26.34
Volatile matter (%)	59.66	61.05	41.83	40.51	37.48	33.85	29.95	28.18	23.54

After 20 days of fermentation, the moisture was 30.6%, and after 42 days, a decrease of 60% compared to the imput materials. The reduction of water content of wates in the biological drying process is shown in Figure 1a with linear equation y = -0.9347x+64.719 (R^2=0.9874).

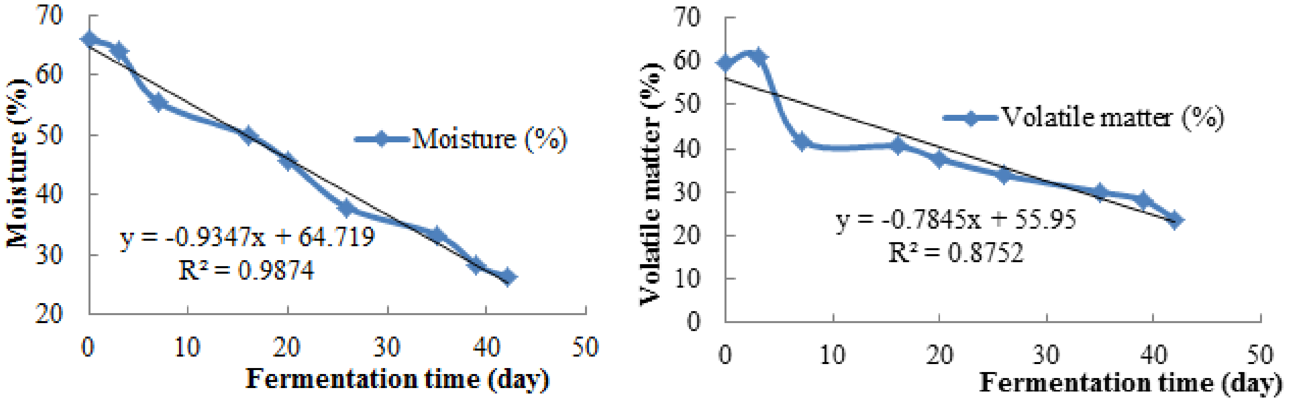

Figure 1: The relation between time of fermentation and moisture content (a) and volatile matter content (b) of wastes

The volatile matter of input wastes was 59.66%, after 42 days of biological drying was reduced to 23.54%. Figure 1b is showing changes over time with linear equation y = -0.7845x+55.95 (R^2=0.8752).

The calorific value of waste increased in the aging phase, from 2,186.14 kJ / kg to 15,749.19 kJ / kg after 42 days. The linear equation is y = 303.18x + 2,388.8 (R^2=0.9848).

Table 3: Variability of heat value of waste during biological drying process

	Input wastes	Fermentation in boxs				Fermentation in piles			
Fermentation time (days)	0	3	7	16	20	26	35	39	42
Heat value (kJ/kg)	2,186.14	3,232.08	6,362.38	8,164.27	9,540.38	12,056.33	13,369.99	15,223.76	15,749.19

After the biological process, dried waste is compressed into 80mm- diameter briquette together with common types of devices to produce rice husk briquette. Rice husk briquettes are ranging from 30-33 cm of length. Rubbish briquette are shorter, ranging from 10-18 cm. Rice husk has very high lignin content (~ 30%). When pressed at high temperatures, lignin becomes good binders. Table 4 shows the efficiency as recovered products in such process differ markedly; in fact the rice husk account for (95.45%) and waste (82.73%). In the heating and pressing, moisture and evaporated organic waste have been reduced better than rice husk material.

Table 4: Comparision between rice husk and dried waste for RDF production

	Input (kg)	Output as briquette (kg)	Efficiency (%)	Heat value of briquette (kJ/kg)
Rice husk	22,0	21,0	95,45	18.960
Dried waste	22,0	18,2	82,73	16.650

4. CONCLUSION

The aerobic composting has significantly reduced humidity while promoting sharply the calorific value of waste. After 42 days of aging, junk is capable of being material for producing RDF. MBT method shows the potential to apply in urban areas of Vietnam to handle (MSW) effectively, so as to limit land filling of waste and contributing to the reduction of quantities of fossils in daily activities.

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Session 6

MSW management

An investigation of household waste generation and composition in Hoi An, Vietnam

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ABSTRACT

A survey to characterize municipal solid waste in Hoi An, a famous world heritage city in Vietnam was carried out at household level. The purpose of this study is to identify generation rate and compositions of household waste from different type of areas of the city. The areas surveyed covered rural, urban and suburban, tourist quarters (Hoi An ancient town), presenting three typical types of urban in Hoi An. The result will contribute to consider harmonized solid waste management for the city. A stratified sampling method was applied for selection of household waste samples in order to evaluate differences between areas of the city in waste generation rate and composition. The following statistical results were obtained: overall mean of waste generation rate was about 0.223 kg capita^{-1} day^{-1}, ranged from 0.207 to 0.240 kg capita^{-1} day^{-1} for 95% confidence interval; the average waste generation per capita in tourist old town and urban area (0.203 and 0.264 kg capita^{-1} day^{-1}) was almost double that of rural area (0.12 kg capita^{-1} day^{-1}) and those differences was statistical significant. In addition, the study found that, degradable waste counted for more than half of amount of household waste (37.5% for Food and 14.17% for Yard waste), Combustible waste (textile, leather, wood, diapers etc.) (13.23%) was highest portions in household waste composition, which mean that biological and thermal treatment technologies could be potential options with the purpose of declining amount of waste to landfill for the city. The result of research also showed that there are differences in waste composition among tourism and other areas, but those were not statistical significant.

Keywords: Municipal solid waste, household waste characterization, stratified sampling, Hoi An, Vietnam

INTRODUCTION

Hoi An is a city on the coast of the East Sea in the South Central Coast region of Vietnam, has natural land area of 6,171.25 ha, total population in 2013 is around 93 thousands with population density of 1,508 people km^{-2} (HASD, 2013). As many cities in Vietnam, Hoi An has a waste treatment facility consisting a composting plan and a landfill site. However, this open dumped landfill has been out of capacity that leads to great of negative effects to the environment and public health.

To develop the waste management system with appropriate treatment technologies, accurate and reliable data on the waste involved are needed (Edjabou, et al., 2015). Waste generation rate and composition have vary spatially and temporally, a waste sampling at generation source method, thus, would be more appropriate and valuable (Bolaane and Ali, 2004) to identify waste variations.

The overall aim of the research was to provide detail household waste generation and composition database in different areas of Hoi An. Therefore, the practiced method was chosen in this study is stratified sampling (Nordtest, 1995,Scheaffer, et al., 2011) to ensure uniform coverage of the geographical area (Dahlén and Lagerkvist, 2008).

MATERIALS AND METHODS

Target Areas

Hoi An comprises 13 administrative wards including an island ward. The city is a unique urban in Vietnam which consists many types of urban including: urban and rural places and, especially, a famous touristic city (Hoi An ancient town). Therefore, in consideration of tourist factors affecting household waste generation, authors decided to divide the city to three strata (ST), which are ST1 is the Hoi An ancient town area including Minh An ward and part of Cam Pho ward, ST2 comprises 8 urban and sub-urban wards and ST3 is a group of the other rural wards (Tan Hiep island is excluded in this study). Detailed information about ST and the number of statistical samples was provided in Table 1.

Table 1. Number of statistical samples was adopted in survey program

Strata	**Type of urban**	**Number of housholds** (HASD, 2013)	**Number of sample (n)**	
			According to (Nordtest, 1995)	No. of household participated
ST1	City center, tourism area	2.752	36	50
ST2	Urban and suburban areas	14.394	185	187
ST3	Rural areas	4.904	64	84
Total	**12 Wards**	**22.530**	**285**	**321**

Sampling Procedure

There were 25 student scientists were recruited from Danang College of Technology (DCT) in Vietnam, who were trained and provided working plans, technical and safety guidelines as well as personal protecting equipment, then divided into 12 groups of 1 – 4 people.

Households were named by a code which presenting the name of Strata (ST1, ST2, ST3) and followed by a number of household order starting from 1 for each Strata. Waste sample collection was carried out daily in the morning in 2 weeks from August 7th to August 20th. During the collecting period, collection from 30 households was not consistent and those data was disregarded by authors. As a consequence, 291 statistical samples was selected for in statistical analysis and estimation (Table 2).

Waste samples was weighted and processed few hours after being collected. An average amount of 105 kg of households waste was sorted daily with a range from 80 to 130 kg per day.

Statistical Analysis

To approximately more closely a Normal probability distribution, the data set were transformed (Brown and Mac Berthouex, 2002) and were used to estimate the mean and the 95% confidence interval as well as applied analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Household waste generation rate

The result of the estimation reported that the overall mean waste generation rate was 0.223 kg capita^{-1} day^{-1} with an average rate between 0.207 and 0.240 kg capita^{-1} day^{-1} in term of 95% confidence interval.

Table 2. Statistical estimates of waste generation

Strata	n	Mean	Median	SD	Coefficient of skewness	Coefficient of kurtosis	SE	95% Confidence interval		
								Mean	LL	UL
ST1	36	0.26	0.21	0.18	2.1	5.85	0.03	0.203	0.046	0.900
ST2	173	0.31	0.27	0.19	1.38	1.82	0.01	0.264	0.085	0.823
ST3	82	0.16	0.13	0.16	4.06	20.67	0.02	0.12	0.024	0.604

Different waste generation from Stratas

An analysis of variance (ANOVA) was carried out to analyze differences of mean of waste generation rate among three area (p-value<0.05). The Post-hoc analysis result showed that only the waste generation rate per capita of ST3 were statistically significantly different from others. Apparently, the per capita waste from urban and sub-urban areas (ST1, ST2) were produced double that of rural area (ST3) as a result of the study, which should be considered in a prediction of waste generation for a waste management planning program.

Tourist area (ST1) produced less waste per capita than urban and suburban area (ST2) as a result of this survey. Family business as well as employment in tourism service of people living in center (ST1) had significant impacts to amount of time family members stay home and have common activities such as lunch or dinner together could be a reason of less waste produced. However, this difference was not statistical significant.

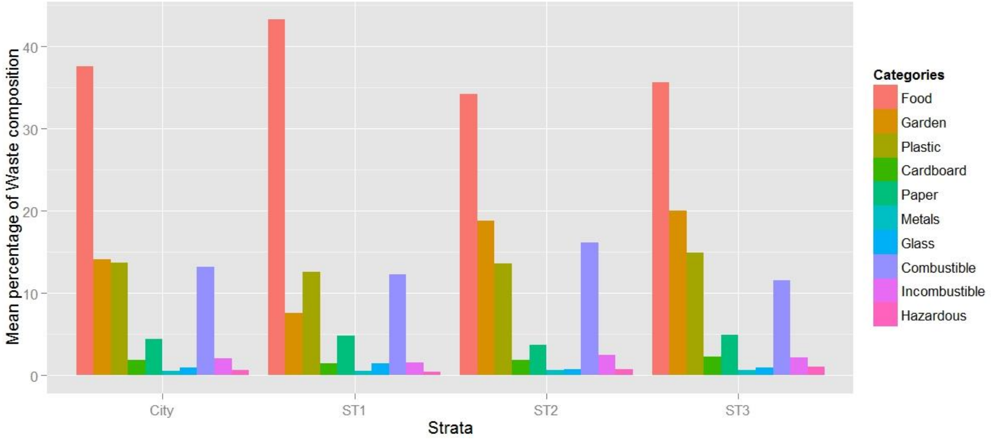

Figure 1. Mean percentage of waste composition

Household waste Composition

Figure 1 indicated that the highest waste fractions in Hoi An city was Food waste (37.55% with the confidence interval of 95% ranged from 19.84-71.07%). Yard waste, Plastic and Combustible materials played as second large fractions at around 13-14% of total waste and other categories such as Cardboard, Paper, Metal, Incombustible were less than 5%. The smallest contributor of waste composition was Hazardous of about 0.7%. In comparison, the portion of Food waste in ST1 was higher (at about 43.3% in average) but less Yard (7.54%) than the other two Strata. ST2 and ST3 which had almost similar percentage of Food and Garden waste of around 35% and 19%, respectively. Less area of backyard and more participation to tourist service activities of many families in this area could be a possible explanation.

Significant quantities of Food waste, Garden waste and Combustible waste proved that we may consider biological and thermal treatment technologies as highly potential treatment options for municipal solid waste. In addition, on-site or small scale biological treatment practices could be care for high percentage of degradable waste in ST3 since the products of biological treatment have a potential market in agricultural areas. An incinerator, meanwhile, could be an appropriate options for Hoi An because of the asset of minimization of waste amount to landfill. Informal recycling activities for plastics, cardboard and some other materials by organized waste pickers at treatment plant are currently adequate, besides the amount of recyclable materials such as paper, cardboard, glass are not so high. A material recovery program, therefore, may not be warranted for now, but should be taken in to account in the future.

CONCLUSION

Households waste characterization in this study provided a baseline data on solid waste situation in Hoi An generally as well as different areas of the city. It showed that there are several potential solid waste treatment options to quickly decline waste to landfill currently. However, to ensure a sustainable waste management system, comprehend studies on waste from other sectors (including tourism) and applications of other treatment options with respect to appropriate scale as well as technologies should be necessary.

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Potential for introducing organic waste diversion to municipal solid waste management in Asia

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ABSTRACT

Currently, in Asian countries, the focus is shifting from the struggle of disposing of municipal solid waste (MSW) to energy recovery from waste, as it is so called “WASTE TO ENERGY”. MSW in Asia includes a larger organic waste component compared to MSW in Western nations, and given that 80% or more of organic waste is comprised of water incineration treatment is not suitable. Consequently, a treatment method, by which organic matter is separated and methane is fermented in order to extract the biogas (resulting in biogas power generation and heat utilization), is effective for Asian cities. However, the issue around biogas businesses (which would carry out the process) is that they can only be established when residents separate organic waste and cooperate with the policy. If more waste were to be converted into energy, a policy would be needed that gains maximum resident cooperation. This paper will have a discussion on citizens' cooperation to separate food waste from MSW at a social experiment in the city of Toyohashi, Japan and suggest some ideas to separate food waste to recover heat energy.

Keywords: municipal solid waste management, organic waste, WASTE TO ENERGY, recycling, Asia

Trends of incinerating trash in Asian cities

Currently, in Asian countries, the focus is shifting from the struggle of disposing of municipal solid waste (MSW) to “WASTE TO ENERGY”, i.e., energy recovery from waste.

In the 1990s in Japan, dioxins generated from waste incineration facilities led to the Act on Special Measures concerning dioxins. Due to this act, incineration plants were renovated on a national scale, and many of those became newly equipped with power generation facilities. Some of them now had gasification melting furnaces, so that advanced incineration could be performed. In other words, as a result of these national policies, Japan holds a track record of high WASTE TO ENERGY as a result of generating power from waste.

The city of Beijing is formulating a construction plan for incineration plants; therefore, the current incineration rate may be higher than it was in 2005. The plan for Beijing was to build nine incineration plants by 2015, and increase the waste processing capacity per day to 8,200 metric tons, and the incineration rate to 40%. However, many Beijing residents opposed the construction of waste processing facilities; thus, this waste incineration plan for Beijing is not progressing as planned. For example, the Liulitun waste incineration plant to be constructed in the Haidian district in Beijing was abandoned after many residents signed petitions. (China-Net, 2011). As shown, citizens of Asian countries, other than Japan, express strong distrust and opposition toward incineration.

Changes in organic waste disposal in Japan

Food waste, i.e., organic waste, is roughly divided into the following categories: industrial waste produced by manufacturers, business-based MSW generated by supermarkets and restaurants, and general household waste as MSW.

As for business-based waste, 82% of it is industrial waste generated by manufacturers, with 1,916 metric tons (2012) generated overall (Ministry of Agriculture, Forestry and Fisheries, 2013). On the other hand, the ratio of organic waste in MSW (combustible waste) varies somewhat based on each municipality, but it is generally 40 to 45%. If the amount of household organic waste is estimated based on this value, it is about 8 to 10 million metric tons, and foodstuff loss (edible parts) in business-based and household organics is estimated to be 5–8 million metric tons. In other words, the main generators of food waste, among MSW, are households. However, according to the Food Recycling Law, it is not required to divert/recycle household and small retail organic waste. Household organic waste is generally collected as combustible waste, and incinerated during intermediate treatment. Therefore, only industrial waste generated by manufacturers is included in the advanced recycling process for food waste.

In recent years, waste treatment facilities built in Japan have been actively recovering heat from organic waste through methane fermentation and using this to create waste power generation. According to the Renewable Energy Law and Feed-in Tariff (FIT) that were set up after the Great East Japan Earthquake in 2011, waste power generation and biogas power generation are being further promoted.

In addition, an increasing number of municipalities are adding methane fermentation treatments to their household organic waste processing through municipal waste treatment facility plans. According to municipal questionnaires surveyed between December 2014 and January 2015, 17% of municipalities in Japan answered that they are conducting methane fermentation treatment for household organic waste (Ministry of Environment and Ministry of Agriculture, Forestry and Fisheries, 2015). According to the same report, the most common recycling method is still composting, constituting about 80% of the whole municipal waste sector. However, with more methane fermentation facilities being built (such as BioCube, in Nagaoka City, in the Niigata Prefecture, that came into operation in 2013, and the Toyohashi facility, in the Aichi Prefecture, anticipated operation to be 2017, and more on the horizon for major urban areas) there has been an increase in residents supporting diverting organic waste to municipality methane fermentation treatment, biogas production, and biogas power generation.

To summarize, recycling organic waste according to businesses has not achieved the desired policy target among sectors other than manufacturing. However, organic waste, among MSW, is showing a trend of moving from simple incineration treatment to WASTE TO ENERGY, with more of it being converted into biogas production and power generation.

Treatment of organic waste in Asia and potential of WASTE TO ENERGY

In Asian countries, residents strongly oppose incineration of trash, and furthermore, with the high cost associated with incineration plant construction and maintenance, it has not gained popularity and therefore is not the main disposal method of waste treatment. That being said, WASTE TO ENERGY (waste power generation) in Japan is being actively promoted in the Regional 3R Forum in Asia, etc. As such, many cities, such as the previously mentioned Jakarta, are considering construction of incineration plants equipped with power generation facilities.

However, MSW in Asia includes a larger organic waste component compared to MSW in Western nations, and given that 80% or more of organic waste is comprised of water incineration treatment is not suitable. Consequently, a treatment method, by which organic matter is separated and methane is fermented in order to extract the biogas (resulting in biogas power generation and heat utilization), is effective for Asian cities. However, the issue around biogas businesses (which would carry out the process) is that they can only be established when residents separate organic waste and cooperate with the policy. If more waste were to be converted into energy, a policy would be needed that gains maximum resident cooperation.

On that point, Korea is advanced in the collection of classified waste. In Korea, directing organic waste to landfill was banned in 2005. Since then, diverting organic waste, other than via incineration, has been actively promoted, and thus both businesses and residents started to separate their organic waste. Currently, out of 4.82 million metric tons of organic waste generated annually (including both business-based and household), 4.76 million metric tons (98.7%) is collected separately (2012) (Gil Jong Oh et al., 2015).

As shown, Korea could be a model for recycling of organic waste in Asia. However, in Japan, and other Asian nations, it is actually difficult to have residents separate their organic waste. For example, the City of Nagaoka uses an economic measure, charging fees for waste collection, where fees for organic waste are less than that of combustible waste. This provides an incentive for residents to separate organic waste, and the planned amount is mostly achieved. However, any other cities in Japan have serious difficulty to continue to let citizens to separate food waste now.

In view of such a situation, a plan may be suggested to Jakarta. Currently, at Bantar Gebang, which is the waste disposal site for Jakarta, about 1,000 waste pickers collect recyclables such as grocery bags, etc. It is probably possible to design a facility and waste treatment method where these informal laborers are hired, both incineration plants and methane fermentation treatment plants are used together, and as a pretreatment, organic waste, etc., is sorted by these laborers, so that organics are sent to a methane fermentation tank, and other recyclables are sold into recycling venues known by these laborers. The remainder would be incinerated.

Separating waste at the source can lower the environmental load associated with recycling. In addition, strict separation at the source not only lowers the environmental load, but also reduces waste treatment costs. Therefore, if each city in Asia could accommodate the cost, it is realistic to employ a method of collecting mixed waste, separating mechanically or with overpowering number of manpower, and recycling organic waste and other recyclables. However, if any municipality is to achieve environmental and economic efficiency in recycling organic waste, it will require cooperation from both residents and businesses, in the form of having them separate organic waste themselves.

Potential of separating organic waste in Japanese households

Finally, using social experiment results of organic waste diversion, we examined the potential of Japanese residents separating organic waste. The City of Toyohashi, where it is planned that 380,000 residents will start separating organic waste as of 2017, is currently still in the process of policymaking.

For two months between May and July 2014, Tomoko Okayama conducted a pilot program on household organic waste separation for the City of Toyohashi in the Maeshiba School District, which is a neighboring community to a sewage treatment plant and the Toyokawa Purification Center in the Aichi Prefecture.

A multilateral analysis was conducted on the rate of cooperation regarding separating organic waste in this social experiment. In this paper, we will not touch on the details of the report, but it was shown that the cooperation rate of organic waste separation was about 55%. According to these results, when introducing rules on organic waste separation for all households in Toyohashi, it is safe to assume that the cooperation rate would be between 30 and 50%. It means that the potential for separation is low, and even if overall separation of organic waste were to be started in 2017, it would be extremely difficult to achieve the targeted amount for Toyohashi. Powerful incentives for organic waste separation, such as those in Nagaoka City, are therefore needed (Okayama, 2015).

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Monitoring source separation of household organic waste in Hanoi, Vietnam

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ABSTRACT

Organic and inorganic waste shall be separated by the generators in the model areas of source separation in Hanoi, Vietnam. This study aimed to monitor the current condition of source separation of organic waste discharged from households. We sampled the waste discharged from 558 households in the model areas of source separation and analyzed the physical composition of each sample to monitor whether citizens appropriately separated and discharged household waste in accordance with the guideline. Out of 558 households, 77 households (14%) disposed of waste separately into two types, 297 households (33%) disposed of mixed waste into green containers, and 184 households (53%) disposed of mixed waste into orange containers. About 42% by weight of inorganic waste was contained in the containers for organic waste collection. One-third of waste disposed of as organic waste by separators was an inorganic waste. More than a half of non-biodegradable waste by weight was disposed of by separators as organic waste, even though it was categorized as inorganic waste according to the rule of source separation.

Keywords: source separation, household, organic waste, composting, developing country

INTRODUCTION

Most of the major cities in developing countries have a problem on increasing in municipal solid waste (MSW) due to concentration of population. MSW is overwhelmingly disposed of at landfill or dumping sites without any pre-treatment. A large amount of methane, one of greenhouse gases, emits to the atmosphere as a result of biodegradation of organic waste, which accounts for a large proportion of MSW, in an anaerobic condition. Organic waste recycling can be proposed as one of the solutions and source separation is one of the ways to change the organic waste flow.

Organic and inorganic waste shall be separately discharged by the generators in the model areas in Hanoi, Vietnam. This source separation system established in 2007 supported by Japan International Cooperation Agency as a three-year technical cooperation project from 2006 and still continues up to now in the two of the model areas after the completion of the project. Organic and inorganic waste are separately transported to the composting site and landfill site, respectively by Hanoi Urban Environment Company (URENCO). This study aimed to monitor the current condition of source separation of organic waste discharged from households in the model areas of source separation in Hanoi.

SOURCE SEPARATION SYSTEM IN HANOI

Source separation system of organic waste is currently operated in the two wards; Phan Chu Trinh ward with 5772 population in Hoan Kiem district and Nguyen Du ward with 6601 population in Hai Ba Trung district. That is, totally 0.2% of citizens in Hanoi (669 million) are involved in source separation system. All citizens as well as business entities such as restaurants and hotels are obligated to separate organic and inorganic waste at source and discharge organic waste into green containers which are designated as waste collection containers with 240 litter and inorganic waste into orange ones, both types of which are set up side by side along the main streets every evening. The both types of waste in the model areas can be disposed of into the designated waste collection containers at 18:00 to 20:30 daily. According to the guideline of source separation designed by Hanoi City, biodegradable food and garden waste are categorized as organic waste, and other waste in addition to non-biodegradable food waste such as seashells, animal bones, and coconut shells are categorized as inorganic waste. Paper, textiles, and wood can be categorized as organic waste scientifically, however, these types of waste are defined as inorganic waste since it takes a longer time to be biodegraded.

MATERIALS AND METHODS

Physical composition analysis

We sampled household waste discharged in the model areas of source separation to monitor whether citizens appropriately separated and discharged household waste in accordance with the guideline. Thus, this study did not cover the waste discharged from business entities and institutions such as restaurants, hotels, offices, hospitals, schools, etc.

Currently, 78 collection points of MSW in the model areas are identified. We made a list of the collection points on excel file and generated a random number per collection point. We arranged the collection points in ascending sequence of the random numbers and selected top 32 values as sampling points of household waste. We planned to sample waste discharged from 640 households from 32 sampling points for eight days from 16 August 2014, that is, waste discharged from 80 households from four sampling points per day. The waste discharged from 20 households was planned to be sampled per sampling point every evening from 18:00. We secured four sampling teams. Each team was made up of four students who belonged to University of Natural Resources and Environment. Staffs of Hanoi URENCO supervised each sampling team.

Sampling teams set carton boxes into both of green and orange collection containers for sampling household waste. Sampling teams waited for household waste disposed of at sampling points at 18:00 to 20:00 every day. Sampling teams tried not to disturb citizens’ discharging household waste or let them discharge household waste as usual. Once citizens finished discharging household waste into the containers, the sampling teams started sampling household waste paying attention to types of collection containers that household waste was discharged into. Sampling teams removed carton boxes from collection containers, took out and contained household waste into sampling plastic bags. We finally attached the identification labels with numbers on the sampling bags. Sampling teams moved to another collection points immediately to sample sufficient number of wastes if considering 20 samples cannot be collected at selected collection points. Totally we sampled 1,112 kg of waste discharged from 558 households at 34 collection points for eight days.

The waste samples were stored for a half day because of practical limitations involved with doing the work at night. The physical composition analysis of household waste was therefore conducted every morning from 8:00 to 10:00 with the previous day's collected samples. We got 20 students of University of Natural Resources and Environment to support the physical composition analysis in addition to the staffs of Hanoi URENCO as supervisors. The students were divided into four teams, and each team consisted of 5students; 2 students for sorting, one student for weighing, one student for recording, and one student for backup. The sampled waste discharged as inorganic waste were manually sorted out per sample into the 14 categories; 1) garden, 2) biodegradable food, 3) non-biodegradable food (sea shells, egg shells, coconut shells, bones, etc.), 4) textiles, 5) wood, 6) plastic, 7) ceramics, 8) paper, 9) diaper, 10) glass, 11) metal, 12) coal ash, 13) rubber and leather, and 14) others. The wastes sorted into the 14 categories at most were weighed, and the weights were recorded. After the sampled inorganic waste of all households were sorted, weighed and recorded, the sampled wastes discharged as organic waste were done in the same manner. The weights were verified to detect data entry errors by comparing the total weight of each sample before and after sorting.

RESULTS AND DISCUSSION

Out of 558 households, 77 households (13.8%) disposed of waste separately into two types, 297 households (33.0%) disposed of mixed waste into green containers, and 184 households (53.2%) disposed of mixed waste into orange containers. Organic waste (biodegradable food and garden waste) and inorganic waste should be disposed of into green and orange containers respectively according to the rule of source separation, however, 41.5% by weight of inorganic waste was contained in the green containers (Table 1). One-third of waste disposed of as organic waste by separators was an inorganic waste as a result of physical composition analysis (Table 2).

Garden waste was the most accurately separated by households (Fig. 1). Non-biodegradable food waste should have been separated as inorganic waste as a rule of source separation, but more than a half of it by weight was disposed of as organic waste. It is possible that some households unintentionally disposed of non-biodegradable food waste as organic waste due to unawareness of the rule. The accuracy of source separation was different from category to category. For example, textiles tended to be disposed of as organic waste, on the other hand, glass, metal, and coal ash tended to be disposed of as inorganic waste.

Table 1 Proportion of organic and inorganic waste disposed of into two types of containers (%, by weight)

	Organic waste	Inorganic waste
Waste discharged in green containers	58.5	41.5
Waste discharged in orange containers	48.0	52.0

Table 2 Proportion of organic and inorganic waste disposed of into green containers by separators and non-separators (%, by weight)

	Organic waste	Inorganic waste
Waste discharged by separators (*n* = 77)	66.7	33.3
Waste discharged by non-separators (*n* = 481)	56.0	44.0

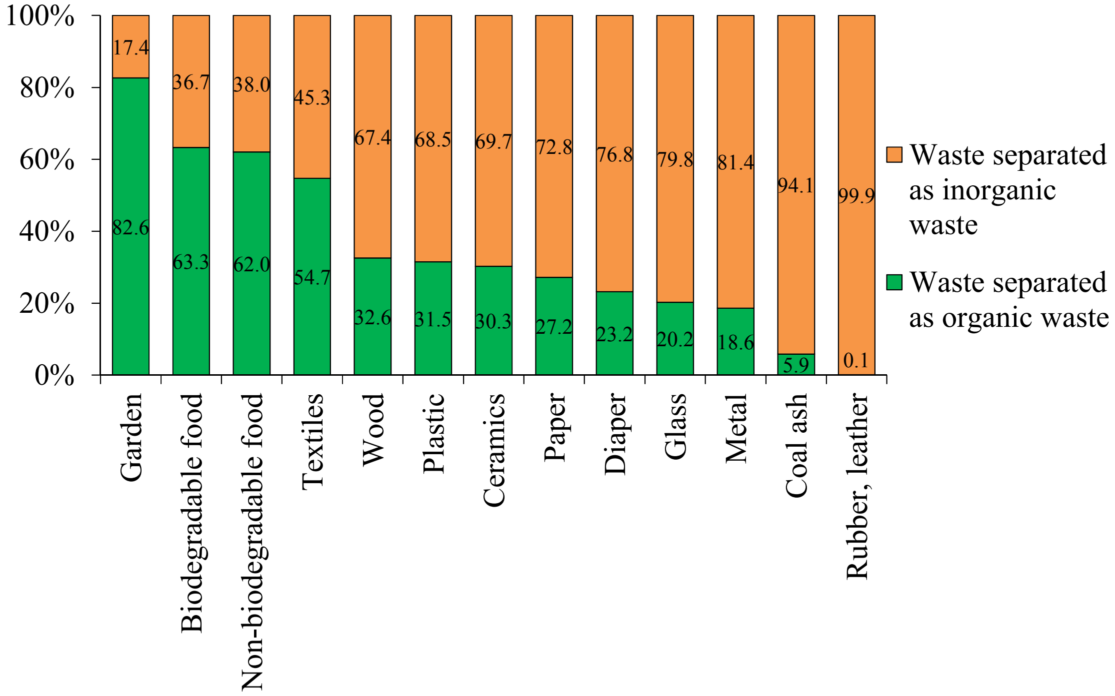

Fig. 1 Accuracy of source separation by 77 households

CONCLUSION

Only 13.8% of households disposed of waste separately into two types (organic and inorganic) in the model areas of source separation in Hanoi. Source separation in Hanoi has a challenge to raise collaboration rate by citizens toward better management of composting production.

ACKNOWLEDGEMENT

This study was supported by the Vietnam Waste Project of Japan International Cooperation Agency.

Study on the current status of methane emissions and integrated domestic waste management in the center of Thai Nguyen city

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ABSTRACT

Thai Nguyen is the grade 1 city. Along with the economic development, urbanization of Thai Nguyen City is the increase of domestic waste and environmental pollution. This study quantified the amount of average waste generated per day in 10 wards downtown was 118,57 tons/day, with a collection rate of 83% (98,42 tons/day). Percentage of recyclable, reusable materials including 62,39% organic matters, 7,36%, rubber, plastic and nylon, 6,83% waste paper, 6,62% metals and fabric, 4,91% ceramic and 2,23% glass. The study also estimated CH_4 emissions based on Dissolved organic carbon (DOC). CH_4 emissions arising from household waste was 4,62 tons/ day respectively with 106,26 tons of CO_2/day. Models of collecting, classifying and processing of domestic waste for Thai city were proposed.

Keywords: Thai Nguyen city, domestic waste, emissions of CH_4, DOC

INTRODUCTION

Solid waste management in general and domestic waste in particular sustainably is a top priority in the strategy of national environmental protection. However the management of household waste in the current phase focuses on the collection and burial of waste. In order to manage domestic waste management, the integrated management orientation is a new approach in waste management.

Thai Nguyen City is a level-1 city under Thai Nguyen province, has the social-economic development, rapid urbanization, the 3rd educational center of the country. Along with economic development, urbanization is the increase in industrial waste, municipal waste and environmental pollution. The management, collection, sorting and reusing waste with systematic and consistent treatment technology will bring significant economic benefits, environmental protection and save resources. "*Study on the current status of methane emissions and integrated management of domestic waste in the centre of Thai Nguyen city*" conducted to contribute to the better waste management of Thai Nguyen city.

MATERIALS AND METHODS

Research Materials

Study on the current status of methane emissions and integrated domestic waste management in 10 Wards: Quang Trung, Dong Quang, Phan Dinh Phung, Hoang Van Thu, Tuc Duyen, Trung Vuong, Gia Sang, Tan Lap, Thinh Dan, Tan Thinh.

Research Methods

Conducting survey in volume of domestic waste generated in 200 households divided among 10 wards in the centre of Thai Nguyen, including the 10% households with high income, 60% households with upper-medium income, 15% households with medium income and 15% households with poor income.

Analysis of domestic solid waste from the household survey, assessing the current status of waste management in the city center was employed. From this analysis, model of integrated solid waste management is proposed.

- *Calculate the amount of dissolved organic carbon (DOC) that can decompose (Nguyen Xuan Hoang and Vo Dinh Long, 2010) as follows:*

$DOC = 0{,}4A + 0{,}17B + 0{,}15C + 0{,}01D$

In which:

A: Percent of paper types, carbon and cloth
B: Percent of yard waste /biodegradable trash (exclude food)
C: Percent of food
D: The percentage of other organic matter.

** Calculate the amount of methane (CH_4) released from waste (IPP, 2010) as follows:*

CH_4 released (tonnes / year) = (WT * WF * MCF * DOC * DOCF * F * 16/12-R) * (1-OX)

In which:

- WT: The total amount of waste generated (tons / year)
- DOCF: error values of DOC (the default value is 0.7)
- WF: Percentage of waste sent to landfill
- F: Percentage of CH_4 in landfill (default value is 0.5)
- MCF: The default value of the methane parameter (0.6)
- R: the recovered methane gas (tons / year)
- DOC: Percent DOC in Waste
- OX: Oxidation Rate

Methods of data processing

The data is processed in MS Excel and statistical SAS 9.0

RESULTS AND DISCUSSION

Current status of waste disposal in the center region of Thai Nguyen City

The total volume of waste generated by 10 central wards in Thai Nguyen City is presented in Table 1.

Table 1: The amount of average waste per person in 10 wards

Order	Wards	Population (people)	Waste from households (kg/person/day)	Waste from other sources (kg/person/day)	Total (tons/day)
1	Quang Trung	23.383	0,66±0,18ns	0,18±0,08ns	19,64
2	Đồng Quang	11.369	0,67±0,16ns	0,34±0,03ns	11,48
3	Phan Đình Phùng	18.533	0,72±0,21ns	0,24±0,18ns	17,79
4	Hoàng Văn Thụ	17.234	0,63±0,12ns	0,21±0,06ns	14,48
5	Túc Duyên	9.312	0,62±0,22ns	0,21±0,11ns	7,73
6	Trưng Vương	8.078	0,69±0,19ns	0,26±0,04ns	7,67
7	Gia Sàng	12.963	0,59±0,26ns	0,13±0,09ns	9,33
8	Tân Lập	12.573	0,65±0,15ns	0,14±0,02ns	9,93
9	Thịnh Đán	15.320	0,53±0,19ns	0,11±0,05	9,80
10	Tân Thịnh	14.667	0,54±0,11ns	0,19±0,10ns	10,71
	Tông	143.432	0,63± 0,21ns	0,20±0,17ns	118,57

Mean values ± Sdt.E; (ns) no difference.

The survey of 200 households in 10 wards showed the average waste per person (from household) in the central area ranged from 0.53 to 0.72 kg / person / day, from other sources was approximately from 0.11 to 0.34 kg / person / day. The average waste disposed per person of the households in the 10 central wards has no difference with statistical significance at the 5% level.

The average waste disposal by households had difference between households with poor, medium income and upper-medium, rich income, but between the poor and medium income households. Among upper-medium and rich households had no differ with statistical significance at 5%.

Table 2: The amount of average waste disposed among households

STT	Household's income	Average waste disposed (kg/person/day)
1	Rich	0,74±0,08[a]
2	Upper-medium	0,69±0,05[a]
3	Medium	0,41±0,03[b]
4	Poor	0,35±0,03[b]

Mean values ± Ste, the same letters are not statistically different at 5%.

According to Le Huy Ba (2000), the volume and quality of urban waste depend on economy. Waste from the wealthy areas is higher than poor areas. Hence economic sectors have great influence on disposing waste. The results of the composition of household waste per capita in the Thai Nguyen city center is clearly shown on the chart 1.

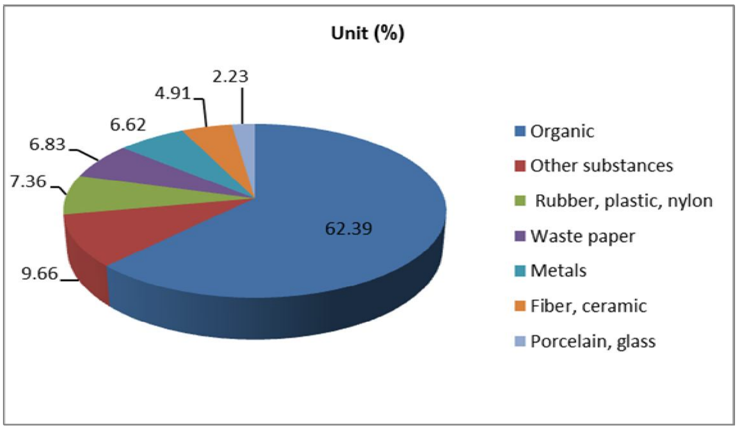

Figure 1: Percentage of household waste composition in Thai Nguyen city

Chart 1 shows the amount of organic waste accounted for 62,39%, 9,66% is rubber, plastic, 7,36% is nylon, 6,83% is waste paper, 6,62% is cloth , 4,91% is fiber, ceramic, 2,23% is glass. Notably, the amount of organic waste, metals, plastics, ... are the source can be recycled, re-used, if it is recycled will reduce the costs of processing and economic benefits.

Calculating the level of greenhouse gas emissions (CH_4) and dissolved organic carbon (DOC) in burying condition of domestic waste in Thai Nguyen City

Calculating the amount of dissolved organic carbon (DOC)

The classification result of the organic waste components are shown in figure 2

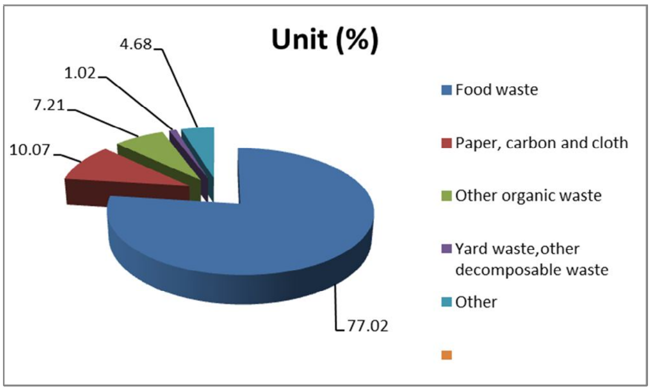

Figure 2. The amount of dissolved organic carbon (DOC) in domestic waste

According to the IPCC (1995), the amount of dissolved organic carbon (DOC) is calculated as follows:

$$DOC = 0{,}4A + 0{,}17B + 0{,}15C + 0{,}01D$$

In which: A = 10,07: Percentage of waste paper, carbon and cloth

B = 1,02: Percentage of yard waste / other decomposable waste (not food waste)

C = 77,02: Percentage food waste

D = 7,21: Percentage of other organic waste

$$DOC = 0{,}4 * 10{,}07 + 0{,}17 * 1{,}02 + 0{,}15 * 77{,}02 + 0{,}01 * 7{,}21 = 16{,}79\%$$

Thus the amount of dissolved organic carbon in the waste in the city centre of Thai Nguyen is 16,79% .

CH_4 emissions released from waste

As IPP (2010), amount of methane recovery is calculated based on the total amount of waste put into landfills. Applying the method USEPA'S LANGEM, correlation value of the methane (CH_4) parameter is corresponding to different kinds of landfills presented in Table 3.

Table 3. Landfill of domestic waste and the correlation value of the methane parameter

Order	Types of landfills (SWDS)	Correlation value of the methane parameter (MCF_x)
1	Managed	1
2	Unmanaged – depth (≥ 5m waste)	0,8
3	Unmanaged - depth (<5m waste)	0,4
4	The default value for landfill not classified	0,6

Through practical investigation in conjunction with the report on the status of waste collection from Thai Nguyen Urban Environment Company, the amount of waste collected in the city center area was 118,57 tons/day, with a collection rate of 83% (98,42 tons / day). With WF is 0,83; MCF = 0,6; WT = 118,57; DOC = 16,79; DOCF = 0,7; F = 0,5; R = 0; OX = 0, the amount of methane is calculated as follows:

$$CH_4 \text{ released (tons / day)} = (WT * WF * MCF * DOC * DOCF * F * 16/12-R) * (1-OX)$$

$$= (118{,}57 * 0{,}83 * 0{,}6 * 0{,}1679 * 0{,}7 * 0{,}5 * 16/12) * (1-0) = 4{,}62 \text{ (tons /day)}$$

CH_4 emission generated from household waste per day in the city center area is 4,62 tons / day. The waste treatment process creates CH_4 emission which is able to cause global warming 23 times higher than CO_2 (106,26 tons CO_2 / day) during a hundred year (Forster et al., 2007). This emission is directly proportional to the amount of waste disposed every year. Without measures to mitigate CH_4 emissions, the environmental consequences are enormous.

Proposed model of integrated domestic waste management in wards of Thai Nguyen city

Diagram of domestic waste management activities in 10 wards of Thai Nguyen city is proposed in Figure 3.

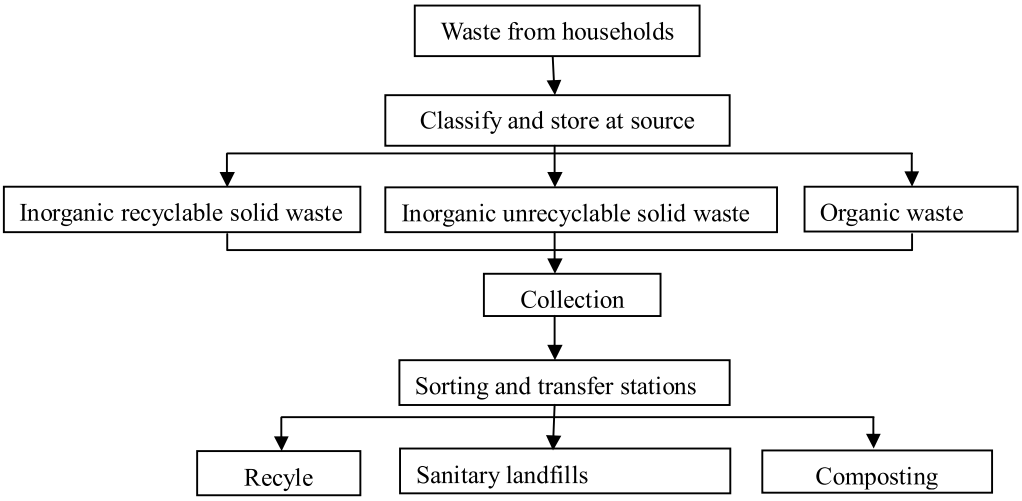

Figure 3. Diagram proposed for household waste management in Thai Nguyen city

This is an important factor determining the whole process of managing waste. Waste in the household is categorized into 3 groups:

Group 1: Organic matter can be biodegrade (blue) as food, yard waste...

Group 2: Inorganic waste can be recycled (red) such as paper, rubber, metal...

Group 3: Inorganic waste can not be recycled (yellow) as brick, stone, porcelain ...

Three groups of solid waste are contained in 3 separate bins or models with 3 bins 3R-W (3R is Reduce-reduce, reuse Reuse-, Recycle-Recycling; W is Water (water) with three different colors. After the garbage is collected and stored in the family will be sanitation workers collected daily by separate shelved trolley, trash taken to the transfer station. Here, for Garbage Group 1 will be transported to the composting plant, group 2 will be collected and sold for recycling facilities, recycling, group 3 will be transported to sanitary landfills.

To thoroughly treat waste classified activities, should invest in building waste treatment stations, including reception point garbage, composting plants, regional landfills, wastewater treatment plants ... That will reduce emissions causing the greenhouse effect (CH4). Hence, it not only brings environmental implications but also bring significant economic benefits (heat recovery, improved quality natural gas ...) and save resources.

CONCLUSION

Percentage of recyclable, reusable materials including 62.39% organic matters, 7.36%, rubber, plastic and nylon, 6.83% waste paper, 6.62% metals and fabric, 4,91% ceramic and 2.23%. glass.

CH_4 emissions arising fromhousehold waste was 4.62 tons/ day respectively with 106.26 tons of CO_2 / day

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Scenarios for Sustainable Municipal Solid Waste Management for Hanoi city: A Life Cycle Assessment Approach.

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ABSTRACT

Sustainable solid waste management (SWM) is a long-term intensive goal of most countries worldwide. However, it is also a challenged target to be achieved due to being involved by many stakeholders. Hanoi City, in an aim to modernize solid waste treatment technology to reduce waste disposal by landfilling and improve sanitation for human living in budget strain condition , is considering various alternative scenarios for municipal solid waste management. These scenarios analyze the combination treatment options among landfilling, composting, incinerating and reuse and recycling at transfer stations and at treatment facilities, which were intensively proposed in Hanoi Solid Waste Management Master Plan to 2020, a vision to 2030. Besides, to appraise which is the most compatible scenario for Hanoi City in practical condition, it requires to use a comparative tools to analyze the waste and financial flow. Life Cycle Assessment (LCA) is optimal choice for this purpose. This study introduces a computer software applying LCA principle with a function to realize above targets as well as recommend its potential application in SWM in Vietnam. Due to the limitation of available data, this study only covers the municipal waste treatment in zone 1 which is defined in the mentioned Master Plan and three scenarios including 1) 100% landfilling, 2) combination of landfilling and composting for organic waste, 3) combination of recycling, incinerating and landfilling. In all 3 scenarios, a proportion of municipal waste is collected as recyclables by informal sector. The results show that the third scenario is the best option for SWM for Hanoi in the future with implementation the waste separation at source program.

Keywords: Life Cycle Assessment, Hanoi, Municipal waste, SWM, Master Plan.

INTRODUCTION

The issue that how to balance between high speed urbanization and modernization with sustainable environmental protection is a significant concern of policy makers in many municipalities. Currently, Hanoi imperatively experiences the gap between annual waste generation rate and capacity of existing waste treatment facilities. Everyday Hanoi City generated 6,400 tons of municipal solid waste and counts about 60% of total generated waste volume in the city. Collection rate differs from region to region. Twelve core districts and Son Tay urban town average rate is 98% while other 17 rural districts at 89% (URENCO annual report, 2014). It is calculated that waste generation rate in Hanoi increases 15% per year while the remaining capacity of 2 main waste treatment facilities (hereinafter refer as facility) is not much. Beside the waste volume is collected, transported and disposed at the designated facilities, a large part is still discharged illegally or temporarily handled unsanitarily at local communes. To tackle these difficulties, it is clear that the land fund for landfilling is limited so selecting waste treatment technology and supporting activities such as waste separation at source, environmental education, etc. become important. In this context, in 2014, the Prime Minister has approved the Solid Waste Treatment Master Plan for Hanoi City (hereinafter refer as Master Plan) to 2030, a vision to 2050, in which formulates plan for expanding existing facilities and develop new ones and proposes applied technologies for them. Accordingly, landfilling, composting, incinerating, recycling are selected. However, in consideration of investing cost, environmental impacts, reduction of landfilling, etc. it needs comparing scenarios which combine technologies applied or proposed for practical socio-economic in Hanoi City through time.

MATERIALS AND METHODS

Subjected study zone

In the Master Plan, SWM of Hanoi City is zoned in three zones depending on geographic and concentrated treatment condition. This study only focus on the zone I which cover the North of Hanoi including core areas and some districts (Nam Tu Liem, Bac Tu Liem, Long Bien, a part of Thanh Tri, Me Linh, Dong Anh, Gia Lam and Soc Son). Population in this zone is 3.8 million people. This is a high density commercial service area.

Municipal solid waste for the study combines household and commercial waste. It is mainly transported to Nam Son waste treatment complex, the biggest facility in Hanoi at present. The complex combines 10 landfill cells for the first phase and high treatment technologies such as incineration, compost, recycling for the second phase which starting operation from June, 2015.

IWM-2, computer software applied LCA principle, analyze inputs and compare the outputs of SWM scenarios.

LCA is a technique for assessing the potential environmental aspects and potential aspects associated with a product (or service) by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with those inputs and outputs and interpreting the results of the inventory and impact phases in relation to the objectives of the study (ISO 14040.2).IWM-2 is developed under LCA principle which provides a way to assess the environmental and economic performance of solid waste systems. It is a user-friendly model for waste managers. It shows the input and output features, and the ability to compare different scenarios. Input and output of each scenario is shown below.

Proposed scenarios

This study proposes three scenarios which present for 3 typical SWM models in Hanoi. The first one is for current working system which most of collected waste is sent directly to landfill. The second one is developed based on studies and pilot implementation of 3R project in Hanoi City from 2006 to 2009 which separated waste into 3 categories: recyclables, organic and other waste. 90% of organic waste were composted. The third one descripts a proposed plan based on direction in the Master Plan that to 2020, Hanoi City will carry out waste separation at source to collect 85% in total generated recyclable waste. Three types of waste are separated including recyclables, combustible and other waste. Inputs for scenarios includes municipal solid waste, electricity, biological additives, water, fuel, lime, etc. Average cost input is used to compare financial aspect. Common outputs are electricity, heat, waste water, residue, compost and fertilizer. Hereinafter is waste volume and characteristics for household and commercial waste, the fundamental input data for three scenarios.

Population (1000person)	Average generation (kg/person/day)	Generated waste volume (ton/day)	Collection rate
3,856	1.1	5927,36	100%

Table 1: Information related municipal solid waste management in zone 1 *(Source: Hanoi URENCO annual report 2014)*

Type of waste	Proportion (%)
Organic waste	51.9
Paper	2.7
Plastic	3.0
Leather, rubber	1.3
Textile	1.6
Glass	0.5
Soil, sand	6.1
Metal	0.9
Other (less than 10mm)	31.9
Total	100.0

Table 2. Household solid waste composition in Hanoi City (*Source: Hanoi's Master Plan for solid waste treatment to 2030, vision to 2050)*

Type of waste	Proportion (%)
Organic waste	55
Paper	16
Plastic	10
Textile	1.,1
Glass	3
Metal	1.4
Other (less than 10mm)	13.5
Total	100

Table 3. Commercial waste composition in Hanoi City (*Source: Hanoi's Master Plan for solid waste treatment to 2030, vision to 2050)*

RESULTS AND DISCUSSION

This study aimed to propose a practical methodology for estimating the methane oxidation behavior of waste landfills. Precise prediction of methane emission must be achieved by investigating the historical trends of disposal of the organic. In this study, the treatment cost that analyzed in scenario 3 is higher than that in scenario 1 and 2 due to application of incineration. However, scenario 3 still shows that the landfill waste volume in this scenarios is smallest. Landfilling is still considered the most economical method, however, landfilling is not the best way in overall social and environmental aspect.

CONCLUSION

This study shows a full picture about environmental solution for domestic solid waste management in Hanoi City using LCA. LCA can be a valued tool for evaluating the environmental sustainable of integrated or individual waste management system. The result of study depends on the characteristic of solid waste and the solid waste management of Hanoi City. The result of environmental assessment is different among areas due to the characteristic of solid waste, technology and, space and other related factors. Besides, an integrated solid waste management system based on waste source separation, with different categories of waste is managed by different technologies, will be more effective than an individual method such as incineration or landfill-ling. However, for a small community where there is only an option as economization, the result of study should be considered.

As this study do not give a deeply assessment of environmental protection for scenarios of 3 zones of Hanoi City, such as GHG emission, water pollution substance emission, so that now, the author is doing deeper research on environmental effect follow these 3 scenarios.

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Session 7

Industrial waste

Kinetics and Equilibrium Studies on the Removal of Borate and Fluoride in Aqueous Solution using Mg-Al oxide

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ABSTRACT

Mg–Al oxide prepared through the thermal treatment of CO_3^{2-} intercalated Mg–Al layered double hydroxide (CO_3·Mg–Al LDH) was found to remove borate and fluoride from an aqueous solution. They were removed by the rehydration of Mg–Al oxide accompanied by combination with $B(OH)_4^-$ and F^-. The removal of B can be explained by way of pseudo-first-order reaction kinetics. The adsorption of B acts upon a Langmuir-type phenomena. Removal of F can be represented by pseudo-second-order reaction kinetics. The adsorption of F by Mg–Al oxide follows a Langmuir-type adsorption.

Keywords: Mg–Al oxide, Borate, Fluoride, Kinetics, Equilibrium

INTRODUCTION

Boron and fluorine are essential for many plants and animals including humans. However, continuous ingestion of excessive amounts of boron and fluorine can lead to disease. To protect human health and the environment, the respective effluent standards for borate and fluoride have been set to less than 10 and 8 mg L^{-1} in Japan. Borate in wastewater is difficult to treat because it does not generate slightly soluble compounds with heavy metal ions or alkaline earth metals. When aluminum salts and calcium hydroxide are added to borate-containing wastewater, the borate concentration in the treated water decreases to less than the effluent standards in Japan. The current treatment process for fluoride containing wastewater generally involves the calcium fluoride method as primary treatment and then co-precipitation with hydroxides as secondary treatment. The current treatment methods for borate and fluoride in wastewater both have the same problem, *i.e.*, the generation of huge quantities of sludge. Therefore, the development of a new treatment technique which minimizes the amount of sludge and can treat borate and fluoride is desired.

The formula of Mg-Al LDH are typically denoted as $[Mg^{2+}_{1-x}Al^{3+}_{x}(OH)_2](A^{n-})_{x/n}\cdot mH_2O$, the significance of x is the molar ratio of $Al^{3+}/(Mg^{2+} + Al^{3+})$ ($0.20 \le x \le 0.33$), A^{n-} is anion, for example CO_3^{2-} or Cl^-. By calcination at 450-800 °C, the CO_3^{2-} intercalated Mg-Al LDH (CO_3•Mg-Al LDH) can be converted to Mg-Al oxide, expressed as Eq. 1:

$$Mg_{1-x}Al_x(OH)_2(CO_3)_{x/2} \rightarrow Mg_{1-x}Al_xO_{1+x/2} + x/2CO_2 + H_2O \quad (1)$$

The Mg-Al oxide is able to incorporate water molecules (rehydration) and anions, resulting in the reconstruction of the structure of LDH:

$$Mg_{1-x}Al_xO_{1+x/2} + x/n\,A^{n-} + (1+x/2)H_2O \rightarrow Mg_{1-x}Al_x(OH)_2A_{x/n} + xOH^- \quad (2)$$

We have already reported the removal of borate and fluoride by Mg-Al LDH in the 1st 3RINCs (Oba, J. et al., 2014; Kameda T. et al., 2015a,b). In this study, therefore, we have examined the removal of borate and fluoride by

Mg-Al oxide. This extended abstract has summarized our published paper (Kameda T. et al., 2015c, 2016).

MATERIALS AND METHODS

Mg–Al oxide was obtained by the thermal decomposition of CO_3•Mg–Al LDH. The Mg–Al oxide contained 13.6 wt% Mg and 7.8 wt% Al, and the Mg/Al molar ratio was 1.9. The Mg–Al oxide was added to the 500 mL of 100 mg/L H_3BO_3 or NaF solution. The successive suspensions were stirred at 10°C–60°C for 840 min with continuous bubbling of N_2 during the procedure. Samples of the suspension were collected at specific time periods and instantly filtered passing through a membrane filter (0.45 μm). The quantity of the Mg–Al oxide required for borate or fluoride removal was 1–5 times the stoichiometric quantities shown in Eq. (3)-(4) and is indicated using the notation eq1–eq5.

$$Mg_{0.67}Al_{0.33}O_{1.17} + 0.33B(OH)_4^- + 1.17H_2O \rightarrow Mg_{0.67}Al_{0.33}(OH)_2(B(OH)_4)_{0.33} + 0.33OH^- \quad (3)$$

$$Mg_{0.67}Al_{0.33}O_{1.17} + 0.33F^- + 1.17H_2O \rightarrow Mg_{0.67}Al_{0.33}(OH)_2(F)_{0.33} + 0.33OH^- \quad (4)$$

The adsorption isotherm study of B and F with Mg-Al oxide was conducted, therefore, a mixed 20 mL 0.01-0.06 M H_3BO_3 or NaF solution and 0.1g Mg-Al oxide was shaken at 30°C for a week using 50 mL screw-top tubes. The concentration of B was estimated from the filtrates using inductively coupled plasma atomic emission spectroscopy (ICP-AES). The residual concentrations of F in the filtrates were determined using a Dionex DX-120 ion chromatograph and a Dionex model AS-12A column (eluent: 2.7 mM Na_2CO_3 and 0.3 mM $NaHCO_3$; flow rate: 1.3 mL min^{-1}).

RESULTS AND DISCUSSION

Removal of borate from an aqueous solution

Fig. 1 shows the change in the concentration of B over time in the Mg–Al oxide suspension in H_3BO_3 solution at various stoichiometric quantities (eqs.) at 30°C. The B concentration decreased with time. The B concentration also decreased as the stoichiometric quantity increased. At eq2, the residual B was observed lesser concentration than the maximum permissible Japanese effluent standards (10 mg/L) after 120 min, and the lowest residual concentration of B was 2.5 mg/L at 240 min. In this case, the pH showed an initial rapid increase but slowed to a more gradual increase with time. The pH reached ~9.5 and 10.0 at eq1 and eq2, respectively. The hydrolysis reaction of boric acid is shown in Eq. (5).

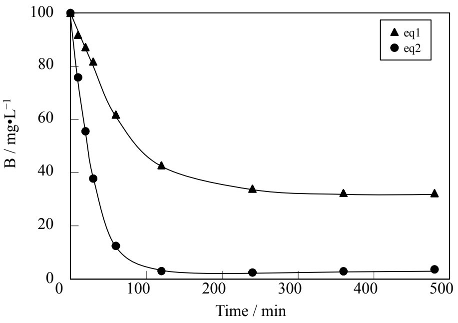

Fig.1 Change in the concentration of B over time in the Mg–Al oxide suspension in H_3BO_3 solution at various stoichiometric quantities (eqs.) at 30 ºC.
Cited from Ref. Kameda T. et al., 2016.

$$H_3BO_3 + H_2O \rightleftarrows H^+ + B(OH)_4^- \quad (5)$$

The acid dissociation constant (pKa) of boric acid is 9.2. In the suspension, more B is considered to be present as $B(OH)_4^-$ than boric acid. Hence, the B removal using Mg-Al oxide is characterized to the rehydration and combination with $B(OH)_4^-$, according to Eq.(3). The reaction kinetics of B with Mg-Al oxide was examined as follows. First-order kinetics, which depend on the concentration of B, are expressed by

$$-\ln(1-x) = kt, \quad (6)$$

where x = degree of B removal, t = reaction time (min), and k = rate constant for B removal (min^{-1}). For the pseudo-first-order plot for removing B using the suspension of Mg–Al oxide in H_3BO_3 solution at various temperatures, consistent linearity was observed at all temperatures, indicating that pseudo-first-order kinetics can be better to represent B removal phenomena. B removal can be represented by pseudo-first-order reaction kinetics.

The apparent rate constants at 10°C, 30°C, and 60°C were 1.0×10^{-3}, 7.2×10^{-3}, and 5.8×10^{-2} min^{-1}, respectively. Therefore, as increasing temperature, the rate constant increased apparently. The apparent activation energy for removing B by Mg-Al oxide was observed 63.5 kJ mol^{-1} which was calculated from the Arrhenius plot. The result recommends that a chemical reaction dominates the removal of B by Mg-Al oxide. The adsorption isotherms displayed a Langmuir-type phenomena, validated by arranging the data obtained from this experiment in terms of the Langmuir equation, expressed as follows:

$$q_e = C_e q_m K_L/(1 + C_e K_L), \qquad (7)$$

where q_e = equilibrium adsorption (mmol g^{-1}), C_e = equilibrium concentration (mM), q_m = maximum adsorption (mmol g^{-1}), and K_L = equilibrium adsorption constant. The Eq. (7) can be represented as

$$C_e/q_e = 1/q_m K_L + C_e/q_m. \qquad (8)$$

For the C_e/q_e versus C_e plot of the adsorption isotherms for the adsorption of B by Mg–Al oxide, a good linear plot with acceptable correlation coefficient was obtained, which indicates that the adsorption of B with Mg-Al oxide followed Langmuir-type phenomena. The q_m and K_L value calculated from the slope and intercept of the linear fit of the data, were 7.4 mmol g^{-1} and 1.9×10^3, respectively.

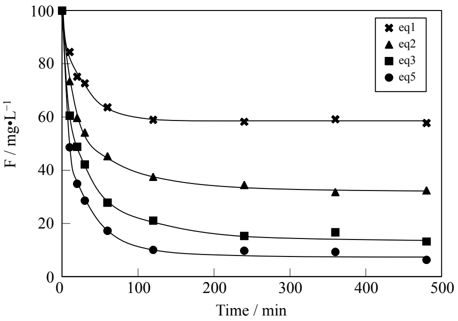

Fig.2 Changes in the concentration of F over time in Mg–Al oxide suspension in NaF solution at various stoichiometric quantities (eqs) at 30 ºC.
Cited from Ref. Kameda T. et al., 2015c.

Removal of fluoride from an aqueous solution

Fig. 2 shows the changes in F concentration over time in the Mg–Al oxide suspension in NaF solution at various stoichiometric quantities (eqs) at 30 °C. In all cases, the concentrations of F decreased with time and with increasing stoichiometric quantity. The lowest residual concentration of F was 6.3 mg/L at 480 minutes at eq5, and was below the effluent standard in Japan (8 mg/L). The removal of F by Mg–Al oxide was attributed to rehydration and combination with F^- according to Eq. (4). In addition, the removal of F increased with increasing temperature. Based on the result, we next examined the kinetics of F removal by Mg–Al oxide. First, the data were arranged according to first-order kinetics, but none of the first-order plots for removal of F at various temperatures showed good linearity, indicating that F removal cannot be represented by first-order reaction kinetics. Pseudo-second-order kinetics were expressed as follows:

$$\mathrm{d}q_t/\mathrm{d}t = k(q_e - q_t)^2 \quad (9)$$

where q_t (mmol g^{-1}) is the amount of F removed at reaction time t, q_e (mmol g^{-1}) is the amount of F removed at equilibrium, and k (g mmol^{-1} min^{-1}) is the rate constant for F removal. Integration of Eq. (9) gives:

$$t/q_t = 1/(kq_e^2) + t/q_e.(10)$$

A pseudo-second-order reaction can predict adsorption behavior by assuming that the rate-determining step consists of chemical adsorption involving valence forces through the sharing or exchange of electrons between the adsorbent and adsorbate. For the pseudo-second-order plots for F removal by a suspension of Mg–Al oxide in NaF solution at various temperatures, plots at all temperatures showed good linearity, indicating that F removal can be represented by pseudo-second-order reaction kinetics. The apparent rate constants at 10°C, 30°C, and 60°C were 2.3×10^{-3}, 2.2×10^{-2}, and 2.5×10^{-1} g mmol^{-1} min^{-1}, respectively. Thus, the apparent rate constant increased with increasing temperature. An Arrhenius plot of the rate constants yielded an apparent activation energy of 73.3 kJ mol^{-1} for F removal by Mg–Al oxide. With chemical adsorption, the reaction rate is known to vary with temperature according to the finite activation energy (8.4 – 83.7 kJ mol^{-1}) in the Arrhenius equation. The apparent activation energy obtained here was within the range for chemical adsorption. Therefore, the removal of F was well described by a pseudo-second-order reaction and the rate-determining step for F removal by Mg–Al oxide was consistent with chemical adsorption involving intercalation of F^- into the reconstructed Mg–Al LDH caused by electrostatic attraction. For the C_e/q_e versus C_e plots for the adsorption isotherms for adsorption of F by Mg–Al oxide, good linearity was obtained, indicating that this process followed Langmuir-type adsorption. The values of q_m and K_L, determined from the slope and intercept of the straight line, were 3.0 mmol g^{-1} and 1.1×10^3, respectively.

CONCLUSION

Mg–Al oxide was demonstrated its ability to uptake B and F from aqueous solutions. B and F were removed through the rehydration of Mg–Al oxide accompanied by combination with $B(OH)_4^-$ and F^-. At eq2, the residual B was observed lesser concentration than the Japanese effluent standards (10 mg/L) after 120 min. B removal can be explained by pseudo-first-order reaction kinetics. The apparent activation energy of 63.5 kJ mol^{-1}, calculated from the Arrhenius plot indicating that a chemical reaction dominates the removal of B by Mg-Al oxide. The adsorption of B by Mg–Al oxide follows a Langmuir-type adsorption. The maximum adsorption was 7.4 mmol g^{-1}, while the equilibrium adsorption constant was 1.9×10^3. The lowest residual concentration of F was 6.3 mg/L at 480 minutes at eq5, and below the effluent standard in Japan (8 mg/L). F removal can be represented by pseudo-second-order reaction kinetics. The apparent activation energy was 73.3 kJ mol^{-1}. The rate-determining step for F removal by Mg–Al oxide was consistent with chemical adsorption involving intercalation of F^- into the regenerated Mg–Al LDH caused by electrostatic attraction. The adsorption of F by Mg–Al oxide follows Langmuir-type adsorption. The values of maximum adsorption and the equilibrium adsorption constant were 3.0 mmol g^{-1} and 1.1×10^3, respectively, for Mg–Al oxide.

ACKNOWLEDGEMENT

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Analysis of the factor of manual sorting efficiency for house demolition waste

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ABSTRACT

Manual sorting is the most basic separating process for mixed waste. There are few researches for evaluating efficiency of the manual sorting quantitatively. Affected factors on the efficiency of the manual sorting are also not well understood. The purpose of this study was to clarify factors related to efficiency of the manual sorting for the house demolition waste. The effect of 3 factors; size of the waste, area of the sorting and number of concurrently operating workers, on efficiency of manual sorting was analyzed. The manual sorting rate for debris fractions of 20 mm over and 10 mm over were $2.7\text{-}2.8\times10^{-3}$ and $1.5\text{-}1.8\times10^{-3}$ m^3/worker/minutes, respectively. The difference of the manual sorting rate between 0.5 and 1.0 m^2/worker of sorting area was not observed. The small number of concurrently operating workers showed high the manual sorting rate in 20 mm over size fraction. The "manual sorting labor" was defined as the value multiplying the number of workers by the sorting time. The highest manual sorting rate was 8.7×10^{-3} m^3/minute at 40 of manual sorting labor. The manual sorting labor will be a potential parameter for maximizing the manual sorting efficiency.

Keywords: Manual sorting, Manual sorting rate, House demolition waste,

INTRODUCTION

Mixed waste is necessary to sort out for higher utilization and reduction of waste. The waste separation technique is not only the mechanical separation, which uses difference of magnetic, gravity, size and color, but also separation by human hand. This Manual (or hand)-sorting is the most basic separation technique applied to over the world. Manual sorting is useful not only for improvement of waste quality for recycling, but also for emergency treatment of disaster waste when machinery will not be soon available. It is important to clarify the condition of optimum the manual sorting for several purposes in order to design this method as an engineered technique. However, there are little attempts to evaluate the performance of manual sorting quantitatively (Michael, 1992). Affecting factors to the efficiency of the manual sorting are also not well understood. The purpose of this study is to clarify factors relating to higher efficiency of the manual sorting for mixed waste. We conducted an experiment of manual sorting using mixed house demolition waste (HDW) and analyzed the effect of 3 factors, which is size of the waste, area of the sorting and number of concurrently operating workers, on the efficiency of manual sorting.

MATERIALS AND METHODS

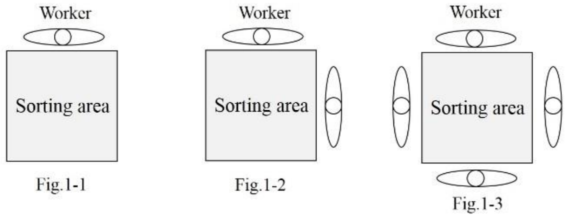

Fig.1-1 Fig.1-2 Fig.1-3

Sorting area and position of the worker for manual sorting experiment
Fig.1-1 One worker position, Fig.1-2 Two worker position,
Fig.1-3 Four worker position

HDW was obtained from a industrial waste treatment facility. 32 m^3 of HDW was sieved by the screen either of 10mm or 20mm mesh. Samples for the manual sorting experiment was the waste remained on the screen. The condtions of manual sorting experiment are shown in Table 1, and the position of the worker and sorting area is indicated in Figure 1. 40×10^{-3} m^3/worker (27 kg/worker) of the waste sample was set on the sorting area in front of sorting worker. The HDW fraction either of the over 10mm or 20 mm by sieving was used for the experiment. The sorting area is set either at the 0.5 m^2/woker or 1.0 m^2/woker. Number of concurrently sorting wokers is set at one, two or four. Each sorting time is 10 minutes.

Table 1 Conditions of manual sorting experiment

RUN	Fraction size	Worker	Sorting area	Amount of waste
Run.A1-1	∮ >20mm	1	0.5 m^2 (0.5 m^2/worker)	40×10^{-3} m^3 (27 kg)
Run.A1-2	∮ >20mm	1	1.0 m^2 (1.0 m^2/worker)	40×10^{-3} m^3 (27 kg)
Run.A2-1	∮ >20mm	2	1.0 m^2 (0.5 m^2/worker)	80×10^{-3} m^3 (54 kg)
Run.A2-2	∮ >20mm	2	2.0 m^2 (1.0 m^2/worker)	80×10^{-3} m^3 (54 kg)
Run.A4-1	∮ >20mm	4	2.0 m^2 (0.5 m^2/worker)	160×10^{-3} m^3 (108 kg)
Run.A4-2	∮ >20mm	4	4.0 m^2 (1.0 m^2/worker)	160×10^{-3} m^3 (108 kg)
Run.B1-1	∮ >10mm	1	1.0 m^2 (0.5 m^2/worker)	40×10^{-3} m^3 (27 kg)
Run.B1-2	∮ >10mm	1	0.5 m^2 (1.0 m^2/worker)	40×10^{-3} m^3 (27 kg)
Run.B2-1	∮ >10mm	2	1.0 m^2 (0.5 m^2/worker)	80×10^{-3} m^3 (54 kg)
Run.B2-2	∮ >10mm	2	2.0 m^2 (1.0 m^2/worker)	80×10^{-3} m^3 (54 kg)
Run.B4-1	∮ >10mm	4	2.0 m^2 (0.5 m^2/worker)	160×10^{-3} m^3 (108 kg)
Run.B4-2	∮ >10mm	4	4.0 m^2 (1.0 m^2/worker)	160×10^{-3} m^3 (108 kg)

HDW fractions were hand-sorted into 18 categories of material; wood, PVC, tire, plastic carpet, other plastic products, paper, cardboard, textile, metal, concrete debris, glass, ceramics, gypsum board, debris, asphalt debris, combustible material, inert mixed waste and other mixed waste. The manual sorting rate was defined as the amount of the separated waste per minutes by a worker (m^3/worker/minutes). The manual sorting labor was defined as multiplying the number of workers and sorting time (woker⋆minutes).

RESULTS AND DISCUSSION

Effects of sorting area on the manual sorting rate per worker were shown figure 2. The manual sorting rate for debris fractions of 20 mm over and 10 mm over were 2.7-2.8 × 10^{-3} and 1.5-1.8×10^{-3} m^3/worker/minutes, respectively. It found that difference of the sorting area at 0.5m^2/worker and 1.0m^2/worker is not given significant effect on the manual sorting rate. The manual sorting rate against the 20 mm over fractions is 1.6 times higher than one of 10 mm over fractions. It is suggested that the large fractions is easy to be selected and picked it up preferentially.

Effects of number of concurrently operating workers on the manual sorting rate per worker were shown figure 3. The manual sorting rate per worker was higher with smaller number of concurrently operating workers in case of sorting the 20 mm over size fraction. The difference of the manual sorting rate per worker each number of concurrently operating workers was not observed clearly in using for 10 mm over size fraction.

Effects of the operating time on the manual sorting rate per worker were shown in figure 4. Experiment period from starting time to 10 minutes, from after 10 minutes to 20 minutes and from after 20 minutes to 30 minutes was defined as Phase 1, Phase 2 and Phase 3, respectively. The manual sorting rate was higher in Phase 1 in all of experimental conditions. It suggests that higher efficiency will be resulted from sorting of lager size of fractions preferentially in Phase 1.

Figure 5 shows the relationship between the manual sorting rate (in m^3/minutes) and manual sorting labor. The highest manual sorting rate is 8.7×10^{-3} m^3/minute at 40 manual sorting labor and observed in case of the 20 mm over fraction sorted on 0.5 m^2/worker. The manual sorting rate became constant over 40 manual sorting labor. The manual sorting labor will be a potential parameter for maximizing the manual sorting rate.

CONCLUSION

The purpose of this study was to clarify factors relating to the higher efficiency of the manual sorting for HDW. Effects of 3 factors (size of the

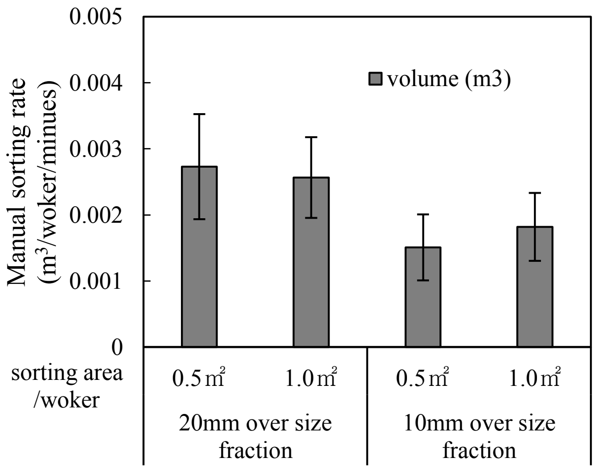

Figure 2. Effect of sorting area on manual sorting rate

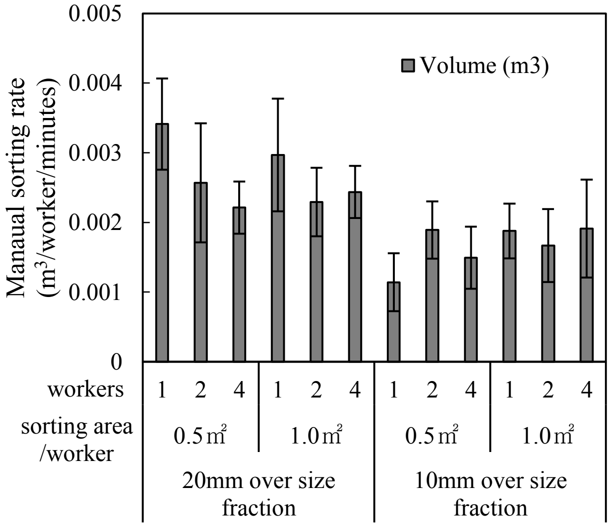

Figure 3. Number of the workers of concurrently sorting

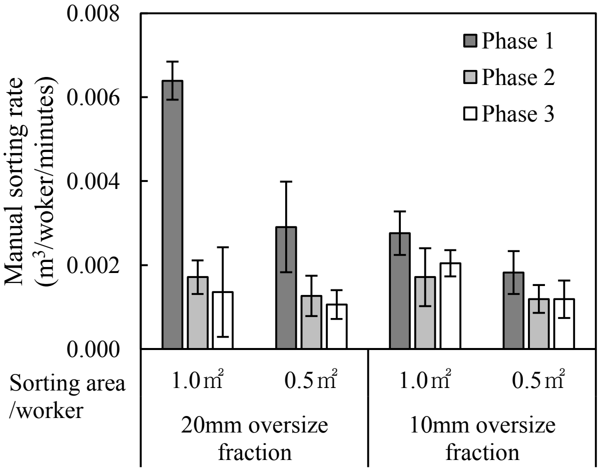

Figure 4 Sorting rate based on operating time

waste, area of the sorting and number of concurrently operating workers) on manual sorting was experimentally estimated. The difference of the manual sorting rate per worker between 0.5 m^2/worker and 1.0 m^2/worker of sorting area was not observed. The small number of concurrently operating workers showed high manual sorting rate on 20 mm over size fraction. The manual sorting labor was defined as multiplying the number of workers by the separation time. The manual sorting rate was highest at 40 manual sorting labor, and the rate was 8.7×10^{-3} m^3/minute. The manual sorting labor will be a potential parameter for maximizing the manual sorting efficiency.

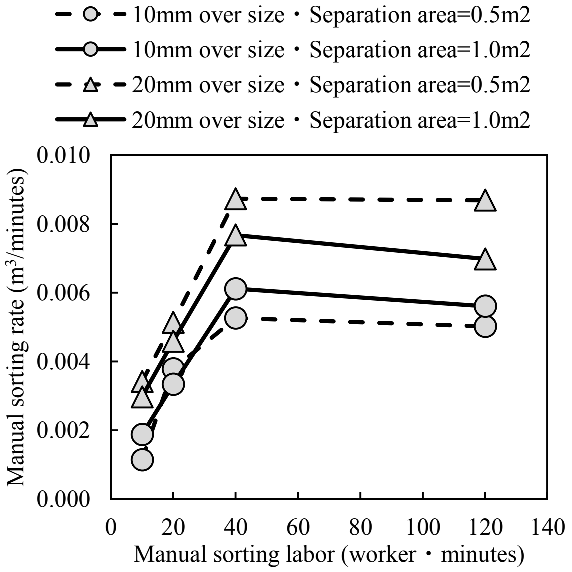

Figure 5 Relation between the sorting rate and manual sorting labor

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Effect of functionalized sites and textural characteristics in the sorption of toxic heavy metal onto ammoniated and chlorinated adsorbents

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ABSTRACT

The presence of toxic heavy metal (THM) ions is of leading concerns due to their toxicity to many life forms [1]. In order to find the key features that affect to the THM sorption capacity of activated carbon (AC), this article studied effects of carbon surface functional groups and textural characteristics for metal sorption. Functionalized sites chemically treated by hydrochloric acid and ammonium hydroxide solution with pure AC (ACP) in different concentrations to obtain modified AC with various porous structures and functionalized groups, named ACH and ACN, respectively. As the results of main inorganic elemental analysis indicated that chlorination treatment removed more minerals than ammoniation treatment methods, had no influence on the adsorption capacity of heavy metals (HMs) by adsorbents, confirming that ash content does not seems to have determinant effect to HM sorption capacity. The results acquired by 77K nitrogen adsorption experiment showed that textural properties have slightly shifted after these treatments but played an important role on THM adsorption capacity. The narrow mesoporous size distribution on the carbon surface chemistry of ammonia-doped AC is more favorable than chloride-doped AC for THM sorption. As for carbon surface functional groups, the data obtained by classical Boehm titration method suggested that, alkaline functional groups including nitrogen-bearing and amine functional groups are desired for THM sorption. In contrast, acidic functional groups mainly oxygen-bearing: carboxyl, carbonyl, lactone and phenol inhibit for THM removal significantly. The chemisorption uptake on AC with chlorinated treatment is decreased possibly due to produce a reduction in the adsorbent-adsorbate dispersive interactions, chloride ion cluster blockings, or competition between hydrogen ions and other cationic metals on the AC surface, thus decreasing the adsorption capacity. It is also related to the FT-IR analysis depicts the presence of a variety of alky halide groups which explain it were against adsorption behavior. On the contrary, the chemisorption capacity on the alkaline-rich AC prepared by ammoniated treatment is enhanced owing to introduce more nitrogen-bearing functional groups on the surface chemistry of AC. The measurement of metal adsorption capacity was also carried out by inductively coupled plasma mass spectrometry (ICP-MS) instrument. The experimental results were found that most of ammonia-doped AC has the highest sorption capacity in the following order: ACN > ACP > ACH.

Keywords: Adsorption; Acidic; Alkaline; Functional group; Toxic heavy metals; Functionalized; Chloride-doped; Nitrogen-doped.

INTRODUCTION

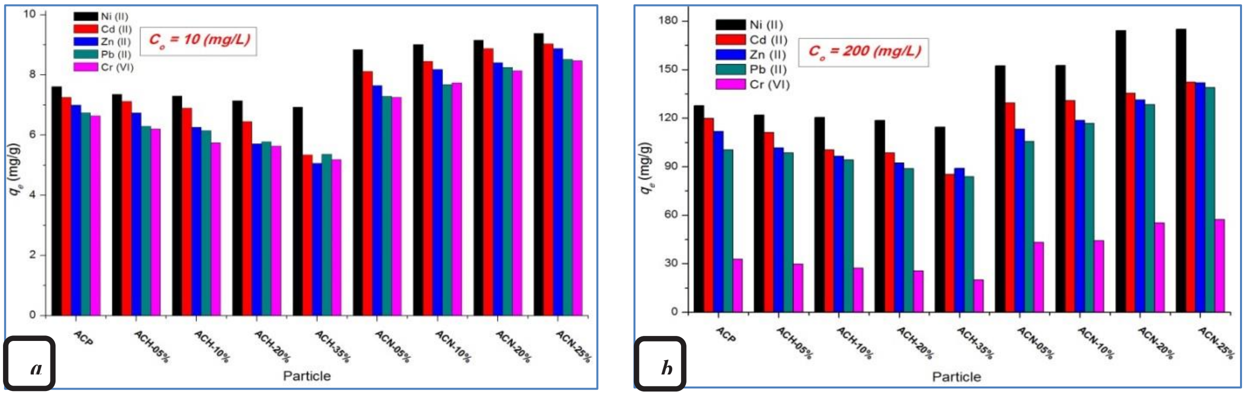
The water contamination due to release of toxic heavy metals (THMs) in ecological environment has been a great concern for environmental engineers as well as scientists. The huge amount of THM pollution in water is daily released to environment as the result of various industrial, agricultural and human activities such as fertilizers, waste water disposal, paper and battery manufacturing, mining, pesticides and fossil fuel which are responsible for causing several damages to all living organisms [2].

MATERIALS AND METHODS

All of the chemicals in this present article were of analytical grade (AR) and supplied form Sigma Aldrich, suitable for laboratory and general use. Anthracite-based activated charcoal, metal standard solution, the chlorinated and ammoniated reagent used for liquid phase modification $NH_3.H_2O$ and HCl were also purchased from Sigma Aldrich. The concentration of chlorinating agents used were at different concentrations of 05; 10; 20; 35 %, and ammoniating agents used were 05; 10; 20; 25 %, were referred as ACH (wt%) and ACN (wt%), respectively. Additionally, nickel, cadmium, zinc, lead, chromium were chosen as for THM contaminants in this study, metal standard solutions used from Cica-reagent (Kanto Chemical Corp Inc., Tokyo, Japan).

RESULT AND DISCUSSION

Removal of THM ions by ACP, ACH and ACN



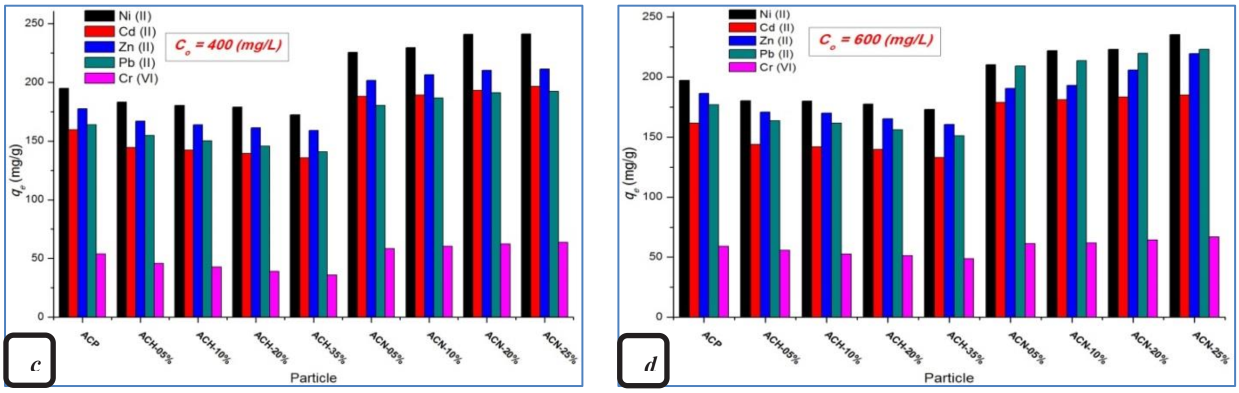


Figure 1. The adsorption capacity of THM ions removal using ACP, ACH and ACN with THM initial concentration of (a) 10 mg/L, (b) 200 mg/L, (c) 400 mg/L and (d) 600 mg/L.

It can be schematically observed from the Figure 1 that ACN-25% boasted the highest THM sorption capacity compared with other ACs. The experimental results were found that most of ammonia-doped AC has the highest sorption capacity in the following order: ammoniated AC > original AC > chlorinated AC.

Distinctly, the removal percentage of THMs under experiments was in the following order Ni^{2+} > Cd^{2+} > Zn^{2+} > Pb^{2+} > Cr^{6+} at all initial concentrations. Additionally, with IR spectrum analysis of original and adsorbed metal ions was schematised in Table 1. The FT-IR spectroscopic characteristics of the free metal salts and those adsorbed metal ions by ACP.

Table 1. FT-IR spectra of metal ions before and after adsorption

Metal ions	Intensities of Infrared Absorption Bands (cm-1)		
	Original metal	Adsorbed metal	Δv
Ni^{2+}	735.49	804.81	69.32
Cd^{2+}	762.08	827.93	65.85
Zn^{2+}	1020.39	1075.52	55.13
Pb^{2+}	1340.05	1387.31	47.26
Cr^{6+}	1090.78	1132.55	41.77

As can be noticed that the increased shifts in the wavenumber bands of original THM ions Ni^{2+}, Cd^{2+}, Zn^{2+}, Pb^{2+}, Cr^{6+} and after adsorption with ACP were 69.32, 65.85, 55.13, 47.26 and 41.77 cm^{-1}, respectively. These increased shifts exposed that there had binding processes taking place onto the carbon surface of ACP. In general, the greater the shift is (Δv), the stronger the interaction and bond between the ACP and the THM ions. In the comparison with the removal percentage result which was in the following order Ni^{2+} > Cd^{2+} > Zn^{2+} > Pb^{2+} > Cr^{6+}, there was a similarly and same trend with the order of the $\Delta v (Ni^{2+}) > \Delta v (Cd^{2+}) > \Delta v (Zn^{2+}) > \Delta v (Pb^{2+}) > \Delta v (Cr^{6+})$.

CONCLUSION

To find the key characteristics that affect to THM ions sorption capacity, the following conclusions could be inferred:

- Nickel and chromium were the metals that had the highest and lowest removal capacity q_e (mg.g^{-1}) at all significant factors including pH, shaking time, adsorbent dose, initial concentration.
- Chlorination treatment removed more mineral compounds than ammoniated treatment, however, the effect of ash content plays an unimportant role and is insignificant on adsorption capacity of THM.
- Functional groups have a determinant influence and are key characteristics on THM adsorption capacity.
- Alkaline functional groups are more favorable for THM sorption.
- Acidic groups decreased the metal removal capacity.

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Recovery Nickel from spent catalyst of fertilizer plant as precursor for exhaust gas treatment model catalysts preparation

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ABSTRACT

In this study, a very promising way of treating and recycling spent nickel catalysts of fertilizer plants in Vietnam was proposed. Firstly, nickel was recovered from spent catalyst using HNO_3- leaching process. Results showed that nickel recovery of over 90% with a purity of over 90% could be achieved with HNO_3 1.6 – 2M; 102^{o}C and 80 min. Then, the leachate solution could be used as precursor to prepare model catalyst for exhaust-gas (CO, HC, NOx) treatment. In comparison with the catalyst prepared from commercially available nickel nitrate, the catalyst prepared from recovered nickel exhibited similar properties and activities. The modification of active phase by transition metal was also investigated. It is feasible to modify active phase by transition metal such as Mn, Ba and Ce for complete oxidation of CO, HC and reduction of NO_x.

Keywords: Spent catalysts, fertilizer plants, leaching, catalyst preparation, CO-HC oxidation, NO_x reduction.

INTRODUCTION

Treatment of spent nickel catalyst from the nitrogenous fertilizer industry using hydrometallurgy processes to recover nickel have been widely applied due to their flexible, environmental-friendly [1]. Ni recovery product is mainly in form of nickel sulphate, which can be used in electroplating [2].

On the other hand, nickel is widely applied in the oxidation-reduction catalyst for gas treatment process [3]. In this study, we investigated the possibility to use nickel recovered from spent catalyst as precursor to prepared catalyst for CO, HC and NOx treatment (de(CO-HC) and de(NOx)). However, for catalyst preparation, the use of nickel nitrate leads to better physical and catalytic properties compared with nickel sulphate or nickel chloride [4]. It is only found that nickel nitrate product is recovered in leaching study of Oza et al.[5]. However, the process proposed by Oza should be improved because of many high energy consumption stages such as: crushing, screening, calcination, agitation.

The objective of this study was to determine the optimal condition for simultaneous maximum of nickel extraction and purity. After that, an energy-saving procedure was proposed. The recovered Ni in form nitrate salt was then used as a precursor for synthesizing the catalysts of de(CO-HC) and $deNO_x$ preparation. The activity of catalyst for CO-HC oxidation and NOx reduction was evaluated by light-off process.

MATERIALS AND METHODS

Leaching procedure

The extraction Ni from spent catalyst of Phu My fertilizer plant in Viet Nam was conducted following the procedure of Oza et al. [5] without crushing, screening, calcination, agitation. The experiment design was performed in order to maximize the recovery and purity by changing the acid concentration, temperature and time of digestion. An inductively coupled-plasma (ICP) was employed to measure the content of the elements in leachate: Ni^{2+}, Al^{3+}, Mg^{2+}.

Catalyst preparation

Catalysts for (CO-HC) and NO_x treatment were prepared by co-precipitation similar to the procedure described by Duprez [6] with some modifications. Active phase $Ni/\gamma\text{-}Al_2O_3$ was modified by representative transition metals (Mn, Ba, Ce). The catalyst was pre-treated at 550 °C for 4 hours under a mixture containing 20 wt.% of H_2 in N_2.

Catalyst characterizations

Surface areas (SA) and pore volumes (PV) of the supports and catalysts were determined from nitrogen isotherms at −196ºC on a TRISTAR 3020 Micromeritics apparatus. XRD patterns were recorded in the $20^o \leq 2\theta \leq 70^o$ range on a Bruker D8 Advance diffractometer using scintillation counter detector, equipped with a CuK radiation source. SEM images were obtained on a EVO MA10 (Carl Zeiss) Scanning Electron Microscope with an accelerating voltage 20 KV.

Catalytic activity measurement

Oxidation and reduction catalytic tests were performed by light-off process using a quartz U-shaped reactor equipped with a temperature programmed controller. The reagent gas mixture was led over the catalyst (0.1 g) at a flow rate of 10 L/h, equivalent to a gas hourly space velocity (GHSV) of 110.000 h^{-1}. The composition of reagent gas is 8.000 ppm CO + 2.000 ppm C_3H_6 + 20 vol.% of O_2 in N_2 for de(CO-HC) test or 500 ppm NO_x + 10000 ppm CO in N_2 for deNO_x test. The inlet and outlet gas compositions were analyzed by on-line analyzer (Ultramat 6E of Siemens, Germany).

RESULTS AND DISCUSSION

The leaching procedure proposed without crushing, screening, calcination, agitation is energy-saving, as well as it avoids environmental contamination with untreated spent catalyst waste. The optimization of leaching shows the recovery (Y_r) and purity (Y_p) function as follow:

$Y_r = 82{,}3 + 3{,}2Z_1 + 2{,}9Z_2 + 4Z_3 + 1{,}8Z_2Z_3 - 2{,}8(Z_1^2 - 0{,}75) - 3{,}5(Z_2^2 - 0{,}75)$

$Y_p = 92{,}7 - 1{,}5Z_1 - 1{,}2Z_3$

Where: Z_1 - acid concentration (M), Z_2 - temperature (^oC) and Z_3 - time digestion (min).

These function expressed that the recovery is proportional with the acid concentration, temperature and time digestion while the purity is inversely related to acid concentration as well as time digestion. The highest leaching efficiency of 94.2% was achieved while the purity was 90,8%. And in case maximization the purity of 91.6%, the recovery was 92.9%. The parameters of leaching were: HNO_3 1.6 – 2M, 102 ^oC and 80 min digestion. The main components in leachate: Ni^{2+} 1.2M; Mg^{2+} 0.06M; Al^{3+} 0.027M.

Then, the leachate was used as precursor for de(CO-HC) and de(NOx) catalysts preparation. Firstly, the influences of nickel loading on xNi/Al_2O_3 catalyst (x: wt.% Ni loading and varied from 5 to 30 wt.%) has been investigated. The XRD analysis demonstrated that the most peaks belong to Ni° crystalline ($2\theta = 44.5°; 52°$) were detected in xNi/Al catalysts. The intensities of these peaks are consistent with the increase of the Ni loading. The BET results show that active phase is well dispersed on the support (also confirmed by SEM-EDX) with the average diameter of the alumina pore size about 5 nm (Figure 1).

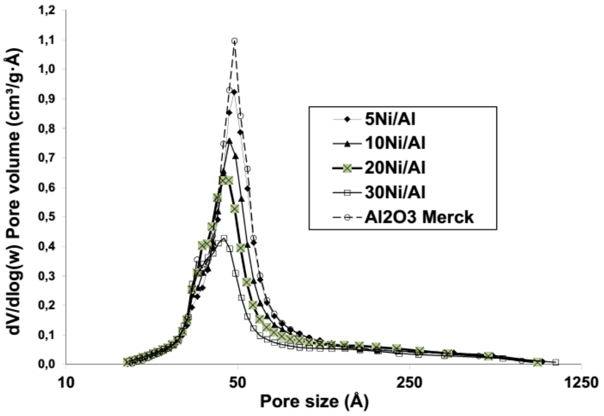
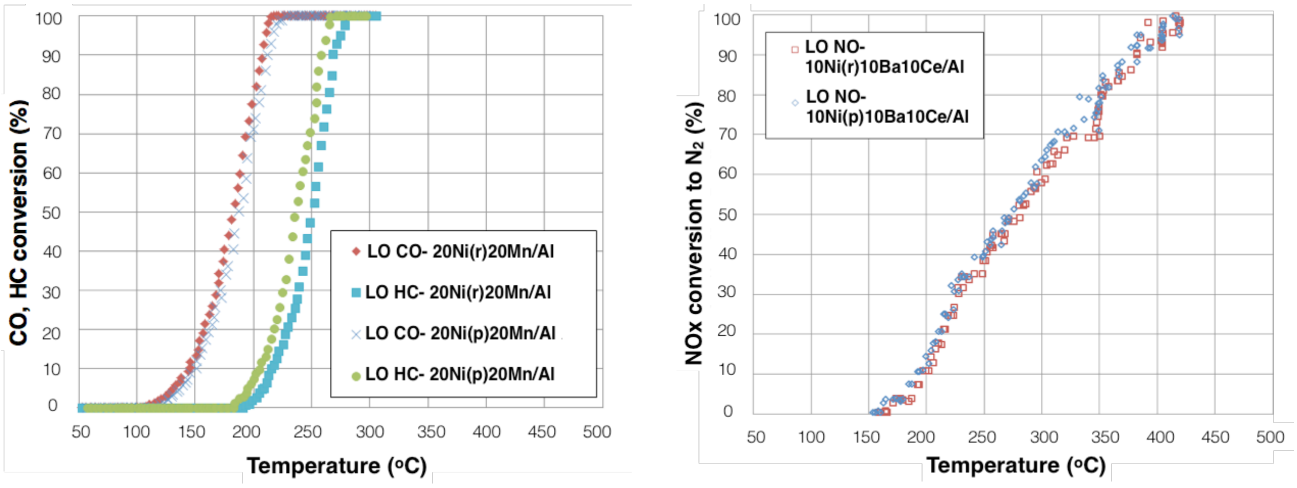


Figure 1: Pore size distribution of the studied catalysts

There is an interesting correlation between the Ni loading and catalytic activity for each application. For de(CO-HC), 20Ni/Al catalyst exhibits highest activity. Whereas for NOx reduction, the 10Ni/Al catalyst is the most suitable one. Based on these catalysts, the modification by metal transition addition was investigated.

The oxidation conversion of CO-HC could be started at 145^{o}C and finished at 270^{o}C over 20Ni20Mn/γ-Al_2O_3 sample (Figure 2a). For NO_x reduction, the completed conversion was obtained below 350^{o}C over 10Ni10Ba10Ce/γ-Al_2O_3 (Figure 2b). These results is roughly similar with the study of Reina et al. [7]. It also appears that compared with the catalyst prepared from commercially available nickel nitrate, this material exhibits similar physical properties and performances.



(a) (b)

Figure 2: Light-off curves CO-HC (a) and NO_x (b) conversions on the catalyst prepared from recovered nickel nitrate (20Ni(r)20Mn/Al and 10Ni(r)10BaCe/Al) and the catalyst prepared from commercial precursor (20Ni(p)20Mn/Al and 10Ni(p)10BaCe/Al).

CONCLUSION

In this study, the leaching efficiency of Ni from spent catalyst of Phu My fertilizer plant in Viet Nam was studied. The leaching efficiency of 92.9% with a purity of 91.6% was achieved under the suitable conditions. It was also shown that the leachate containing nickel can be used as precursor for synthesizing the de(CO-HC) and deNO_x catalysts. With some modifications by transition metal addition, 100% CO-HC oxidation to CO_2, H_2O can be carried out over 20Ni(r)20Mn/γ-Al_2O_3 catalyst at 270^oC. The temperature for total reduction of NO_x is below 350^oC over 10Ni(r)10Ba10Ce//γ-Al_2O_3 sample at high volumetric flow condition (GHSV = 110.000 h^{-1}). It is very promising to recover Ni as a precursor for synthesizing the catalysts for treatment of CO, HC and NO_x.

ACKNOWLEDGEMENT

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A study of hydrometallurgy process to recover rare earths in spent FCC catalyst from Dung Quat Refinery. The influence of decoking and alkali treatment on spent catalyst characteristics and yield of the leaching process.

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ABSTRACT

Fluid catalytic cracking (FCC) is one of the most important conversion processes in petroleum refining, which generates a large proportion of spent catalyst per year. Rare earth metals present in spent catalyst, which have high economic value, can be recover for other applications. This is meaningful from both industrial and environmental point of views. In this study, two methods to pretreat spent FCC catalyst prior to recovery process were proposed: decoking and alkali treatment. The objective of pretreatment is to increase the efficiency of leaching process under mild condition (2 M HNO_3 at 50 ^oC). The results showed that both pretreatment methods had positive effect on increasing the yield of the leaching process. Decoking at 500 ^oC was sufficient to eliminate carbon deposited on spent FCC catalyst, hence the increase in leaching yield. The effect of alkali treatment on zeolite structure was investigated. The results proved that alkali treatment destabilized zeolite in spent catalyst and resulted in the decrease in crystallinity. Additionally, pretreatment with NH_3 had additional destructive effect on zeolite structure, thus obtaining more rare earth ions than sample treated with NaOH.

Keywords: Spent FCC catalyst, rare earth metal, leaching, decoking, alkali treatment.

INTRODUCTION

It cannot be denied that fluid catalytic cracking (FCC) plays a significant role in an integrated refinery as the primary conversion process of crude oil to lighter products. The operation of FCC units require about 500.000 tons of FCC catalyst per year, which results in producing about 360.000 tons of spent catalyst each year[1]. In Viet Nam, Dung Quat refinery produces about 20 tons of spent catalyst per day, which is equal to about 7.300 tons per year [2]. The typical spent catalyst can often contain rare earth oxide contents of at least 0.5 wt.% and a zeolite content of a at least 5 wt.% [3]. With China presently producing more than 90% of the global rare earths (RE) output and its increasingly tight export quota, the rest of the world is confronted with a RE supply risk. Many countries will have to rely on rare earths which are recover from industrial waste (scrap metals, magnets, nickel-metal hydride batteries, lamp phosphors…) [4].

Hydrometallurgical process not only can recover metals which have high economic value but also removed those that are environmentally hazardous before disposal or recycling. However, in recent studies, the yield of the leaching process is relatively low at mild condition but increase as the reaction condition is more critical (higher temperature [5] or more concentrated acid solution [6]). Therefore, the development of a technically feasible and economically acceptable solution for recycling rare earths from FCC catalyst is a task that must be fulfilled.

MATERIALS AND METHODS

Leaching procedure: The extraction of rare earths from spent FCC catalyst collected from Dung Quat Refinery was conducted by using HNO_3 (from 2 M to 7 M) with stirring speed of 200 rpm and solid/liquid ratio of 1/3 at 50 ^oC for 60 mins.

Decoking: The spent catalyst was calcined at 500 ^oC in air for 3 hours then the calcined catalyst was leached following the leaching procedure above with 2 M HNO_3.

Alkali treatment: Alkali treatment was carried out with different bases (NaOH and NH_3). Initially, an appropriate amount of base was added to the spent catalyst to achieve the desired pH value. The resulting mixture was stirred with the stirring speed of 200 rpm at 50 ^oC for 60 mins and frequently checked to ensure that the pH value was maintained. After filtration, the solid residue was drying at 100 ^oC for 24 hours. Then the treated catalyst was leached following the leaching procedure above with 2 M HNO_3.

Sample characterization: X-ray Fluorescence was employed on a Bruker S4 to determine the concentration of desired elements (La, Ce, Al, Si) in initial spent catalyst and leached samples.

XRD patterns were recorded on a Bruker D8 Advance diffractometer. The influence of pre-treatment condition to the zeolite structure of FCC catalyst were studied by "relative crystallinity" values [7]. The initial spent FCC catalyst was chosen as the standard for intensity comparison.

RESULTS AND DISCUSSION

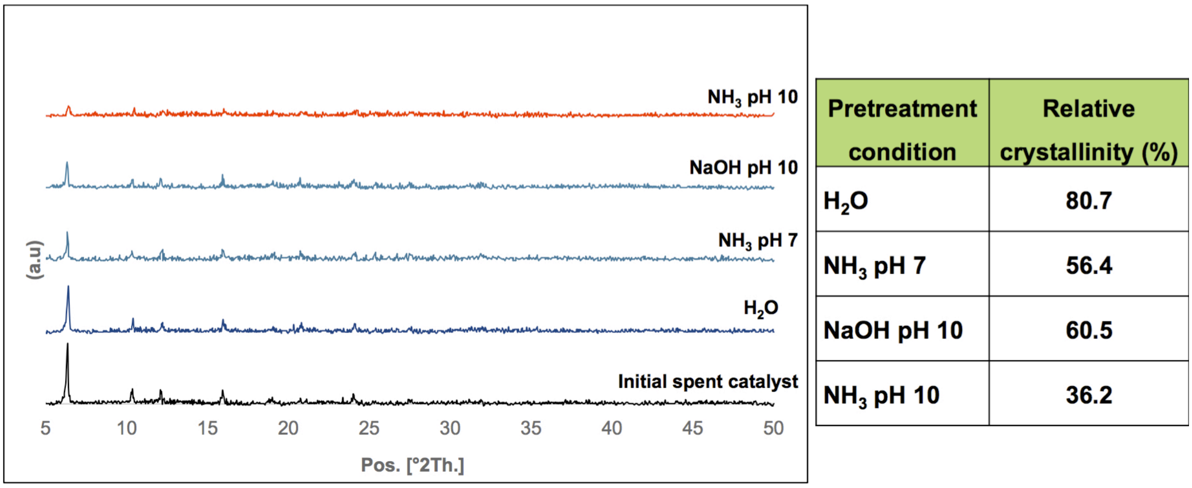
The composition analysis of the spent catalyst was colected from Dung Quat refinery is summarised in Table 1. It is clear that metal contaminants such as vanadium, nickel, iron anand coke which deposited on catalyst during cracking process, were found in spent catalyst sample. The La_2O_3 content is about 2.5 wt.% whereas CeO_2 is present only in 0.18 wt.% of the total weight.

Table 1: Analyses of the spent FCC catalyst powder by XRF and coke analyzer (for C).

Component	SiO_2	Al_2O_3	**La_2O_3**	Fe_2O_3	TiO_2	NiO	P_2O_5	Na_2O	CaO	**CeO_2**	V_2O_5	K_2O	C*
Content (wt.%)	46.81	45.40	**2.52**	1.52	1.38	0.53	0.33	0.32	0.23	**0.18**	0.14	0.12	0.21

For the leaching process, the standard deviations of repetition are all below 5 %, indicating an acceptable repeatability. Decoking at 500 ^oC in air is sufficient to remove 90 wt.% of carbon deposited on spent catalyst and leads to the increase in yield of leaching process from 79.2% to 84.0% (Table 2).

Alkali treatment results demonstrated that there is correlation between zeolite destruction and pH value. The increase in pH value of basic solution leads to the increase in structural damage observed in spent catalyst. Moreover, XRD analysis results indicate that the presence of NH_3 have an additional destructive effect (Figure 1). This conclusion was confirmed by BET surface area analysis. Further investigation showed that the NH_3 effect was only observed when metal contaminants were present in FCC catalyst.



Pretreatment condition	Relative crystallinity (%)
H_2O	80.7
NH_3 pH 7	56.4
NaOH pH 10	60.5
NH_3 pH 10	36.2

Figure 1: XRD patterns of spent catalyst treated with different bases and the influence of pretreatment condition on the relative crysallinity of zeolite structure.

Leaching results of pretreated spent catalyst with bases demonstrate that the more structural damage the pretreatment causes, the higher efficiency of leaching process is attained (Table 2). In comparison with leaching yield of 85.5% when initial spent catalyst leached with 7 M HNO_3, the pretreatment with NH_3 at pH 10 can reach higher leaching yield at less concentrated HNO_3 solution (2 M).

Table 2: Leaching yields in dependence on acid concentrations and pre-treatment conditions. Stirring speed of 200 rpm, solid/liquid ratio of 1/3 at 50 °C for 60 mins.

Conditions	Spent catalyst + 0.5 M HNO_3	Spent catalyst + 2 M HNO_3	Spent catalyst + 3.5 M HNO_3	Spent catalyst + 7 M HNO_3	Spent catalyst **decoked** + 2 M HNO_3	Spent catalyst **pretreated in NaOH pH 10** + 2 M HNO_3	Spent catalyst **pretreated in NH_3 pH 10** + 2 M HNO_3
Leaching yield (%)	45.1	79.2	81.8	85.5	84.0	83.9	86.4
Relative crystallinity of starting material (%)	100	100	100	100	100	60.5	36.2

CONCLUSION

In this study, two methods for spent FCC catalyst pretreatment prior to leaching process were proposed. The pretreatment by decoking at 500 ^{o}C in air led to the increase in yield of the leaching process because pore blockage caused by carbon deposition was eliminated during decoking process. X-ray diffraction results informed that alkali treatment decreased the crystallinity of spent catalyst. The increase in pH value of the treatment step resulted in the increase in structural damage of zeolite structure. Moreover, the presence of NH_3 was found to enhance the destruction of zeolite framework even further. The leaching tests showed that the leaching of alkali treated spent catalyst with 2 M HNO_3 was able to recover more rare earth metals than the leaching of initial spent catalyst with 7 M HNO_3.

In conclusion, decoking and alkali treatment were proved to have positive effect on increasing the yield of the leaching process. These pretreatment methods can improved the leaching yield without the increase in temperature or acid concentration of leaching step, which hold promising potentials for high efficiency of recovery of rare earths under mild condition from spent FCC catalyst.

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Session 8

3R technology

Effect of alumina reinforcement particle in direct recycling aluminium (AA6061) by hot press forging

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ABSTRACT

Lightweight, durable and infinitely recyclable aluminium has become an essential element of daily life. When demands on the element is high, the waste correspondent to it will undoubtedly increase. The impact of aluminium recycling on the environment has been profound. The direct recycling process is being introduced as an alternative technique of solid state recycling, do give the better solution in obtaining merely mechanical and physical properties of the primary alloys. This paper deals with the mechanical and physical responses of aluminium after being executed with the Hot press forging process. All chips were machined from the same AA6061 ingot. The process begin with cleaning all the chips with acetone. Then, the chips were poured into a mould and subjected to hot press forging subsequently. The Holding time is being manipulated and the responses were investigated. The AA6061 matrix composite, reinforced with Al_2O_3, recycled by Hot press forging, was compared to the unreinforced material produced by the same route and at the same highest Holding time. Due to the high strength of alumina, the Ultimate tensile strength (UTS) and the hardness were found higher for reinforced materials. Other responses that were measured on the sample included the Elongation to Failure (ETF), Density, and the Microhardness (HV).

Keywords: Sustainable direct recycling, Metal recycling, Hot press forging, Aluminium recycling, Aluminium AA6061, Reinforced particle

INTRODUCTION

Aluminium recycling has been activated in the early 1900s where the purpose of this activity were to concentrate the energy uptake and to save the surroundings. The primary aluminium production (mining of ore) required 113 gigajoule per tonne of energy. However, the secondary production (conventional aluminium recycling of scrap) only needed about 13.6 gigajoule per tonne of energy (Rombach, 1998). Currently, there are several methods that had been introduced as a new approach of recycling metal chips which comply with the direct conversion of chips into a compact metal through either cold pressed, hot extrusion or hot forged. This new approach will significantly eliminate melting process(Sharma & Nakagawa, 1977). It had been identified that alumina particles made a major increase in hardness, tensile strength, elastic modulus and a significant increase in tensile elongation (Ceschini, Minak, & Morri, 2009). Besides that, it is discovered that there is an effect on the quantity and distribution of the matrix whenever the reinforcement phase is introduced into the comminute aluminium and aluminium-alloy chips (Gronostajski, Marciniak, & Matuszak, 2000).

In this paper, the effects of holding time (1 to 2 hours) for the aluminium chips toward the mechanical properties were discussed. The discussion will also comply with the reinforced aluminium with alumina particle and then, the results will be compared to the unreinforced material that was subjected to the same holding time. All specimens were prepared by the same process of hot press forging.

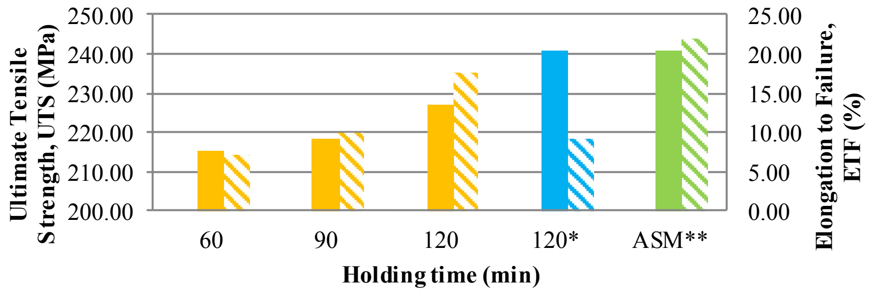
MATERIALS AND METHODS

The AA6061 aluminium alloy chip was prepared by milling an ingot using Sodick-MC430L high speed machining. Yusuf (2013) and Lajis et al., (2014), studied and suggested the medium size chip yield better specimen performance. The cleaned and dried process followed the Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques. The chips are then undergoing the drying process in the furnace at 60ºC of temperature.

The process of mixing Aluminium AA6061 with 1wt-% alumina and Al_2O_3 powder (<1 µm) is prepared in SYH 15 3D mixing machine. In fact, the recycling process utilized the hot press procedures to forge the chips into compacted form and desired shape. This process was conducted not only by varying the holding times for 60 minutes, 90 minutes, and 120 minutes but also, at a constant force of 350 kN.

The Alumina, Al_2O_3 and the 12.0 grams of total aluminium 6061 are being poured into a mould. The hot press machine are operated at the specified parameters. The shaping process previously resulted from the preparation of standard tensile specimen. The testing was conducted not only by using the Universal Testing Machine for tensile test, the Hardness Vickers Tester for microhardness but also, by using the Density Balance for density measurement.

RESULTS AND DISCUSSION



* Specimen reinforced with 1wt-% Alumina

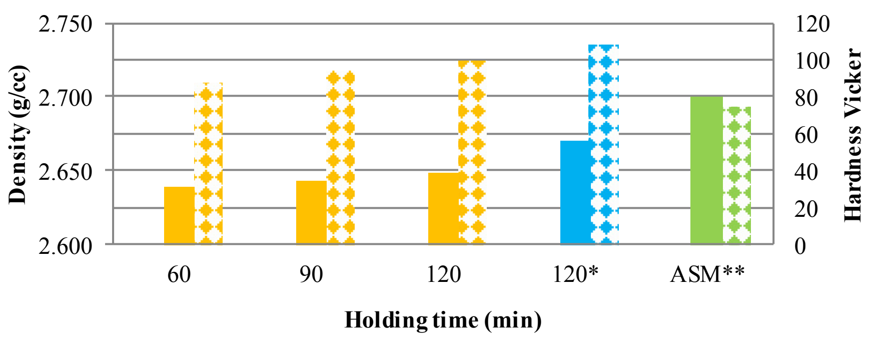
** Data for Aluminium 6061-T4 from (ASM International, 2009)

Figure 1: UTS and ETF at different holding time

Figure 1 illustrated the ultimate tensile strength (UTS) and the elongation to failure (ETF) percentage value that was presented conferring to the holding time. The UTS value increases from 215.19 MPa (60 minutes) to 226.96 MPa (120 minutes). The maximum UTS was recorded for the reinforced aluminium with 1wt-% alumina by the value of 240.96 MPa. The holding time shows a significant roles in this process , because it allows the aluminium to have better consolidation at constant heat. A ductile material (most metals and polymers) will record the highest elongation percentage, while brittle materials like ceramics tend to show very low elongation percentage because they do not plastically deform. A significant increment of ETF value can be seen in Figure 1 when the holding time increases in values. On the contrary, the reinforced aluminium yield ETF of 9.16%, which drop drastically when compared to the unreinforced aluminium at the same holding time.

Dheylan et al., (2005) found that due to the constraints imposed on the deformation caused by the presence of the hard and brittle Al_2O_3 particles in the soft and ductile 6061 aluminium alloy matrix, a higher applied stress is required to initiate the plastic deformation in the matrix. Additionally, the presence of Al_2O_3 particles clusters can lead to the enhancement of local stresses, from the restriction of plastic deformation (Ceschini, Minak, & Morri, 2006). This in turn will result the increment value of UTS of the composite.

Densities and hardness were depicted in Figure 2. It shows that the density of unreinforced aluminium increases from 2.640 g/cc (60 minutes) to 2.649g/cc (120 minutes). In contrast, the density of the reinforced material is 2.657 g/cc, which are the highest density among the materials.



* Specimen reinforced with 1wt-% Alumina

** Data for Aluminium 6061-T4 from (ASM International, 2009)

Figure 2 Density and hardness at different holding time

When pressing aluminium chip under the presence of heat and high force, voids will be created between the chips. Since the alumina size is much smaller (<1µm) than the aluminium chip, alumina tends to fill the cavity between the chip and fill up the gap. In addition to that, the filled cavity will reduce the composite porosity and thus, will result a better density of the specimen.

The Microhardness data at 60 minutes holding time is 87.32 HV. This value is gradually increased to 99.20 HV at 120 minutes. The hardness for composite material exhibits about 107.95 HV, 8% higher than the unreinforced material. The increment value of hardness is contributed by hard properties of alumina imbedded in aluminium, which then, had increased the constraint of plastic deformation of the matrix.

As temperature increases, more solid will dissolve and mix in the matrix for supersaturation. This is due to the increased diffusion kinetics and higher solubility limits at higher temperatures. In addition to that, another output of the chart is related to the soaking time. It shows that, at the temperature value below 530ºC, with the increases value of soaking time, a satisfactory degree of solution of the undissolved or precipitated soluble phase constituents will form a good homogeneity of solid solutions.

CONCLUSION

As the holding time increased, not only a good homogeneity form of solid solutions will be created, but also, exhibits good properties of material by providing sufficient period for the alloy chips to consolidate among them. This in turn, will result the increment value of the UTS, density and microhardness reading when the holding time rises from 60 minute to 120 minute. Moreover, the presence of Al_2O_3 particle in the soft and ductile 6061 aluminium alloy matrix resulted both positive and negative responds. The hard and brittle Al_2O_3 properties lead to higher UTS value and low ETF reading. In addition, a small size of alumina will make possible for the particle to conceal the cavity between the pressed chips, thus increase the composite density.

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P/Ca Ratio Dependency of Water Holding Capacity of Soil/Sand with Apatite-synthesized Coal Fly Ash

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ABSTRACT

Utilization of the Coal Fly Ash (FA), by-product of coal fired power generation, is becoming a worldwide problem that can't be ignored. In this research, utilizing FA as water holding agency for soils is aimed to stop serious desertification problem. Calcium phosphate synthesized FA (apatite synthesized FA) with 4 different Phosphorus/Calcium ratio (P/Ca ratio) were tested in this study. The relationship of P/Ca ratio of synthesized FA and their effect on Water Holding Capacity (WHC) of Decomposed Granite Soil (DGS) and Silica Sand (SS) were analyzed at 40 ºC and under natural condition (N.C.). WHC experiments were carried out under different conditions like FA mixing ratio, soil/sand type, drying temperature, and FA treatment method. Experimental results shows that the effect of apatite synthesis on WHC of pure FA has no obvious trend at 40 °C as a function of P/Ca ratio. When apatite-synthesized FA with P/Ca ratio of 11 was amended, it increased WHC of both DGS and SS at 40 °C. However, FA amendment gave different impacts on WHC of soil and sand. They depend on FA mixing ratio, drying temperature, soil type, and treatment method.

Keywords: Coal Fly Ash Amendment, Soil and Sand, Water Holding Capacity, Apatite-synthesis, P/Ca ratio dependency

INTRODUCTION

Coal is one of major electric power sources all over the world. About 40% of electricity is generated by coal-fired power plants in year 2010 global average1). Fly ash (FA) and bottom ash (BA) are two major by-products from coal-fired power generation. Global FA generation was 500 million Mg in 20102). As the world average, FA recycle ratio is estimated to be about 16 %2). Thus, huge amount of FA has not been used but disposed in controlled landfill sites and/or open dumping sites. It has caused serious pollutions finally. This study focuses on FA application for soil amelioration, in particular water holding agents from the view point of anti-desertification in arid area like northern and western China. If FA can be recycled as water holding agent after necessary treatment for environmental safety, it will contribute into anti-desertification and FA recycling management at the same time. This study focuses on the treatment of FA by apatite synthesis to investigate the effect of apatite-synthesized FA amendment with different Phosphorous/Calcium ratios (P/Ca ratio) on water holding capacity of soil and sand.

MATERIALS AND METHODS

Soils and coal fly ash properties

In this research, Decomposed Granite Soil (DGS) and Silica Sand (SS) were tested for their water holding capacity (WHC). FA used was taken from a coal-fired power plant in Japan. Elemental content of tested FA was analyzed by Energy Dispersive X-Ray Fluorescence spectrometer$^{3)}$.

Pretreatment of FA

In this research, apatite was synthesized on FA surface with 4 different P/Ca ratios. In pattern 1 (P/Ca = 3), 200 g of raw FA was mixed with 10 ml of 0.2 mol/L Na_3PO_4 solution first, and then mixed with 40 ml of saturated $Ca(OH)_2$ solution. In pattern 2 (P/Ca = 7.12), 200 g of raw FA was mixed with 30 ml of 0.2 mol/L Na_3PO_4 solution first, and then mixed with 50 ml of saturated $Ca(OH)_2$ solution. In pattern 3 (P/Ca = 11.67), 200 g of raw FA was mixed with 40 ml of 0.2 mol/L Na_3PO_4 solution first, and then mixed with 40 ml of saturated $Ca(OH)_2$ solution. In pattern4 (P/Ca = 16), 200 g of raw FA was mixed with 55 ml of 0.2 mol/L Na_3PO_4 solution first, and then mixed with 40 ml of saturated $Ca(OH)_2$ solution. All treated FA were dried at 105 ºC for over 24 hours, crushed softly, and then utilized for WHC experiments.

Water Holding Capacity Measurement

WHC of soil, raw/treated FA, and soils amended with raw/treated FA were measured by drying experiments. 7.5 g of pure water was added to 17.5 g of dried sample to adjust initial water content as 30 wt%. FA amending ratios are 10 wt%, 20 wt% and 30 wt%. Moistened samples were dried under natural condition (around 20 ºC) for 12 hours or dried isothermally in an oven at 40 ºC for 12 hours. The weights of moistened samples were measured at 1 hour intervals to monitor water retention in the sample. According to drying experimental data, water retention curves were drawn, which are weight-based relative percentages of remained water in the sample at different drying times. The concept of WHC calculation is illustrated in Figure 1. In this study, WHC was calculated as the area of water retention curve.

RESULTS AND DISCUSSION

WHC of soil/sand, raw FA and apatite-synthesized FA

WHC of raw/apatite-synthesized FA, soil and sand are shown in Figure 2. Figure 2(B) shows clearly that raw FA and all apatite-synthesized FA have almost the same WHC with soils under N.C. On the other hand, comparison of Figure 2(A) and (B) suggests that WHC of raw FA significantly decreased by 56.72 % when drying temperature increased to 40 ºC. WHC of

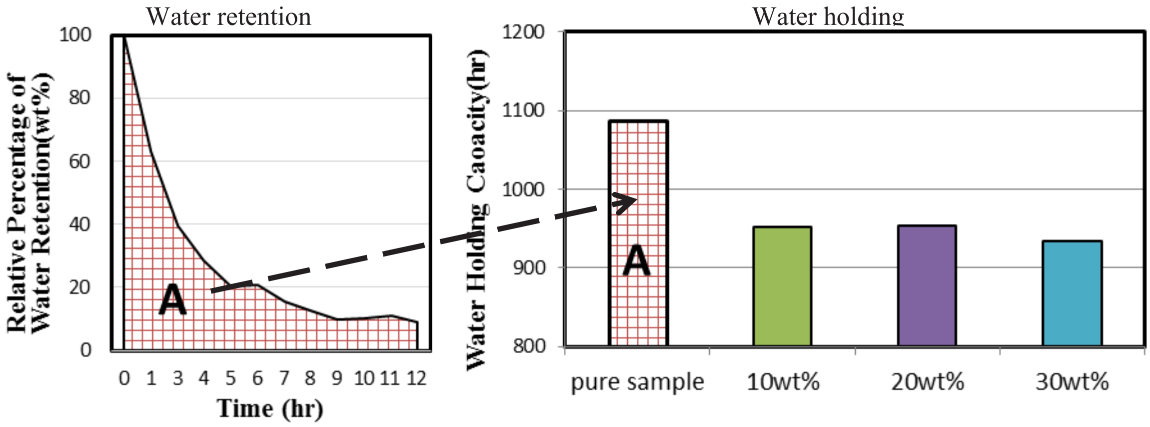

Figure 1. Calculation concept of WHC based on water retention curve

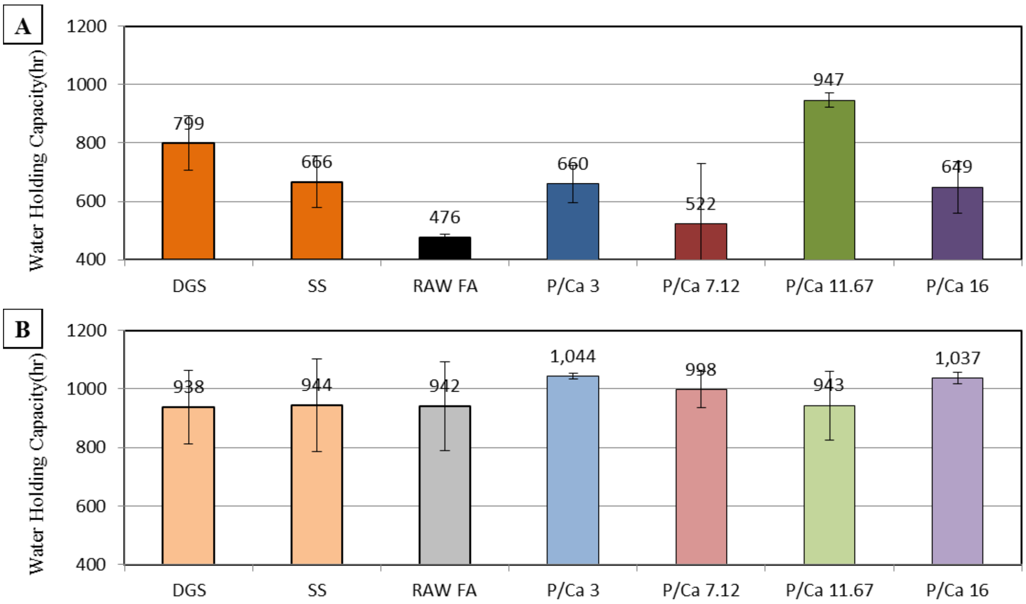

Figure 2. WHC of soil/sand, raw/apatite-synthesized FA with different P/Ca ratio (DGS: decomposed granite soil, SS: silica sand, Raw: raw FA, apatite-synthesized FA was expressed by different P/Ca ratios [A] 40 ºC, [B] N.C.)

apatite-synthesized FA also decreased by 36.8 % for P/Ca = 3, 47.7 % for P/Ca = 7.12, and 37.4 % for P/Ca = 16. In contrast, apatite-synthesized FA with P/Ca ratio of 11.67 had almost the same WHC at 40 ºC. Compared to WHC of raw FA at 40 ºC, apatite-synthesized FA has higher WHC with any P/Ca ratios, in particular 11.67. Its WHC is twice higher than that of raw FA. The lowest increase of WHC was shown by apatite-synthesized FA with P/Ca = 7.12 and the increase rate was about 10 %. Apatite-synthesized FA with P/Ca = 3 and P/Ca = 16 increased WHC for about 40 %. Among all FA samples, the apatite synthesis over FA particle gave a positive effect on increasing WHC of FA in spite of different performance levels. Although DGS and SS have almost equal WHC under natural condition, SS has lower WHC than DGS at 40 ºC. This result clearly suggest that WHC of treated FA has temperature dependency, soil type dependency, and P/Ca ratio dependency. Such dependency appears clearly at high temperature (40 ºC).

Comparison of WHC among soil/sand amended by apatite-synthesized FA

WHC of DGS and SS amended by apatite-synthesized FA with different P/Ca ratios and different mixing ratios at 40 ºC is shown in Figure 3. Figure 3 shows that apatite-synthesized FA with P/Ca ratio of 3 and 11.67 gave positive effect on WHC of DGS. Increasing percentage of WHC was about 8 %. When apatite-synthesized FA with P/Ca ratio of 3 was amended to DGS, DGS has almost equal WHC at any mixing ratios. In contrast, WHC of DGS increased with increase of FA mixing ratio when treated FA with P/Ca ratio of 11.67 was amended. The highest increasing percentage of WHC was about 22 %. Raw FA and apatite-synthesized FA with P/Ca ratio of 7.12 and 16 gave negative effect on WHC of DGS. Raw FA decreased WHC the most and the reduction was about 18 % at mixing ratio of 30 wt%. When P/Ca ratio was 7.12, apatite-synthesized FA decreased WHC of DGS for about 11 %. The amendment of treated FA with P/Ca of 16 decreased WHC for 6 %.

The effects of apatite-synthesized FA amendment on WHC of SS at 40 ºC are different from DGS. Except for raw FA and apatite-synthesized FA with P/Ca of 7.12, all other

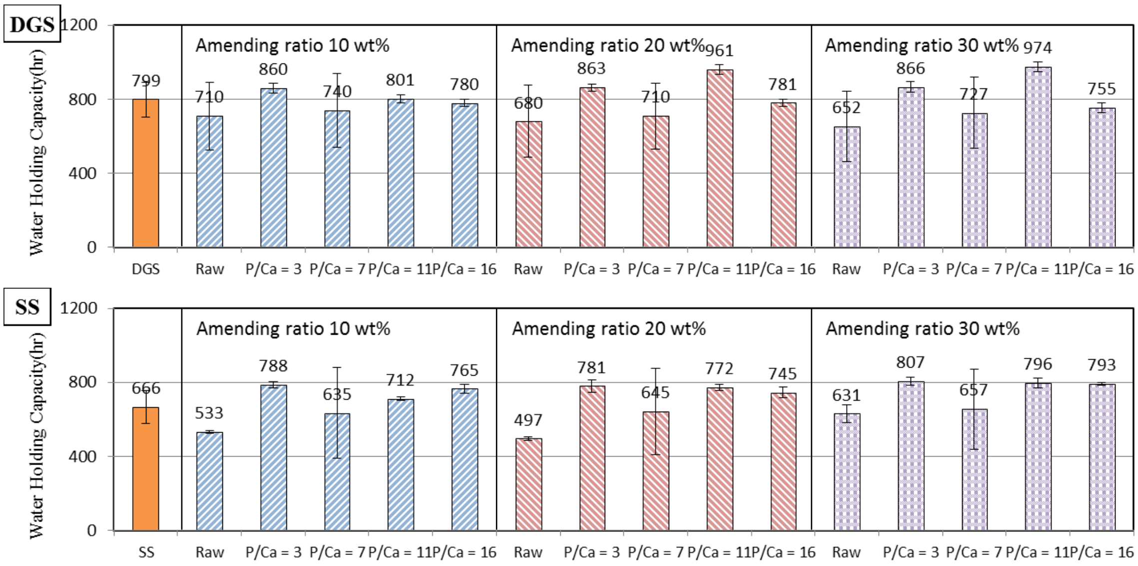

Figure 3. WHC of DGS and SS amended by raw FA, apatite-synthesized FA with P/Ca ratio of 3, 7.12,11.67 and 16, and at mixing ratio of 10 wt%, 20 wt% and 30 wt%

apatite-synthesized FA gave positive effect on WHC of SS. Their performances were similar and the average increasing percentage is about 16 %. On the other hand, raw FA amendment decreased WHC of SS for about 25 % and 5 % WHC reduction was caused by apatite-synthesized FA with P/Ca of 7.12. Mixing ratio dependency of WHC of FA-amended was found for treated FA with P/Ca of 7.1 and 11.67. However, no obvious dependency appears for treated FA with other P/Ca ratios.

Experimental results are summarized that FA amendment influenced WHC of both DGS and SS. The effect of FA amendment were very complex. Although soil type dependency was clearly shown, mixing ratio dependency was not as obvious as that was expected.

CONCLUSION

The effect of apatite synthesis on WHC of pure FA has no obvious trend at 40 °C with respect to P/Ca ratio. FA amendment gave different impacts on WHC of DGS and SS. They depend on FA mixing ratio, drying temperature, soil type, and treatment method. Apatite-synthesized FA with P/Ca ratio of 11 was effective to increase WHC of both DGS and SS at 40 °C.

ACKNOWLEDGEMENT

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Bioresource recovery and nutrient removal from livestock wastewater applying submerged membrane filtration in a continuous photobioioreactor

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ABSTRACT

Livestock wastewater has been causing various problems in ecosystem due to strong concentrations of nutrients. A photobioreactor producing microalgal biomass is one of the sustainable technology to remove nutrient in livestock wastewater and fix carbon dioxide (CO_2) as a carbon source simultaneously. In this study, we tested a membrane photobioreactor (MPBR) growing *botryococcus braunii* stain for tertiary treatment of livestock wastewater. A submerged membrane module was applied to improve quality of effluents as well as productivity of biomass. The MPBR was operated by decreasing hydraulic retention time (HRT) from 5 to 3 days, and we evaluated the performance of biomass production based on carbon mass balance. Results demonstrated that matching supply and demand of inorganic carbon together with pH was the key to obtain high biomass productivity. Determined effluent concentrations of nitrogen and phosphorus was lower than detection limits, which indicates that MPBR can obtain high qualities of effluents with enhanced biomass productivity. This MPBR can be a viable option to control the effluent quality of problematic livestock wastewater treatment while producing a useful bioresources convertible to bioenergy.

Keywords: Microalgae, Biomass production, Photobioreactor, Microfiltration, Livestock wastewater

INTRODUCTION

The livestock wastewater contains a huge amount of nutrients such as nitrogen and phosphorus, two of the important contributing factors for eutrophication. While the main objective of former wastewater treatment system focuses on decomposition of organic compounds, more advanced technology has been required to treat other nutrients. Past literature indicated that microalgae can be used for wastewater treatment via assimilation of nutrients as a form of microalgal growth. Besides, it may have caused less harmful effects for ecosystem and generated no secondary pollution if the produced biomass is recycled as a useful bioresource (Martínez, M.E. and Sánchez S., et al. 2000). Promising end-products of cultivated microalgal biomass are biodiesel (lipid contents) and biogas (carbohydrates and proteins) (Harun, Davidson, et al. 2011). These technologies has been known as carbon neutral since they decreases the greenhouse effects by consuming CO_2 via photosynthesis.

The biomass harvesting from photobioreactor is one of the key factors to determine cost and efficiency. To improve this, many researchers have studied appropriate methods such as coagulation, flocculation and centrifugation (Anthony, Ellis et al. 2013, Dassey, Theegala, 2013). Among them, membrane technology is considered as a progressive method for cultivating biomass since membrane filtration can provide complete separation between water and solid particle (Posten, C., 2009).

The main objectives of this study were to evaluate the performance of photobioreactor using microalgae for tertiary treatment of livestock wastewater and the efficiency of membrane filtration to improve solid retention time (SRT) in reactor. The photoautotrophic growth of biomass and removal of nutrients were evaluated simultaneously.

MATERIALS AND METHODS

Algae seeding and wastewater

The culture of *botryococcus braunii* strain was selected for operating MPBR. This strain contains relatively larger contents of lipids, which can be transformed to biodiesel, such as fatty acids, glycerol and strolls. Inoculmn was prepared using BG-11 medium that is widely used for photoautotrophic microorganism. Light irradiance was set to 220 μmol E/m^2/s, 25℃(temperature) and 150rpm (mixing speed). The secondary-effluent of livestock wastewater treatment, supplied by other national research institute, was autoclaved to prevent other microbial contaminations. The characteristics of the effluent are shown in **Table.1**.

Table 1. Characteristics of livestock wastewater

Parameter	Unit	Value	Method
pH		8.4	pH meter (Horiba, Japan)
Total solids (TS)	mg TS/L	290.8 ± 10.90	Standard method
Total suspended solids (TSS)	mg TSS/L	110.0 ± 0.00	Standard method
Chemical oxygen demand (COD_{cr})	mg O_2/L	125.4 ± 22.40	Standard method
Total organic carbon (TOC)	mg C/L	27.7 ± 0.30	TOC analyzer (Shimadzu, Japan)
Total nitrogen (TN)	mg N/L	26.3 ± 1.30	HACH
Ammonia nitrogen (NH_3-N)	mg NH_3-N/L	22.5 ± 1.10	Standard method
Total phosphorus (TP)	mg P/L	0.6 ± 0.04	HACH

Analytical method

Produced biomass was quantified using linear regression between dry weight and optical density at 750nm (OD_{750}) using a UV-spectrophotometer (HACH DR 3900, USA) (Bayoma, Garcés, 2014). Any additional filtration was not performed for MPBR effluent due to the nominal pore size of used membrane was 0.4μm. Total carbon, total organic carbon and C_i (inorganic carbon) was analyzed using a TOC analyzer-LCPH (Shimadzu, Japan). The pH of samples from reactor and effluents were analyzed using benchtop pH/water quality analyzer (Horiba scientific, Japan). The effluents were analyzed for COD and NH_4^+ following the *Standard Methods* (Method 5220B and Method 4500-NH_3 F) (Eaton, Clesceri et al. 2005). Total nitrogen (TN) and total phosphorus (TP) were analyzed by HACH kits (TNT 827 and 844).

Membrane photobioreactor (MPBR) set-up and operation

The MPBR was designed by wide-neck glass bottle with a volume of 800 mL. Inorganic carbon (C_i) was supplied constantly as 6 L_{air}/min using an aeration pump (Hoppa, Japan). Microfiltration (MF) membrane (Mitsubishi rayon, Japan) was used to build a submerged membrane module. The hydraulic retention time (HRT) was controlled with flow rate adjustment using a two-channel peristaltic pump (Thermo scientific, USA). The changes of biomass concentration and speciation of inorganic carbon were monitored at each HRT.

RESULTS AND DISCUSSION

Microalgae growth

Figure 1 (a) shows the variations of biomass concentration and pH according to HRT. Drastic increase of biomass concentration was observed at HRT 5 days, and biomass concentration reached steady-state within 7 days. Its concentration was approximately 3400 g/m^3. When the HRT was decreased to 4 days, the maintenance of steady state was possible even though the biomass concentration was slightly decreased to around 2700 g/m^3. At the global steady state of HRT 4 days, we harvested the biomass to test the photosynthetic activity of *botryococcus braunii* at the even shorter HRT (3 days). Clearly, similar increasing trends of the biomass concentration was observed and corresponding biomass concentration reached even higher (3700 g/m^3) than that of HRT 4 days (3500 g/m^3). These results indicate that HRT 3 days with the SRT 11 days is the best operating condition for continuous MPBR operation.

Inorganic carbon supply

Figure 1 (b) demonstrates the concentrations of inorganic carbon species. Other research indicated that phototrophic microorganisms uses inorganic carbon as CO_2 (*aq*) and HCO_3^- form, and thus pH control is highly important (Shibata, Ohkawa et al. 2001). In this experiments, HCO_3^- was supplied as the major inorganic carbon since pH was well maintained between 9-10, which can contribute to normal photosynthetic biomass growth.

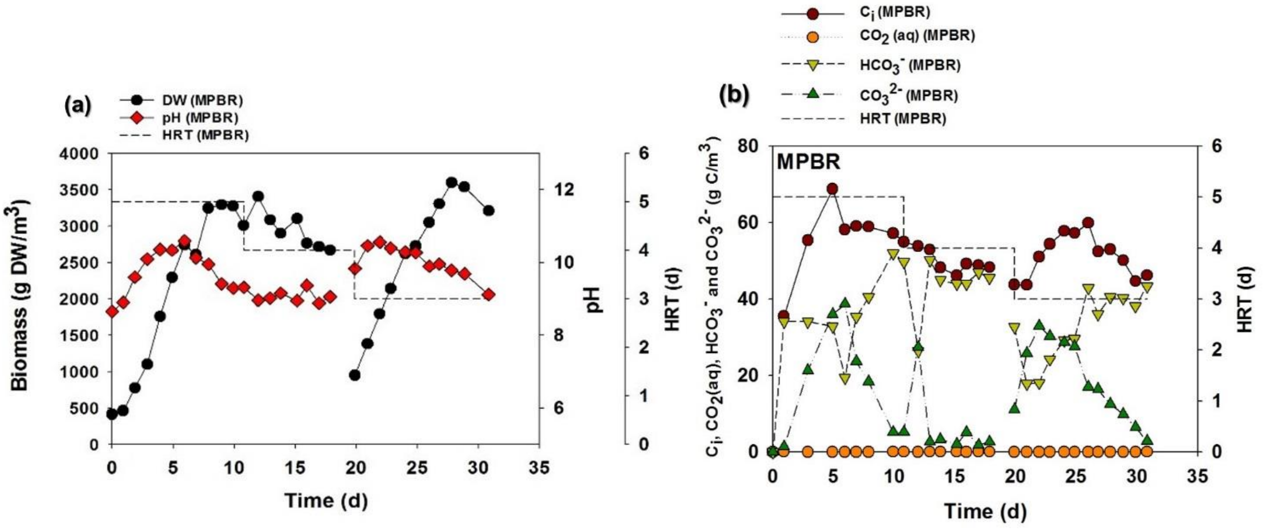

Figure 1. (a) Kinetics of biomass and pH in the MPBR,
(b) Variations of inorganic carbon species ($CO_{2\,(aq)}$, HCO_3^-, and CO_3^{2-}) at each HRT

CONCLUSION

This study aimed to suggest an advanced photobioreactor, MPBR, for tertiary treatment of livestock wastewater. Submerged MF module with a 0.2μm of nominal pore-size made effluent quality improved and biomass productivity enhanced simultaneously. Suggested MPBR can remove nitrogen and phosphorus contents of influent almost completely demonstrating solid free and high quality of effluent. Inorganic carbon (C_i) was revealed as one of the most important factors for the rapid growth of microalgae. Results demonstrated that approximately 3500 g/m^3 of biomass concentration was possible at steady state on a dry weight basis. By controlling harvesting strategy, current MPBR can produce at least 2.04 g of biomass every 7 days from a liter of PMBR volume satisfying effluent standards.

ACKNOWLEDGEMENT

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Bioresource Recovery from Livestock Wastewater using Photoautotrophic Sequencing Batch Reactor (PSBR)

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ABSTRACT

Photoautotrophic sequencing batch reactor (PSBR) was tested to investigate the feasibility of applying microalgae, *Botryococcus barunii*, in treating secondary effluent of livestock wastewater treatment plant. Continuous experimental results present that PSBR utilizes over 84% of supplied phosphorus and 65% of ammonia via photoautotrophic biomass growth. Under the range of hydraulic retention time (HRT) tested (3-5 day), *Botoryococcus braunii* was revealed as a promising candidate for renewable resource recycle due to rapid fixation of CO_2, nitrogen and phosphorous. The control of CO_2 supply, light irradiation, and extended solid retention time (SRT) were the keys to maintain biomass productivity as well as wastewater treatability. Among HRT tested, HRT 5 day demonstrates the best removal efficiencies of ammonia (97%) and phosphorus (99%) since it enables proper maintenance of SRT (34 days). Overall, this study identifies how PSBR control the recovery of bioresource from wastes, and how it associated with the biomass production rate, inorganic carbon utilization rate, and nutrients uptake rates of *Botryococcus barunii*.

Keywords: Livestock wastewater, photoautotrophic growth, sequencing batch reactor, bioresource recovery, nutrient removal

INTRODUCTION

Domestic livestock farms have been increased to meet demands from human society thus a total generation of livestock wastewater has increased up to 173,052 m^3/day in Korea as of 2013. Most livestock wastewater contains strong concentrations of organic matters and nutrients, which are responsible for severe environmental consequences such as bad water quality and eventual eutrophication in lakes and rivers (Park, J.M., and Jin, H. F., 2010).

One of promising approach is to utilize microalgae because it is renewable and carbon-neutral if we adapt waste-to-energy strategy, which reduce atmospheric CO_2 and produce biomass resource convertible to bioenergy while removing nutrients from water body (Kim, H.C. and Choi, W.J., et al. 2014).

In this study, we suggest a robust treatment method of livestock wastewater using a novel photoautotrophic sequencing batch reactor (PSBR) growing *Botryococcus braunii*. Continuous experiments were conducted to optimize light intensity, temperature, pH, and aeration rate according to designated hydraulic retention time (HRT) and solid retention time (SRT). We also evaluate removal efficiencies of nutrients, organics, inorganics in livestock wastewater, which are notorious pollutants in the field of air and water pollution.

MATERIALS AND METHODS

Table.1 summarizes the experimental set-up of PSBR, which is consisted of a 0.8 L tubular reactor made of glass, a magnetic stirrer with a spin bar, a multi-channel peristaltic pump for influent/effluent control, light sources (38.75 W/m^2) supplied by LED bars to the exterior PSBR surface, a sampling port with connection tubing, air pumps with membrane filter (0.45μm, PVDF) for sufficient CO_2 supply, and a effluent port.

In order to prevent contamination, livestock wastewater was autoclaved at 120 °C for 15 min and used as an influent. Its characteristic was determined following standard methods (Eaton, A.D. and Clesceri, L.S., et al. 2005). TOC and TIC were determined using TOC analyser (Shimadzu, Japan). Soluble chemical oxygen demand (SCOD), total-nitrogen (T-N), total-phosphorus (T-P), total organic carbon (TOC), total inorganic carbon (TIC), and pH were 137.9 ± 36.4 mgCOD/L, 32.7 ± 5.7 mgN/L, 1.2 ± 0.9 mgP/L, 86.1 ± 31.3 mgC/L, 8.3 ± 11.5 mgC/L, and 10.4 ± 1.2, respectively.

Table 1. Operating conditions of PSBR

Item	Units	Ex.1	Ex.2
Independent variable			
HRT	day	5	3
Operating period	day	15	9
Influent / effluent	mL	160	267
Fixed variables			
Working volume	L	0.8	
Seeding volume	L	0.4	
BG-11(Initial substrate)	L	0.2	
Feeding for substrate	Livestock wastewater		
Temperature	℃	25.0 ~ 28.0	
Illuminated	W/m^2	38.8	
Aeration	L/min	7.0	
Operating sequence of PSBR			
Fill	hours	3	
React		12	
Settle		6	
Decant		3	

Table.1 also shows the sequences of PSBR consisted of feed, react (photosynthesis), settle, and draw steps as a day-cycle. PSBR can maintain longer SRT than HRT, which prevents washout of microalgae naturally. We reduced HRT from 5-day to 3-day when steady state was observed after three times of each HRT. As an inoculum, the green alga *Botryococcus braunii* was selected for the experiment. We monitored the performance of the PSBR by analysing samples taken from the sampling port according to a prescribed sampling plan. For calculating biomass concentration, optical density (OD) was determined directly using a UV-visible spectrophotometer (DR 3900, HACH) at a wavelength of 730 nm, and the OD value was converted to DW using calibration curve determined.(Ge, Yaming. and Liu, Junzhi., 2011) DW was determined as a measure of total suspended solids (TSS) (Standard Method 2540D). To represent the steady-state concentrations, we averaged the last three days of data for a run.

RESULTS AND DISCUSSION

Photoautotrophic growth of *Botryococcus barunii* biomass

Figure 1 shows the variation of biomass concentration according to HRTs of PSBR, which are 5-day and 3-day, respectively. Steady state biomass concentrations were achieved within 6 days in the case of HRT 5-day, and little change of initial biomass concentration was observed at the HRT of 3-day.

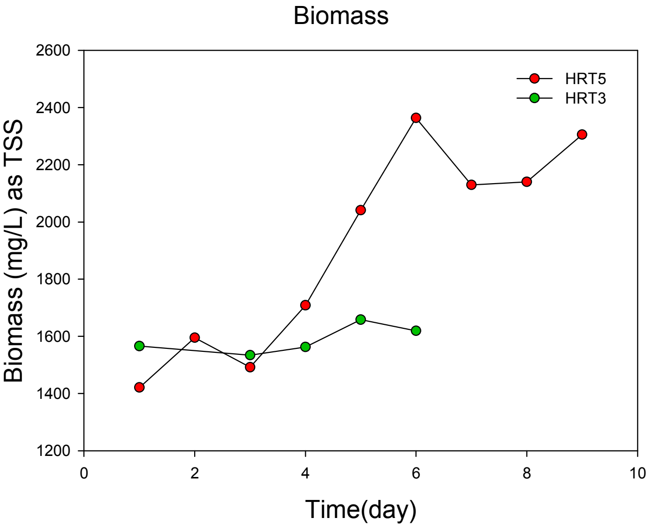

Figure 1. Variations of Biomass concentration

When the HRT was 5-day, the biomass concentration drastically increased as high as 2.4 g TSS/L but it stabilized to 2.2 g TSS/L afterwards. At HRT 3 day, average biomass concentration of PSBR at steady-state was 1.6 g TSS/L, and biomass concentration did not change significantly after start-up. This phenomenon indicates that such a high dilution rate of 0.375 d^{-1} was enough for *Botryococcus barunii* to sustain themselves in PSBR without washout of biomass. Estimated SRT of the operating conditions were revealed as 34 days (HRT 5-day) and 21 days (HRT 3-day), respectively.

These results mean that PSBR may have a control over the continuous photoautotrophic recovery of CO_2 and nutrients in that short HRT. Calculated biomass production rates (BPR) were revealed as 65 mg TSS/L/d (HRT 5-day) and 77.4 mg TSS/L/d (HRT 3-day), respectively.

Removal nutrient

We analyzed removal rates of phosphorus and ammonia. Results indicated that phosphorus removal efficiencies were 84% at HRT 3-day and 97% HRT 5-day, respectively. Ammonia was almost completely removed (99%) at HRT 5-day while at HRT 3-day it was only 67%. These results are comparable to other studies, which showed similar removal efficiencies in the case of piggery wastewater treatment (Lee, S.I. and Park, J.H., 1996, Bernet, n. and Delgenes, N., 2000)

Mass balance of TIC

Additionally, we calculated TIC mass balances to estimate photoautotrophic utilization of TIC. The same TIC supply rate were maintained to both reactors as 2.1 g CO_2-C/L/d. Effluent TIC concentration was 0.4 mg/L at both conditions. This low concentration means that photoautotrophic TIC uptake is significantly limiting compared to TIC supply. Considering stoichiometric constant of 0.5 for carbon content among biomass, TIC utilization rate and utilization efficiency were 1.6 g C/d and 1.9 %. pHs of both condition were around 10.7 on average. It indicates the dominance of CO_3^{2} in the reactor, which is unavailable to microalgae among species comprising TIC, rather than $CO_{2(aq)}$ or HCO_3^-.

CONCLUSIONS

In this study, we suggested a novel PSBR which removes nutrients from livestock wastewater with high efficiency. Experimental results indicate that PSBR can manage CO_2, nitrogen, and phosphorus simultaneously. Stoichiometry and mass balance reveal that properly controlled operating condition promotes balanced uptake rate of CO_2 and nutrients. With this work, it is possible to understand how PSBR performs and key information necessary to achieve reliable operation of a highly productive PSBR for the livestock wastewater treatment.

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Recovery potential of ammonium phosphate based crystal from high strength ammonium nitrogen waste stream

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ABSTRACT

Ammonium phosphate crystals in the form of diammonium phosphate (DAP) and monoammounium phosphate (MAP) are very valuable resources with diverse usage including fertilizer source. This study presents the recovering method of those ammonuium phosphate based crystals from a high strength ammonium nitrogen waste stream. A high concentration (3,000 mg/L) synthetic ammonia solution was stripped at a range between 0.073 ~ 0.088 mol/hr and absorbed in a phosphoric acid solution at different concentrations varying from 4.3 to 17.2 mol/L. Ammonium phosphate was crystalized when the phosphoric acid concentration was 8.6 mol/L. Based on the analysis of nitrogen and phosphorus nitrogen to phosphorus ratio of the crystal was 1.4:1 which indicated that the crystal was a mixture of MAP and DAP. The morphology of the crystal was more similar to the commercial DAP and MAP.

Keywords: diammonium phosphate (DAP), mmounium phosphate (MAP), ammonium phosphate crystal, ammonia stripping, nitrogen recovery.

INTRODUCTION

The sources with high concentrations of ammonia nitrogen are very diverse in industrial waste streams such as coke-plant, textile, tannery, landfill leachate, fertilizer wastewater and especially in anaerobic digestion liquor (Jung J.Y., Chung Y.C., et al., 2004). In addition to wastewater sludge, livestock manure and agricultural wastes have been treated in anaerobic fermentation processes with a large number of benefits such as methane recovery, reduction of volatile solids and organic concentrations, and pathogen removal. In spite of many benefits, anaerobic biogas fermentation process is unable to treat nutrients sufficiently (Jiang A., Zhang T., et al., 2010). Approximately 43 million tons of livestock manures are produced yearly in Korea, and their ammonia nitrogen concentrations are enormously high in the range between 2,100 and 3,500 mg/L. Such a high concentration of ammonia nitrogen leads to a serious of environmental concerns such as toxicity to aquatic life and eutrophication, if discharged to water without a proper treatment.

Recently, development of technologies tends to shift from mere removal of nitrogen to recovery of nitrogen under a sustainable concept. A typical recovery form of nitrogen (together with phosphorus) is struvite which is a chemical fertilizer consisting of magnesium, ammonium and phosphate. Recovery of struvite has been largely practiced in high strength nitrogen waste streams such as anaerobic digestion liquor (Battistoni P., Fava G., et al., 1997). It would be economically and environmentally beneficiary compared to commercial nitrogen fertilizer, which is typically produced by reaction nitrogen with hydrogen from natural gas. In addition to struvite, other nitrogen and phosphorus complexes such as enhanced struvite (ES) and diammonium phosphate (DAP) as known to be a possible recovery products of nitrogen and phosphorus from waste streams (Gaterell M. R., Gay R., et al., 2000). These two types of chemicals recovered are more usable and valuable than struvite in the market.

The DAP and monoammonium phosphate (MAP) has become a leading nitrogen and phosphorus based fertilizer product with many benefits. Their usage is not limited to agricultural area such as fertilizer but some other industrial area such as fire retardants, yeast nutrient in wine making, an additive in cigarettes and pH control chemical in textile. The DAP and MAP , is one of a series of water-soluble ammonium phosphate salts, which can be produced when ammonia gas reacts with phosphoric acid, as shown in Eq.1 and Eq.2.

$$2NH_3(g) + H_3PO_4(aq) \rightarrow (NH_4)_2HPO_4(s) \qquad (1)$$

$$NH_3(g) + H_3PO_4(aq) \rightarrow NH_4H_2PO_4(s) \qquad (2)$$

The basic idea of this study is to recover DAP and MAP from nitrogen containing waste streams by integrating ammonia stripping process with absorption in phosphoric acid solution. The possibility of DAP and MAP crystal formation was investigated by transferring ammonia gas into phosphoric acid solution with different concentration and volume throughout a lab-scale bath experiment.

MATERIALS AND METHODS

A lab-scale experimental setup for DAP and MAP formation is shown in Fig.1. The entire system was composed of ammonia stripping tank and absorbing reactor, where the ammonia gas stripped-over reacts with phosphoric acid (H_3PO_4) forming, DAP or MAP as a final product. An industrial grade of nitrogen gas (99.9% N_2) as continuously supplied at 7 mL/min into the stripping tank. The absorbing reactor was closed but its top was connected with a condenser in order to minimize the loss of ammonia gas due to vaporization. These two tanks were placed in a water bath where the temperature was maintained at an optimal value of 50^{o} C.

The stripping tank with 1L working volume continuously received the synthetic ammonia liquor at the concentration of 3,000 mg N/L at the flowrate of 2 mL/min and discharged it at the same flow rate after stripping, continuously input and discharged at flowrate of 2 mL/min. The initial pH of the ammonia liquor was set at 11 by dosing sodium hydroxide (NaOH) in order to enhance ammonia stripping efficiency. Four different conditions were tested by changing the concentration and volume of H_3PO_4 solution in the absorbing reactor as shown in table 1.

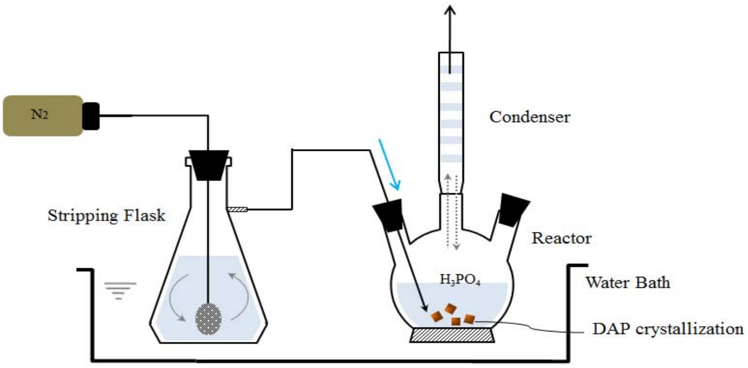

Figure 1 Schematic diagram for lab scale DAP and MAP production

After 2hr reaction, the liquid samples were collected from the absorbing reactor to measure NH_4^+, PO_4^{3-}, TN, and TP. In case of crystal formation, the crystals were dried at 70° C on the drying oven for 24 hours and then their mass were weighed. The crystals were melted again in 100 mL deionized water (DIW) and the nitrogen and phosphorus content were measured. Those four nitrogen and phosphorus components were analyzed by using reaction kit (HACH, CO, USA)

RESULTS AND DISCUSSION

Table 1 summarized the results of ammonia absorption and crystallization efficiency. Ammonia absorption efficiency increased as the volume of phosphoric acid increased. However, crystallization was more affected by the concentration of the phosphoric acid. Crystal was formed when the phosphoric acid concentration was 8.6 mol/L and its volume was smaller than 20 mL. Because of the relatively high solubility of DAP and MAP (Gargouri M., Chtara V., et al., 2012), the larger volume of solution resulted in lower possibility of the crystal formation. Also, at the same solution volume, the crystal was not formed in phosphoric acid solution at a higher concentration (17.2 mol/L). The pH of MAP around the dissolving granule ranges from an acid pH of 3.5-4.2, the pH surrounding the DAP granule is alkaline with a pH of 7.8-8.2 (Mubarak et al., 2013). Compared to NH_3 transfer rate, too high concentration of phosphoric acid leaded to the protonation of ammonia before DAP or MAP formed.

Table 1 Effects of the formation of crystal on the volume of absorbing solution and the concentration of H_3PO_4.

Volume of H_3PO_4 (mL)	Concentration of H_3PO_4 (mol/L)	NH_3 transfer rate (mol/hr)	Absorption efficiency (%)	Recovery of DAP (%)*
10	8.6	0.088	45.1	32.8
20	17.2	0.087	48.9	0
20	8.6	0.073	48.5	83.2
40	4.3	0.077	66.3	0

*base on absorbed N in reactor

The figure 2 shows the crystals formed in the reactor and the structure of crystal observed by the electron microscope. Microscopic observation shows that the crystal has a rectangular shape and the shape like ice cube and was looked very similar with that of commercial DAP. However, based on the component analysis of the crystal and molar ratio between nitrogen and phosphorus was estimated at 2:1.36, which means that the crystal formation was mixed of DAP and MAP possibly.

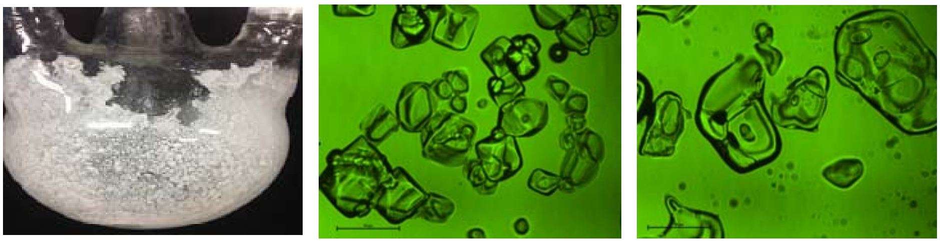
(a) (b) (c)

Figure 2 Crystal after reaction (a) and microscopic view of crystal formed in reactor (b) and commercial DAP crystal (c)

CONCLUSION

This study proposed a practical methodology for formation of DAP or MAP using ammonia nitrogen from a high strength ammonium nitrogen waste stream. DAP or MAP crystal was obtained by chemical reaction between ammonia nitrogen stripped and phosphoric acid in absorbing solution. The optimal concentration and volume of phosphoric acid to form the ammonium phosphate crystal was near 8.6 and 20 mL. Too high concentration and too large volume of phosphoric acid did not lead to crystal formation. The crystal formed by reaction was considered as a mixture of MAP and DAP. Both MAP and DAP are valuable fertilizer resource, so this method would be effectively used for recovery of ammonia nitrogen from high strength ammonia waste stream such as effluent of anaerobic digester for livestock manure treatment.

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Regeneration of V_2O_5 spent catalyst for sulfuric acid manufacturing plants in Vietnam

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ABSTRACT

Deactivated vanadium catalysts for SO_2 oxidation in sulfuric acid manufacture were subjected to an oxidation process for regeneration. The fresh and spent LP-110 catalysts were supplied by Tan Binh Chemical Company. A model standard catalyst with equivalent composition to the spent catalyst was prepared to determine regeneration efficiency. The results revealed that the spent catalyst exposed to a 5% oxygen flow at 550^{o}C for 1 h has been recovered 77% of its standard activity and achieved 65% of the fresh catalyst activity. Complete recovery of its fresh activity was done by adding up the vital elements that have been lost during service.

Keywords: V_2O_5 catalyst, off-site regeneration, SO_2 oxidation reaction, sulfuric acid manufacturing

INTRODUCTION

Regular catalyst replacement in sulfuric acid industry in Vietnam has been released untreated a vast amount of deactivated V_2O_5 catalyst, which is classified under P-listed acute hazardous waste and may cause long-term destructive effects to the ecosystem (US-EPA, 1994). Depletion of the active phase due to significant reduction of V(V) and precipitation of V compound has been claimed to be responsible for the catalyst deactivation, apart from poison contamination and active phase expenditure due to physical attrition and thermal sublimation (Krämer et al., 2012). It has been stated that restoring activity of the catalyst that suffered V precipitation and deactivation could be done by heating to redissolve or decompose and reoxidize V compounds (Boghosian et al., 1989). However, overheating the deactivated catalysts in an oxygen-rich atmosphere may results in interaction between the vanadium containing phases and the support, which leads to irreversible changes of the active phase and thus to permanent loss of activity (Anderson and Boudart 1996).

The purpose of this work is to study the re-oxidation condition for re-activating and re-using off-site deactivated catalysts based on V_2O_5 for sulfuric acid manufacturing in Vietnam.

MATERIALS AND METHODS

Collection of spent catalysts

Spent catalyst sample was collected off-site in waste tanks filled with the Monsanto LP-110 ring-type catalyst (MECS Far East Ltd., Hong Kong) discharged from 5 beds of the SO_2 converter in sulfuric acid plant of Tan Binh Chemical Company located in Dong Nai Province, Viet Nam. There are at least 3 different colors visually detectable in the collected spent sample, including orange yellow, blueish yellow and blueish green rings corresponding to colors of different oxidation states of vanadium. The fresh catalyst, LP-110 ring type (MECS) for use in sulfuric acid manufacture was provided by Tan Binh Chemical Company.

Re-oxidation in oxygen gas at moderated temperature

Spent catalyst sample was pre-treated by heating at 100^oC for 1 h to remove any SO_2, SO_3 and water remaining in the catalyst involved in the sulfuric acid manufacturing. Approximately 10.5 – 13.5 g (15 rings) of the treated samples were loaded into a quartz tube reactor, supported by a quartz frit (4-mm thick, average porosity 40-70 micron) fused into tubing. Temperature of the catalyst bed was determined by placing a K-type temperature indicator 3 mm apart from the catalyst bed. The catalyst bed was heated to the desired temperature, ranged from 350^oC to 600^oC, with a heating rate of 20^oC/min in a nitrogen flow and held up for 30 minutes. The catalyst regeneration process was then started by flowing 1L/min gas stream with oxygen content varied from 1% to 21% through the catalyst bed for a 60-to-180 minute period. The catalyst samples being re-oxidized were then cooled down to 40^oC before subjected to the subsequent process of catalytic activity evaluation.

Evaluation of catalyst activity and regeneration efficiency

All experiments for catalytic activity evaluation were carried out using unconverted feed gas, i.e., 10% SO_2, 11% O_2 and 79% N_2, reflecting the conditions in the first bed of the SO_2 converter, with evaluation condition of 1 g sample weight, 450^oC temperature, 1 L/min total reactant gas flow of SO_2, O_2 and N_2 with molar ratio $SO_2 : O_2 = 10 : 11$ and 38,710 h^{-1} gas hourly space velocity (GHSV). For determination of SO_2 conversion of the catalyst samples, the total gas stream passing through the bypass tube and through the reactor tube, namely unreacted and reacted gas stream respectively, were titrated against an exactly same volume of a standard solution of iodine, following the colorimetric Ripper method (Amerine and Ough, 1976). The SO_2 conversion was determined by calculating the difference in time required for each solution reaching the titration endpoint.

$$H(\%) = 100 * (1 - t_{bypass}/t_{reactor})$$

where t_{bypass} and $t_{reactor}$ are times for titrating 1 L/min flow of the unreacted and reacted gas against 250 ml standard (0.1M) solution of iodine contained in a conical flask swirled continuously, respectively.

To determine efficiency of the activity regeneration, comparison between the SO_2 conversion of the regenerated spent catalyst and that of a standard fresh catalyst with equivalent composition. The standard fresh catalyst was prepared by adding sulfates of potassium, sodium and iron (Guangdong, China) to a kneader contained a quantity of silica gel (230 – 400 mesh, HiMedia, India), followed by adding sufficient amounts of ammonium metavanadate (Guangdong, China) and distilled water to produce a paste. The kneaded paste is extruded to ring shape followed by drying and heating at 350^oC for 3 h.

RESULTS AND DISCUSSION

Effects of oxidative parameters

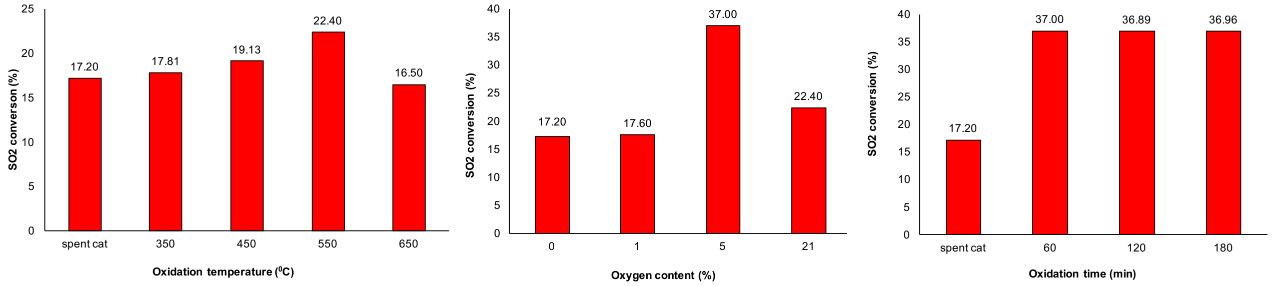

Figure 1. SO_2 conversion (%) as a function of oxidation temperature, oxygen content and oxidation time

Fig. 1 shows catalytic activity of the spent catalysts which were re-oxidized in different conditions. The spent catalyst recovered part of its activity while exposed to air for 1 h, which was increased gradually to 22.4% at 550°C and decreased at higher temperature. Exposed to various dilute oxygen stream at 550°C for 1 h, the spent catalyst recovered significantly and maintained at 37% in 5% oxygen stream for longer exposure. According to results of temperature-programmed oxidation/reduction test performed on the spent catalyst before and after re-oxidation (not shown), it was found that precipitates of V with different oxidation states were recovered to different extents in the spent catalyst exposed to the oxygen streams. It’s noteworthy to mention that in the oxidation atmosphere of 5% and 21% oxygen diluted in nitrogen the spent catalyst recovered remarkably V^{+5} species to the similar extent. However, the low-valence V species in the spent catalyst re-oxidized by the diluted 5% oxygen stream were recovered to a higher extent compared to those in the spent catalyst re-oxidized by the diluted 21% oxygen stream. The result shows that the higher the recovery efficiency of V^{+5} and low-valence V species, the higher activity of the generated spent catalyst.

Regeneration efficiency

Table 1 shows the element composition and activity of the fresh catalyst compared to those of the spent catalyst before and after exposure in an appropriate regeneration condition of exposure to a dilute oxygen stream (5% O_2 in N_2) at 550°C for 1 h. Properties and activity of the standard catalyst are also included as reference for efficiency evaluation. The results indicated that the vanadium catalyst being released from the industrial converter has lost 70% of its fresh activity. It is referred from the measures of elemental content in the deactivated catalyst that enriched ionic impurity and considerably lost vanadium, alkaline metals and SiO_2 were responsible for the catalyst deactivation. Being re-oxidized properly, the deactivated catalyst recovered its activity from 17.2% (before oxidation) to 37.0% (after oxidation), which reached to 77% of its standard activity and to 65% of its fresh activity by recovering the low-valence V precipitates.

Table 1. Elemental content, performance and regeneration efficiency of the catalysts

Catalyst	Elemental content (%)					SO_2 conversion (%)		Regeneration efficiency (%)
	V	K	Na	Fe	Si	Origin	After re-oxidation	
Fresh	10.5	19.8	1.0	2.2	38.8	57.7	-	-
Standard	8.1	15.3	0.8	3.7	33.5	48.3	-	-

Spent	8.2	15.5	0.7	3.5	33.6	17.2	37.0	65 (fresh) 77 (standard)

Off-site regeneration of deactivated vanadium catalyst

For deactivated vanadium catalysts released from the industrial convertor, 103% fresh activity of the deactivated catalyst was recovered in a procedure of destruction, regeneration and re-shaping, including grinding and re-oxidizing in 5% O_2 in N_2 stream at 550^{o}C for 1 h, followed by kneading with ammonium metavanadate, sulfates of potassium and silica for make-up V, K and Si, respectively. The paste was extruded into rings of 4 mm inner dia., 10 mm outer dia. and 20 mm height, further dried and heated at 350^{o}C for 3 h.

CONCLUSION

This study aimed to propose a procedure for re-activating the hazardous vanadium catalyst disposed untreated in schedule, which is about 10 – 20% every two years from the sulfuric acid industry in Vietnam. Adequate recovery of the spent catalyst activity should be achieved by exposing to a dilute oxygen stream, which was proved to be 5% oxygen in nitrogen, at temperature at 550^{o}C for 1 h. Complete recovery of the spent catalyst activity should be accomplished by an approach of re-activating active vanadium species which were changed to low-valence inactive forms and/or precipitated out; and adding essential components which were lost during service.

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Session 9

E - waste

e-waste management in Europe and China – a comparison

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ABSTRACT

Taking the challenge to manage waste electrical and electronic equipment (e-waste) as a complex waste stream, both Europe and China have developed specific regulations. In the future similar e-waste generation rates can be expected. In Europe e-waste collection is based on existing municipal structures. Additionally, retail and other take back channels are in place. In China the informal sector dominates e-waste collection, being more competitive and flexible and offering payment to consumers.

In Europe manual dismantling as a first treatment step has been gradually replaced by mechanical break up of appliances, followed by sorting out of hazardous and valuable components. In the subsequent second treatment level, cathode ray tubes are separated, whereby compound materials like motors, coils, etc. are mechanically treated, printed circuit boards go to special smelters, and plastics are separated and partly material recycled. In China through the recent years large capacities for dismantling have been installed. Dismantling follows similar principles as in European plants. However the second treatment level is only partly implemented in Chinese recycling facilities.

In EU producers are obliged to organise collection and treatment. This has led to a larger number of producer responsibility organisations. Financed and controlled by producers and importers, these systems aim to fulfil legal requirements at optimised costs subject to compliance with environmental standards and monitoring requirements. The Chinese system is built on a state controlled fund which subsidies acknowledged recyclers. The recyclers need this financial support to compete with informal recyclers, operating at lower costs and neglecting environmental standards. The results show that the main differences in e-waste management between the two regions are collection and funding mechanism.

Keywords: e-waste, collection, treatment, China

INTRODUCTION

Today, the management of Waste Electrical and Electronical Equipment (WEEE) is a core element, as part of Waste Management strategies, beside the management of other waste streams such as residual (mixed) household waste, recyclables and hazardous waste. A key driver is the rapid increase in quantity of WEEE, which is characterised by its partly hazardous nature (content of heavy metals, polychlorinated biphenyls, brominated flame retardants and other hazardous materials) and its content of valuable materials (copper, precious metals, other metals including "critical" metals, as defined in EC, 2010). Furthermore, the role of producers ("Extended Producer Responsibility") in collection and recycling schemes and the potential influence on future design criteria for more environmental friendly products ("Eco design") make WEEE a focus point.

MATERIALS AND METHODS

In order to compare the management of e-waste in Europe and China, the following aspects were considered:

- Generation of e-waste and collection: based on statistics in Europe, a comparison was drawn for equipment rates of households with selected electrical and electronic devices, giving some indication how e-waste quantities in China may develop in the next years. Concerning collection, data and findings from our project activities in both regions were compiled, completed by literature review.
- Treatment technologies for e-waste in China undergo actually a quick change. In the course of the last three years (2012 - 2015) 12 recycling facilities situated along China's East coast have been visited by the authors, enabling to analyse the technology applied and to compare it to European technology.
- System setup comprises responsibility for end-of-life appliances, organisational implementation of take-back and treatment as well as financial aspects. The relevant legislation both in Europe and China and the implementation was studied using literature and expert interviews.

RESULTS AND DISCUSSION

Today, the level of equipment with electrical and electronic devices (amount and type) within households in urban China and the European Union is similar, which means that medium term we can expect similar WEEE generation rates. However, there are large differences between Europe and China, when it comes to the collection of WEEE: Throughout the EU a network of formal collection has been well established primarily through municipalities, partly through collection at retailers, at reuse centres and though scrap dealers. These collection schemes to date recover 3.2 mio. t of a total of 9 mio. t generated (Baldé et al., 2015) in the EU. More efforts are need in the coming years to achieve higher collection rates for small WEEE, e.g through more convenient kerbside collection, additional containers in public places, at retailers, and public awareness campaigns supporting collection. In China, WEEE collection is dominated by informal structures. Only in a few cases are recycler or producer operated formal collection schemes in place, but these systems struggle with high costs of collection and a lack of subsidises through the WEEE system. A second reason for the dominance of the informal system is the fact that informal collectors offer convenient home collection and additional payment for obsolete appliances; a service level which is difficult to match by other collection schemes. In 2014, 1.5 mio t of WEEE from a generated total of 6.0 mio t has been recycled in formal treatment plants.

When comparing the Chinese recycling technologies to EU standards, there are no significant differences in dismantling technology for CRT-TV sets, PCs, refrigerators and air conditioners. Washing machines are rarely dismantled in Europe, but instead treated in shredders after removal of capacitors while in China this is a common treatment. The biggest difference is in the treatment of PCBs. He and Xu (2014) describe that in China PCBs treatment takes place mainly by means of density based separation (wet crushing and wet separation) or dry mechanical processing (scraping, corona separator, cyclones). He and Xu note that metal concentrates from these processes can be refined by smelting processes, however it is questionable if this actually takes place. Further non-metal materials from PCB are often processed into Wood Plastic Compounds. The authors see this recycling path worth further, more detailed analysis, considering the level of flame retardants in plastics from PCBs and the typical use of Wood Plastic Compounds as cover material for terraces, pathways etc. with its exposure to rain and wind. With mechanical treatment of PCBs only the copper content can be recovered, while precious metals are lost. He and Xu (2014) note a recovery metal rate of 60 to 70% in density separation (crushing and water separation), while the rest is lost.

For the European WEEE systems, EPR is the guiding principle, where producers are responsible for the end-of-life management of their products. The national implementation of the European WEEE Directive shows, that not in all member states producers finance the full chain from collection to recycling of WEEE. Furthermore, the involvement of local authorities and retail in collection is not uniform across members of the European Union. Monopolistic and competitive compliance schemes exist in parallel, both with specific advantages and disadvantages. Monitoring is seen as a task of state authorities, and partly outsourced to private bodies.

The main target of the Chinese WEEE system is to strengthen formal recycling processes. Producers are only indirectly involved, being obliged to pay a tax on products brought onto the domestic market, but there is no obligation for producers to fund WEEE collection. Municipalities and retailers do not have a designated role in WEEE collection. Funding of WEEE recycling is organised by state authorities, therefore no competing systems are in place. Monitoring is seen as a task of local (provincial) authorities.

CONCLUSION

While in EU WEEE collection is tightly linked to established municipal waste collection schemes, familiar to local population, the main limitations lays in the collection of small WEEE, with devices being disposed of together with household waste and or via uncontrolled trading. In contrast, WEEE collection in China relies on informal collection systems, which are most convenient for citizens; the main limitation is, beside poor working conditions of informal collectors, the value orientation, meaning that this way of collection does not target end-of-life products like fluorescent lamps, which are hazardous materials, but do not represent significant material value.

Concerning treatment technology, European technology has been established earlier, is more advanced and able to recover metals, including precious metals at high recycling rates. Limitations are the high costs of treatment, specifically when competing with uncontrolled export. In China today, many technologies applied are identical to European ones, e.g. dismantling, separation technology, etc. Limitations are recycling processes where hazardous materials such as flame retardants are transferred into products and missing technology for metallurgical treatment of printed circuit boards and other precious metal containing components, leading to a loss of precious metals.

Comparing the system setup, the involvement of producers in collection and recycling represents the major difference between EU and China. Both approaches have limitations to satisfactorily manage the entire waste stream, although for different reasons: losses in WEEE in the EU derive from uncontrolled export and disposal of small WEEE with household waste, while in China the informal recycling sector prevails because its practices are economically more competitive than their formal counterpart.

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Environmental impacts from Waste Electrical and Electronic Equipment recycling activities at craft villages in Vietnam

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ABSTRACT

Waste of Electronic and Electrical Equipment (WEEE) management in Vietnam poses real challenges for policymakers, managers, authorities and even for collectors and recyclers. Those challenges come from the geographical location of the country with long coastal line and contiguity with China, Cambodia and Laos. They can be from the management activities themselves and also from the treatment activities from collectors and recyclers.

It is very important to state that the dominion of informal sector in collection, transportation and recycling, especially the involvement of craft villages, leads to many difficulties in data monitoring and collection as the WEEE handled is scattered among recycling craft villages and by illegal importation activities. Moreover, appliances sold at private service shops seem impractical to count. The above reasons, combined with the lack of a monitoring data system lead to the inconsistence in the data that is a challenge for calculating and predicting WEEE generation of Vietnam.

This research focus on the current situation for WEEE management in which, sources of WEEE in Vietnam and WEEE collection and treatment (dismantling and recycling of PCBs, copper, aluminum, ferrous, and plastic with input/output data) at craft villages are investigated. From the present situation, the research proposes several options for improvement such as the improvement via application of Cleaner Production (CP), investment of centralized workshops with cleaner technologies and waste treatment facilities, approach based on Life Cycle Assessment. The results of the research can help policymakers and authorities in making decisions in what will be the best solution for WEEE management in Vietnam.

Keywords: Waste of Electronic and Electrical Equipment (WEEE), Vietnam, e-waste, craft villages.

INTRODUCTION

Waste of Electronic and Electrical Equipment (WEEE) management in Vietnam poses real challenges for policymakers, managers, authorities and even for collectors and recyclers. Those challenges come from the geographical location of the country with long coastal line and contiguity with China and Cambodia. They can be from the management activities themselves and also from the treatment activities from collectors and recyclers.

It is very important to state that the dominion of informal sector in collection, transportation and recycling the outputs from WEEE dismantling process (Printed Circuit Boards (PCBs), copper, aluminum, ferrous and plastic). Especially the involvement of craft villages leads to many difficulties in data monitoring and collection. Moreover, appliances traded at secondhand markets seem impractical to count. In combination with the lack of a monitoring data system, it leads to the inconsistence in the data of WEEE generation. The main data is from national projects and in most of cases, they are unreliable and old and absent alternative data.

The research presents some figures on generated WEEE in Vietnam and how WEEE is treated at craft villages with the focuses on the recycling processes of PCBs, copper, aluminum, ferrous, and plastics.

SOURCES OF WEEE

WEEE generated in Vietnam origins both from imported and domestic sources. Imported WEEE are the transboundary from other countries to Vietnam. The illegal routes of WEEE among Cambodia, Vietnam and China are detectable and are is driven by the price of WEEE (NIES and INEST, 2011). From the estimated data in the report of Urban Environment One Member State-Owner Limited Company - URENCO (2007), the annual growth rate for targeted EEE products (TV, PC, mobile phones, refrigerators, air conditioners and washing machine) can be expected from 18 – 20%, except for mobile phone (1% per year) in the 2015 – 2020 period. The generation of WEEE per capita of Vietnam is predicted to reach 4.4 kg in 2020 if WEEE in Vietnam are mainly from targeted EEE products and the average annual population growth rate from 2014 to 2020 remains at 1.01.

WEEE TREATMENT ACTIVITIES IN VIETNAM

Vietnamese WEEE recycling system has been described by URENCO (2007) and Duc-Quang *et al.* (2009, 2010) and included collectors, service shops, recyclers and exporters with the appearance of second-hand market and the involvement of craft villages – "*villages with a profession that is separated from agricultural activities for an independent manufacturing/processing and that profession attracts the workforce of the village and creates main income for the habitants"* (Phuong, 2011). The collection and recycling of WEEE and used EEE in Vietnam rely on both the informal and formal sector but informality is predominated. The recycling chain of WEEE included: (1) collection, (2) dismantling and processing, (3) end-processing, and (4) reuse and refurbishment.

a. Collection and transportation

There are thousands of peddlers going from house-to-house to buy all types of recyclable waste to sell them at service shops, dealers or collectors by using motorcycles, bicycles or bamboo frame on shoulders. The informal WEEE handling system is very active and successful.

b. Reuse and refurbishment

Appliances after collection is classified by peddlers, repairers, and service shops. The high quality of disposed appliance can be repaired or refurbished, and sold as fake new ones or taken part in second-hand markets considered as "shadow markets". The broken or used-EEE can be repaired many times or damaged part(s) can be replaced by repair shops till the repair is impossible.

c. Dismantling and Pre-processing

These steps are counted for many waste recycling villages where WEEE are dismantled and sorted manually into parts by workers working at no or with low level of protective equipment.

During the dismantling, gases are released to the environment. Oil is collected and sold. Plastics are shredded then sold for further recycling. Metals are collected for metal recycling. Cathode ray tubes are separated manually: the metal parts follow the metal processing; CRT glass is collected, broken up manually without separation of panel and funnel parts, or dumped; PCB parts are dismantled into parts such as electricity wires, metal components, electronic components (IC, chips, transistors) and circuit boards. Lead-acid batteries are dismantled and sorted into plastic, liquid acid, lead electrodes and lead partitions.

The capacity, operation time, number of workers, etc. from dismantling workshops mainly depend on buyers from China.

d. End-processing:

The end-processing consists of the metal recovery from the pre-processing step and final treatment of the residues.

1. PCBs: Most common treatment process for PCBs at craft villages is to remove tradable electronic components (IC, chips, transistors), the rest (circuit boards without or with small electronic components) is shredded to small pieces by using dry or wet shredding process for exporting. Newer technology is using a vertical rolling equipment with heat provided to separate solders, transistors, capacitors and circuit boards. The circuit boards are processed for copper recovery. The residues from screening step can be used to make ultra-light bricks or landfilled/dumped.

Gold recovery from PCBs: at some small workshops scattered in Bac Ninh and Hai Phong, chips containing gold and gold fingers from PCBs are treated under hydrometallurgical process.

2. Metal recycling: Metal recycling relied on craft villages in most of the cases, except for ferrous, because ferrous parts can be ended up at large scale steel manufacturers.

For *iron and steel*, technologies using at crat villages are (1) coal furnace that was used for a very long time, and (2) induction furnace (medium-frequency electricity furnace) imported from China to produce steel billets. The electricity consumption to produce each tone of steel billets is still high in comperation to Best Available Technologies or its at larger industrial scale.

For *copper*, there are several traditional copper casting craft villages making products for decorating and worshiping purposes, copper statues such as Dai Bai village (Bac Ninh province), Ngu Xa village (Hanoi), etc. The copper scraps used as input materials are a mixture of coppers from WEEE and from domestic sources. NIES and INEST (2011) evaluated the copper scraps coming from WEEE source has a proportion of 30 – 50 % of the total mass recycled. The recycling processes include the using of coal or firewood, additional metals (Sn, Pb, etc.), clay (for molds).

For *aluminum*, several craft villages (Binh Yen village in Nam Dinh province, Man Xa village in Bac Ninh province, etc.) are in charge of recycling aluminum scraps to produce motorcycle parts, cooking pots, ... The technology used at craft villages is the small coal furnace in batch. Besides the consumption of aluminum scrap, coal and electricity, some products require surface treatment steps that involve NaOH, $NaNO_3$, H_2SO_4, Chromic Acid.

Lead is recycled mainly from lead-acid batteries. At craft villages, such as Dong Mai craft village (Hung Yen province) leads are melted using coal furnace to make the lead ingots. Only few smelters have the off-gas treatment system (settling chamber, filter bag) to recover the lead from dust.

3. Plastic recycling: Plastics from WEEE (and other sources such as packaging materials, plastic containers) can be recycled at Khoai village, Minh Khai village (Hung Yen province) and many other enterprises. To produce final products such as plastic bags and other products, the plastic is treated via 2 processes: (1) making regenerative plastic pellets and (2) producing final products from the

regenerative plastic pellets. Common technologies are blow molding to produce plastic bags, injection molding to produce machine parts, plastic chair; spinning for plastic fiber making; etc.

DISCUSSION AND CONCLUSION

Data on WEEE generated and treated in Vietnam are inconsistent, unreliable and old as the missing of systematic data collection and monitoring by the dominance of informal sectors.

WEEE recycling activities in Vietnam relies on the role of many craft villages for dismantling, recycling of metals and plastics with old technologies. There is no recycling facility at craft villages with modern technologies to recover other metals.

It is potential to apply Cleaner Production (CP) methodology at recycling craft villages to improve their effectiveness in material and energy consumption. With many workshops at the same technologies, CP can be easily multiplied. Saving potentials from CP application can be up to 50% electricity consumption for plastic recycling, 70% Chromic Acid consumption during surface treatment of aluminum products, 45% electricity consumption for steel making process.

Risk Assessment is another systematic approach to evaluate the working condition at craft villages as WEEE containing hazard components. In long term, the approach based on Life Cycle Assessment must be applied to understand whole environmental impacts from WEEE recycling activities. In order to do so, the Life Cycle Inventory is needed.

From the picture of WEEE value chain, combined with the analysis from application of systematic approaches (CP, Risk Assessment, LCA), they are valuable for policymakers to issue appropriate policies, regulations and financial tools to cope with the specific situation of WEEE recycling activities in Vietnam, such as a centralized workshop with cleaner technologies and waste treatment facilities, to support for the development of Life Cycle Inventory for LCA, etc.

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Environmental Information Needed to Manage and Recycle Waste Photovoltaic Modules

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EXTENDED ABSTRACT

Since our society has been pursuing sustainable development and mitigating climate change, our economy has been changing to reduce fossil fuel-based power plants and to increase renewable energy generation systems. In particular, photovoltaic (PV) systems have been actively developed and installed in developed and developing countries over the last a few decades. Due to their limited service time of about twenty years, waste PV modules have been recently generated, starting from the European countries. Because PV modules have a variety of valuable and toxic materials and substances, we need to clearly identify potential environmental impacts derived from waste PV modules to safely manage and to effectively recycle waste PV modules. Thus, the objective of this study is to figure out the key environmental impacts, i.e., hazardous waste, resource depletion, and toxicity potential from heavy metals contained in three types of PV modules (i.e., polycrystalline silicon, amorphous silicon thin film, copper-indium-gallium-selenide (CIGS) thin film). The hazardous waste potential is assessed by using Toxicity Characteristics Leaching Procedure (TCLP) and Total Threshold Limiting Concentrations (TTCL). The resource and toxicity potentials are evaluated by using metal contents and respective characterization factors used in life cycle impact assessment methods. The TCLP results showed that the polycrystalline silicon- and CIGS thin film-based modules have high hazardous waste potential because the lead and cadmium exceed the regulatory limits, respectively. The TTLC results showed that the CIGS thin film-based module exceeds the regulatory limit for selenium. Overall, the CIGS thin film has the highest resource depletion and toxicity potential, and the polycrystalline silicon-based module has the next highest potentials. The amorphous silicon thin film-based module has the lowest potentials. The resource potentials are derived primarily from silver, tin, and selenium. The toxicity potentials are derived primarily from nickel, and mercury for cancer; from arsenic, cadmium, molybdenum, and mercury for non-cancer; and from copper, and silver for ecotoxicity. Therefore, the valuable and toxic heavy metals should be dealt with high priority in safely managing and effectively recycling waste PV systems.

Keywords: environmental impact, heavy metal, resource, toxicity, waste photovoltaic module

Development of ICT-base Automatic Sorting System for Recycling of MSW

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ABSTRACT

Thanks to the government's recycling policy, the recycling rate of municipal solid waste(MSW) has increased continuously to 60% in 2014 and thus the landfill rate has been gradually decreasing. Recyclable materials such as paper packs, glass bottles, metal cans, synthetic resin packaging, etc. are separatedly discharged from households via drop-off systems in Korea. The collected recyclable materials are delivered to recycling centers or material recovery facilities(MRF) and then either hand-sorted and/or automatically sorted by material's type. At the recycling centers, near-infrared ray(NIR) sensors are used to separate plastics by resin type at high throughputs. Black plastics, however, could not be detected by NIR and therefore hand-sorted into different types.

In the present study, ICT-base total recycling system is proposed to effectively recover recyclable items from the mixture. Some of the automatic sorters based on using IR/Raman optical sensors are used to identify and recover the black plastics after applying NIR systems. The present communication gives a brief review of the current status of the recycling processes and process renovation of the existing recycling centers.

Keywords: recycling, MSW, automatic sorting, optical sensor, black plastics

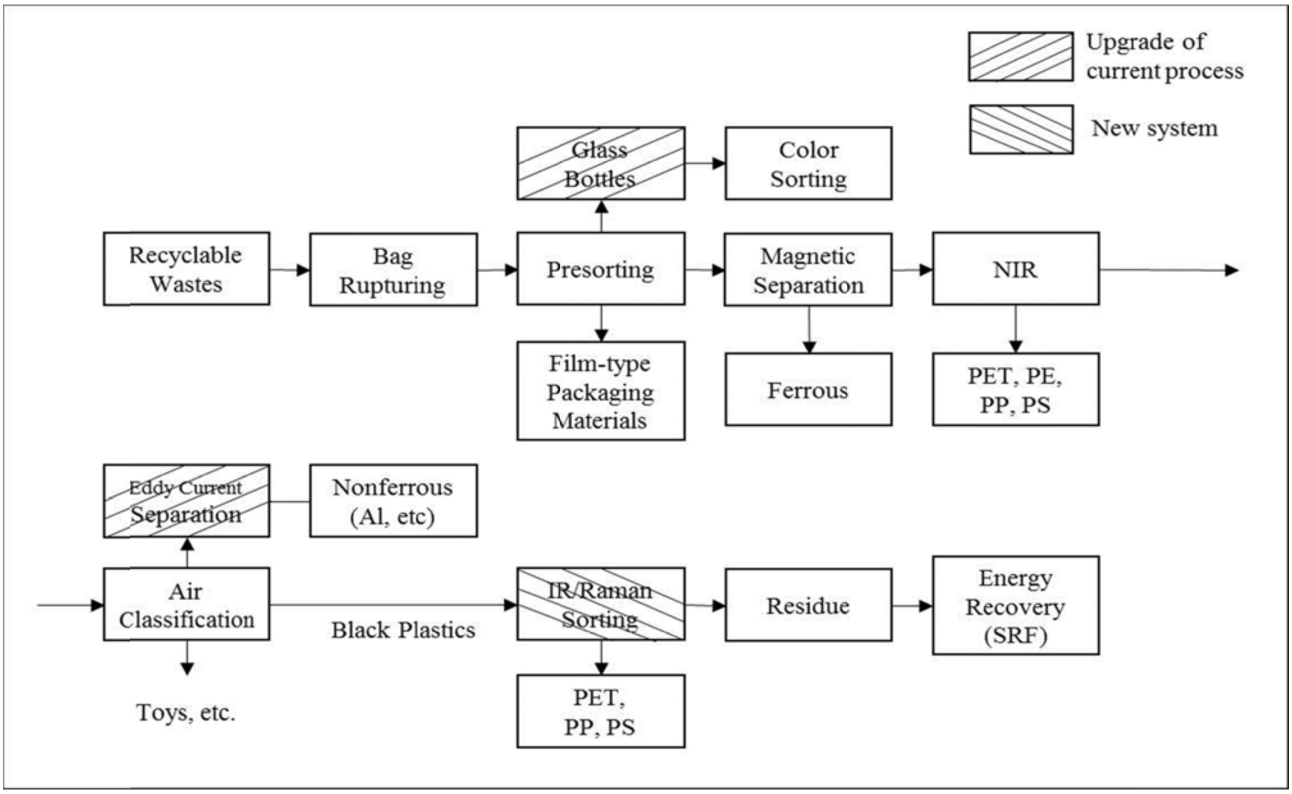
INTRODUCTION

More than 5.5 million ton of recyclable wastes are discharged annually from households and delivered to recycling centers(RC) and/or MRF. About 60% of the total generation of MSW was recycled in 2014, however, current recycling processes depend on simple shredding and hand sorting processes due to lack of separation technology. At the RC or MRF, recyclable wastes are mainly hand-sorted in advance to remove the large-scale and/or inappropriate wastes, such as toys, small e-wastes, textiles, etc.

In the case of glass bottles, unbroken bottles are sorted by using a color sorter to recycle transparent, green and brown-colored bottles. However, a large amount of cullets are finally disposed in landfill sites. Synthetic resin packaging is one of the main items in recyclable wastes, taking up to 27% of the total waste. In most cases, plastics are recovered based on their types by hand sorting. Hand sorting, however, is labor-intensive and costly. In turn automatic sorters based on using optical sensors, i.e., near-infrared ray(NIR sensors), are widely used for plastics sorting. One of the drawbacks of the NIR sensors is not capable of separating black plastics. In the present study, ICT-base total recycling system is proposed to upgrade the current sorting processes and to adopt new optical sensing system for automatic identification of black plastics by types (PET, PP, PS, etc.). The IR/Raman-base system is being developed to enhance the identification of black plastics and then tested at actual recycling plant.

RESULTS AND DISCUSSION

Fig. 1 shows the flowsheet of the total recycling system proposed at the one of recycling centers. The process consists of presorting after rupturing the bags, color-sorting for glass bottles, magnetic separation and plastics sorting with NIR detection, etc. At the presorting stage, inappropriate items are removed in advance by hand sorting to prevent mechanical troubles at the subsequent processing stages.



Plastics.

In the present study, cullets yielded after color-sorting of glass bottles are further treated to promote recycling of glass bottles and to minimize the amount of wastes going to landfill. A color sorting unit will be added after sorting of unbroken glass bottles. The cullets larger than 30mm in diameter will be additionally recovered and recycled. To improve the recovery of Al-base nonferrous metals, the efficiency of an eddy-current separator will be improved by installing a vibrating feeder to prevent the tangling of wastes. In addition, rotational speed of the permanent magnet drum in the separator will be modified by adding a variable speed gear.

NIR sensors are capable of separating plastics by resin type, however, black plastics are not identifiable by NIR sensors. At present, new sensor technologies based on IR/Raman are under developed to automatically identify the plastics by resin type. The sensing system will be installed at an existing recycling plant and tested for its level of accuracy.

CONCLUSION

The waste policy of Korea, based on the principle of resource circulation, has played an important role in reducing waste production at source and minimizing untreated wastes in landfill. In present study, ICT-base total recycling system is proposed to promote the recovery of recyclable wastes. The new system consists of color-sorting of glass cullet, improvement of the existing eddy-current separator, installation of new optical sensing system for black-base plastics after applying NIR sensors. In order to operate the new system more effectively, ICT-base software was developed to incorporate with the hardware system. The system will be tested at an operating recycling plant and the efficiency of the plant operation will be discussed.

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Preliminary Assessment of Home Electronic Waste in Vietnam using Material Flow Analysis, a case study for CRT TV

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ABSTRACT

The electronic waste (e-waste) is now rising in Vietnam as emergence issue, not only by its impact to environment and public health, but also its role as a "urban mine" source, in term of materials. In order to sustainability manage of e-waste, in particular, and other mine-city sources, in common, an Extended Producer Responsibility (EPR) system is proposed to apply in Vietnam from 1-July-2017.

In this research, Material Flow Analysis using Markov Matrix is applied to assess the performance of the EPR system in case of e-waste in Vietnam. The Cathode Ray Tube Television (CRT TV) is selected to be the research objective due to its popular and the high volume of hazardous waste among the home appliances. It is found that the recent benefit that obtained from recycling process (almost dismantling) is very small (1.5 – 5 USD/unit), since the most valuable materials can be recovered are copper with small amount, and then following by iron and plastic. The others are disposed or illegally exported such as the CRT glass, printed circuit board (PCB), magnet and unused parts. Considering that the cost of hazardous waste treatment is not put into account, it is found that when the EPR system comes into effect, the CRT TV will be ignored by the dismantler and the recycler. The situation can be changed only when a proper technology that can handle the PCB and CRT glass, is developed in Vietnam.

Keywords: Electronic Waste, EPR, Recycling, Markov matrix, Material flow

INTRODUCTION

At present, the home electronic appliance waste (e-waste) in Vietnam is featured by three main characters: (1) high increase rate [1, 2]; (2) recover only intermediate value of the waste based on the dismantling process [3]; and (3) without the management of legal system [3]. It is differed with the situation in China, Pakistan or India, where the e-waste is fully utilized regardless the negative impact to environment and public health, and also differed with many other ASEAN countries, where the Best Available Technologies (BATs) for e-waste recycling are applied to utilize the value of e-waste under the legal management [4].

This research aimed to assess the current flow of e-waste, and then to develop different scenarios that related to the involved stakeholders and waste flows under the pressure of Decision 16/2015/QĐ-TTg (Decision 16) dated 22, May, 2015 prescribing retrieval and disposal of discarded products, based on the published information, field survey and questionnaires for specialists. Since e-waste is composed by many types of appliance with very different material contents that might be affected to the waste flow, CRT TV was selected as the research target due to its popular and the high volume of hazardous waste.

MATERIALS AND METHODS

Field Survey

The field survey is applied to clarify the flow of e-waste in Vietnam, including the ways to discarded home appliance in households, the situation of dismantling process, the way to treat with different parts of e-waste as well as the financial flow of waste. The volume of wasted CRT TV is obtained from our previous work on e-waste inventory in the urban area of Hanoi [1].

Experimental work

The sample CRT TVs are collected from households in Hanoi area from 2012-2014. The experiment is conducted in the pilot system for e-waste dismantling and recycling that is installed in the School of Environmental Science and Technology (INEST), Hanoi University of Science and Technology. Considering the capacity of recycling technology in Vietnam at the present time and in the near future, it is aimed to dismantle the appliance into printed circuit board (PCB), glass, plastic, copper wire/pieces, iron, magnetic and unused parts such as rubber, paper, cloth, wax, tape, etc..

Material Flow Analysis

The diagram of recent e-waste flows and involved stakeholders is built from published information and data obtained from field trips. It is important to note that the flows of e-waste are much depended on the output benefit. At the moment, many parts of e-waste cannot be recycled/treated in Vietnam, such as PCB, Cathode Ray Tube (CRT) from TV/monitor, Brome Flame Retardant plastic (BFR), etc. To support the calculation, the Markov matrix was used to generalize the e-waste flows and the involved stakeholder.

RESULTS AND DISCUSSION

Field Survey

The field survey data shown that most of the CRT TV used in household (urban Hanoi) within the last 5 years was purchased from the sale agent, but not junk shop (352/403 units). The discarding ways mostly include selling to the private collector (33.7%), then giving to the next user (30.1%), selling to the service shop (17 %), keeping at home (7.1%) and others. It is considered that the rate of keeping at home, or storage place, tended to reduce, (cf. URENCO, 2007 [5] and Nguyen et.al, 2009 [2]). Normally, the buying price of a discarded CRT TV from user is less than 10 USD, and the buying price of dismantler from collector is less than 15 USD, depended on the size and weight of TV.

The material content of discarded TV

For CRT TV, the valuable materials are composed by metals (copper and iron), PCB and plastic, then follows panel glass (can be recycled) as shown in Table 1. It is clear that the CRT TV has very high rate of hazardous compounds, mostly come from leaded – glass (funnel glass).

Table 1. Types of material content of experiment CRT TV

Types of Material	Weight (kg/unit)	Average Percentage (%)	Types of Material	Weight (kg/unit)	Average Percentage (%)
Front case*	0.88 – 2.9	8.5	Other plastic	0.12– 0.24	1.08
Back case	1.0 – 3.1	10.36	Iron (band, part, etc.)	0.37–1.23	4.28
Lead free glass (panel)	3.6 – 18.9	42.35	Magnet	0.17–0.46	1.51

Leaded glass (funnel)	1.7 – 9.3	22.02	PCB	1.0–1.74	7.28
Copper (wire, part, etc.)	0.12– 0.7	1.89	Unused materials**	0.051 – 1.675	0.73

*: Including ABS, HIPS, ABS/PC, PPO

**: The unused materials composed of rubber, paper, tape, small piece of plastic, cloth, etc.

The summarization of e-waste flow in Vietnam

To date, the flow of e-waste in common and CRT TV in particular is described in detail by Huynh et.al (2015) and Yoshida A. et.al (2015). At the present time, only copper, iron and plastic are evidently recycled in Vietnam, other parts, including CRT glass, fluorescene powder are disposed or exported after crushing.

The current flow of e-waste and the involved stakeholder in Vietnam is summarized by Markov Matrix based on the Markov chain, *S*. Markov chain *S* (*P*, *U*, *C*, *S*, *D*, *R*, *IE*, *LT*) is defined as the set of states involving the move of the disposed of appliances, where *P* is producer or retailer, *U* is consumer, *C* is private collector, *J* is junk shop, *D* is dismantler, *R* is recycler, *IE* is exporter (illegal) and *T* is the waste processor (legal). Table 2 described the change of flow under the Decision 16.

Table 2. The summarization of e-waste flow in Vietnam under the Decision 16

	P	**U**	**C**	**J**	**D**	**R**				**T**
						Iron	*Copper*	*PCB*	*Plastic*	
Producer (P)	0	Q_{P-U}	0	0	0	0	0	0	0	**0**
User (U)	0	0	Q_{U-C}	Q_{U-J}	Q_{U-D}	0	0	0	0	**Q_{U-T}**
Collector (C)	0	Q_{C-U}	0	Q_{C-J}	Q_{C-D}	0	0	0	0	**0**
Junk shop (J)	0	Q_{J-U}	Q_{J-C}	0	Q_{J-D}	0	0	0	0	**Q_{J-T}**
Dismantler (D)	0	0	0	0	0	Q_{D-Ri}	Q_{D-Rc}	**Q_{D-Rp}**	Q_{D-Rp}	**$Q_{D-T}+Q_{D-Tg}$**
Recycler (R)	0	0	0	0		0	0		0	**0**
Exporter (IE)	0	0	0	0		0	0		0	**0**
Treatment (T)	**0**	**0**	**0**	**0**		**0**	**0**		**0**	**0**

The benefit flows of the recycling system in Vietnam can be based on the Markov matrix form, where each row of the n x n monetary flow matrix M of the system then can be estimated by using formula:

$$M_i = \sum_{j=1}^{n} Q_i B_{ij}$$

, where $B_{i,j}$ is the benefit that sector *i* got from sector *j* for an unit of production.

The price (cost) of waste and materials are obtained from INEST field trip that conducted from 2012-2014 on private collector, dismantler and recycler. Other costs are obtained from public price quote. Based on the the current price of waste and material, it is found that a CRT TV can generate the benefit of 30.000 – 120.000 VNĐ (1.5 to 5 USD) depending on the weight, as seen in Table 3.

Table 3. Benefit obtained from dismantling and recycling of CRT TV

Type	**Plastic**	**Iron**	**Copper**	**Glass**	**PCB**
Price (USD/kg)	0.2 – 0.5	0.3 – 0.35	5 – 7	1-5	0.5 – 1.8
Benefit (USD)	0.45 - 1.4	0.1 – 0.34	0.67 – 3.7	~ 1	0.87 - 3.1

Environmental paying	-	-	-	(-) 0.25-12.8	<<
PCB Recycling	-	-	-	-	0.8 – 1.4
CRT glass Recycling	-	-	-	0.26 – 1.28	-

Orientation of CRT TV management in Vietnam

Since CRT TV is included in the appendix of Decision 16, it is needed to take back and legally treated, the current waste flow should significantly change to meet the requirement, which will come to effect on 1, July, 2017. It is found that without the financial support from producer or Vietnamese Government, the benefit of present waste flow is approximately zero, since it is needed to take into account the cost for special treat of hazardous waste including PCB, CRT glass (environmental paying). It is not taken into account the cost for normal treatment of solid waste including unused materials and parts that are not worth for recovery. Nevertheless, if an available technology is installed in Vietnam that can recycle the CRT leaded glass and PCB, the estimated benefit from CRT TV recycling can be doubled, and thus, can attract the involved stakeholder to keep it under the management of the new system in Vietnam.

CONCLUSION

The study aimed to assess the flow of e-waste in Vietnam by using Material Flow Analysis based on the Markov chain in the case of CRT TV. It is found that under the impact of benefit, the role of intermediate stakeholders, the infrastructure for e-waste treatment and monetary distribution flows under the pressure of legislation are the main factors that caused failure for the application of EPR system in Vietnam.

Based on the calculation, it is needed to develop a better technology for utilize the PCB and CRT glass, as well as the plastic cabinet in Vietnam, for the increase of benefit from the recycling process and reducing the cost for hazardous treatment, thus, allows Vietnam to success control the wasted CRT TV in particular, and e-waste, in common, as a secondary resource instead of waste.

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Session 10

Anaerobic digestion

AVOIDANCE OF INHIBITIONS OF THE BIOLOGICAL WASTE TREATMENT BY MASS FLOW ANALYSIS

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ABSTRACT

Different parameters are used to assess the efficiency of biogas plants. The most common parameters used in practice are VS destruction and COD reduction. Both parameters indicate the mass conversion of organic matter into biogas. During anaerobic operation more parameters need to be balanced e.g. nitrogen and sulphur. The mass flow balance can be used to assess the quality of the operation process based on sampling and analysis. In principle a quantification of mass transfer processes is only feasible with regard to mass flow balances. The anaerobic reactor is considered a "black box" with following interfaces: sewer gas, inlet and outlet (Svardal, 1991). The validation of measurements is facilitated by applying closed balances. In the following the balances of different anaerobic systems will be discussed with respect to the parameters nitrogen and sulphur and conclusions will be given for optimizing the operation of biogas plants.

Keywords: biowaste, anaerobic digestion, mass flow analyses, sulphur, nitrogen

INTRODUCTION

Only by quantification of a substance and its transformation products within the system the anaerobic reactor can be quantified. The quality of the plant operation can be assessed by balancing. The focus of qualification is the sampling and the analysis.

The degradation rate of organic material is determined by the chemical parameters carbon (measured as TC and TOC) or by COD and VS as sum parameters. For balancing the parameters, the input and output of the anaerobic reactor need to be determined. The biogas volume and biogas composition is usually more accurate and easier to determine than the organic content of the substrate in the digestate by appropriate chemical analysis. The COD and VS removal can be determined basing on the biogas production and the amount and the components of substrate (VDI, 2006).The VS is an open balance sheet, their plausibility cannot be verified. The COD balance sheet is a closed record; the plausibility of the measured data can be examined with it. The two parameters COD and TOC are the basis for calculating the amount of methane production. Both parameters allow a plausibility test.

350 ml CH_4 are created from 1 g degraded COD. About 10% of the COD load is implemented to form biomass (VDI, 2006). Accordingly about 320 ml of methane are formed by a complete degradation of 1 g COD_{deg}. The plausibility of data can be determined by a COD balance by measuring the COD in the influent, in the process and the amount of methane. By means of this plausibility check, all other data are subject to control.

MATERIALS AND METHODS

Effect of nitrogen concentration on the pH

The pH in the anaerobic reactor is calculated as the result of the buffer effect of NH_3 / NH_4^+ and HCO_3^- / CO_2. It results mainly from the reaction of alkaline or acid reactive metabolites and the available buffer systems, of which the CO_2^-/HCO_3^- buffer system is crucial. Carbon dioxide dissolves in water to unstable carbonic acid, which decomposes to bicarbonate and H^+ (Braun, 1982).

The NH_4^+-N - NH_3-N - balance of the liquid phase shifts with increasing pH in favour of the ammonia (Figure 1). Due to rising temperatures and therefore consequently the rise in pH, inhibition effects occur more quickly at high temperatures and high pH values. The CO_2 concentration and pH depend on the reactor height. In the following discussion, the pH-value for NH_4^+-N-concentration of 2 g/l in the reactor is calculated (Figure 1). The pH value increases with the temperature.

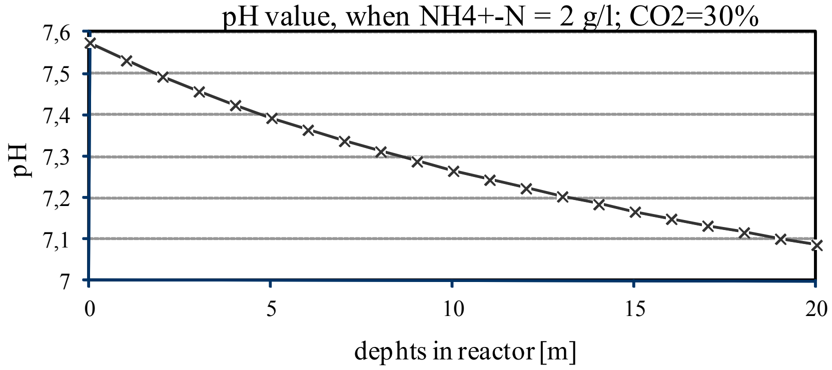

Figure 1: pH-value depending on the height of the fermenter in mesophilic and thermophilic operation under otherwise similar conditions (modified by [6])

Effect of sulphur in the anaerobic process

Substrates, that contain sulphur, produce H_2S during the anaerobic process. This leads to the inhibition of the process, because H_2S acts toxic on methane bacteria and uses up the hydrogen that is needed by the methane bacteria. Even in low concentrations sulphide is extremely toxic to most organisms because it inhibits enzymes of the aerobic respiratory chain (Borkenstein, 2006). The threshold of odour of H_2S is between 0.002 and 0.15 ppm, depending on the personal sensitivity. Occupational safety guidelines specify a maximum allowable concentration (MAK) of 10 ppm. First serious damage to health occurs at a concentration of 20 ppm.

During the fermentation of sulphur containing compounds, a significant proportion of hydrogen sulphide is formed in the reactor. During combustion the toxic sulphur dioxide (SO_2) develops. Additionally, H_2S and SO_2 contribute to the corrosion of valves and engine components and lead to an accelerated acidification of the engine oil.

RESULTS AND DISCUSSION

TKN balance sheet of a biogas plant

The TKN balance sheet shows the pathways of nitrogen in the system of the biogas plant. In a special case the water cycle has kept approximately 80 tonnes of nitrogen in the system. The circulating water is used for homogenisation and liquefaction of the organic waste. It was detected that about 67% of the nitrogen load of input substrate (with the biowaste) come from the water recirculation.

Knowledge of these mechanisms is important if a change in the operation, as the thermophilic operation is to be modelled and implemented. Under thermophilic conditions, the equilibrium between NH_4^+-N and NH_3 shifts towards a NH_3 surplus (Figure 2) which can reach toxic concentrations for the microorganisms.

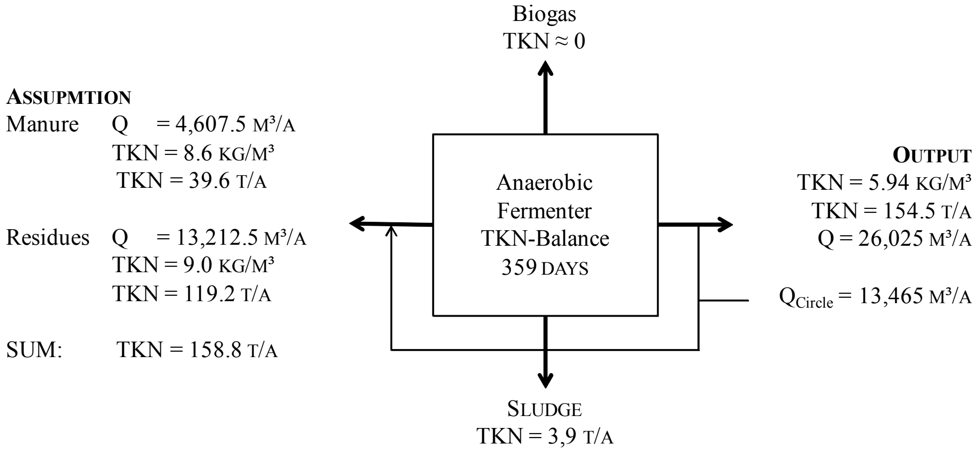

Figure 2: TKN balance sheet of a biogas plant within one year

Sulphur balance in a MBT

The aim of the investigations was the detection of sulphur sources and discharges in the system. Household waste, industrial waste and bulky waste are processed in the MBT plant. These fractions have different sulphur potentials. For the biological treatment the household waste and industrial waste that is similar to household waste are interesting, because only these fractions contain the organic fraction which is used for fermentation. The balance sheet of the biological stage of a MBT plant bases on extensive measurements. This system was not presented as a black box like the other two balance sheets. Samples were taken from several places in the system.

In all the organic fractions of residual waste, sulphur is found in the form of salt and sulphur amino acids. Organic sulphur is estimated at a percentage of about 0.25 m.-% (Weigand and Marber (2005). For the balance sheet, both the solid and the liquid samples had been analysed regarding parameter total Sulphur, sulphate sulphur, organic sulphur and pyrite sulphur.

The concentrations of sulphur in the input are subject to strong fluctuations. The highest concentrations of total sulphur were measured in the solids of the decanters, in the process water and in the concentrate of the reverse osmosis. Like the reverse osmosis the solid residue of the decanter is ejected from the system. The process water, however, is used for the mashing of the substrate before the pulper and contributes significantly to the sulphur concentration in the system.

Looking at the data from the measurements of fluid samples it's to be assumed that the sulphate concentrations in the aeration tank, in the liquid phase of the effluent of the decanter and in the process water in the pulper had been very high. The concentrate of the reverse osmosis is a sink and can therefore only be considered concerning the calculation of circulation water. During the aerobic stage sulphur compounds are oxidised to sulphate. The sulphate is lead back into the process via process water circulation.

On the basis of the balance sheet, sulphur sources in the biological system and sulphur sinks can be detected. In this example, the sulphur loads resulting from the circulation water are very high and amounts about 60% of the total sulphur load in the biological system of the MBT plant. For example, if the sulphur output of the reverse osmosis increases to 20%, the sulphur load from the circulation water can be decreased by more than 6% or 2.2 kg/h. Another way of reducing the sulphur load in the system is the reduction in the hydrolysis. The hydrolysis was considered as "black box" because of missing data.

CONCLUSION

Using two examples of material flow analysis, the possibilities and problems of balancing (TKN) can be identified. In a material flow analysis, which was based on the sulphur flows in the MBT, just mass flows can be identified. The material flow analysis allows a review of the capability of measurements of plants on to be converted into plant-related material balances. For this reason, sources and discharges of substances can be determined. Based on this approach, optimization measurements can be identified and developed.

Due to the inhomogeneity of the substrates in the organic waste and residues as well as the problematic part of the determination of various individual parameters in mixed substrates, errors can occur in the analysis result. Therefore, the validity check is an important instrument to test the data. Furthermore, balancing and material flows can contribute to the understanding of the anaerobic system. For parameters for balancing, mass flow shortages can be determined positively or negatively by a mass flow calculation. About the ratio between the individual parameters, erroneous data can be detected. In the introduced samples, the circulation of 80 tons of Nitrogen in biogas plant was detected. By removal of nitrogen from the circulation water, a thermophilic operation of this plant is possible and efficient. In the MBT plant the main sulphur input was caused by the circulation water. By the partly treatment of the circulation water in the installed reverse osmosis the inhibition of the anaerobic digestion process could be abrogated.

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In-situ Biomethane Production System Integrated with Thermophilic Plug Flow Reactor and External CO_2 Stripper

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ABSTRACT

A simple in-situ biomethane production system was developed to take advantage of the different solubilities of CO_2 and CH_4. The methane enrichment system consists of thermophilic plug-flow sorghum digester coupled with a leachate recycle loop to an external CO_2 stripper.

Quantitative evaluation of the system variables defined the effect of recycle ratio (RR) and digester alkalinity/CO_2 ratio (ACR) on offgas methane content, biogas productivity and total volatile solids (TVS) removal efficiency at a fixed sweep gas flow rate. The results showed that the offgas methane content reached 95 % at the recycle ratios of approximately 3.2 L/L CO_2 with its corresponding ACR of 12.9 g alkalinity/L CO_2 at the digester alkalinity concentration of 4 g/L as $CaCO_3$. At this operational condition the methane productivity was 0.92 v/v-d (93 % of the control) and TVS removal efficiency was 86 % which corresponds to 95 % of the control..

Keywords: methane enrichment, anaerobic digestion, CO_2 stripping, plug flow reactor, leachate recycle

INTRODUCTION

The global energy crisis and rapid increase in energy demand are the major driver for renewable energies. Among the renewable bioenergy supply, the biogas produced from anaerobic biological processes has been a promising alternative. Traditionally substrates utilized in anaerobic conversion technology included sewage sludge, animal manure, food waste and other similar digestible wastes from municipalities, industries and agricultural sectors. Most of these residues are limited in quantity to produce a massive production of biogas. Efforts have been made to produce substantial quantities of methane through the anaerobic co-fermentation technology utilizing co-substrates such as sorghum and cow manure, rather than a single substrate.

Biogas normally contains 35-45 % carbon dioxide (CO_2), 55-65 % methane (CH_4) and small quantity of hydrogen sulfide by volume. Depending on the ultimate use, different biogas treatment steps are necessary. Especially it is important to upgrade the biogas to meet the standards for the grid injection and the use of vehicle fuel which requires a high energy content and purity in the biomethane. However, upgrading adds to the costs. It is therefore important to optimize the upgrading process with regard to low investment and operational costs, high methane content, and low methane emission, etc. Several techniques for biogas upgrading have been developed and commercialized; Absorption techniques (Water Scrubbing, Organic Physical Scrubbing, Chemical Scrubbing), Membrane, PSA (Pressure Swing Adsorption), Cryogenic Upgrading, In-situ Methane Enrichment (IME) System etc. Such physico-chemical processes are estimated to be approximately 2,000 Euros of specific investment costs per upgrading capacity of 1,000 m^3 biogas/hr (Beil M., Beyrich W. et al., 2013).

A concept on the In-situ process first described by Jewell W. and Kang, H., et al. (1988) was based solely on the differential solubilities of CH_4 and CO_2 under ambient pressure throughout the IME system. For water the saturation solubility of CH_4 equals 0.16 % of the saturation solubility of CO_2 at 55℃ and ambient pressure. The hypothesized process used continuously recycled CO_2-rich leachate from the plug flow reactor to an external CO_2 stripping column. The stripper was operated using a sweep gas(N_2) to decrease the partial pressure of CO_2 in the leachate, thus stripping the CO_2 in the leachate. The CO_2-stripped leachate recycled back to the plug flow reactor where is able to absorb CO_2 produced from fermentation of sorghum fed, and eventually upgrade biogas to produce enriched CH_4 gas. The CH_4 content of the plug flow reactor in such IME system will be affected by variables such as recycle ration, alkalinity and pH. The objective of this study was to optimize system variables to produce biomethane in a simple in-situ methane enrichment system.

MATERIALS AND METHODS

As shown in Figure 1, the biomethane production system were low solids plug flow sorghum digester coupled with a leachate recycle loop to an external stripper. As the title implies, a plug flow reactor was one which organic solids(sorghum) passed through the reactor and discharged in the same sequence in which they enter. Total reactor volume was 13.5 liters with an effective volume of 12 liters. Nylon mesh bags(pore size of approximately 0.594 mm) containing chopped sorghum(length of 1-3 cm) were utilized as discrete packet of solids to pass through the reactor and are wasted in the same sequence in which they enter, providing a plug flow regime. The schedule for wasting solids was determined based on solids density (or compaction) and restriction to liquid flow. By attaching a numbered tag to each nylon bag as it was placed into the reactor, that same bag with its contents could be easily identified as it wasted from the reactor. Thus the exact solid retention time (SRT) could easily be determined (Kang H., Jeong J.H. et al., 2012). This operational mode was unique in comparison with those of continuously stirred tank reactor (CSTR) and semi-continuously fed and mixed reactor (SCFMR).

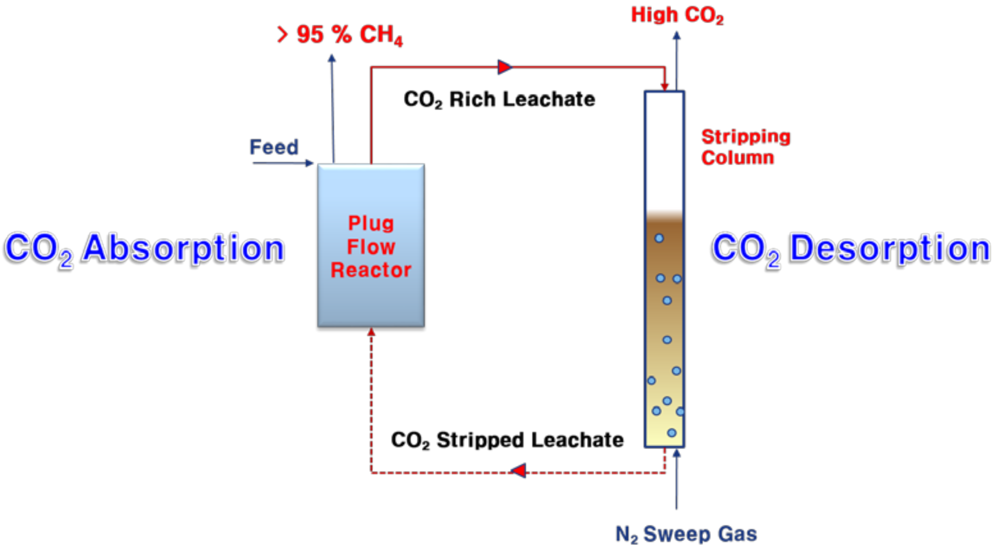

Figure 1. Schematic diagram of in-situ methane enrichment system

The stripper consisted of a 1.5 m tall column(10 cm ID) with a liquid volume of 2 L Leachate was pumped from the base of the stripper back to the top of the plug flow reactor using a peristaltic pump. Sweep gas(compressed nitrogen) was introduced into the bottom of the stripper through a stone gas diffuser at a rate of 0.71 min^{-1}. Sorghum, a candidate 'energy crop', was used throughout the study. Leachate recycle rate were expressed in three ways. The first was based on the volume of leachate recycled per unit digester wet mass per day (LRR, L/kg-day). The second expression was found by dividing the rate of LRR by the rate digester CO_2 production, yielding a 'recycle ratio' (L leachate/L CO_2 produced). The third one was calculated by multiplying the recycle ratio by the leachate alkalinity concentration, yielding a ratio of relative CO_2 transport capacity to the CO_2 production rate, termed the 'alkalinity/CO_2 ratio' (Richard B., Herndon F. et al, 1994).

RESULTS AND DISCUSSION

Figure 2 shows the relationship between the recycle ratio (L/L CO_2) and CH_4 content at 55℃ for alkalinity concentration of 2, 4, 6 and 8 g/L as $CaCO_3$. However digester alkalinity conditions of 6 g/L and 8 g/L led to less effective CH_4 enrichment with their corresponding alkalinity/CO_2 ratios (ACRs) over 18.5 and 21.2 required to reach 95 % CH_4.

As alkalinity concentration increased, less leachate recycle required to achieve a given methane purity. As would be expected, recycling requirement were lower for an alkalinity of 4g/L as $CaCO_3$ than for an alkalinity of 2 g/L as $CaCO_3$ due to the higher CO_2 carrying capacity resulting from higher alkalinity. Recycle ratios necessary to achieve 95 % offgas CH_4 contents were approximately 2.6 and 3.2 L/L CO_2 at alkalinity of 8 and 4 g Alk/L CO_2, respectively.

The effect of alkalinity to CO_2 ratio (ACR) on methane content at 55℃ for different alkalinity concentration is illustrated in Figure 3.

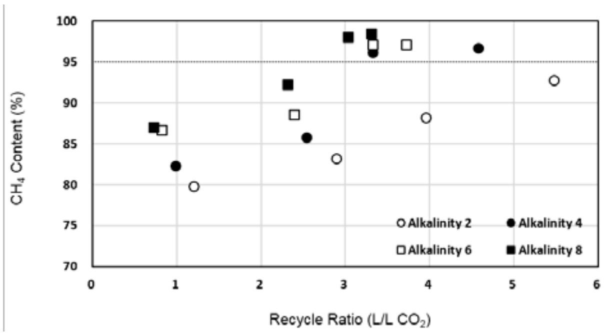

Figure 2. Effect of recycle ratio on CH_4 content at different alkalinites

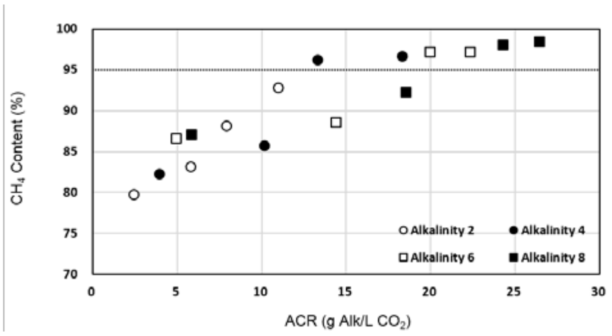

Figure 3. Effect of alkalinity/CO_2 ratio on CH_4 content at different alkalinites

An alkalinity/CO_2 ratio of approximately 12.9 g Alk/L CO_2 was required to reach CH_4 contents of 95 % when the digester operated at alkalinity concentration of 4 g/L as $CaCO_3$.

The effect of recycle ratio on CH_4 productivity at different digester alkalinity concentration are illustrated in Figure 4. Generally recycle ratio increases, less CH_4 productivity is observed at a given digester alkalinity. However alkalinity concentration increases, higher CH_4 productivity is noticed at a given leachate recycle rate.

The optimum methane productivity of 0.92 v/v-d was achieved at digester alkalinity of 4 g/L as $CaCO_3$ that was 94 % of the control with the recycle ratio of 3.2 L/L CO_2 which corresponds to ACR of 12.9 g Alk/L CO_2. At this operational condition, CH_4 content was 95 % and TVS removal efficiency was 86 %.

Figure 5 illustrated the effect of recycle ratio on TVS removal efficiency for alkalinity concentration of 2, 4, 6 and 8 g/L as $CaCO_3$. Increase in recycle ratio and ACR led to high TVS removal efficiency, ranging 73-96 % for all digester alkalinity concentrations.

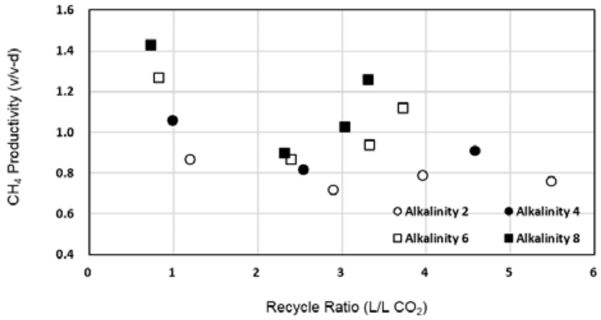

Figure 4. Effect of recycle ratio on CH_4 productivity at different alkalinites

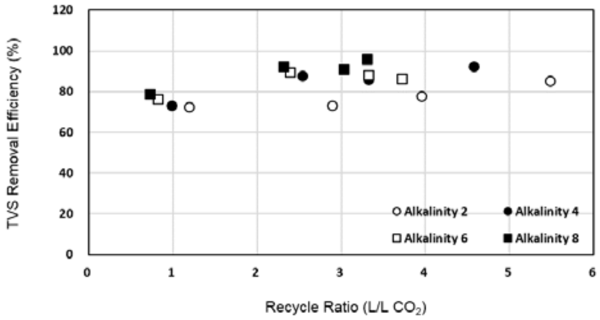

Figure 5. Effect of recycle ratio on TVS removal efficiency at different alkalinites

CONCLUSION

The offgas methane content over 95 % and the optimum methane productivity of 0.92 v/v-d (93 % of the control) were achieved at the recycle ratio of approximately 3.2 L/L CO_2 with its corresponding ACR of 12.9 g alkalinity/L CO_2 for the digester alkalinity concentration of 4 g/L as $CaCO_3$. At this operational condition, TVS removal efficiency was 86 % which corresponds to 95 % of the control.

ACKNOWLEDGEMENT

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Available Market Potential of Biomethane for RFS policy

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ABSTRACT

This study estimated domestically available energy amount of biomethane including landfill gas (LFG) as a transportation fuel by 2035. Biomethane can be produced from organic waste resources such as food waste (water). The synergy effect can be expected with the expansion of waste-to-energy facilities driven by the government. In Korea, Renewable Fuel Standard (RFS) is a regulation that aims to replace fossil fuels (i.e. diesel, gasoline, natural gas etc.) with biofuels by ensuring that transportation fuels contain a constant volume of renewable fuels. The plan to include biomethane in the RFS program is currently under consideration depending on the infrastructures. However, little research has been carried out regarding the domestic energy potential and contribution level of biomethane for the implementation of RFS in the field of 'gas'. The amount of available energy that could be supplied was predicted through four stages of 'theoretical-', 'geographical-', 'technical-' and 'market potential' by considering geographical, technical, economic conditions, etc. Energy efficiency and added value of biogas are largely influenced by the site conditions and the neighboring infrastructures. So, how much of the natural gas used in transportation could be substituted with biomethane was examined by setting limits to the amount of organic wastes generated within urban areas. As a result, the market potential of biomethane including landfill gas was approximately 307 x 10^6 Nm^3/yr, which corresponded to 25% of the natural gas supply for transportation could be replaced by biomethane. Moreover, the potential was estimated to 437 x 10^6 Nm^3/yr in 2035.

Keywords: RFS, biomethane, transportation fuel, market potential, dissemination contribution

INTRODUCTION

Renewable energy that uses carbon neutral waste resources and biomass as a feedstock is receiving much attention in transportation which takes up approximately 20% of the total greenhouse gas emissions. Among various dissemination policies, Renewable Fuel Standards (RFS) obligates the use of a fixed amount of biofuel as a transportation fuel and has implemented in respect of biodiesel in Korea. The RFS policy is expected to introduce the biomethane depending on infrastructure, but not much research has been carried out other than the research and development (R&D) for biomethane as a vehicle fuel. Therefore, the absence of domestic conditions analysis regarding biomethane for the policy is highlighted. This study estimated domestically available market potential and dissemination contribution of biomethane from various organic wastes and landfill gas (LFG).

MATERIALS AND METHODS

First of all, a prediction model of generation amounts was selected considering the characteristics of each organic waste and was forecasted by 2035. And then, available energy potential of biomethane was predicted based on the generation amounts and the domestic location conditions. In addition, the contribution level of biomethane on the dissemination targets of RFS policy was estimated. The potential that could be realistically supplied was calculated through four stages of 'theoretical-', 'geographical-', 'technical-' and 'market potential' by considering location, technology, economic condition, etc (Table 1).

Table 1 The estimation methods of generation amounts and available potentials

	Food waste	Food wastewater	Livestock manure	Concentrated sewage sludge	Animal/plant residues
Generation estimation model	· Future population – consumption disbursement, trend(log) analysis	· Trend(log) analysis reflecting 'food waste' generation trend	· Manure generation through the number of Livestock and livestock manure factor	· Corresponding to 9 times of sewage sludge generation amounts	· Trend(log and linear) analysis(refer to the data from 2003 to 2012)
Theoretical potential	· Total discharged amount of food waste(mixed + separated discharge) · Theoretical biogas production: 158.6Nm^3/ton	· Theoretical and geographical potential of food wastewater are already included in food waste potential(exclude redundancy)	· Total amount of livestock manure domestically	· Total amount of concentrated sewage sludge · Theoretical production of biogas: 31.7Nm^3/ton	· Total discharged animal/plant residues · Theoretical production of biogas: 160.2Nm^3/ton
Geographical potential	· Amount of food waste by separated discharge		· Applying species: cow, milk cow, pig(exclude if the manure is suitable for compost or too insignificant)	· Reflecting 70% of the capacity of anaerobic digesters in sewer treatment facilities	· Amount of declared in 'Allbaro system'
Technical potential	· Biogas production (by an empirical formula): 126.9Nm^3/ton	· Biogas production (by an empirical formula): 65.4Nm^3/ton	· Present biogas techniques are restrictively applied to pig manure: 732Nm^3/ton-vs	· Biogas production (by an empirical formula): 15.9Nm^3/ton	· Biogas production (by an empirical formula): 112.1Nm^3/ton
Market potential	· Except material recycling amount such as compost (85% recycling ratio in 2013) · Expecting that the ratio of other purposes would be 69% in 2035	· Except 18% which is treated by other purposes. · Reflecting the use of food wastewater for recycling leachate at landfill sites	· Reflecting the plan: the recycling of livestock manures from Ministry of Agriculture, Food and Rural Affairs	· Biogas yield would increase 10~20% depending on the development of available technologies	· Except the amounts of other purposes(recycling ratio 85%)

To predict the landfill gas emissions, LandGEM (Landfill Gas Emissions Model) was applied as a model. LandGEM assumes that methane generation is at its peak shortly after initial waste placement (EPA, 2005).

$$Q_{CH4} = \sum_{i=1}^{n} \sum_{i=0.1}^{1} kL_0 \left(\frac{M_i}{10}\right) e^{-kt_{i}}$$

Q_{CH4} = estimated methane generation flow rate (m^3/yr)
i = i-year time increment
n = (year of the calculation) – (initial year of waste acceptance)
j = 0.1-year time increment
k = methane generation rate (1/yr)
Lo = potential methane generation capacity (m^3/ton)
M_i = mass of solid waste disposed in the ith year (ton)
t_{ij} = age of the j^{th} section of waste mass disposed in the i^{th} year (decimal years)

RESULTS AND DISCUSSION

Energy efficiency of biomethane is largely influenced by the biogas production site and the neighboring site conditions, so the location conditions are taken into account when estimating the available energy amount for transportation (FNR, 2012). In other countries where upgrading performances are high, areas where a natural gas pipeline network or compressed natural gas stations exist or where installation of a huge centralized biogas plant is feasible - in other words urban areas - are more advantageous for upgrading of biogas (IEA, 2014).

For the introduction of the RFS system, how much of the natural gas used in transportation could be substituted with biomethane was examined by setting limits to the amount of organic waste generated in urban areas. The results showed that the market potential of biomethane including landfill gas was approximately 307 x 10^6 Nm^3/yr, which corresponded to 25% of the natural gas supply for transportation could be substituted with biomethane. Moreover, with reference to 2018, the market potential of biomethane available for transportation was forecasted to contribute up to 22% of the natural gas supply for transportation. The potential was estimated to 437 x 10^6 Nm^3/yr in 2035.

However, the obligatory mix ratio could increase every year after the introduction of RFS, and the increase of gas supply for transportation in the future would be higher than the increase rate of the market potential of biomethane estimated in this study. Therefore, the contribution level of biomethane is expected to gradually decrease.

A plan to continuously increase the biomethane production amount is required to improve the efficient utilization of biogas. There still exist various problems in operating facilities using biogas, and inefficiency of some operating facilities has resulted in low production efficiency of biogas.

Until now, the government treasury has funded to assist the installation cost of the facilities as an incentive to promote the use of biogas. However, in order to encourage high operational efficiency of the biogas facilities, incentives could be given to facility managers who have achieved higher production than average biogas yield.

Furthermore, the efficiency can be improved by setting the level of support based on the scale of the biogas plant, the type of feedstock, application of best available technology, etc.

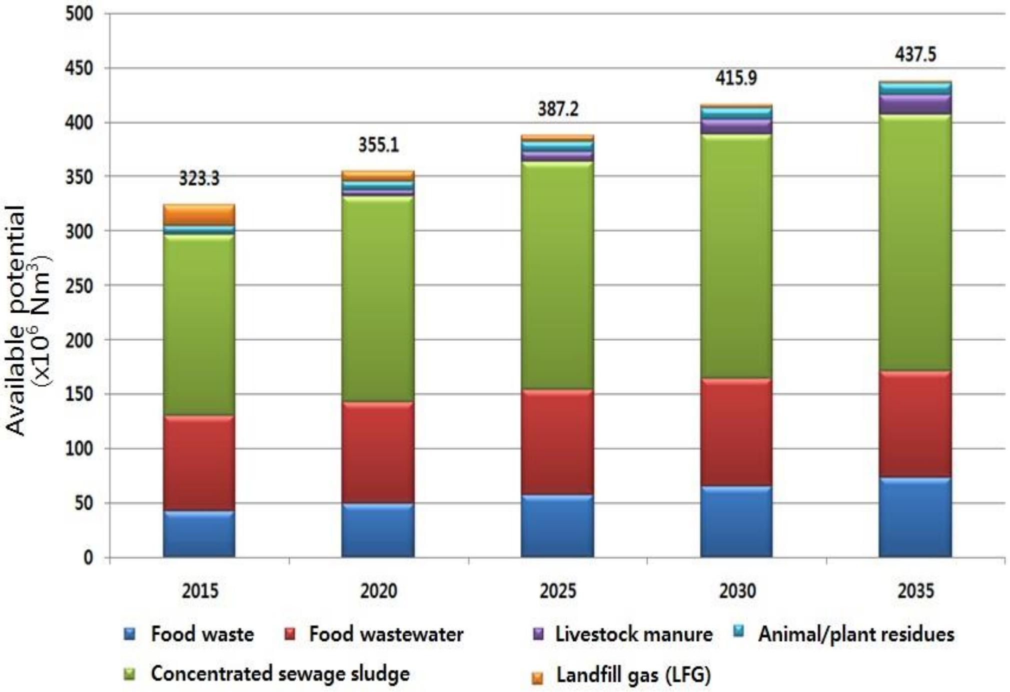

Figure 1 Available potential of biomethane as a transportation fuel

CONCLUSION

Assuming that 2% of natural gas for transportation is replaced by biomethane, it corresponds to 29 x 10^6 Nm^3/yr (approximately 9% of market potential of biomethane). However, RFS annual mixing rate may be increased upon introduction and the growth rate of the natural gas supply for transport would be higher than that of market potential of biomethane calculated in this study. Therefore, it is vital to ensure a stable supply of biomethane, to improve efficiency in technical development and management, and to lay out specific quality requirements for promoting the use of biomethane as a transportation fuel for efficient implementation of RFS policy.

ACKNOWLEDGEMENT

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Ability of biological digesting method for domestic solid waste treatment in Vietnam.

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ABSTRACT

The amount of solid waste is rapidly increasing but the management and treatment has not really achieved the desired effect. Having many applied technologies to treat solid waste but this moment there is no technological model is really suitable to Vietnam's conditions.

Vietnam has many favorable conditions for handling domestic solid waste by biological digesting method, but the composting plans has been under construction over the years, almost of plants are ineffective. Hence, the need to have more research on the possibility of applying the biological digesting method for domestic solid waste treatment in Vietnam.

The author has studied the ability of domestic solid waste mixed with the different components (mud of drainage system, sump sludge, agricultural production, livestock waste, waste of aquatic products processing industry), with different proportions and different probiotics. This research opens up new prospects in turning solid waste into resources.

Keywords: solid waste, Viet Nam, domestic solid waste, biological digesting.

INTRODUCTION

Solid waste management is a problem that appeals a great interest of the community and is a hot spot for environmental protection in Vietnam at present. In the line with process of our country's strong industrialization and modernization, the amount of solid waste is also continuously increasing, creating enormous pressures on for environmental protection. According to the investigation, survey and estimation of Ministry of Natural Resources and Environment, the volume of solid waste generated nationwide by 2014 was about 23 million tons, equivalent to about 63,000 tons/per day, including municipal domestic solid waste generated about 32,000 ton per day. Only in Hanoi city and Ho Chi Minh City, the volume of solid waste generated: 6420 tons per day and 6739 tons/per day [2]. Growth of increasing waste in Vietnam is very high, averages about 10-16% per year. Forecast of total volume of municipal domestic solid waste in 2020 was 61.600 ton/per day and in 2025 was 83.200 tons/per day [1].

Face to the rapid increase of solid waste, the management and treatment in recent year has not really met the requirements for environmental protection. In fact, the unsafe management and treatment have left serious consequences on environment, negative impacts on public health such as unsanitary landfills, and solid waste incinerators without exhaust treatment system, pollution of the waste treatment plants... Until this moment there is no technological model of solid waste management is really suitable to Vietnam's conditions. Therefore, management and safe handling of waste, especially the selection of treatment technologies appropriate solid waste, in order to minimize the risk of environmental pollution and limit the negative impacts on human health and use resources from waste is one of the urgent problems of environmental protection in our country in the current period.

MATERIALS AND METHODS

1, Methods of domestic solid waste disposal

- Mechanical method: reduce garbage volume
- Biological digesting method
- Incineration method
- Landfilling method

2, Assessing application of solidwaste treatment technologies in Vietnam

A, Incineration Method

At present, in Vietnam there is a tendency to invest massively in domestic solid waste incinerators at district and commune levels. According to report of localities, there are 50 domestic solid waste incinerators nationwide, most of them are small-capacity incinerators. The fact that the processing efficiency of many incinerators is not high, generated gases are not controlled strictly, the risk of generating Dioxin, Furan, causes air pollution. The investment in many small capacity incinerators at district and commune levels lead to disperse the waste disposal, difficulty in controlling the emission of secondary pollutants in air. Even with a number of large-capacity incinerators, it does exist some problems: sorting, loading is not optimal; no energy recovered from waste treatment process; Pollution control is not guaranteed.

B, Biological digesting method

Equipment system in technological line of treatment plants imported from foreign countries often have been made technological and equipment improvements that fit the characteristics of domestic solid waste not sorted at source and climate conditions in Vietnam. Some composting technologies of domestic solid waste into organic fertilizer are studied and applied meet the criteria for landfill limit, however, technology completion and replication deployment have faced many difficulties due to limited capital investment of private enterprise; The uniformity, modernity, automation of equipment system in technological line are not high; Solid waste treatment technologies have not been produced on an industrial scale.

C, Landfilling Method

Up to 2013, there have been 458 solid waste landfills with the scale above 1ha, in addition, the small-scale landfills have not been fully counted. Among 458 landfills, there are 121 sanitary landfills and 377 unsanitary landfills. Unsanitary landfills are almost temporary landfills, open-cast, there is no system to collect, treat leachate which lead to environmental pollution. At mane domestic solid waste treatment plants with landfilling method, pollution control processes are not really effective in environmental protection, there is still a pressing issue in society.

RESULTS AND DISCUSSION

Vietnam is a country with easily decomposed organic composition in domestic solid waste highly accounted for 55-77,2%, plastic composition accounted for 8-16%; metal composition accounted for 2%; hazardous waste is in domestic waste less than 1%. Forecast for the future, composition of solid waste will change significantly due to high consumption, increase in diversity of commodities. From now to 2026, in cities in Vietnam, organic waste composition in domestic solid waste is still significantly high, at over 50%. Therefore, Vietnam should develop process technology of compost fertilizer production from organic matter of municipal solid waste, pay attention to sorting solid waste at source in order to reduce the contamination for input materials, also reduce sorting stage in technological line of processing solid waste.

According to the study by the Institute of Strategic studies and industrial policy of Ministry of Industry at strategic environmental assessment report "Environmental industry development plan to 2020, vision to 2030" evaluated by Ministry of Natural Resources and Environment: organic solid waste for fertilizer production and energy account high percentage (17.588 thousand tons in 2020 and 36.659 thousand tons in 2030).

There are some ways to dispose organic composition in domestic solid waste:

- *Domestic solid waste + Mud of drainage system:* In Vietnam, mud of drainage system has very high content of heavy metal, so when mixed with domestic solid waste will generate output fertilizer product which has content of heavy metal several times higher than permissible standards. This is failed lesson to implement the project in Hai Phong.
- *Domestic solid waste + sump sludge:* This study direction has been interested. Many research projects have tested and the results are good, gas recovery to generate electricity. It needs building modern and large scale treatment plants to implement this project. This pattern match suitably to apply in large urban areas.
- *Domestic solid waste + agricultural production, livestock waste*: it is suitable for rural areas with farm crop, livestock.
- *Domestic solid waste + waste of aquatic products processing industry*: Vietnam has lots of islands, long coastline, mostly coastal cities. Besides, our country has many rivers, lakes, canals, ponds. Aquatic products processing industry brings a great economic value, also generates large amount of waste causing environmental pollution. The mixing of waste of aquatic products processing industry and domestic solid waste generates organic fertilizers which have high nutritional value without mixing N,P,K ingredients. This is a very new direction which needs studying. This model can be applied both on small scale (household, group of households) and large scale (treatment plants). The wastewater from aquatic products processing industry: separate wastewater from seafood processing and then put into processing sump; wastewater from washed material phase, finished product, cooling water for finished product after boiling, waste water from employees, water from tools washed and factory washed…collected separately into the wastewater treatment plant.

CONCLUSION

- Composition of organic solid waste accounts high proportion in domestic solid waste in Vietnam. In addition, by-products from livestock production, agro-processing, seafood, especially wastewater from seafood processing plants, mud from wastewater treatment system, sump sludge generate a huge amount of waste causing environmental pollution if these sources of wastewater are not disposed. Besides, Vietnam is a tropical monsoon country, with high humidity, creates a favorable environment for microorganisms growing rapidly. Therefore, biological composting method for domestic solid waste processing is very suitable.

- In Vietnam, organic composition processing technology in domestic solid waste mainly is aerobic composting technology. The composting plans has been under construction over the years, but now almost of plants are ineffective, operate moderately or closed. Anaerobic composting method is currently interested in research, is an innovative approach which also dispose polluted composition, has generated valuable products as well (organic humus, biogas, ..). It needs analysis of the happenings of anaerobic composting process, the relationship between inputs (ingredients, size of composting materials; rate and type of supplementary finished products) and the elements during the operation (temperature and humidity of the environment in winter and summer in Vietnam) to create optimal conditions for the process of anaerobic composting, create good quality products ..

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The potential of biogas recovery from anaerobic co-digestion of fecal sludge and mixed fruit and vegetable waste

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ABSTRACT

According to some surveys, the amount of fecal sludge (FS) in urban areas of Vietnam is relatively high. It can be up to hundreds of tons/year in the big cities. Therefore the management and treatment fecal sludge are urgent problems currently. Ingredients in fecal sludge such as total nitrogen (TN), total phosphorus (TP) and alkalinity are high but the ratio C/N is often lower. So the anaerobic co-digestion fecal sludge with other organic wastes with C/N higher can be recovery biogas. This study was conducted with experiment model in mesospheric fermentation conditions with time of 35 days in the solid waste laboratory of National University of Civil Engineering. Fecal sludge (FS) and mixed fruit and vegetable waste (FV) had been mixed with the ratios at 1:0; 4:1; 3:1; 2:1 and 1:1 by weight in five parallel models. Experimental results showed that at ratio of 3:1 yielded higher biogas production with 0.365 m^3/kg VS. Also at the ratio parameters of process such as the change about height, temperature, pH and COD were consistent with anaerobic digestion process and the amount of fecal sludge treated was high relatively.

Keywords: fecal sludge, anaerobic digestion, biogas

INTRODUCTION

According to the strategy of integrated management of solid waste in Vietnam until 2025 and vision to 2050 has been approved by the Prime Minister; fecal sludge (FS) in urban centers in 2020 will be 9,100 tons per day and may be up to 13,500 tons per day in 2025. However, currently in most of urban centers fecal sludge is often dumped directly into the environment in many different forms; this has caused serious environmental problems. With components as organic matter, solids, total nitrogen (TN), total phosphorus (TP) and helminths eggs in fecal sludge are usually high so the finding solutions to treat the sludge, recovery resource and destroying the germs is very urgent now.

In Vietnam has some urban such as Hanoi and Ho Chi Minh City use co-composting methods fecal sludge with organic waste. This method is simple but has some drawbacks such as needing dewatering of sludge before composting, supplying gas, generating odors, leachate and CO_2 during the composting. To overcome these drawbacks, anaerobic digestion to recovery biogas is a solution. According to some studies, anaerobic digestion of fecal sludge at a temperature of 15 – 30^0 C can generate 15-90 ml biogas/g dry fecal sludge and the biogas will be higher if conditions of the process are optimal (Song et al 2012). However, it has not yet been proven for fecal sludge alone in semi-centralized to centralized treatment in urban areas because the composition of nutrients in fecal sludge is not optimal, the rate of C/N is often low. Besides, mixed fruit and vegetable waste (FV) with high carbon content are also generated with large amount from the markets.

Therefore, anaerobic co-digestion of FS and FV can produce biogas higher. This study was done to evaluate the potential of biogas recovery from fecal sludge when it is mixed with fruit vegetable waste at different ratios in laboratory scale experiments, as a basis for further research on optimal operating conditions.

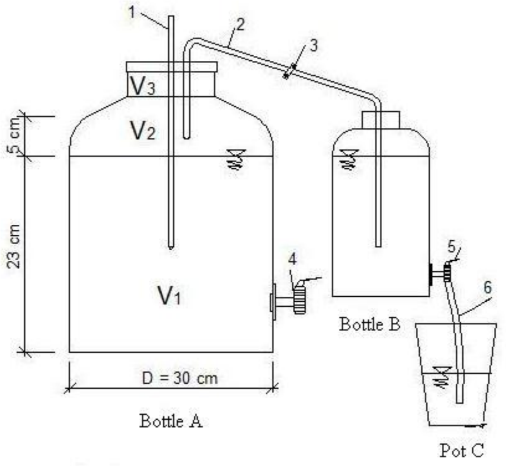
MATERIALS AND METHODS

Raw materials and reactor preparation

Collect fecal sludge: fecal sludge was drawn at the public toilets and the septic tanks in Hanoi and was gathered in the sludge tank at Cau Dien plant Hanoi. This tank was brushed scum and stirred then took about 80 liters and transferred to the laboratory.

Collect fruit and vegetable mixed waste: mixed fruit and vegetable waste was collected at the location of the garbage collecting in Dong Xuan market and Long Bien market in Hanoi. The mixed fruit and vegetable waste for experiment was chopped size from 1 – 3 cm and mixed well.

Experiment model: The experiment models were prepared as follows:



Note:

Bottle A: the reactor by glass with volume is 20 liters

Bottle B: collecting biogas from bottle A with volume is 5 liters

Pot C: collecting water from bottle B

1. Thermometer to measure temperature in bottle A
2. Soft plastic pipe to collect biogas from bottle A
3. Clamp valve
4. Valve to take sampling
5. Valve always opening
6. Plastic tube to collect water into a basin C

Determination characteristics of raw materials and co-digestion

FS and FV were analyzed for various parameters such as moisture content (MC), total solids (TS), volatile solids (VS), total nitrogen (TN), total organic carbon (TOC). FS and FV were mixed at different ratios of 1:0, 4:1, 3:1, 2:1 and 1:1 by weight, respectively. The reactor was operated under the temperature 30ºC which represents mesospheric condition. The retention time was 35 days. The biogas production, temperature, pH, and COD in leachate were monitored every day.

RESULTS AND DISCUSSION

Characteristic of fecal sludge and fruit and vegetable mixed waste

The characteristics of fecal sludge and fruit and vegetable mixed waste are shown in Table 1.

Table 1: Characteristics of FS and FV before digestion

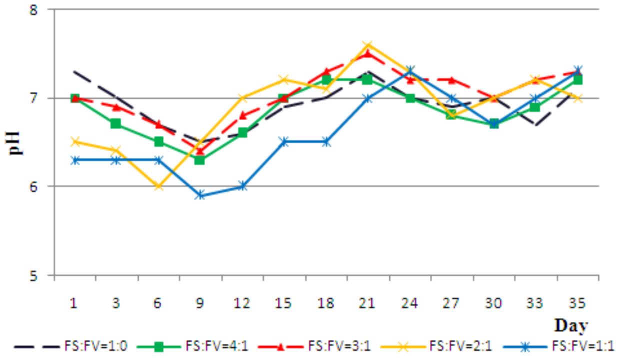
Raw material	MC (%)	TS (%)	VS (%TS)	TN (mg/gTS)	TOC (mg/gTS)	C/N
FS	94.73	5.27	51.79	30.54	365.07	11.95
FV	84,19	15.81	75.64	9.56	376.14	39.34

%MC and TN in FS is high but the rate of C/N is 11.95 low relatively compared with conditions of anaerobic digestion. In FV the C/N rate is 39.34 suitable for mixing with FS to have nutrients appropriately.

Results of anaerobic co-digestion process

The change of pH and COD in the reactors

The changes of pH and COD in reactors are shown in figure 2 and 3:



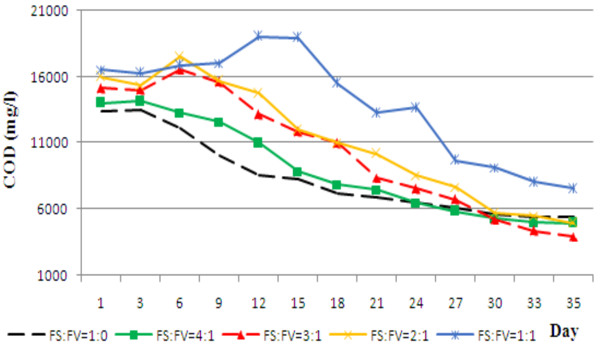


Fig.2. The change of pH in the reactors **Fig. 3. The change of COD in leachate of the reactors**

From the Fig.2, it can be seen that for FS to FV ratio at 1:0; 4:1; 3:1 and 2:1 pH ranged from 6 to 7.6 relatively suitable for anaerobic digestion process. Only for FS to FV ratio at 1:1 pH was less than 6 from 8th to 12th day then it rose and ranged from 6.3 to 7.3. So, it can see that the buffering capacity of FS was quite good; it helped to stabilize pH in the anaerobic digestion process.

The Fig.3 shows that for FS to FV ratio at 4:1; 3:1; 2:1 and 1:1 COD in leachate increased in the early stage then it decreased. For FS to FV ratio at 1: 0, COD was not rising and felled quickly, however it only reduced 55%. For FS to FV ratio at 3:1 the reduction of COD was highest 74.04%. At ratio of 1:1 the increase of COD was observed during the first fifteen days and it only began decreased then. After 35 days the total COD reduction at this ratio was the lowest with 50.1%. Thus, it can be seen that, anaerobic digestion in FS took place very fast and ended also very quickly. When FS was mixed with FV the process was slower and it changed at different mixing ratios.

Biogas production in the reactors

Cumulative gas production at different mixing ratios with time is shown in Fig.4:

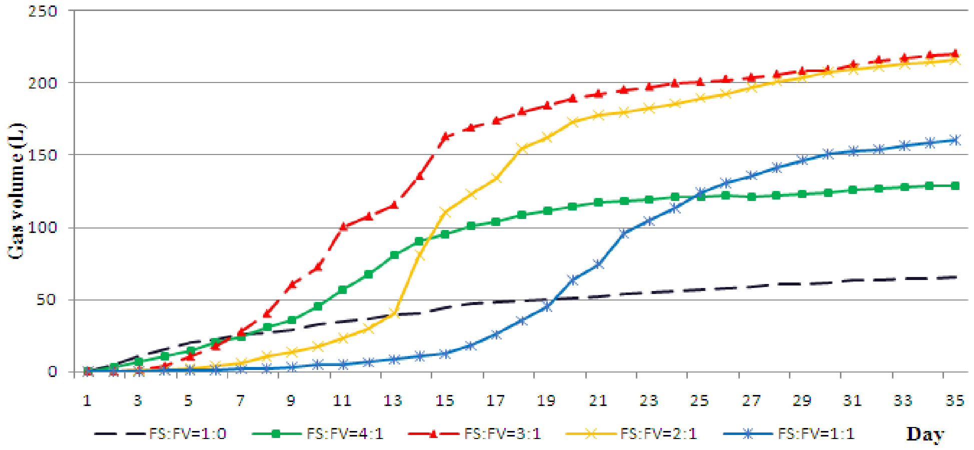


Fig.4. Cumulative biogas production with time at different mixing ratios

From Fig. 6, it can be seen that the biogas production still showed an upward trend, but the experiment was conducted for 35 days only. Fig.6 also shows that biogas production at the ratio of 3:1 (FS:FV) was 220.28 L and was the highest among four different mixing ratios (1:0; 4:1; 2:1 and 1:1) used in this study. For FS to FV ratio at 1:0, biogas production was the lowest with 65.67 L after 35 days. At the ratio of 1:1 the biogas production was increasing slowly during the first 15 days then faster. After 35 days, cumulative biogas production was 160.52 L.

CONCLUSION

This study shown that, the capable of anaerobic digestion of FS is very rapid. However, biogas production is low due to improper nutrient. When mixing FS with FV in the different ratios, biogas volume is higher. It was found that the maximum quantity of biogas was generated at a mixing ratio of 3:1 and was 220.28 L. However, a longer digestion period may be required because the biogas production was still increasing slowly after 35 days at every mixing ratio.

Ratio FS to FV at 3:1 was considered to be the optimum mixing ratio based on higher biogas production, the change of parameters of anaerobic digestion process and the amount of fecal sludge can be treated. At this ratio, the gas yield was 0.364 m3/kgVS which is equivalents to biogas yield of Pig slurry (0.25-0.50 m3/kgVS) and Poultry slurry (0.35-0.60 m3/kgVS) (AL SEADI 2001). Thus, the potential of recovery biogas when mixing fecal sludge and mixed fruit and vegetable waste is high relatively. However, it should be more specific study about operating mode to give greater efficiency.

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Session 11

Hazardous waste

Metal species in municipal solid waste incineration fly ash particles estimated by correlation analysis at micro-scale level

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ABSTRACT

Heavy metal species in raw and chelate-treated MSWI fly ash particles were estimated in this study. Point analysis of raw MSWI fly ash particles suggested that heavy metal adsorption to fly ash particle surface does not depend on elemental composition of particle surface. Micro-scale correlation analysis by line profile seems to be useful for estimation of metal species. Fe and Zn species are estimated to be Fe oxide (FeO, Fe_2O_3, and Fe_3O_4) and various Zn species ($ZnCl_2$ in fine fly ash particle, $ZnO \cdot SiO_2$, $ZnAl_2O_4$, and $ZnFeO_4$ in larger fly ash particle) respectively. However, some relative intensity of major elements varies widely with respect to heavy metals even at micro-scale level. Therefore, a MSWI fly ash particle has heterogeneous characteristics.

Keywords: municipal solid waste, fly ash, chelate treatment, heavy metal, correlation analysis

INTRODUCTION

In Japan, municipal solid waste (MSW) is mainly incinerated to reduce their volume and weight. Incineration ratio of MSW has remained approximately constant in the last decade (about 78 %). Municipal solid waste incineration (MSWI) bottom ash and fly ash are generated as major byproducts in incineration process. Heavy metals mainly concentrate on fly ash by volatilization in exhaust gas cooling process at incinerator. Therefore, metal immobilization treatment is required before landfill disposal. In Japan, chelate treatment is a major treatment. Its main immobilization mechanism is complexation between heavy metals and chelate reagent. However, identification of metal species in MSWI fly ash is important in order to understand leaching behaviors of heavy metals. Species and chemical forms of heavy metals in MSWI fly ash have been analyzed by XRD, XANES, sequential chemical extraction, and geochemical modeling. However, heavy metal species in raw and chelate-treated MSWI fly ash are still uncertain. Therefore, this study investigated correlation between heavy metals and major elements at micro-scale level to estimate heavy metal species.

MATERIALS AND METHODS

MSWI fly ash samples

Raw MSWI fly ash sample was used in this study. It was taken from MSWI facility plant (incineration capacity: 250 Mg/d). Raw MSWI fly ash sample was collected from inlet side of fabric filter in stoker-type incinerator. It was subjected to chelate treatment for metal immobilization. Chelate reagent used in this facility is potassium diethyldithiocarbamate [$(C_2H_5)_2NCS_2K$]. Chelate-treated MSWI fly ash sample used in this study was taken from a chelate reagent mixing apparatus.

Microscopic observation and elemental distribution analysis

Raw and chelate-treated MSWI fly ash particle surface were coated by Pt using vapor deposition apparatus before observation. Their morphological surface characteristics were observed using scanning electron microscope (SEM: JSM-6610LA, JEOL Ltd., Japan). Elemental composition of MSWI fly ash particle was analyzed using energy dispersive X-ray analyzer attached to SEM (SEM-EDX: EX-94300S4L1Q, JEOL Ltd., Japan). Point analysis was conducted 500 times to detect metal-rich point on raw and chelate-treated MSWI fly ash particles respectively. Elemental mapping was also conducted to investigate heavy metal distribution on MSWI fly ash particle surface.

Micro-scale correlation analysis

After elemental mapping, the surface of a MSWI fly ash particle was divided to 5 parts from the edge to the opposite side edge horizontally or vertically. Line profile of elemental distribution for each vertical/horizontal part was analyzed based on elemental mapping data. This means that line profiles were analyzed based on relative intensity data of major elements on a MSWI fly ash particle surface. Obtained relative intensity was plotted with respect to distance from one side to the other. Correlation coefficients of major elements with respect to heavy metal were calculated based on line profiles. Finally, heavy metal species were estimated comparing with other results reported by previous researches.

RESULTS AND DISCUSSION

Elemental compositions of metal-rich or metal-poor MSWI fly ash particles

Metal-rich sites were detected at 159 points and 88 points on raw and chelate-treated MSWI fly ash particles, respectively. Major elements of raw and chelate-treated MSWI fly ash particles were Al, Ca, Cl, Na, O, and Si (see Figure 1). Its mean values of metal-rich and metal-poor raw MSWI fly ash particles were almost the same. Heavy metals in MSW are evaporated in a combustor and are adsorbed to fly ash particle surface in exhaust gas cooling process. Therefore, this result suggests that heavy metal adsorption does not depend on elemental composition of particle surface. In addition, heavy metals distributed on entire surface uniformly in most cases. Mean value of elemental composition of chelate-treated MSWI fly ash were also almost the same between metal-rich and metal-poor particles (see Figure 1). Heavy metals in chelate-treated MSWI fly ash particle surface also distributed on entire surface uniformly. Mineralogical characteristics of MSWI fly ash were changed dramatically owing to moistening in chelate treatment[1)]. Incorporation and/or adsorption of heavy metals by secondary minerals in weathered MSWI bottom ash also has been reported[2)]. Therefore, it is expected that heavy metals might be concentrated on specific secondary minerals generated by chelate treatment. However,

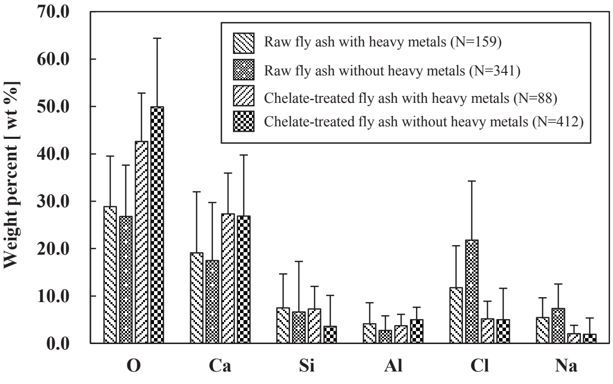

Fig. 1. Elemental composition of metal-rich or metal-poor MSWI fly ash particles

mean value of elemental composition has no significant difference between metal-rich and metal-poor chelate-treated MSWI fly ash particles. This means that heavy metals does not concentrate on specific minerals3).

Estimated metal species in MSWI fly ash particles

28 metal-rich MSWI fly ash particles were observed in raw and chelate-treated MSWI fly ash samples (see Table 1). Correlation of major elements with respect to heavy metals was investigated using line profile data in order to estimate heavy metal species. Fe and Zn species were analyzed in this study.

Iron (Fe)

7 Fe-rich MSWI fly ash particles were observed. Fe coexisted with Ti and Zn on 6 particles out of 7 particles. It has been reported that heavy metals are entrapped by secondary generated goethite (α-FeOOH) in weathered MSWI bottom ash2). Therefore, Fe in MSWI fly ash also might have a possibility as secondary adsorption site of heavy metals in the weathering process after landfill disposal. Relative intensity of Fe had positive correlation with Al, O, and Si (see Figure 2). Fe species in MSWI fly ash has been reported as wüstite (FeO), hematite (Fe_2O_3), and magnetite (Fe_3O_4) by XRD4). It has been reported that chemical forms of Fe categorized by sequential chemical extraction are mainly Fe-Mn oxide form and residual form5-7). Therefore, Fe species are estimated to be Fe oxide on Al/Ca/Si-matrices.

Zinc (Zn)

12 Zn-rich MSWI fly ash particles were observed. Relative intensity of Zn had positive correlation with Ca, Na, and O (see Figure 2). Zn species in MSWI fly ash has been reported as K_2ZnCl_4, $ZnCl_2$, $ZnFeO_4$, $ZnAl_2O_4$, Zn_2SiO_4 by XRD and XAFS8-10). However, relative intensity of Zn often had negative correlation with Al, Cl, and Si. Therefore, it is considered that Zn might have various species in MSWI fly ash. Chemical form of Zn,

Table 1 The number of metal-rich row and chelate-treated MSWI fly ash particles

Concentrated heavy metals	Cr, Ti	Fe	Fe, Ti	Fe, Zn	Mn	Ti	Zn	Total
Metal-rich raw fly ash particle	1	1	0	5	1	3	6	17
Metal-rich chelate-treated fly ash particle	0	0	1	0	0	9	1	11

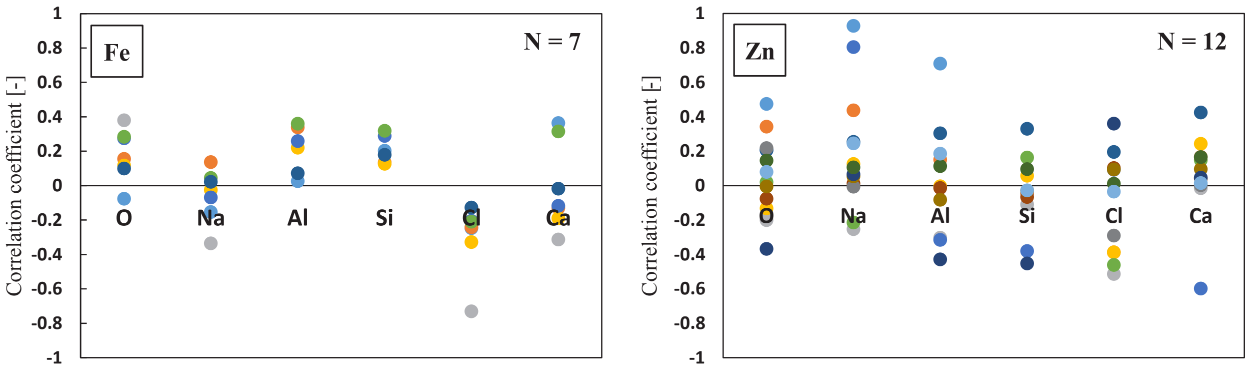

Fig. 2. Correlation coefficient of major elements with respect to heavy metals

analyzed by sequential chemical extraction, suggests many chemical forms of Zn such as exchangeable, carbonated, Fe-Mn oxide, and residual form^7, 11)^. In addition, Zn leachability was simulated by geochemical modeling. It is zero at pH from 7 to 13 because of $ZnO•SiO_2$ precipitation^12)^. It has been reported that Cl mainly concentrated fine particle (= 1μm) and form metal chloride^13)^. Therefore, Zn species are estimated to be $ZnCl_2$ in fine fly ash particle and $ZnO•SiO_2$, $ZnAl_2O_4$, or $ZnFeO_4$ in larger fly ash particle. According to this results and reported results, it is suggested that Zn exists as $ZnCl_2$, $ZnO•SiO_2$, $ZnAl_2O_4$, or $ZnFeO_4$ mainly in Ca-base matrix of fly ash particles.

CONCLUSION

Point analysis of raw MSWI fly ash particles suggested that heavy metal adsorption to fly ash particle surface during exhaust gas cooling process of a waste incinerator does not depend on elemental composition of particle surface. Micro-scale correlation analysis using line profile data seems to be useful for estimation of heavy metal species. Fe species are estimated to be Fe oxide (FeO, Fe_2O_3, and Fe_3O_4). Zn seems to exist as $ZnCl_2$, $ZnO•SiO_2$, $ZnAl_2O_4$, or $ZnFeO_4$ mainly in Ca-base matrix of fly ash particles. However, relative intensity of major elements sometimes varies widely with respect to heavy metals. This means that even one MSWI fly ash particle has heterogeneous characteristics at even micro-scale level.

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Mercury Waste Management in Vietnam
Current Status and Future Needs

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ABSTRACT

Mercury is a naturally occurring metal. It has been used in many household, medical and industrial products because of its unique properties.

Mercury is a toxin that affects human health and environment; it is needed to have the actions to reduce the risk associated with mercury.

At the present, in Vietnam mercury has been widely used in industrial production (gold hand-mining, lighting equipment, coal burning in cement factories, thermal power plants, fertilizer…), medical appliance (dental amalgam filling, thermo-meter..) but has not been managed well and strictly.

Recent years, Vietnamese Government has paid more attention on the mercury management, some initial investigations on mercury emission from industrial sector as well as from the healthcare sector were carried out with the financial supported by the Governments and the foreign organizations such as GEF, UNDP, WHO.

This presentation will share the information on mercury waste management through the above study in Vietnam.

Keywords: mercury sources, mercury emission, hazardous waste management, health Impacts.

INTRODUCTION

Mercury pollution is a serious global environmental and public health problem which causes a variety of adverse impacts throughout the world. If discarded as a waste, mercury will eventually make its way into the environment where organisms living in rivers, lakes, or moist earth transform it into methyl mercury, highly toxic organic mercury. This type of mercury, which affects nerves and brains at very low levels, persists and accumulates in animals, fish and it can harm to public health and the environment at locations far from the original source of their release.

Vietnam is under the pressure of economic and social development, environmental pollution caused by chemical emissions has become a major problem. Based on the experience of countries in the world, chemical emissions control is an effective way to control environmental pollution. However, this approach is relatively new to Vietnam.

In the absence of programs that promote the use of mercury-free medical instruments, and without management systems to assure both the proper clean-up of breakages and spills and proper final disposal, the total amount of mercury released to the environment by health-care institutions in Vietnam is growing rapidly.

Being aware of the above concern, Prime Minister of Vietnam agreed with Vietnam's entry into Minamata Treaty on Mercury by Decision N^o. 1811/QĐ-TTg dated 04/10/2013,

The Vietnamese Government has officially joined the United Nations Minamata Convention on Mercury with a view to ensure protection of human health and environment from negatives impacts of mercury and its compound. This would help to systematically control mercury, avoiding smuggling and mercury un-managed use in Vietnam

MATERIALS AND METHODS

Data and information in this paper were mainly collected from the following sources:

- Regional Environmental Monitoring Stations (REMS)/Institute for Environmental Science & Engineering (IESE);
- Ministry of Health (MOH)
- Vietnam Environmental Administration, Ministry of Natural Resources and Environment (MONRE)
- Vietnam Chemicals Agency, Minister of Industry and Trade (MOIT)

RESULTS AND DISCUSSION

Mercury usage: In Vietnam, mercury is used for batteries, electric lightning, dental amalgams, thermometers, blood-pressure gauges and inorganic reagents however, no data on annual mercury consumption.

Mercury waste and emissions: Mercury is widely used in health-care practice in thermometers, blood pressure measurement instruments and other devices.

The Major Sources of Mercury Waste in Vietnam

Cement Production: In 2011, the development plan of cement industry for the period from 2011-2020 and orientation up to the year 2030 was approved by The Prime Minister in Decision No1488/QĐ -TTg dated 29/08/2011.

- Thermal power plants
- Chlor-Alkali Production
- Electric Lamp Manufacturing
- Chemical Fertilizer Production
- Small scale gold hand-mining Activities
- Medical appliance (Dental amalgams, thermometers, blood-pressure gauges)

Substantial releases of mercury to the environment occur as a result of breakages, spills, improper disposal and other means. The data from a survey of 18 hospitals where the rapid assessment tool was applied show that for non-resident patients or clients, about 20 to 30 thermometers are used in each facility (of which 15 to

20 are frequently used), and 2 to 4 thermometers are broken per month. Ministry of Health regulations state that each resident patient should use 1 thermometer, but the actual number is lower due to budget. Estimated mercury releases from broken thermometers are ranging from 1.1g mercury/bed-year - 2.4g mercury/bed-year which depends on the types and scale of the hospital [7]. The amalgam containing mercury with very small quantity (0.3 kg/year) currently is collected and stored (sink in water to avoid the evaporation) in hazardous waste store at hospital [1].

Several of industrial sectors in Vietnam are concerning with mercury consumption and emission such as: Thermal power (15 large scale plants); Cement production (app. 30 medium /large scale plants); Metal production (8 large scale plants) and others, however, up to present, there is no data on potential of pollution caused by mercury emission from industrial sectors in Vietnam. Under supporting of GEF, an initial study on identifying of the mercury emission from 4 typical processing activities (Cement Production, thermal power plants, Small-scale gold mining; Municipal solid waste landfills) was conducted. The results of the studies shown that, mercury emission from small-scale gold-mining (1,800 kg/year) and from Cement Plants (1,470 kg/year) represent the biggest source of mercury pollution.

Mercury waste management: No facility has a standard procedure for separating mercury-containing waste for treatment. Mercury waste is generally collected and incinerated together with other health-care waste in hospital incinerators or central incinerators, or disposed in municipal landfills.

There are no specific policies on mercury in health care in Vietnam. Mercury waste is classified as hazardous chemical waste and heavy metal containing waste that can be managed according the Law on Chemical (2007); Health-Care Waste Management Regulations (2007); Circular on Hazardous waste Management (2015);

The major challenges for mercury waste management in Vietnam can be summarized as:

- Lack of knowledge about proper management systems for mercury waste
- Lack of knowledge of pollution prevention, waste minimization, segregation and proper mercury waste management practices
- Lack of coordination and cooperation;
- Lack of information exchange;

CONCLUSION

In order to stop the anthropogenic mercury releases from mercury waste, it is important to eliminate non-essential uses of mercury in consumer, household, and commercial products, thereby reducing potential mercury releases to the environment associated with the production, uses, and disposal of mercury-containing products.

The Minamata Convention provides for controls and reductions across a range of products, processes and industries where mercury is used, released or emitted. The treaty also addresses the direct mining of mercury, export and import of the metal and safe storage of waste mercury.

Vietnam's joining to the Treaty has not only upheld country's position in international arena but also brought many benefits: perfecting national legislation on mercury management for ensuring protection of human health and environment from negatives impacts of mercury and its compound. This would help to systematically control mercury, avoiding smuggling and mercury un-managed use in Vietnam. In addition, joining to the Treaty creates conditions for the country in learning experience on mercury management and establishing cooperation in researching and developing mercury-free products and optimal technologies to minimize mercury disposal.

Identification and inventories of mercury waste including sampling and measurement of mercury in some sources/effluents is the first step to develop a legal frame work on mercury waste and used mercury-containing products as well as to develop proper solutions for sound management of mercury for Vietnam.

ACKNOWLEDGEMENT

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A Comparative Analysis of Recycling Systems and Statistics of Waste Battery in Korea, Japan, and Germany

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ABSTRACT

In the past few decades, remarkable technical development in battery manufacturing industry has been made to meet the needs of light-weight and portable design by consumers. Occurrence of the electronic devices is strongly related to development and enhancement of batteries. Currently, management of waste batteries is gaining concerns all around the globe because they have hazardous materials and improper disposal of such waste may result in adverse impacts on the environment and human health. In Korea, used batteries have been included in EPR (Extended Producer Responsibility) policy since 2003 for effective recovery and recycling of the waste from consumer. This paper aims to give a comprehensive overview of waste batteries management systems and statistical investigation by using comparative analysis between Korea, Japan, and Germany.

Keywords: Waste Batteries, Collection, EPR, Recycling, Comparative Analysis

INTRODUCTION

Batteries play an important role of electricity supply and such devices are needed for use in daily life. All over the world, the use of batteries has been increasing because of growth of wireless electric and electronic equipment and outdoor activity. As a result, waste batteries are overflowing in the waste streams. Ultimately, it may cause many problems regarding environmental pollution and human health impacts as well as the depletion of useful resources in society.

Battery is often too small and can be easily discarded into waste streams. It may be mixed with other waste or just thrown away in a garbage collection box. Valuable resources in batteries such as cobalt, nickel, as well as rare metals can be recovered by recycling process, once collected. Furthermore, toxic substances in batteries are harmful to people owing to their potential fire hazards and toxicity of heavy metals such as mercury and cadmium. If waste batteries go through municipal waste streams, it could dispose of landfills and incineration facilities for treatment. In this study, the management systems of waste batteries in Korea, Japan and Germany have been compared to elucidate the characteristics of battery collection and recycling.

MATERIALS AND METHODS

The data required for this study were collected from the literature review, statistics developed by the Korea Ministry of Environment (MOE), discussion with the experts, survey and field visits to the local government office, MOE, recycling facilities in and around Korea. In addition, a number of reports and websites have been carefully reviewed to examine a comparative study of the management system of waste batteries in Japan and Germany.

RESULTS AND DISCUSSION

1. Korea

In 2003, Korea MOE implemented EPR system of battery to enforce producers and importers of batteries for recycling. They take the responsibilities to recycle waste batteries up to assigned target recycling rate that the Ministry has set each year. Applicable batteries of the EPR system include Mercury, Silver Oxide, Lithium primary, Nickel Cadmium, Manganese/Alkaline Manganese, Nickel Metal Hybrid batteries (6 mandatory recycling items). Figure 1 shows the management system of waste batteries in Korea. Households/consumers can dispose of battery collection box installed by local municipalities that is the subject to waste battery recycling.

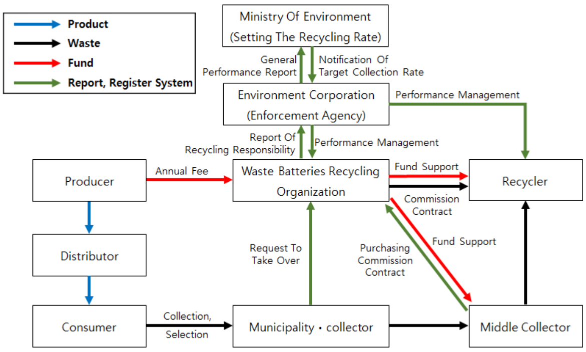

Figure 1. Management system of waste batteries in Korea

2. Japan

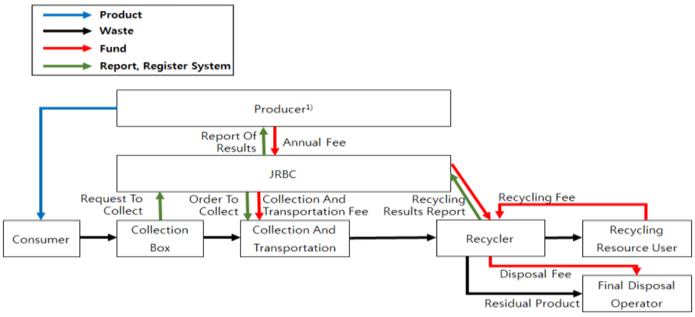

Figure 2. Management system of waste batteries in Japan

Japan classifies batteries as primary battery (Manganese, Alkaline, Lithium primary and Silver Oxide battery), button battery (Alkali button, Zinc Air battery), and secondary battery (Nickel Cadmium, Nickel Metal Hybrid, Lithium ion). While primary and button batteries are typically collected by local municipalities, producers have an obligation to collect secondary batteries in cooperation with

JBRC(Japanese Battery Recycling Cooperation). Figure 2 illustrates the management system of waste batteries in Japan.

3. Germany

Germany has started EPR system with four collection organizations of waste batteries such as GRS, REBAT, and ERP. The role of the organizations is varied with different province, and they concentrate on collection, sorting, and recycling of waste batteries. Also, they carry out take-back system (Reverse Logistics), allowing distributor to collect back waste batteries from consumer for free. Germany promulgated Batteries Act (Batteriegesetz/BattG) in 2009, based on European Union batteries directive 2006:66:EC. Figure 3 shows the management system of waste batteries in Germany. Customers can discharge waste batteries through collection box in company, public institution, retail shops, and others installed by Joint Collection Organization.

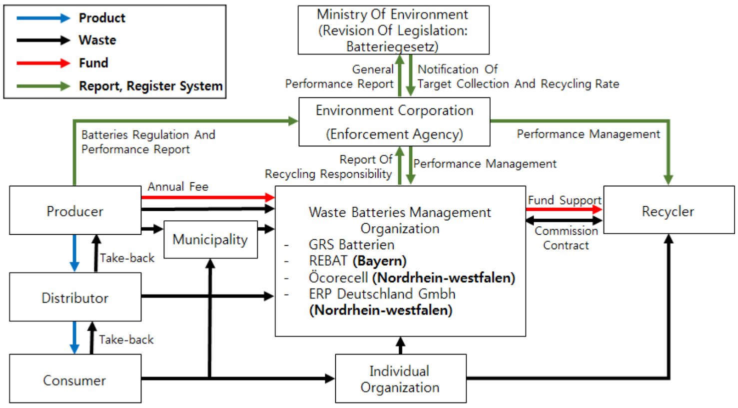

Figure 3. Management system of waste batteries in Germany

4. Comparison of three countries

Table 1 shows the result of a comparative analysis concerning the waste batteries management system and statistics at a glance between Korea, Japan, and Germany. Korea and Germany has implemented EPR system for producer and importer of batteries in order to accomplish their duties to take back products they made. In Korea and Japan, municipality has a significant role of collection of waste batteries for recycling. Retailers are an important pathway of battery collection, Korea is still lack of the pathway of retailers.

Table 1. Comparison of waste batteries management system and statistics (2013, 2014)

		Korea	Japan	Germany
Population		51,515,399	127,103,388	80,996,685
Country area		99,720 ㎢	377,915 ㎢	357,022 ㎢
EPR system		Yes	No	Yes
Collection System	**Household**	Collected By Municipality→	Collected By Municipality or BAJ,	Take-Back System, Distributor → Joint or

		Recycling Facility	JBRC → Recycling Facility	Individual Organization → Recycling Facility
	Business Operators	Collected By Municipality or Directly Collected by Organization → Recycling Facility	Directly Collected by Organization or BAJ, JBRC → Recycling Facility	Take-Back System, Distributor → Joint or Individual Organization → Recycling Facility
Finance burden		**Collection, Transportation** : Municipality, Organization **Treatment** : Producer	**- Primary Battery -** • Household: Municipality • Business operators: End-Users - **Button and Secondary Battery** : Producer and Importer	**Collection, Transportation, Treatment**: Producer, Importer, and Distributor by charging organization's annual fee
POM(ton)		12,514	101,500	43,979
Collection amount (ton)		2,945	13,526	19,142
Collection rate		23.53%	13.32%	44.2%
Basic Unit Collection rate(g/person/yr)		57.17	106.42	236.33
Recycling amount (ton)		1,547	1,160	19,832
Recycling rate		[100%]1)	Nickel Cadmium: 72% Nickel Metal Hybrid:77% Lithium Ion: 44% Small Lead-Acid: 51%	Portable:100%

1) [Estimate] : In Korea, we suppose recycling rate is 100% because all the waste batteries that we collect enter in recycling process.

CONCLUSION

The purpose of this study was to present management overview of battery recycling and management systems of three countries (Korea, Japan, and Germany) using comparative analysis. Based on the results, Germany collects much more batteries than Korea, although the EPR system has been employed in both countries. In Japan, the primary battery is usually collected by local municipality, while the secondary battery is managed by the JBRC. There is a need for better effective collection of waste batteries in Korea by adopting various collection programs including take-back by retailers, collection from industrial sectors, and economic incentives to consumers.

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Correlation between leaching concentration and content of Hg for phosphor powder and glass from linear spent fluorescent lamps

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ABSTRACT

In order to make a correlation between leaching concentration and content of mercury for phosphor powder and glass from spent linear-type fluorescent lamps, content of mercury test and leaching tests such as Korea extraction test (KET) and toxicity characteristics leaching procedure (TCLP) were carried for the linear spent fluorescent lamps (SFLs). In the content of mercury test, the content of mercury was directly analyzed by DMA-80. In leaching test, it can be obtained the average value from samples of components prepared. Among the parameters in leaching test, pH is the most important to leach metals in phosphor powders. From the results of content of mercury test and leaching test from SFLs, mercury concentrations in leaching fluids under TCLP is generally higher than those under KET. As the content of mercury in glass and phosphor powder increased, leaching concentrations by KET and TCLP were increased linearly.

Keywords: Leaching test, mercury content, phosphor powder, glass, spent fluorescent lamps

INTRODUCTION

Even though the hazard for broken fluorescent lamp to the environment and human health is asserted steadily due to the emission of mercury, most spent fluorescent lamps(SFLs) have not been treated properly in most Asian countries including Korea. Mercury is recognized as a substance of Minamata disease among residents in the Minamata Bay region, Japan. Minamata Convention on mercury as a global treaty was started from 2013 to protect human health and environment from mercury pollution.

In order to control SFLs in Korea(Republic of), the Extended Producer Responsibility(EPR) system was applied to SFLs from 2004. In Korea, about 31.3 million SFLs were recycled and recycling rates was about 26.8% in 2012. However, there was no regulation to control SFLs. Even though the standard level of leaching concentration for mercury in Korea extraction test (KET) was 5 ppb, the standard level of leaching concentration for mercury could not applied to SFLs because SFLs were not classified to be a specified waste in Korea[3]. According to Waste Management Act in Korea, Korea extraction test can apply to specific wastes only to verify specified wastes or not among specified wastes. Since SFLs generated mainly from household and public sectors, SFLs were not specific wastes in Korea. In the United States, SFLs were controlled by Universal Act and the standard level of leaching concentration for mercury in toxicity characteristics leaching procedure (TCLP) could apply to SFLs.

In this study, mercury content and leaching concentration were carried out to estimate the correlation of mercury from SFLs. Also, the relationship between content and leaching concentration was estimated for mercury. From the experimental results, it was recommended that the hazardous components of lamps should be separated from other components to recycle the components from SFLs.

MATERIALS AND METHODS

Materials and Analysis

The basic information of SFL samples of leaching test such as KET and TCLP and content test can be shown in Table 1. The major components of SFLs were mainly glass, phosphor powder, and metals. In SFLs, the portion of glass was 92.6%. All samples of the components from SFL were separated efficiently by separation facilities because most of mercury in SFLs exists in phosphor powder.

Table 1. The major components of liner fluorescent lamp

Code	Specification	Major components	Weight [g]	Ratio [%]
FHF32SS EX-D	Wattage : 32W Diameter : 28mm Length : 1198mm	Glass	153.22	92.61
		Phosphor powder	3.30	1.99
		Non-ferrous metals	7.24	4.38
		Etc.	1.68	1.02
		Total	165.44	100.0

Experimental methods

The objective of Korea Extraction Test(KET) is to determine if a waste is a hazardous matter specified under the regulatory level of Korean Waste Management Act. In KET, the sample of components of 100g was used with the solution of 1000ml with the range of initial pH 5.8~6.3. In order to adjust pH in the solution, HCl was used a reagent. After making solution, put the sample and the solution into 500mL Erlenmeyer flask and shook with shaker having 4~5cm vibration range continuously for 6 hours at 200rpm on room temperature. The shaken solution was filtered using glass fiber filter.

The purpose of TCLP is to decide if a waste may satisfy with a hazardous waste code listed in 40CFR (Code of Federal Regulations) Part 26 under Resource Conservation and Recovery Act (RCRA). The range of initial pH in phosphor powders was very high representing between 11.0 and 13.0. Even though an initial leaching fluid should be 4.83 in TCLP, pH in the mixed leaching fluid with phosphor powder is almost the same as pH of phosphor powder. Since pH in the mixed leaching fluid with phosphor powder in TCLP is over 5.0, leaching fluid #2(pH =2.88) should be used.

DMA-80(Direct Mercury Analyzer) using the EPA method 7473 was used to analyze the content of mercury of the sample. AAS(Atomic absorption spectroscopy) was used to analyze the leaching concentration of mercury after carrying out KET and TCLP. Atomic Absorption Spectrometer(AAS) using the Korean Standard Method (ES 06400.1) was used to analyze the leaching concentration of mercury of leaching solution for the sample. Measurements were conducted 3 times for every sample estimated the leaching concentration and content from their average value.

RESULTS AND DISCUSSION

Mercury content and leaching concentrations such as KET and TCLP from SFLs were shown in Table 2. Generally, leaching concentration by KET was lower than TCLP because pH of leaching solvent in KET was higher than pH of leaching solvent in TCLP.

As the mercury content in glass is increased from 0.209 mg/kg to 166.7 mg/kg, leaching concentrations by KET and TCLP are increased from 0.0 ppm to 0.018 ppm and 0.0 ppm to 0.0.063 ppm, respectively. As the mercury content in phosphor powder is increased from 504 mg/kg to 3522 mg/kg, leaching concentrations by KET and TCLP are increased from 0.075 ppm to 0.0384 ppm and 0.148 ppm to 0.658 ppm, respectively.

Table 2. The result of mercury content and leaching concentrations

Type	KET [mg/L]	TCLP [mg/L]	Mercury Content [mg/kg]
Glass	N/D	N/D	0.209
	0.002	0.006	2.020
	0.011	0.038	19.968
	0.015	0.055	64.548
	0.018	0.063	166.667
Phosphor powder	0.075	0.148	503.982
	0.101	0.186	1065.147
	0.184	0.365	1921.641
	0.332	0.488	2825.575
	0.384	0.658	3522.070

CONCLUSION

Korea extraction test (KET), toxicity characteristics leaching procedure (TCLP), and mercury content test were carried to make a correlation between leaching concentration and content of mercury for phosphor powder and glass from spent linear-type fluorescent lamps. From the results of leaching test for components from SFLs, mercury concentrations in leaching fluids under TCLP is generally higher than those under KET. And the correlation between the content and leaching concentration such as KET and TCLP for mercury in glass and phosphor powder from spent fluorescent lamps can be presented by a linear form. As increasing content of mercury, hence, leaching concentrations of mercury in KET and TCLP were increased.

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Mercury Emission from Waste Incinerator and Future Trend

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ABSTRACT

Mercury and mercury compounds could have adverse effect on human health due to long-term exposure, contamination and bioaccumulation. Also, it has also long distance transportation characteristic between nations. In MINAMATA convention, waste incineration facility was classified to major mercury emission source. In this study, mercury emission from waste incineration was estimated using emission factor and waste incineration activities. In 2012, mercury emissions were 0.012 ton/yr, 0.170 ton/yr from municipal solid and industrial waste incineration facilities, respectively. According to scenario of changing activity, mercury emission from waste incineration facilities in 2020 was expected to increase 21.50% comparing to 2012. Also, mercury removal efficiency were changed by applying best available technologies and reduction of mercury emission could be calculated. According to scenario of applying best available technologies, mercury emission could be decreased to 56.80%, annually.

Keywords: Waste incineration, Mercury emission, Best available technology, Activity, Scenario

INTRODUCTION

Mercury and mercury compounds are present in trace amounts from environment, but it can have a bad effect on human health due to long-term exposure, contamination and bioaccumulation. (Sarabia, R et al., 1998; Grandjean P. and Budtz-Jørgensen.E., 2007; Gardnera M. et al., 2010) It has also long distance transportation characteristic between nations. MINAMATA convention for the protection of public health was adopted in 2013, and mercury emission from anthropogenic was interested in management of air quality. In convention, waste incineration facility was classified to major mercury emission source. (UNEP 2014) Mercury emission could be estimated by emission factors that were derived by mercury concentration in flue gas. And there were various studies about mercury emissions from anthropogenic sources using mercury emission factor. (Park et al., 2008; Kim et al., 2010) Mercury emission was mainly effect on activity and configuration of air pollutant control device. (N. Pirrone et al., 2001) Also, mercury could be controlled by co-benefit effect of existing air pollutant control devices that induced to change of emission factor.

In this study, mercury emission was estimated using emission factor that was derived in previous studies about waste incineration mercury emission. Also, mercury removal efficiency was changed by applying best available technologies and reduction of mercury emission calculated.

MATERIALS AND METHODS

Calculation of mercury emission

For estimating mercury emission from waste incineration, activity of incinerated waste was investigated by statistics data about waste generation and treatment in Republic of Korea. And emission factor was applied to calculate the mercury emission. It could be derived by the following equation (1).

$$F_{Hg} = \frac{C_{Hg} \times Q \times 10^{-3}}{A_{hr}} \quad (1)$$

Where, F_{Hg} is mercury emission factor (mg-Hg/ton-waste), C_{Hg} is mercury concentration in flue gas (ug/Sm^3), Q is flow rate of flue gas per hour (Sm^3/hr), A_{hr} is activity of incinerated waste per hour (ton/hr). In this study, average emission factor was used to calculation because there were over 150 facilities in Republic of Korea. It could be changed by applying additional air pollutant control devices because co-benefit effect, and it could be changed by the following equation (2).

$$F^*_{Hg} = \frac{C^{*Hg} \times Q \times 10^{-3}}{A_{hr}} \quad (2)$$

Where, F^*_{Hg} is mercury emission factor by applying best available technology (mg-Hg/ton-waste), C^*_{Hg} is reduction of mercury concentration in flue gas by applying best available technology (ug/Sm^3). And mercury emission could be calculated by the following equation (3).

$$E_{Hg} = F_{Hg} \times A_{yr} \quad (3)$$

Where, E_{Hg} is mercury emission (ton-Hg/yr), A_{yr} is activity of waste per year (ton/yr). Also, future activity predicted in 2020 using historical statistics, and then future mercury emission calculated using equation (3).

RESULTS AND DISCUSSION

Mercury emission from waste incineration

Waste incineration facility could be classified by waste type. In this study, municipal solid waste and industrial waste were conducted to estimate mercury emission. Generally, municipal solid waste had large variation and low mercury content. Also, facilities already equipped sufficient configurations because of controlling of air pollutant containing dioxin, (Lee, 2004) and typically consisted of semi dry reactor, bag filter, selective catalytic reduction or selective non-catalytic reduction. In this reason, mercury emission was 0.012 ton/yr from municipal solid waste incineration facilities though mercury emission in outlet of incinerator was 1.864 ton/yr. But industrial waste could be mixed waste with high mercury contents. And typical configuration of air pollutant control devices consisted of selective non-catalytic reduction, semi dry reactor or activated carbon injection, bag filter, wet scrubber. Because of that, mercury emission was 0.170 ton/yr from industrial waste incineration facilities though mercury emission in outlet of incinerator was 0.243 ton/yr in 2012.

Mercury emission scenario

Mercury emission could be changed by activity and configuration of air pollutant control devices. Activity directly affected to mercury emission because it effected on mercury input, and it was proportional to economic growth. According to changing activity and applying best available technologies, mercury emission were calculated to 2020 and shown under Figure 1. Activities of municipal and industrial waste showed average growth rate at 11.34%, 8.64%, respectively. In 2020, mercury emission from waste incineration facilities was expected to increase 21.50% comparing to 2012. But development of technology increased the mercury control efficiency in flue gas. In municipal solid waste incineration, best available technologies were semi dry reactor and selective catalytic reduction that were could increase mercury removal efficiency by mercury oxidation and particulate mercury conversion. (Deepak Pudasainee et al., 2010) In this scenario, mercury removal efficiency could be increased to 98% and emission factor could be decreased to 9.43 mg/ton. Also, in industrial waste incineration, best available technologies were semi dry reactor and wet scrubber that were could increase mercury removal efficiency by mercury oxidation. (Deepak Pudasainee et al., 2010) In this scenario, mercury removal efficiency could be increased to 98% and emission factor could be decreased to 124.10 mg/ton. As a results, mercury emission could be decreased to 56.80%, annually.

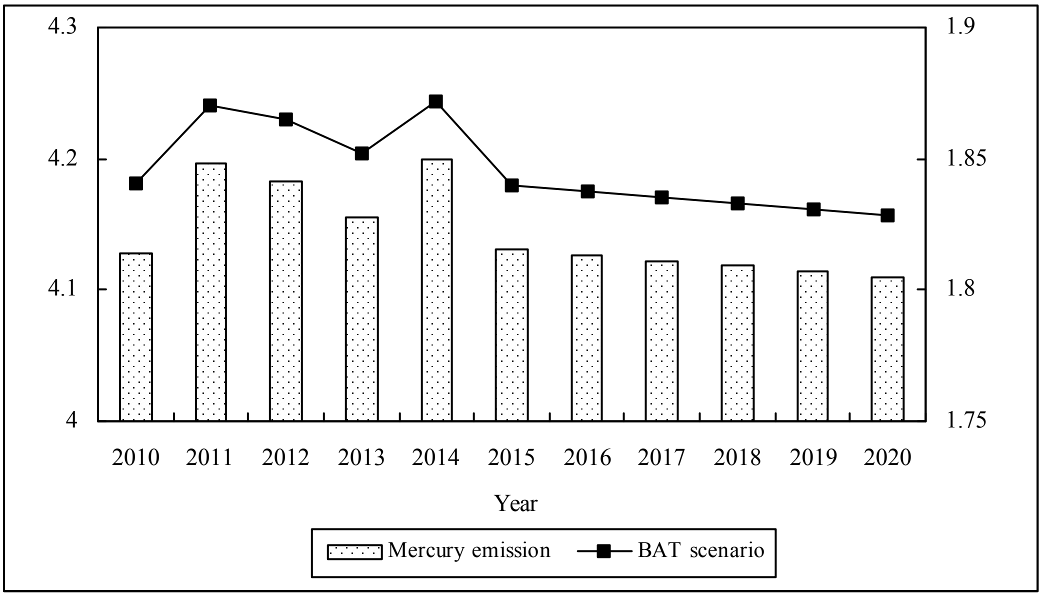

Figure 1. **Mercury emission scenarios in waste incineration facility**

CONCLUSION

This study aimed to estimating mercury emission from waste incineration facilities in 2012 and predicting mercury emission by scenario about activity and best available technology.

1. Municipal solid waste incineration facilities already equipped sufficient configurations, and mercury emission was 0.012 ton/yr, though mercury emission in outlet of incinerator was 1.864 ton/yr. But industrial waste incineration facilities could be mixed waste with high mercury contents, and mercury emission was 0.170 ton/yr though mercury emission in outlet of incinerator was 0.243

ton/yr in 2012.

2. Activities of municipal and industrial waste showed average growth rate at 11.34%, 8.64%, respectively. According to scenario of changing activity, mercury emission from waste incineration facilities was expected to increase 21.50% in 2020 comparing to 2012. According to scenario of applying best available technologies, mercury emission could be decreased to 56.80%, annually.

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Effects of calcium based additives on the PAHs formation during sewage sludge incineration in a fluidized bed combustor

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ABSTRACT

In this paper, the control of polycyclic aromatic hydrocarbons (PAHs) emission by adding calcium based additives (CaO, $Ca(OH)_2$ and $CaCO_3$) during sewage sludge incineration in a fluidized bed combustor (FBC) were investigated. In order to discover PAHs control mechanism, the effects of calcium based additive's types, CaO/S and particle size on PAHs concentrations or PAHs TEQ concentration were also conducted. The experimental results indicated that PAHs and PAHs TEQ concentration removal efficiencies by adding calcium based additives followed the sequence of $CaO>Ca(OH)_2>CaCO_3$. Meanwhile, the increase of CaO/S and decrease of particle size were benefit for suppressing PAHs formation. Moreover, it was concluded that the adsorption and catalytic effect of calcium based additives were responsible for inhibiting PAHs formation.

Keywords: PAHs reduction, calcium based additives, sewage sludge, incineration

INTRODUCTION

PAHs are a class of organic matters composed by more than two benzene rings, which are considered to be a potential health hazardous substance due to its immunotoxicity, genotoxicity, carcinogenicity, reproductive toxicity properties. World Health Organization (WHO) and many countries have prescribed the PAHs emission standards. It was estimated that the global total annual emission of 16 PAHs in 2007 was 530000 tons. Among them, South (87000 tons), East (111000 tons), and Southeast Asia (52000 tons) were the regions with the highest PAHs emission densities, contributing half of the global total PAHs emissions (Shen et al., 2013). China is considered as the high amount of PAH emissions country, contributing approximately 22% of the total global PAH emissions (Wang et al., 2015).

PAHs are mainly generated from straw burning, coal combustion, coking and MSW incineration. In order to reduce PAHs emission, many methods or technologies was tried during coal/MSW combustion. Tseng et al. (2002) reported that Ca-based additives had a good performance for reducing polycyclic aromatic hydrocarbons (PAHs). Wey et al. (2006) found that the removal efficiency of PAHs by adding CaO were not apparent because alkaline metals such as Na, K were easily sintered with silica sand and decrease the fluidization quality of a fluidized bed incinerator. Mastral et al. (2001) claimed that Ca-based additives may promote the PAHs emission.

In order to discover the influence of Ca base additive on PAHs emission, PAHs concentration during sewage sludge incineration in a FBC with and without adding calcium based additives were investigated. At the same time, effects of calcium based additive's types (CaO, $Ca(OH)_2$ and $CaCO_3$), CaO/S and particle size on PAHs concentrations were also conducted.

MATERIALS AND METHODS

The sewage sludge used as fuel was sampled from a wastewater treatment plant in Wuhan, China. Prior to use, sewage sludge was dried, milled and sieved to less than 200 µm. The weight percentages of C, H, O, N, and S in the coal were 22.91%, 4.06%, 68.20%, 4.04% and 0.79%, respectively. Proximate analysis revealed that the weight percentages of fixed carbon, moisture, ash, and volatile matter were 2.25%, 45.53%, 45.39%, and 6.83%, respectively. In this experiment, silica sand (150~200 µm) was used as bed materials, the critical fluidization velocity of silica sand is 0.063 m/s. Meanwhile, the commercially available CaO, $CaCO_3$ and $Ca(OH)_2$ were used as additives. The properties of the Ca-based additives were represented in Table 1. The fluidized bed combustor used in this experiment was described in detail in our previous paper (Qin et al., 2014). The sample and analysis procedure of PAHs was also described in our previous paper (Han et al., 2012).

Table 1 The characteristics of Ca-based additives

Name	Diameter (µm)	Specific surface area (m^2/g)
CaO	~74	22.78
CaO	74~150	20.34
CaO	150~300	18.77
CaO	300~	15.36
$Ca(OH)_2$	~74	13.24
$CaCO_3$	~74	7.29

RESULTS AND DISCUSSION

The combustion temperature, the excess air ratio, gas residence time, Ca/S and particle size of additives were separately fixed to 850 ^oC, 1.2, 15s, 1.0 and ~74 µm when CaO, $Ca(OH)_2$ and $CaCO_3$ were used as additives. Table 2 presented the concentrations of individual and grouped PAHs under different calcium based additives. The concentrations of the two-ring (NaP) and three-ring PAHs (AcPy, AcP, Flu, PhA and AnT) were increased, while the four-ring (mainly FluA, Pyr, BaA), five-ring (mainly BbP, BaP) and six-ring PAHs (mainly BghiP and InP) were decreased by adding calcium based additives. The total PAHs concentration with no additives was 1.731 mg/Nm^3, whereas the total PAHs concentration by adding CaO, $Ca(OH)_2$ and $CaCO_3$ were in the sequence as 1.058, 1.202, and 1.625 mg/Nm^3. Comparing the removal efficiency of PAHs by adding different calcium based additives indicated that the performance of calcium based additives followed the sequence of CaO>$Ca(OH)_2$>$CaCO_3$. Table 2 also presented the individual and grouped PAHs TEQ concentrations under different calcium based additives. The results indicated that the two-ring and three-ring PAHs TEQ concentrations were slightly increased, whereas the four-ring, five-ring, six-ring PAHs, and the total PAHs TEQ concentrations were dramatically decreased by adding calcium based additives. For example, the dominated five-ring PAHs TEQ concentration with no additives was 183.4 µg·TEQ·Nm^{-3}, while the dominated five-ring PAHs TEQ concentration by adding CaO, $Ca(OH)_2$ and $CaCO_3$ were decreased to 45.5, 71.1, 87.1 µg·TEQ·Nm^{-3}. As for the total PAHs TEQ concentration, compared with no additives, the total PAHs TEQ concentration by adding CaO, $Ca(OH)_2$ and $CaCO_3$ were decreased by 174.5, 159.4 and 140.5µg·TEQ·Nm^{-3}. Comparing PAHs TEQ concentrations by adding different calcium based additives, the performance of calcium based additives followed the sequence of CaO>Ca(OH)$_2$>CaCO$_3$. The above values indicated that calcium based additives had a good performance for reducing PAHs TEQ concentration. It was postulated that there were two mechanisms caused the above phenomenon. Firstly, the specific surface areas of CaO, Ca(OH)$_2$ and CaCO$_3$ were 22.78 m^2/g, 13.24 m^2/g and 7.29 m^2/g, respectively, which was consisted with PAHs removal efficiency sequence. Hence, calcium based additives could capture more gaseous hydrocarbons released from sewage sludge, which reduced hydrocarbon in the diluted zone and bubbled zone of FBC. According to PAHs formation mechanism, gaseous hydrocarbon is the precursor of PAHs. Thus, PAHs formation could be suppressed by calcium based additives. On the other hand, calcium based additives may enhance the combustion efficiency, which promoted the low molar weight PAHs formation and suppressed the middle molar weight and high molar weight PAHs formation due to catalytic effect (Mastral et al., 2001).

Table 2 PAHs and PAHs TEQ concentration under different calcium based additives

PAHs	PAHs conc. (mg/Nm^3)				PAHs TEQ conc.(µg TEQ Nm^{-3})			
	Additives				Additives			
	No additive	CaO	Ca(OH)$_2$	CaCO$_3$	No additive	CaO	Ca(OH)$_2$	CaCO$_3$
NaP	0.354	0.386	0.630	0.665	0.354	0.386	0.630	0.665
PAHs of 2-rings	0.354	0.386	0.630	0.665	0.354	0.386	0.630	0.665
AcPy	0.026	0.028	0.135	0.182	0.026	0.028	0.135	0.182
AcP	0.031	0.054	0.061	0.154	0.031	0.054	0.061	0.154
Flu	0.104	0.158	0.121	0.150	0.104	0.158	0.121	0.150
PhA	0.050	0.063	0.059	0.070	0.050	0.063	0.059	0.070
AnT	0.025	0.056	0.047	0.128	0.250	0.560	0.470	1.280
∑PAHs of 3-rings	0.236	0.359	0.423	0.684	0.461	0.763	0.846	1.836
FluA	0.219	0.087	0.000	0.000	0.219	0.087	0.000	0.000
Pyr	0.101	0.000	0.000	0.000	0.101	0.000	0.000	0.000
BaA	0.316	0.111	0.000	0.000	31.60	11.10	0.00	0.00
Chr	0.000	0.000	0.051	0.063	0.00	0.00	0.51	0.63
∑PAHs of 4-rings	0.636	0.198	0.051	0.063	31.92	11.19	0.51	0.63
BbF	0.033	0.033	0.000	0.000	3.30	3.30	0.00	0.00
BkF	0.101	0.032	0.031	0.111	10.10	3.20	3.10	11.10
BaP	0.170	0.039	0.068	0.076	171.0	39.0	68.0	76.0
DbA	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
∑PAHs of 5-rings	0.304	0.104	0.099	0.187	183.4	45.5	71.1	87.1
InP	0.159	0.000	0.000	0.017	15.9	0.00	0.00	1.70
BghiP	0.042	0.011	0.000	0.009	0.42	0.11	0.00	0.09
∑PAHs of 6-rings	0.201	0.011	0.000	0.026	16.31	0.11	0.00	1.79
∑PAHs cont.	1.731	1.058	1.202	1.625	232.5	57.9	73.1	91.9

CONCLUSION

The removal mechanism of polycyclic aromatic hydrocarbons (PAHs) by adding calcium based additives (CaO, Ca(OH)$_2$ and CaCO$_3$) during sewage sludge incineration in a fluidized bed combustor (FBC) were investigated. The following conclusions have been drawn:

The experimental results indicated that PAHs or PAHs TEQ concentration control efficiencies by adding calcium based additives followed the sequence of CaO>$Ca(OH)_2$>$CaCO_3$. Meanwhile, PAHs removal efficiencies by adding calcium based additives can be increased by increasing CaO/S and decreasing CaO particle size. Moreover, CaO additives promoted the low molar weight PAHs formation and suppressed the middle molar weight and high molar weight PAHs formation due to catalytic effect. It was also found that both the adsorption and catalytic effect of calcium based additives were responsible for inhibiting PAHs formation.

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Session 12

Disaster waste

Analyses of a Waste Management Company Activities in the Great East Japan Earthquake

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ABSTRACT

In the event of great disasters such as earthquakes, tsunami and floods, disaster waste, including trash and debris are generated in enormous quantities. Disaster waste is normally disposed of by municipalities (by departments in special instances) as general waste. However, when its quantity becomes excessive it cannot be dealt by municipalities alone, and the association with private disposal services such as local industrial waste disposers becomes a requirement.

The Great East Japan Earthquake occurred on March 11th 2011 in the Tohoku District of Japan. The tsunami wave generated by this earthquake brought catastrophic damage to the coast of Pacific of the Tohoku district and the Kanto district. After the Great East Japan Earthquake, one of the local corporations of the affected area took various measures as part of its corporate defenses. Since competitors still exist, even during disasters corporations need to execute on a managerial strategy as part of their risk management.

Intelligence activities are believed to create excellent information in order to make decisions for performing specific measures to counter the strategies of rivals and competitors, by gathering, analyzing, and evaluating information.

This study will analyze a company activities from the aspect of intelligence activities and managerial strategy during the recovery phases of the Great East Japan Earthquake, and will discuss the correct uses and applicability of intelligence necessary for industrial waste disposal contractors located in devastated areas, and efficient techniques, as well as the characteristics of intelligence activities during the recovery phase.

Keywords: disaster waste, disaster recovery, intelligence activities, managerial strategy

INTRODUCTION

Disaster waste is normally treated by municipalities as general waste in Japan. However, when its quantity becomes excessive, it cannot be disposed of by municipalities alone, and an association with private disposal services such as local industrial waste disposers becomes a requirement. At this point, it is assumed that the disposers themselves have also been exposed to the disaster.

In fact, after the Great East Japan Earthquake, Sendai Kankyo Kaihatsu Co., Ltd. (hereinafter referred to as "S-company") located in Sendai-City was forced to take various unprecedented measures, as one of the waste management companies located on the area stricken by the earthquake.

In the immediate aftermath, due to the effect of the earthquake and tsunami, gathering information necessary to business activities was extremely difficult, and various uncertain information had spread. The measures countering harmful rumors and cooperation with the authorities that S-company conducted under these circumstances can all be attributed to managerial decisions. These decisions were made based on the experience and instinct of the management, and were not a result of intelligence analysis made consciously at that point. However, at the present day, these activities are realized as examples of intelligence activities.

This study analyzes the S-company activities from the points of view of intelligence activities and a managerial strategy.

DISASTER WASTE

Disaster waste is any waste generated as a result of natural disasters such as earthquakes, tsunami and floods. It includes debris (pieces of concrete, waste wood, etc., generated when removing damaged buildings), domestic garbage (domestic and bulk garbage that is temporarily generated in big quantities due to an earthquake), raw sewage (raw sewage scooped up from portable toilets), and waste with risks of environmental pollution (asbestos, PCB, etc.). Since it is difficult to separate general waste from industrial waste, in cases of disaster the municipalities (departments in special cases) shall dispose of them as general waste.

In the Great East Japan Earthquake, a lot of waste (mainly debris) was generated. The Ministry of the Environment estimates its total quantity to be 24.9 million tons over the three prefectures Tohoku, Miyagi, Iwate and Fukushima. Assuming that these 24.9 million tons are all general waste, it would be the equivalent of the quantity generated by 10 million people over six years.

INTELLIGENCE ACTIVITIES AND MANAGERIAL STRATEGY DURING RECOVERY PHASES

Intelligence Activities during Recovery Phase

“Intelligence”, in this study, refers to exact and actionable information useful for decision making, gathered at the time of disaster. “Intelligence activities” refer to the enactment of the gathering, analysis, and evaluation of information that a corporation must carry out in times of disaster as part of an entire intelligence cycle (Figure 1).

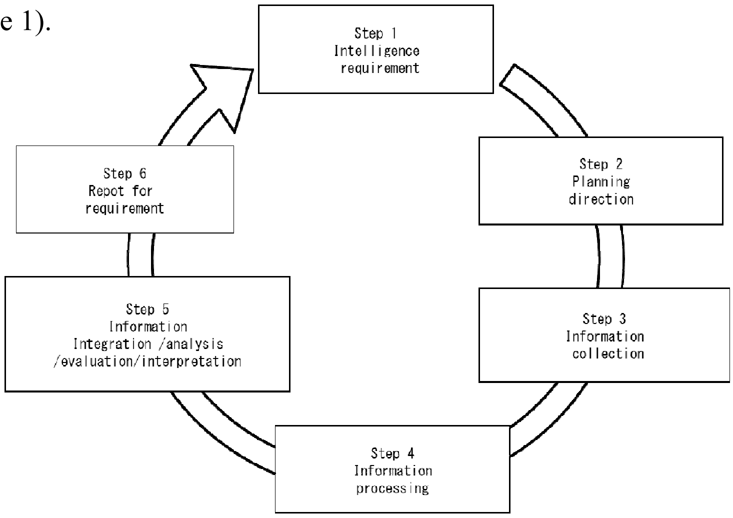

Figure 1. Intelligence cycle

The intelligence cycle processes for the production of intelligence triggered by the intelligence requirement from the decision makers who require the acquisition of intelligence. These processes are: collection of information done by the information side, information analysis (integration, analysis, evaluation, and interpretation of information), and publication of intelligence.

According to the previous study by Yoshinari, Ohuchi and Sugasawa, intelligence activities can generally be categorized into defensive intelligence activities and aggressive intelligence activities. Defensive intelligence activities and aggressive intelligence activities are reflected each in a defensive managerial strategy and an aggressive managerial strategy. The following details are known to be their characteristics.

Defensive Managerial Strategy during Recovery Phase

The purpose of the defensive managerial strategy is to find the answer to the setup theme from the flow of data. The defensive managerial strategy is valid in the following situations.

- In terms of existing competition, changes in the current situation may be detected by following up changes through the flow of data,
- For example, when changes in the product mix and price strategy, or dangers jeopardizing the position of the company are found, management will immediately be placed on alert.
- The fact that it allows a company to become a market leader putting greater effort in strategies to maintain market share, rather than revolutionary actions, is a good example.

The actual defensive managerial strategy of S-company in the Great East Japan Earthquake is as follows. The first concern for about the Great East Japan Earthquake was damage caused by misinformation. S-company had to swiftly inform its customers and partners that it had no damage at all. Misinformation might have caused damage based on the following two premises.

(1) Although S-company had no damage, people might have believed that it would not be able to deal with industrial waste because S-company was a Sendai-based enterprise and the waste disposal sites would be seriously damaged by the earthquake and tsunami.

(2) People might have believed that S-company would not take in regular industrial waste, giving priority to disaster waste disposal.

In fact, there have been misunderstandings on the part of some of S-company customers who saw news footage immediately after the earthquake, thinking that Sendai-City was also affected by the tsunami. Later, as information became more accurate, there were clients who got worried about premise (2).

S-company started taking measures against damage caused by the Great East Japan Earthquake. S-company telephoned, faxed, and e-mailed its clients from the Tokyo office and the headquarters, explaining that it had no damage at all and would accept its refuse as usual. Thanks to these efforts, S-company was able to prevent its customers from going to its competitors, and managed to continue its contracts. S-company understood that in order to prevent damage caused by misinformation, it was important to swiftly spread accurate information and prevent misunderstandings.

Aggressive Managerial Strategy during Recovery Phase

The aggressive managerial strategy aims at nailing down the coming opportunities. The aggressive managerial strategy are effective in the following situations.

- Changes in data collection means, according to environmental changes and management policy, changes are needed.
- A broad range follow-up is needed, and an elaborate information collection means is required.
- For example, to urge the management' s swift caution based on the fact that prominent competitors have fired certain experts from Research and Development sections, due to the recent decline of the economy. As a result, the management can consider this situation a favorable opportunity.

S-company confirmed that upon occurrence of the Great East Japan Earthquake, other waste management companies located in the affected area, who are its competitors, were harmed by the disaster and S-company was the only enterprise able to proactively operate from the following day of the earthquake.

Furthermore S-company offered its services to Sendai-City for the recovery from disaster and was practically in charge of waste disposal for the city, was expected to relate to an aggressive tactic in future business activities, and could be positioned as the aggressive managerial strategy.

CONCLUSION

This study have analyzed S-company activities from the aspect of intelligence activities and managerial strategy during the recovery phases of the Great East Japan Earthquake, and have indicated S-company activities are the defensive managerial strategy and an aggressive managerial strategy.

The validity of the defensive managerial strategy and an aggressive managerial strategy in the recovery phases is demonstrated by the fact that S-company is currently a good-standing company in Sendai-City.

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Challenges and Potential in Disaster Waste Recycling: A Malaysian case study

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ABSTRACT

This paper aims to discuss the challenges faced in recycling of waste generated from flood disaster in Malaysia. The study included waste composition analysis in order to determine the types of waste generated after a disaster, namely flood, and the potential usage of the wastes generated. Consecutively, the challenges of recycling these wastes was investigated in order to propose appropriate actions to ensure the viability of the disaster waste for recycling purpose. The main types of wastes generated after the flood event were wood and concrete, contributing 44% and 29%, respectively. Both components have high potential to be reused/ recycled in construction activities, particularly in rebuilding and reconstructing affected area. Yet, these 'resources' were not tapped due to its physical nature which was found to be highly comingled with other waste types namely dirt and mud. Thus, local authorities did not store the components in designated area but indiscriminately disposed them off together with other waste into the disposal sites. This is mainly due to the fact that no specific directives or guidelines were provided to guide the local municipality on the appropriate handling of these disaster wastes. Should recycling take place, the revenue to be obtained could reach RM 7 million or USD 1.62 million. Therefore, it is crucial that specific regulations or at least dedicated guidelines are formulated in order to allow the sustainable use of disaster waste. This not only will enable convenient usage of the resources available from disaster event but also ensure effective management of the waste which has been known to have negative impact to human health and environment if mishandled.

Keywords: disaster waste management, concrete, recycling, flood waste.

INTRODUCTION

Effective waste management is very important to ensure that resources can be used sustainably and not disposed unnecessarily. This can be achieved via the implementation of an integrated waste management system whereby strategic action such as waste prevention, reduction, reutilization, recycling and energy conversion are being practiced. Nevertheless, not all of the theoretical applications are practical in the real life in the context of an individual country. While 3R (Reduce, Reuse, Recycle) is very effectively implemented in many developed nations such as Japan and Singapore, it failed to give similar success story to most developing countries. This situation is particularly true in countries that lack specific guidelines on recycling and/or other good practices.

Malaysia being a transitory country is also affected with the lack of an effective integrated waste management system. As a result, approximately 85% of the wastes generated daily are sent off for disposal to

166 landfills or dump sites in the country (Fauziah and Agamuthu, 2012). The total daily generation of municipal solid waste (MSW) has exceeded 38,000 tonnes, and is rapidly increasing. It alarms the authorities and waste managers since landfill space is also being rapidly exhausted and finding new landfill site is nearly impossible due to the increase in the price of land. The recently enforced regulations pertaining to waste separation on 1st September 2015, under the Solid Waste and Public Cleansing Management Act 2007, are yet to bear any fruit. Therefore, recycling was only estimated to be 15% of the total waste generated, which also takes into account the contribution of the informal sector within the recycling industry. To worsen the situation in waste handling, local authorities and the waste managers also have to deal with disaster waste as in 2014.

In December 2014 and January 2015, a major flood event had taken place where five of the 13 states namely Kelantan, Terengganu, Pahang, Perak and Johor were affected seriously. As a result enormous amount of wastes (more than 200,000 tonnes) were generated due to severe damage to the houses, buildings and infrastructures (Agamuthu et al, 2015). Recycling is found to offer the best practical solution in dealing with the gargantuan amount of waste within a short period of time. Unfortunately, the strategy which is highly practical in Japan is nearly impossible to be applied in Malaysian context. Therefore, this paper is meant to investigate the waste situation in Malaysia particularly for flood waste recycling, as a case study. Specifically, it aims to estimate the flood waste generation in Kelantan, a state which was the most severely hit by the 2014 flood event, and to investigate the potential of flood waste recycling and its challenges.

MATERIALS AND METHODS

The study was conducted in Kelantan, Malaysia in all areas which were severely impacted by the flood in 2014. This is based on the number of victims involved namely Kuala Krai**,** Gua Musang,Tanah Merah,Tumpat,Kota Bharu, obtained from the National Security Council of Malaysia. This study covered northern, southern and central Kelantan.

In order to determine the percentage of recyclables, composition study was conducted by manually separating waste from randomly selected residences. The wastes were grouped into 25 types according to categories used by Fauziah (2010). Additionally, 625 questionnaires (96% confidence level; 4% error) were distributed to flood victims to allow the estimation of property loss and waste generated. Calculation was finally done to determine the economic value of recyclable materials in the flood waste stream.

The challenges to recycle the disaster waste were obtained via interview with relevant stakeholder, namely local municipalities, waste managers and the general public. Also, observation on the physical appearance of waste at the affected area during site visits enable researchers to suggest the challenges, supported by the statement given by the stakeholders.

RESULTS AND DISCUSSION

The study reveals that the highest percentage of waste generated were sourced from damage to property rather than typical municipal solid waste. The largest component was wood which contributed 44%, followed by concrete (29%). These two main construction and demolition wastes were found to dominate in most of the study areas. Figure 1 illustrates the composition of flood waste in Kelantan, resulting from the 2014 flood event.

Figure 1 Composition of waste collected after the 2014 flood event in Kelantan.

The total flood waste accumulated in Kelantan was comparable to the daily MSW generation (35,000 tonnes) by Malaysian in total (Agamuthu et al, 2015). It implies that the potential of recycling may divert recyclables from the flood stream for economic gains. Table 1 lists the waste items which has recycling potential recorded during the waste composition study immediately after the flood.

Table 1 Tonnage of recyclables accumulated in the flood waste stream in Kelantan

Waste types	Average weight (tonnes)	Examples of items found
Wood	36,678	Wooden planks, furniture, crates
Metal	5,816	Concrete bars, house grills, fences, pipes, kitchen utensils, furniture, barrel, cans.
Concrete	23,742	Bricks, concrete blocks, culverts
Plastics	448	Pipes, containers, bags, polystyrene
Rubber	5,413	Shoes, mattress, tyres
Textile	1,041	Clothes, rags, other textile materials
Paper	23	Newsprint, mixed paper, corrugated papers
Mixed combustible	2,171	Furniture (sofa), other organic waste
Electronic wastes	835	Household appliances, IT gadgets

The recycling options which may include reuse of the material for similar purpose such as concrete waste to be mixed with additive to produce concrete, reprocessing of waste to generate new items such as the reprocessing of plastic into other plastic products, or even for energy conversion, can be incorporated in order to maximize the usage to its fullest potential. Otherwise, some of these wastes can be sold for reasonable income for the local municipalities and/or waste managers. Table 2 lists the different recyclables with their potential to create economic gains from the flood waste stream in Kelantan.

Table 2 Estimated revenue to be obtained from recyclables in flood waste in Kelantan.

Recyclables	Price per kg	Estimated generation (kg)	Estimated Selling revenue (RM)
Plastic	RM0.20	633,297	126,659
Metal	RM0.40	7,247,136	2,898,854
Glass	RM0.10	310,024	31,002
Wood	RM1.25	1,668,514	2,085,642
Concrete	RM0.08	22,648,088	1,811,847
TOTAL	**RM 6,954,004 (USD 1,630,700)**		

It is obvious that there is a huge potential to generate economic gains by diverting the recyclables from the flood waste stream in Kelantan. However, there are several challenges faced by the relevant stakeholders, namely local municipalities and the waste managers. Among the obvious challenge is the high contamination level of the recyclables. This is due to the fact that the flood wastes were highly comingled with other contaminants including dirt and mud, thus this reduced its market value. In addition to that, the items contain high moisture level that values for items like wood and paper is reduced. Since the waste is very mixed, separation activities can be very difficult and expensive. Also, a dedicated area is needed if waste separation is to be conducted. The fact that the clearing of flood waste in these area was conducted on an *ad hoc* manner, to expedite the cleaning process and to avoid spreading of disease, the challenges are found highly tedious to be immediately overcame. Thus, proper planning by the government is necessary including provision on the guidelines in flood waste handling. This not only will enable some economic benefits from the recycling option but also allow the waste to be managed in a more sustainable manner where it does not create pollution, while reduce the dependency for virgin resources. Hence waste sent to landfill will be reduced.

CONCLUSION

This study reveals that flood wastes generated in many countries including Malaysia are highly dominated with concrete and wood waste, in addition to other recyclable items. Therefore, there is a high potential to tap this source prior to its disposal to landfills. Significant economic gains can be obtained via recycling strategy while reducing the dependency to landfill disposal. Nevertheless, many challenges will arise in order to execute such a practice, including the low quality recyclables and its highly mixed nature. Yet, this issue can be solved if proper guidelines in handling the flood waste are available. Not only it would ensure the utilization of the available resources namely the recyclables, but it will also provide a more sustainable waste management strategy for the country in dealing with its disaster waste.

ACKNOWLEDGEMENT

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Collection of NaCl, KCl, RbCl and CsCl by ice-cooled copper tube in a coiled form: a laboratory study

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Abstract

Collection efficiency of alkali metal halides (NaCl, KCl, RbCl and CsCl) in flue gas from waste incinerator has been concerned since the accident of nuclear power plant. Examination of gas including gaseous, fine particles (0.1 — 2.5 μm) and ultrafine particles (<0.1 μm) is indispensable for gas measurement. The article describes a simple gas sampling method using ice-cooled copper tube in a coiled form (ICTC). Alkali metal halides sampled in the ICTC sampling train condense and coagulate followed by collision against the wall induced by centrifugal movement. By flushing the tube with water, the alkali metal halides are dissolved and recovered. Volatilized and partially condensed four kinds of alkali metal halides were introduced the ICTC sampling train and recovered. Two tubes in serial captured them perfectly.

Keywords: Gas sampling, Cesium chloride, Fine particles, Bag filter

Introduction

Waste combustion can be a source of fine particles (0.1 — 2.5 μm) and ultra fine particles (<0.1 μm). The mechanism of formation is volatilization in combustion zone followed by condensation and nucleation in flue gas, which have been evidenced for metallic compounds [1] and alkali metal halides [2]. These particles are of concern from a viewpoint of gas/particles separation, for which "annual denuder tube followed by filter" has been applied [3, 4]. In particular, ultra fine particle is important because of its notable toxicity [5]. However, sampling of ultra fine particles faces some problem; namely, a traditional gas impinger method recovered only several decades percentage [6].

After the accident of nuclear power plant in Japan, behavior of Cs in waste combustion has been focused [7]. A predominant form in the process is thought to be CsCl, which is volatile in combustion zone, however, would condense as being cooled. Before bag filter, both gaseous and particulate form are possible for CsCl. Collection efficiency of "particulate Cs" at bag filter in municipal solid waste combustion has been reported to be more than 99.9% in general by the survey of NIES [7]; however, gaseous and ultra fine particles might be missed through the sampling train, because the employed gas sampling train was thimble filter collection followed by gas bubbler.

The paper is for improving the sampling method of alkali metal halides including CsCl in gaseous and particulate phase. Considering that alkali metal halides condense and coagulate as being cooled, a new gas sampling method using an ice-cooled copper tube in a coiled form (ICTC) is now attempted. The gas is introduced into ICTC, in which gaseous alkali metal halides condense; afterwards, they collide against the inner surface of the tube by centrifugal force. After gas collection, the deposition of alkali metal halides inside the tube is recovered by flushing with water. The different point between ICTC and denuder tube is their temperature and shape; namely, ICTC cools analyte to turn to condensed phase, and captures the particles by centrifugal movement, whereas linear denuder tube collects only gaseous analyte by diffusion to inner wall. Besides, flushing the ICTC with water just before the sampling makes the inner surface wet; thereby, alkali metal halides will be dissolved. The paper describes laboratory test of ICTC by introducing vaporized and partially condensed NaCl, KCl, RbCl and CsCl.

Experimental

Materials

Sodium chloride (NaCl, > 99.5%), potassium chloride (KCl, > 99.5%), rubidium chloride (RbCl, > 95.0%), and cesium chloride (CsCl, > 99.0%) were purchased from Wako Pure Chemical (Japan). Copper tube for gas piping (od 3 mm, id 2 mm, GL Science, Japan) was used.

Volatilization of alkali metal halides

The scheme of the instrumentation is given in Fig 1. An quartz tube with a tapered end was heated by two serial furnaces (heated length of 300 mm for each): 1st furnace was adjusted at 900ºC for volatilization and 2nd at 200ºC. An ceramic heat insulator(thickness of 30 mm) was placed between the two furnaces. The tapered end of the quartz tube was inserted into a glass holder of thimble filter in the region of 200ºC, the outlet of the holder was connected to the gas sampling train. In this study, no thimble filter was set at the holder, because the purpose of the examination was to check recovery rate of volatilized alkali metal halides.

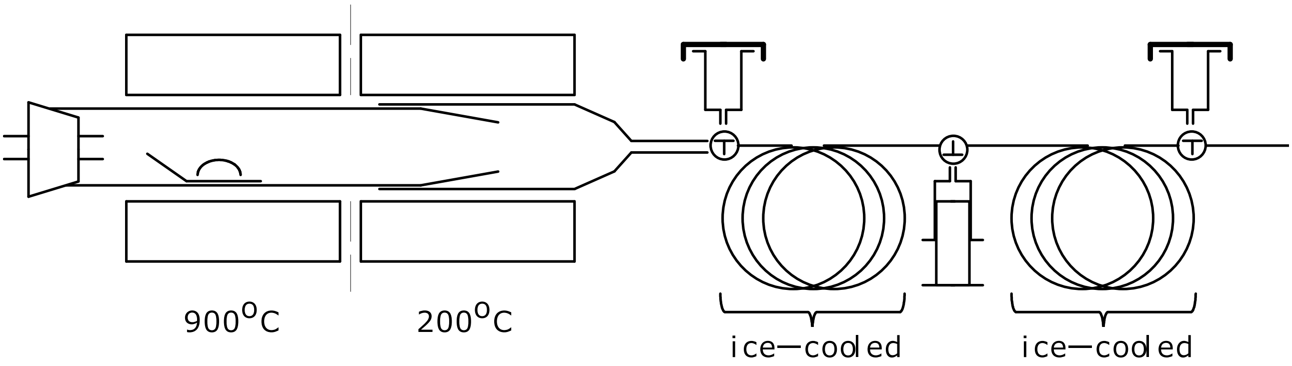

Fig 1 Alkali metal halides mounted on a flat-shaped boat was volatilized in the quartz tube at 900ºC. The gas was introduced into the glass holder whose end was connected the ICTC sampling train. The analyte from the ICTC sampling train was flushed with water and recovered at the interim syringe.

Gas sampling by ice-cooled copper tube in a coiled form (ICTC)

The ICTC was a copper tube (od 3 mm and id 2 mm) of 5 m long in a coiled form whose diameter was 10 cm. The train of gas sampling line consisted of the front three-way cock, 1st ICTC, the interim three-way cock, 2nd ICTC and the rear three-way cock in a series. Gas was suctioned at a rate of 4 L min^{-1} from the rear three-way cock.

After gas sampling, the analyte was collected by flushing with water. When the 1st ICTC is flushed, 10 mL of water was poured to a reservoir attached to the front three-way cock followed by drawing the syringe at the interim three-way cock. In the same way, the flushing water from the 2nd ICTC was supplied from the reservoir at the rear and collected at the interim. The reservoirs at front and rear three-way cocks was kept attached and capped throughout the experiment in order to minimize blank value induced by any contamination.

Determination of alkali halides by electric conductivity

The concentration of alkali metal halide in the ICTC-flushed water was determined by electric conductivity (EC). The instrumentation used was EC detector in ion chromatograph (Shimadzu PIA-1000). The sample was injected and directly transferred to EC detector; whereby, peak area signal [μ V・s] was proportional to EC.

Procedure

One milligram of NaCl, KCl, RbCl or CsCl was mounted on a flat-shaped boat. After placing the boat inside the quartz tube at the zone of room temperature, the gas suction of 4 L min^{-1} was started. The ICTC train was flushed with deionized water, whose EC was measured several times until the blank value became stable. Subsequently, the boat was placed in the 900°C region to volatilize the sample for 6 min. Collecting ICTC-flushed sample at the volume of 10 mL for each ICTC, the EC was separately measured. Subtracting blank EC value, concentration of alkali metal halide was determined.

Results and discussion

Quantification of alkali metal halides

Analytical curve of EC versus concentration of alkali metal halide was proportional in the range of 0.1 ~ 40 mg L^{-1}:

C_{Na} [mgNa L^{-1}] = 309 000 S (NaCl as standard);
C_{K} [mgK L^{-1}] = 158 000 S (KCl as standard);
C_{Rb} [mgRb L^{-1}] = 103 000 S (RbCl as standard);
and
C_{Cs} [mgCs L^{-1}] = 70 000 S (CsCl as standard).

where,
S: peak area [μ V・s].

Volatilization from boat

All four kinds of alkali metal halides mounted on the flat-shaped boat was completely volatilized with the condition of 900°C and 4 L min^{-1}. The shape of the boat was important to blow off total alkali metal halide as well as temperature and gas flow rate.

Capture of alkali metal halides in ICTC

Figure 2 denotes the amount of alkali metal halide mounted on the boat and collected at the ICTC train. The ratio of collected NaCl and KCl to the mounted amount on the boat was 45 ~ 46%. The rest remained in the quartz tube, which was observed to become white; in other words, devitrification occurred.

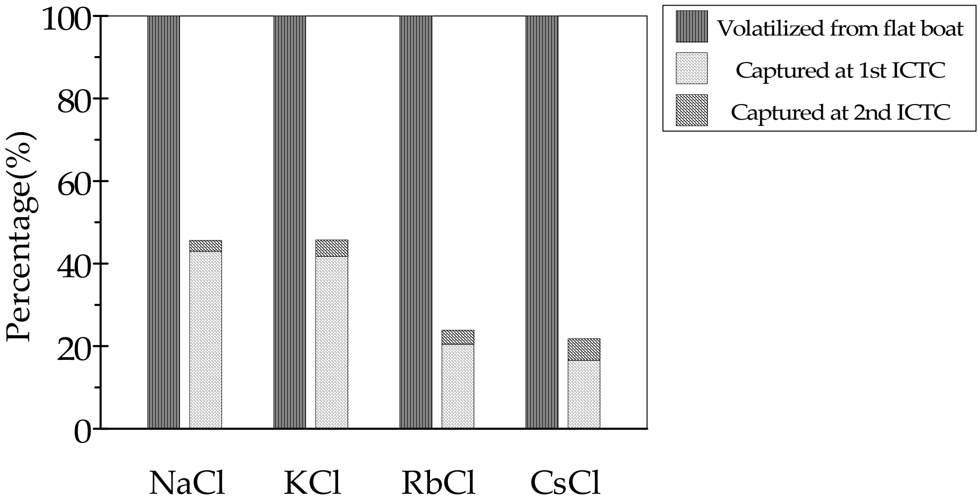

Fig 2 Alkali metal halides mounted on flat boat and recovered at ICTC sampling train

Of the collected NaCl and KCl, more than 90% was in the 1st ICTC. Since no gaseous NaCl and KCl can not exist in the ice-cooled condition, the collection of those compounds including fine and ultrafine particles was considered to be perfect.

The ratio of collected RbCl and CsCl to the mounted amount on the boat was as low as 24 and 22%, respectively. The reactivity of gaseous RbCl and CsCl was thought to be higher than NaCl and KCl. If only condensation would occur in the quartz tube, more RbCl and CsCl could survive than NaCl and KCl, because the volatility of RbCl and CsCl is higher than that of NaCl and KCl. However, the experimental results have shown the reverse; in other words, gaseous RbCl and CsCl should have reacted with quartz tube more intensively than NaCl and KCl.

The distribution between 1st and 2nd ICTC was 86 to 14% for RbCl, and 77 and 23% for CsCl, which indicated that CsCl can produce smaller particles than others. Cooling followed by condensation in the ICTC was very critical. During the process of the study, stainless tubing was tried prior to copper; however, it resulted in incomplete collection. Supposedly, the reason was due to the difference of heat transfer efficiency. Copper tubing could cool the vapor quickly; thereby, alkali metal halides condense immediately, while stainless tubing could not.

Importance of blank control

In the next step of this study, a capture efficiency by thimble filter is to be examined. Quantification of alkali metal halides in trace level is needed; namely, stable analytical blank is absolutely necessary. However, at this stage, the blank EC of 1st and 2nd ICTC was considerably high, i.e. 50000 μV・s and 20000 μV・s, respectively. They are equivalent with 1.6 and 0.6 μgNa; 3.2 and 1.3 μgK; 4.8 and 1.9 μgRb; and 7.1 and 2.9 μgCs. It is deemed that the origin of the blank EC is corrosion of copper induced by air. The problem must be solved to study thimble filter collection efficiency.

Conclusions

A new gas sampling method to collect alkali metal halides such as NaCl, KCl, RbCl and CsCl was developed and checked with volatilized alkali metal halides. The instrumentation was ice-cooled copper tube in a coiled form(ICTC), through which the sample was introduced. Being cooled, gaseous alkali metal halides condense and coagulate in a coil-formed narrow tube, in which the particles deposit inside the tube forced by centrifugal movement. The tube was flushed with deionized water to dissolve the deposition. An collection efficiency was checked by two serial ICTCs; thereby, satisfactory result was obtained. Minimization of blank should be furthermore accomplished.

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Evaluation of building debris of Kathmandu Valley, Nepal after Gorkha Earthquake and its potential treatment option

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ABSTRACT

Significant quantities of building waste were generated from the collapsed residential buildings and dilapidated buildings as a result of disastrous Gorkha earthquake struck Nepal on 25 April, 2015. The building waste consists of the large fractions materials that can be used or recycled. To reduce the amount of primary resource usage and the cost of clearing and final disposal of the disaster waste, building material from the waste should be reclaimed and recycled with thoughtful planning. In this paper, in relation to the field damage investigation of the earthquake hit area and based on the building types, different types of building waste produced from each building is estimated and evaluated. A mathematical model for quantifying the specific building materials from each type of building per unit area and total building waste is proposed. Also the treatment potential of the building waste are analyzed to determine actual recycling, reusing and landfill amount of building waste from each building type. Finally, the treatment potential of building waste material will guide the related stakeholders to manage disaster waste as well as to reclaim the useful building materials from the disaster waste make the post-earthquake reconstruction environment friendly and cost effective.

Keywords: Gorkha earthquake, building types, building waste, treatment potential

INTRODUCTION

On 25th April 2015, Nepal was hit with a powerful Gorkha Earthquake of magnitude M 7.8 with the epicenter at Barpak, Gorkha, 80 km northwest of Kathmandu Valley. Again, on 12th May 2015, major aftershock of magnitude M 7.3 caused large devastation in 14 districts of Nepal. According to the Government of Nepal, a total of 8,856 people lost their lives and 22,309 people injured, over 600,000 buildings are completely collapsed and more than 280,000 buildings are partially damaged in the whole country.

Kathmandu is the Capital of Nepal and Kathmandu valley consists of 3 districts, Kathmandu, Lalitpur and Bhaktapur and was hit severely by the Gorkha Earthquake destroying 73,317 buildings fully and 67,871 buildings partially (SWMTSC, 2015). The large amount of the debris waste generated after the earthquake has become a big problem as it occupies large space and management of this enormous amount of building debris with proper treatment is becoming the challenge to the government (Xiao, J., Xie, H. et al., 2012). Building materials are the important resources to reclaim the construction materials for new construction of the infrastructures in reconstruction phase which can supply the demand of aggregates and building materials to larger extent with reduced extraction of virgin materials from the nature with reduction in energy and emission for processing of these materials (Yang, C.P., 2009). Proper data of the building debris is necessary for planning appropriate treatment options which in turn helps the concerned agencies to formulate appropriate strategy to reduce the cost in clearing the debris. For the post-earthquake reconstruction, the building waste is not only the burden but also resources which ought to be considered to be reclaimed.

So, the assessment of the building waste should be made accurately and scientifically with special attention regarding the problems. Collecting the data of amount of building waste from different building materials is important for better reclaiming of building waste. This data is useful for the strategy of treatment and resource utilization in the post-earthquake reconstruction activities.

METHODS

The method of the study is based on the case study by assuming the fact that the amount of building debris is equivalent to the amount of building materials used during construction in the building. For this purpose, buildings constructed in Vyas Municipality, Tanahun, Nepal are chosen to represent the building types. Based on the experience of author as Civil Engineer in Nepal, the buildings of similar made in urban area are similar all over Nepal. With the details drawings and estimates of the public buildings and the drawings of the residential buildings obtained, detail quantity for residential buildings is estimated and quantities of building materials for the different building types are calculated for the analysis purpose. Types of the buildings area a.) 2 storied Reinforced Cement Concrete (RCC) roofed RCC frame building; b.) single storied RCC roofed RCC frame structure and c.) Corrugated Galvanized Iron (CGI) sheet roofed load bearing building in public building case. Similarly, types of buildings were two examples of 2 storied RCC roofed, RCC frame building and two examples of single storied CGI roofed load bearing building in residential building case. Also for the purpose of analysis, quantity estimates for RCC roofed, load bearing building are produced from RCC roofed, RCC frame buildings by replacing quantities of footing, beams and columns of RCC framed structure by masonry footing and column with increment of the wall thickness by 1.5 to 2 times as that of RCC framed structure. Total and individual quantities of each building materials are calculated. Also, the total and individual quantities of each material per square meter of the plinth area of buildings are calculated.

The amount of building waste can be calculated according to the following equation for different types of the building.

$$\mathbf{Q_i} = \sum_{\boldsymbol{c}} \sum_{\boldsymbol{m}} \sum_{\boldsymbol{k}} \boldsymbol{F(c)} * \boldsymbol{M(c, m, k)} * \boldsymbol{R(m, k, i)} \ldots\ldots\ldots \mathbf{(1)}$$

Where, **Q** is the total quantity of the debris waste generated, **F** is floor area of the building (m^2), **M** is quantity of building material (Kg/m^2), **R** is treatment option ratio (Percentage), **c** is type of building, **m** is materials of building, **k** is types of particular material , **i** is treatment type (reuse, recycle and landfill)

For the treatment of each type of building waste materials, treatment options reuse, recycle and landfill are the best options in case of Nepal and are applied for the research. Further, reusability, recyclability and landfill of each type of building waste materials are assumed as per Nepalese context. For this, the 55% bricks can be reused, 33% can be recycled as base aggregate materials and remaining dust and waste for landfill. Similarly, reinforcement bars can be sent for recycling upto 97%; concrete from the structural parts can be recycled upto 90% and 80% from cement plaster, flooring, foundation etc. Also 75% of the wood/timber is reused and 25% can be recycled to use the wood in other form or use as fuel wood. Wood/timber doesn’t need to landfill. Metals like truss pipe, chain gate, rolling shutter etc. are 25% reused and 75% recycled. CGI sheet is reused almost 55% and 45% recycled. These assumed proportions for different building waste are used to determine the quantity of each building materials per square meter for different types building under consideration. Also the quantity of individual material type, quantities of each material under different treatment and total quantity of all materials can also be determined with the help of plinth area, building type and number of the buildings.

RESULTS AND DISCUSSION

From the calculation, the quantity of each building waste and total waste per square meter is calculated as shown in Table1. This shows that the RCC roofed, RCC framed building and RCC roofed, load bearing building of similar storied type produce almost equal building waste in total in both case of public and residential building type. The total quantity of waste produced by a single storied RCC houses per square meter of plinth area are also close to each other. However the amount of building waste produced per unit areas of similar made differ with the number of stories as well as for public or residential purpose. Total building waste produced per square meter of plinth area for the CGI roofed, load bearing building is the least among the house types in both case of public and residential building type.

Table 1: **Composition of main constituents of different type of buildings**

Weight of Materials (tons) per sq.m. of different conditions of buildings

S.N.	Building Materials	P1 RRRF 2S	P1 RRLB 2S	P2 RRRF 1S	P2 RRLB 1S	P3 CGRLB 1S	R1 RRRF 2S	R1 RRLB 2S	R2 RRRF 2S	R2 RRLB 2S	R3 CGRLB 1S	R4 CGRLB 1S
1	Masonry (Bricks/Stone)	0.99	1.43	1.71	2.28	1.45	1.44	2.37	1.53	2.20	2.03	2.16
2	Concrete and Cement finish	0.95	0.56	1.30	0.77	0.40	1.40	0.76	1.26	0.66	0.48	0.56
3	Reinforcement bars	0.03	0.01	0.05	0.01	0.00	0.04	0.01	0.04	0.01	0.00	0.01
4	Wood/Timber	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5	Others	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.01	0.01	0.03	0.03
	Total	**1.98**	**2.01**	**3.08**	**3.06**	**1.89**	**2.89**	**3.15**	**2.84**	**2.88**	**2.55**	**2.76**

P-- Public Building **R**--Residential Building **2S** -- 2 Storied **1S** -- 1 Storied

RRRF--- RCC Roof and RCC Frame **RRLB**--- RCC Roof and Load Bearing Wall **CGIRLB** ---- Corrugated Iron Sheet Roof and Load Bearing Wall

Considering the case of building types in Nepal and China as shown in Figure 1 and comparing between the RCC roof, RCC framed and RCC roofed, load bearing, total waste produced per square meter of plinth area is more in Nepalese case. Also the proportion of use of brick more higher than concrete in Nepalese case but the concrete proportion is fairly more in Chinese building and use of brick is much less.

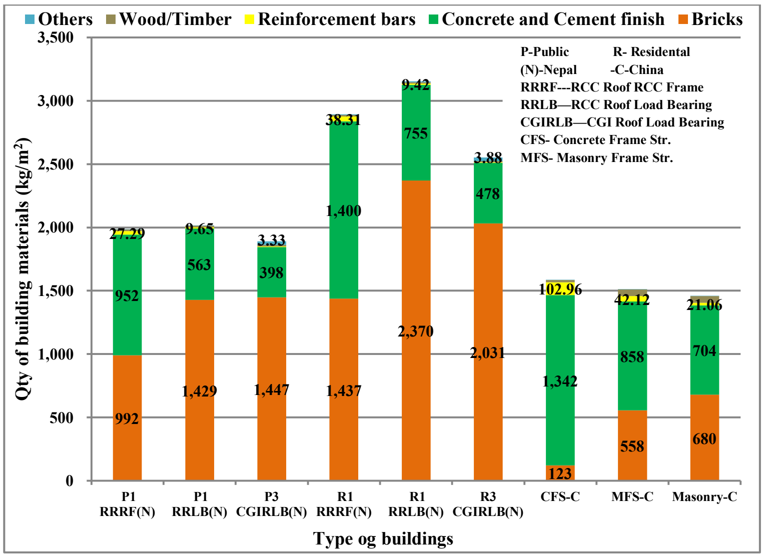


Figure 1: Comparison of total building waste per sq.m. in Nepal and China (Xiao, J., Xie, H. et al., 2012)

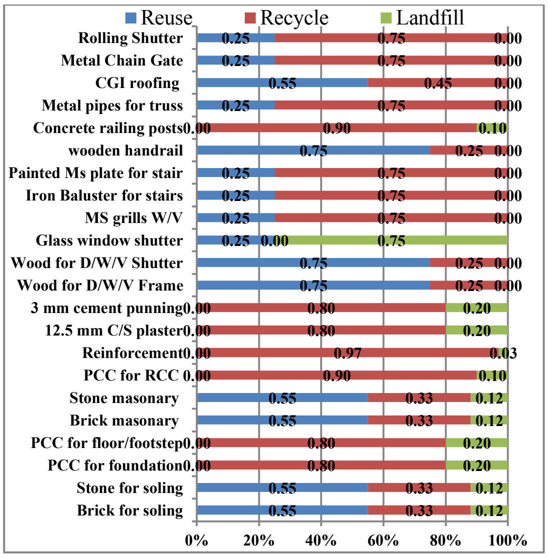
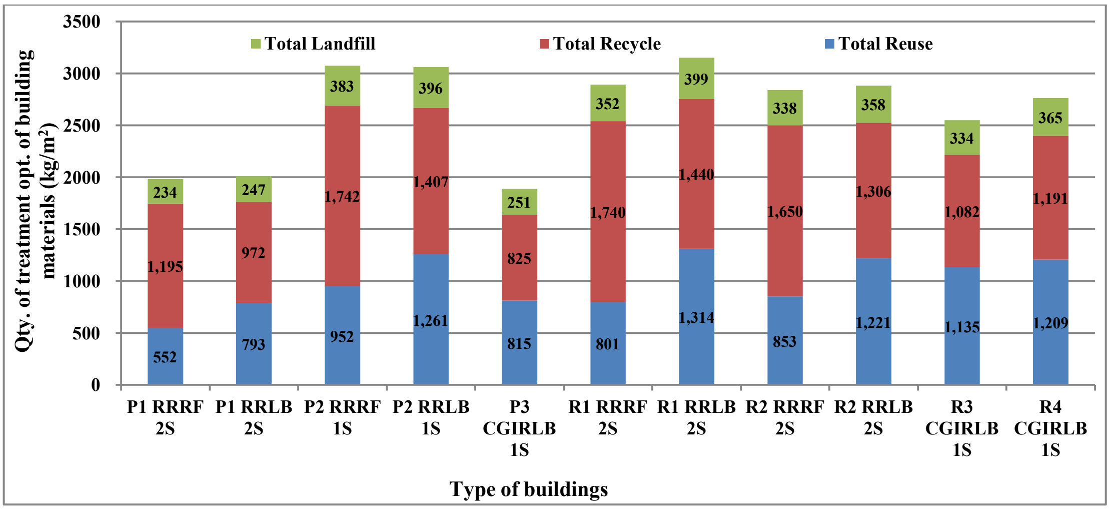


Figure 2: Tentative treatment potential of building waste

Tentative treatment potential of the building waste is given in Figure 2 for each of the building materials. According to this, the treatment options like reuse, recycle and landfill of the building materials from the debris are calculated per square meter of the plinth area and shown in Figure 3. From this it is seen that the quantity of masonry is more for load bearing (LB) wall type than RCC frame type, as the thickness of the wall is more in this case to bear the structural load whereas the load is taken and transferred by the RCC frame (beams and column) in framed structure. So the thickness of the wall in RCC framed structure is less.

The potential of recyclable fraction of the building debris is the maximum for each type of the building. Similarly, the second largest fraction is the reusable materials and landfill in the least fraction.



P-- Public Building
R--Residential Building
2S -- 2 Storied
1S -- 1 Storied
RRRF--- RCC Roof and RCC Frame
RRLB--- RCC Roof and Load Bearing Wall
CGIRLB ---- Corrugated Iron Sheet Roof and Load Bearing Wall

Figure 3: Potential treatment quantities of building waste per unit area of different types of buildings

Treatment percentage for the different building materials, for which the recycling percentage is 42-64%, reuse percentage is 24-44% and the landfill percentage is 11-13% among all types of the building.

CONCLUSION:

The quantity of individual and total building waste per unit area is different for buildings of different structural form as well as the number of stories of the building. Similar type of buildings generate different amount of waste in different proportion per unit area in different country scenario. Large fraction of waste from each type of building is brick and concrete waste. The treatment options for building waste can manage the post-earthquake debris management and reconstruction by allowing around 90% of building materials as resource by reusing it or by recycling and very less amount to be disposed to the landfill. In future, based on this estimate and calculation with the data of damaged buildings with structural types, floor area, number of stories and the actual treatment potential ratio; the exact amount of individual and total building waste can be determined for the specific treatment option and final management.

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Research on Tracking Routes of Simulated Debris Released from Coastal Areas of Tohoku Region in Japan

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ABSTRACT

The purpose of this research is to contribute to the development of countermeasures to help prevent secondary disasters that may happen in the future by tracing tracking routes of marine debris generated by the tsunamis of the Great East Japan Earthquake using simulated debris. According to the results of investigation for the tracking routes of simulated debris released from the coastal areas of the Tohoku region are as follows: (1) As a result of releasing 18 pieces of simulated debris, two washed ashore on the Japanese coast, while four reached the western coast of the North American continent in Canada and the US. (2) Many pieces of the simulated debris were caught up by the western garbage patch where marine debris in the Pacific Ocean accumulates, but some of them escaped from the patch and floated eastwards. (3) To understand the tracking routes of marine debris in the Pacific Ocean, it is necessary to investigate the detailed conditions of western and eastern garbage patches in the future.

Keywords: tracking route, simulated debris, Great East Japan Earthquake, marine debris

INTRODUCTION

Disaster waste generated by the Great East Japan Earthquake and the subsequent tsunamis, that which washed ashore in coastal areas not only hindered the navigation of ships by blocking ports and harbors but also had a strong impact on industrial activities and the living environment of these areas. To solve "marine debris problems" on the Japan Sea side of Western Japan, where waste that is considered to come from overseas and inland areas of Japan is washed ashore regularly and in large quantities, our university has promoted research on the relationship between the sources of emissions and the generation of marine debris and the solution of the actual situation of generation of debris washed ashore. Additionally, we have promoted measures to reduce the generation of marine debris and recovery treatments during the three years from FY2009 to FY2011. All of these activities have been performed as a research project approved for Grant-in-Aid for Scientific Research about Establishing a Sound Material-Cycle Society, the Ministry of Environment. Furthermore, while developing these research results, we conducted research on the marine debris caused by the earthquake over a two year period starting in FY2012 as a research project approved with the same funding by the Ministry of the Environment. The purpose of this research is to contribute to the development of preventive measures to help prevent secondary disasters that may happen in the future by tracing the movement routes of marine debris generated by the tsunamis of the Great East Japan Earthquake using simulated debris and then summarizing what damage could take place, along with measures to minimize the damage based on the investigations of previous disasters, and proposing ways of transmitting information to interested parties and associated institutions in Japan and overseas in order to take advantage of the information. Since FY2014, we have continued an investigation tracing the tracking routes of simulated debris with Argos transmitter as our voluntary investigation. The results are reported below.

METHODS

The simulated debris used for this investigation were containers that were released containing Argos System Transmitters developed by Nomad Science Inc.

The Argos System Transmitter is a mechanism that calculates the position of a transmitter and accumulates information on a server by analyzing the Doppler effect of a radio wave that reaches a special satellite from the transmitter. Users can access the server via the Internet to obtain positioning information. On whichever ocean the transmitter is, when the satellite passes over the transmitter, positioning information can be obtained. The satellite passes over each transmitter a few times a day.

Our university released simulated debris equipped with Argos transmitters three times in FY2011. In FY2012, we continued to measure positioning information and conducted a 4th release in January 2013. The types, properties and release conditions of the simulated debris used in the release tests during the four times in total are shown in Figure 1.

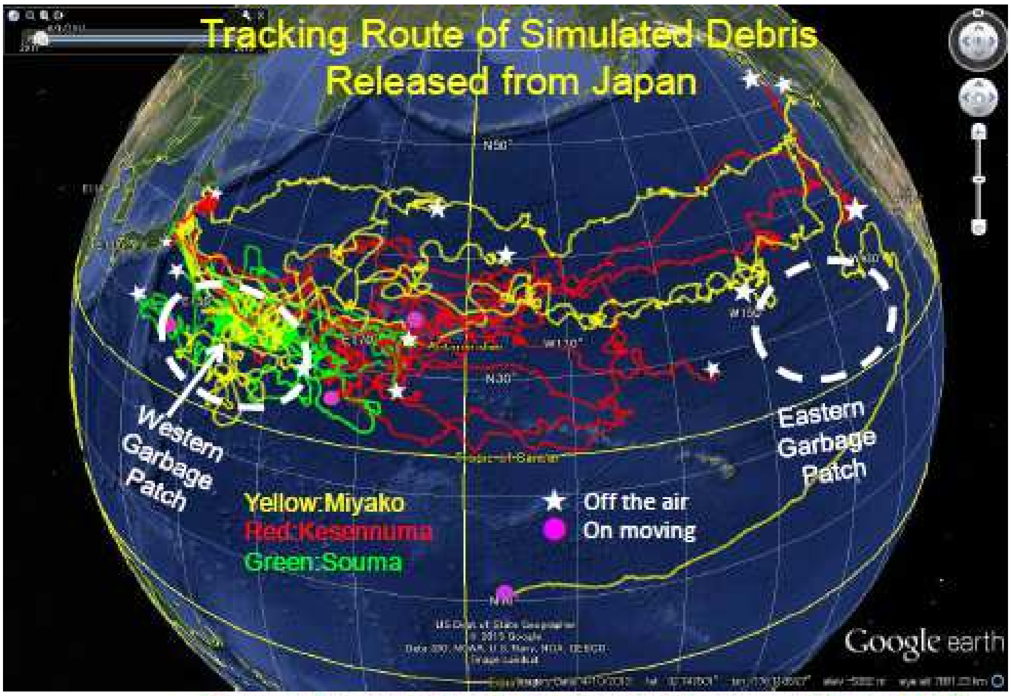
With annual improvements being applied, the life of the batteries in the simulated debris is assumed to be within six months for the 1st release, within 30 months for the 2nd and 3rd releases and within 60 months for the 4th release. The positioning information is thus observed at present for the four simulated debris released during the 4th release in January 2013 with no communication interruptions, while only the positioning information of the two floating type debris released from offshore Miyako and Kesennuma are continually understood.

RESULTS AND DISCUSSION

Figure 2 shows the routes of the movement of the total 18 simulated debris released thus far. Results of the observed floating debris on the ocean generated by the earthquake show that in addition to those that washed ashore onto Japanese coastal areas of the Pacific Ocean, one piece

Type of simulated debris	Subsurface type 	Standard type 	Floating type 
Sinking rate	82%	35-50%	13%
Actual floating debris assumed	Driftwood and wood containing seawater	Refrigerators, tires, containers, etc.	Floating ships and buoys
Influences they were subject to	Strong influence of ocean currents	Both ocean currents and wind	Strong influence of wind
Number of debris	3	12	3
Time of release #1 Time of release #2 Time of release #3 Time of release #4	January 2013	June 2011 October 2011 January 2012 January 2013	January 2013
Point of release (Common for 4 releases)	Offshore Miyako, Iwate Prefecture Offshore Kesennuma, Miyagi Prefecture Offshore Soma, Fukushima Prefecture		

Figure 1. Types, properties and release conditions of simulated debris released



Sustainable Research Institute, Tottori University of Environmental Studies (TUES)

Figure 2. Routes of the movement of the total 18 simulated debris released from coastal areas in the Tohoku Region

of simulated debris released from offshore Miyako, Iwate Prefecture washed ashore on the coast of the state of Oregon, US, one year and nine months afterward and three more pieces of simulated debris reached Canada and the west coast of the US following that. As these pieces of simulated debris showed no signs of any attachment of marine organisms, it thus turned out that the negative influences on the ocean eco-system on the coast caused by the arrival of floating debris in the ocean, which was a matter of concern on the US side, was not necessarily caused by debris washed that ashore and was therefore possibly limited.

In addition, as a secondary disaster of floating debris caused by the earthquake, the arrival of debris on the west coast of the US, islands and other coastal areas attracted attention, but as Figure 2 shows, some are caught up in the currents of the Pacific Ocean and remain there, and it has turned out that some debris has reached both the eastern and western patches of the Great Pacific Garbage Patch.

CONCLUSION

(1) As a result of releasing 18 pieces of simulated debris from the coast of the Tohoku Region, two washed ashore on the Japanese coast, while four reached the western coast of the North American continent in Canada and the US.

(2) Many pieces of the simulated debris were caught up by the western garbage patch where marine debris in the Pacific Ocean accumulates, but some of them left the patch and floated eastwards.

(3) Attention should be paid to the fact that one of the pieces of simulated debris (floating object on the ocean released from offshore Miyako) moved south along the west coast of the US and then further west at low latitudes.

(4) To understand the routes of the movement of marine debris in the Pacific Ocean, it is necessary to investigate the detailed conditions of western and eastern garbage patches in the future.

ACKNOWLEDGMENT

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Session 13

MFA, SFA, IOA

Outlook for Future Material Flows of Mercury in Japan in context of the Minamata Convention on Mercury

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ABSTRACT

In response to the adoption of the Minamata Convention on Mercury, Japan is currently engaged in its ratification process. In order to consider the environmentally sound management of mercury, it is essential to have an understanding its future material flows. This paper aims to develop an outlook of mercury flows in Japan to 2030, focusing on atmospheric and waste emissions from industrial uses and the disposal of mercury-added products. Mercury emissions from industrial uses are not expected to change significantly from the current status except for a decrease in emissions from waste incinerators, due to the limited impact of new regulations based on the amended Air Pollution Control Act. Meanwhile, emissions from the disposal of mercury-added products are expected to decline steadily, in accordance with the scheduled phase-out of mercury use in products, with emissions estimated at approximately three tons in 2030. This study suggests that mercury discharged as by-product of industrial uses is likely to be the main mercury-related issue in Japan. Given that most mercury is currently recovered and exported, trends in future amounts of surplus mercury should be examined in light of future global trends in the supply-demand balance of mercury.

Keywords: mercury waste, material flows, surplus mercury, emission inventories, Minamata Convention

INTRODUCTION

The Minamata Convention on Mercury was adopted in Minamata, Japan in October 2013. Although Japan had already shifted to mercury-free alternatives in manufacturing processes, resulting in a significant decrease in domestic demand for mercury from a peak of approximately 2,500 tons in 1964 to 10 tons in recent years (MOEJ, 2014a), the Convention is still expected to have some impact on the flow of mercury in Japan. In the domestic ratification process for the Convention, Japan promulgated three pieces of legislation in 2015, including one new act: Act on Preventing Environmental Pollution by Mercury; Amended Air Pollution Control Act; and Amended Cabinet Order of Waste Management and Public Cleansing Act.

Figure 1 shows material flows of mercury in Japan. The main stream is the import of mercury contained in raw materials and fuels for industrial use (73 tons), and it is ultimately collected in the form of mercury-containing sludge discharged by industry, mainly from non-ferrous manufacturing. This mercury is refined either for export (72 tons) or for domestic production (8 tons). In order to consider adequate schemes for the environmentally-sound management of mercury, it is important to understand future flows of mercury. With respect to the impacts of the Convention, this paper estimates future flows of mercury, focusing on industrial uses and at mercury–added products.

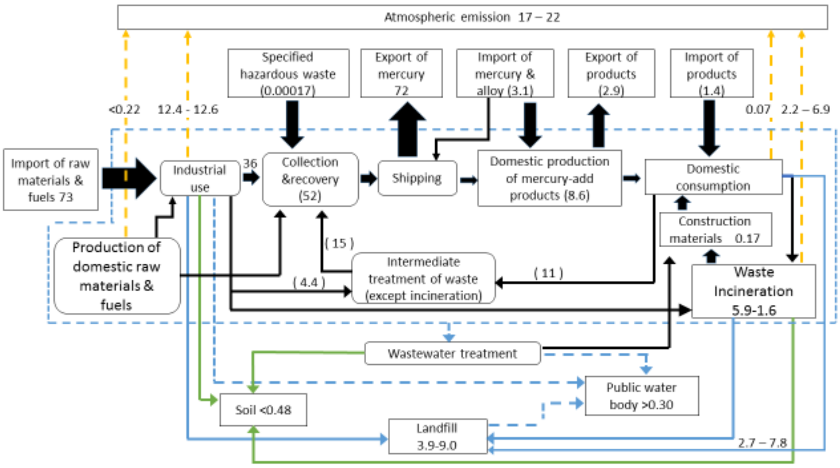

Figure 1. Material flow of mercury in Japan in FY2010 (MOEJ, 2014a)

MATERIALS AND METHODS

Estimated flows at points of industrial use

Based on the Air Pollution Control Act as amended in 2015, emission standards are required to be established for five types of facilities, corresponding to the Convention: coal-fired industrial boilers, coal-fired power plants, non-ferrous metal manufacturing facilities, waste incineration facilities, and cement manufacturing facilities. Although iron and steel production is not included in the categories of targeted point sources listed under Annex D of the Convention, due to its relatively large emissions of mercury in Japan, iron and steel production facilities are supposed to be designated as “facilities needing emission controls” for requiring voluntary actions to reduce emissions. Six facilities account for 94–96% of atmospheric emissions of mercury in Japan. The estimates of future mercury emissions from industrial uses, therefore, focus on those six facilities. Details of atmospheric emissions and emissions to waste or recovery of mercury are shown in Table 1 (MOEJ, 2013; MOEJ, 2014b). As there are different approaches to estimate emissions, country-specific measurement data is given a priority in this paper, where available and reasonable. A key point here is that those atmospheric emissions can be associated with a by-product or related waste stream.

Table 1. Details of mercury emissions from industrial use (to be updated in January 2016)

Category		Atmospheric emissions in FY2010 (t-Hg)	Emissions to waste or recovery in FY2010 (t-Hg)	Atmospheric emission factor	Related activity in FY2010	Atmospheric emission reduction efficiency
Coal-fired power plants		0.83–1.0	0.61	4.43 μg/kWh	232 TWh	–
Coal-fired industrial boilers		0.21	0.002	0.0454 mg/kg	17 Gt-coal	0.271
Non-ferrous metal production		0.94	37.2	18.6 μg/Nm^3	50 GNm^3	–
Waste incineration	Municipal waste	1.3–1.9	9.1–18.7	16–61mg/t	35 Mt	–
	Industrial waste	0.73–4.1	0.67–3.8	48 mg/t	22 Mt	–
	Sewage sludge	0.17–0.85	0.05–0.23	0.31–1.6 mg/kg	1.0 Mt-dry	0.479
Cement production		5.3	0	112 mg/t	47 Mt-clinker	–
Iron and steel production	Primary steel production	4.1	0.04	0.89–36 mg/t	225 Mt-production	–
	Secondary steel production	0.62	0.088	253 mg/t	25 Mt-steel	–
Other		0.84	2.2			
Total		17–21	50–63			

Atmospheric emissions of mercury to the year 2030 are estimated by the following formula, in accordance with a future scenario developed for this paper using future activity plans published by industries, in the context of environmental reports on measurements of greenhouse gas emissions:

$$E_{air} = \Sigma_i (CHG_i \times AC_i \times AF_i \times EE_i) \qquad (1)$$

E_{air}: Hg atmospheric emissions (t)
CHG: Hg concentration in raw material, fuel, or waste
AC: Consumption of raw material, fuel, or waste
AF: Factor on change of activity (by comparing with activity amount in base year 2010）
EE: Atmospheric emission reduction efficiency (calculated with ratio and type of facilities introducing exhaust gas treatment equipment)
i: Industrial category

Estimated flows in mercury-added products

With respect to demand for mercury-added products, most such products are expected to be phased out by 2020 in accordance with a schedule in Annex A of the Convention. Details for emissions of mercury from disposed mercury-added products (MOEJ, 2015) are shown in Table 2. A time lag between the production and disposal of products is considered in these estimates, in accordance with future scenarios developed for this research.

Table 2. Details of mercury emissions from mercury-added products

Products		Recovered Hg in FY2010 (t-Hg)	Product use of Hg in 2010 (t-Hg)	Average service life	Future scenario
Batteries		0.55	0.996	2 years (silver oxide)* 2 weeks (zinc-air)	Phased out by 2020, except for zinc-air batteries remaining at same level.
Switches and relays		0.34	0	–	Already phased out.
Lamps	CFLs/LELs	1.69	1.7	4.1 years (household) * 2.5 years (business)*	Replaced by LEDs by 2020.
	CCFLs/EEELs		0.88	900 days*	Replaced by LEDs by 2020.
	HPMVs		0.46	3 years*	Use for general lightning and cars will be phased out by 2020 (66% of HPMV).
Medical measuring devices		0.52	1.9	10 years* (sphygmomanometer)	Phased out by 2020. Assumed collection campaign of thermometers in 2017–2019.
Industrial measuring devices			0.85	–	Use for high-precision measurement will continue.
Others		1.9	1.19	–	Hg compounds for research and traditional uses remain at same level.
Total		5.0	7.9		

Note: The yearly disposal ratio is calculated by Weibull distribution, using 2.4 for shape parameter.

RESULTS AND DISCUSSION

Based on the scenarios developed for this paper, emissions from industrial use are not expected to change significantly by 2030, and they remain at approximately 17 tons to the atmosphere and 59-63 tons to waste per year, probably because their emissions are not intentional, and are directly related to the amount of activity and quality of raw material and fuels. Another explanation could be that atmospheric emission standards under the amended Air Pollution Act are expected to allow current emission levels to continue if an existing facility is equipped with exhaust-gas treatment equipment regarded as best available techniques and best environmental practices (BAT/BEP). Emissions from waste incinerators are expected to decrease in accordance with the phase-out of mercury in products.

Meanwhile, Figure 2 shows annual emissions from mercury-added products steadily decreasing, from 8.95 tons in 2017 to 2.83 tons in 2030. Lamps containing mercury will be mostly phased out of stocks within ten years after their production has ended, with the exception for high pressure mercury vapor (HPMV) lamps. Approximately three tons of mercury emissions from essential uses are expected to continue annually. If around 30% of mercury is recovered, the remaining mercury will be released to the atmosphere.

For methodologies used for estimates, there is a need to further elaborate the proportions of mercury emitted to the atmosphere and to waste, since gaps remain between input and output quantities in available statistics. Uncertainties relating to unknown stocks of mercury-added products should also be addressed.

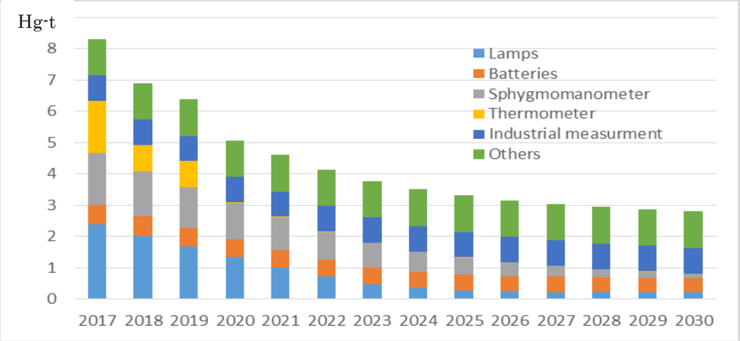

Figure 2. Future estimates of mercury discharged from mercury-added products

CONCLUSION

The aim of this study was to develop an outlook of future flows of mercury in Japan. Estimates developed for this study show that the largest quantities of mercury emissions will still be contained in sludge and dust discharged as by-products of industrial processes, which at low concentrations (<100 ppm) currently go to final disposal (landfill) and at high concentrations (>10,000ppm) go to recovery of mercury and to export (MOEJ, 2014b). Given that global mercury demand is expected to decline after 2020, there may be a surplus of mercury supplies, resulting in the need for early consideration of long-term storage and/or disposal in Japan. In this context, there is a need to estimate the amounts of possible future surpluses of mercury, based on consideration of the balance of global supply and demand of mercury.

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Current management practices of PBDEs containing wastes in automobiles by substance flow analysis in Korea

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ABSTRACT

Polybrominated diphenyl ethers (PBDEs), a class of brominated flame retardants, have been widely used in a various industry including automobile industry. This study focused on a quantitative substance flow analysis of PBDEs in automobile in order to identify the management practice of PBDEs containing waste in end-of-life vehicles (ELVs). In this study, the PBDEs were analyzed by field sampling to several ELVs treatment facilities with instrumental analysis using XRF and GC/MS method. The system boundary of substance flow analysis (SFA) included from manufacturing, use to disposal stage of automobile. Based on the results of this SFA study, it was investigated that ASR(automobile shredded residues) and seat fabric were the main components of PBDEs containing waste in ELVs. The major treatment channels of these components were incineration (68%), energy recycling (13%), and landfill (6%).

Keywords: PBDEs, ELVs, Substance flow analysis, Waste management practice, ASR

INTRODUCTION

Many previous studies have shown that various kinds of hazardous chemical substances can be found in concerning levels in end of life vehicles (ELVs), of which approximately 90 million unit of automobile was produced in the whole world in 2014.1),2) Among the hazardous chemical substances found in ELVs, polybrominated diphenyl ethers (PBDEs) are gaining global concerns as it was added as a new persistent organic pollutants (POPs) in 4th meeting of Stockholm convention (2009). In South Korea, recycling and treatment of ELV is regulated by the Korea electronic and ELV recycling law. In Korea RoHS regulation, there is no regulation for PBDEs in automobile whereas PBDEs concentration is limited less than 0.1% by weight for waste electrical electronic equipment (WEEE)3). In addition, there is very few available information regarding PBDEs level in ELVs as well as distribution channel of PBDEs in life-cycle of automobile. From this background, the aim of this study were 1) to investigate the substance flow of PBDEs in automobile through the analyzing the ELV samples as well as statistical assumption of mass flow of automobile, and 2) to identify management practice of PBDEs containing wastes in ELV.

MATERIAL AND METHODS

Sampling and instrumental analysis

92 automobile component samples and 36 automobile waste samples were taken from 9 ELVs and 14 automobile waste treatment sites. Samples were collected from 6 different types of automobiles from automobile junkyards and 5 different regions of automobile waste treatment facilities in Korea. Automobile seat fabric, seat polyurethane foam(PUF), interior lights cover, floor covering, headliner, seat belt, shredded bumper, ASR(Automobile Shredded Residue), door trim fabric, dash board, sound proof material, fuel line are included in the samples. First, a screening survey of bromine (Br) in each sample was conducted by using a X-ray fluorescence (XRF) analyzer. The samples containing 0.01% by weight of Br were selected for further chemical analysis. Identification and quantification of PBDEs were performed by GC/MS (Gas Chromatography Mass Spectrometry).

Method and assumption of SFA

SFA was conducted by using STAN 2.5 for easy graphical interpretation. The system boundary for the SFA included from manufacturing to disposal stage of automobile, as depicted in Figure 1.

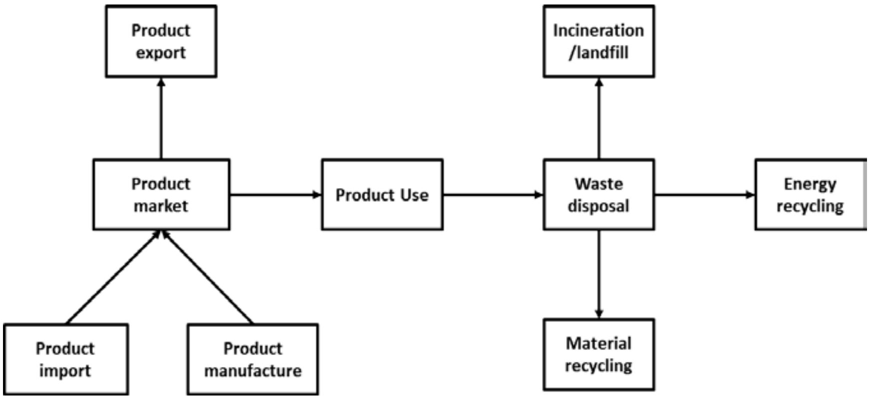

Figure 1. Life cycle of Product

The number of automobile of each life cycle with the average weight of each component (ASR, seat fabric) was used to calculate total amount of the input in the system boundary$^{4)}$.

Data collection

In this study, the relevant data were collected from available statistical reports (Korean Statistical Information Service, 2015; KECO, 2015) and literature review (KEI, 2015). Several field site visits to ELVs treatment facilities were made to interviews with the experts.

RESULT AND DISCUSSION

Result of PBDEs concentration in samples

The XRF survey showed that 34 out of 128 samples investigated (27% of the total) contained more than 0.01% by weight of Br, indicating that the use of PBDEs in ELVs is limited. Among the 34 samples exceeding 0.01% by weight of Br, all of the samples employed for further chemical analysis. Subsequent analysis by GC/MS showed that 28 samples were treated with PBDEs (Table 1).

Table 1. Result of PBDEs concentration in samples **(Unit: ppm)**

Samples	PBDEs concentration (Min)	PBDEs concentration (Max)
Seat fabric	25,158	65,841
ASR	217	2,710
Interior lights cover	10,865	10,865
Floor cover/ headliners	833	4,295
Seatbelt	469	469

Result of SFA of PBDEs in automobile (ASR, Automobile seat cover) in Korea

Based on the results of PBDEs concentrations in the samples, it was known that PBDEs were used in limited components in automobile. Samples containing PBDEs more than 0.01% by weight such as interior light cover, floor cover, headliners, seatbelt finally would have been disposed in ASR streams. The substance flow analysis of PBDEs in automobile with mass fraction of ASR and seat fabric of whole automobile has been conducted, as Figure 2 .

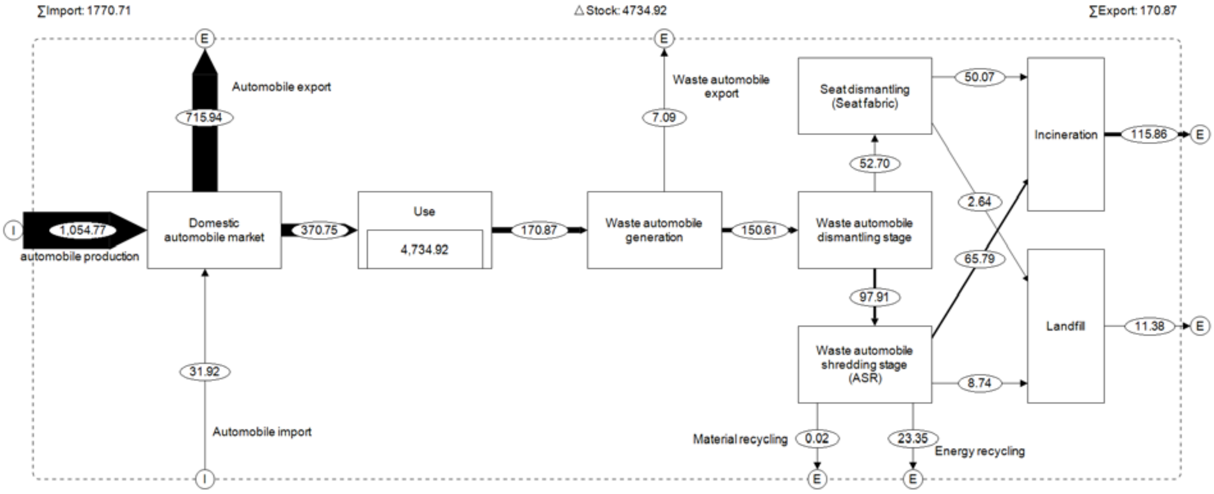

Figure 2. Substance flow analysis of PBDEs in automobile

In 2014, approximately 371 ton of PBDEs in automobile were put on the domestic market through the manufacture (1,055 ton), export (716 ton), import (32 ton). In use stage, approximately 4,735 ton of PBDEs in automobile were stocked generating approximately 171 ton of PBDEs in ELVs. In disposal stage, approximately 116 ton of PBDEs in ELVs were incinerated, approximately 11 ton of PBDEs in ELVs were landfilled, and 23 ton of PBDEs in ELVs were recycled as energy.

Current management practice of PBDEs containing wastes (ASR, automobile seat cover) in Korea

As a result of substance flow analysis of PBDEs in automobile, it was investigated that PBDEs containing wastes in automobile were mainly generated in the form of ASR and seat fabric. In case of seat fabric, approximately 66 ton of PBDEs in seat fabric was generated in disposal stage in 2014. Approximately 52 ton of PBDEs in seat fabric (79%) was dismantled in informal area later incinerated or landfilled. Approximately 13 ton of PBDEs in seat fabric (21%) was disposed with ASR. In case of ASR, approximately 110 ton of PBDEs in ASR was generated in disposal stage in 2014. Approximately 66 ton of PBDEs in ASR (60%) was incinerated, 9 ton of PBDEs in ASR (8%) was landfilled, and 23 ton of PBDEs in ASR (21%) was recycled as energy.

CONCLUSION

This study aimed to present current management flow of PBDEs containing wastes in automobile by conducting substance flow analysis of PBDEs in automobile in Korea. The results of the SFA indicate that ASR and seat fabric were the main components of PBDEs containing wastes in automobile. On disposal stage, 116 ton of PBDEs in ELVs (68%) was incinerated, 11 ton of PBDEs in ELVs (6%) was landfilled, and 23 ton of PBDEs in ELVs (13%) was recycled as energy recovery.

ACKNOWLEDGEMENT

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Estimation of In-Use Polybrominated Diphenyl Ether (PBDE) Stocks in Japan

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ABSTRACT

In this study, we estimate the in-use stocks of polybrominated diphenyl ethers (PBDEs) in Japan using a population balance model. The estimation is based on the domestic demand information of PBDEs (new products put on the market) and the assumed survival rate of these products. The results clearly show that for a wide range of the two parameters (shape and scale of the Weibull distribution) on survival rate of PBDE products, the relatively decreasing speed of penta-, octa-, and deca-BDEs stocks in use satisfies the following pattern: penta- > octa- > deca-BDEs, which is consistent with the changes in PBDE levels in ambient air. In addition, the amount and time trend of in-use PBDE stocks in Japan reveal that deca-BDE persist in society whereas penta- and octa-BDEs may approach undetectable levels in the near future. This information is useful for building policy measures to reduce the emission of PBDEs.

Keywords: polybrominated diphenyl ether, in-use stock, population balance model, survival rate

INTRODUCTION

Polybrominated diphenyl ethers (PBDEs) are some of the most widely used brominated flame retardants (BFRs), and include three major PBDE technical mixtures: penta-BDEs, octa-BDEs, and deca-BDE. Due to their toxicity, penta- and octa-BDEs were phased out and listed as persistent organic pollutants (POPs) in the 2009 Stockholm Convention. In Japan, changes in domestic demand for commercial penta-, octa-, and deca-PBDEs occurred even earlier. Penta- and octa-BDEs were phased out in 1990 and 1999 respectively. Deca-BDE is still in use, but its domestic demand is gradually decreasing (from 10,000 ton in FY1990 to 900 ton in FY2013) (JMOE 2014).

The largest stock of deca-BDE exists in consumer products currently in use, and emissions from such products were estimated to be the largest source of deca-BDE into the air (Sakai et al., 2006). Consideration of the emissions during the service life of products containing deca-BDE is therefore important. In addition, Csiszar et al. (2014), in their modelling study, concluded that secondary emissions (chemical volatilization from water or soil) of PBDEs are minimal when compared to emissions from on-going use. Therefore, estimating the amount of PBDE stocks in products is important to understand the emission sources of PBDEs better, which will be important in building policy measures to reduce emissions of PBDEs.

The aim of this study was to estimate the amount and time trend of PBDE stocks in Japan. We used a population balance model to estimate the stocks of penta-, octa-, and deca-BDEs in Japan from 1985 to 2013. The results were discussed by comparing them with the annual trend of atmospheric concentrations of PBDEs in Japan from 2009 to 2012.

MATERIALS AND METHODS

Population balance model

The in-use stock of penta-, octa-, and deca-BDEs was estimated by a population balance model. The population balance model combines statistics on annual demand for PBDEs (JMOE 2014) and a survival function for the lifetime of the products containing PBDEs (Eq.1) and estimates the in-use stock of PBDEs (Eq.2).

$$F(d) = \exp\left\{-\left(\frac{d}{\eta}\right)^{m}\right\} \qquad \textbf{(Eq.1)}$$

where *m* is shape parameter of the Weibull distribution, η is the scale parameter of the Weibull distribution, and *F(d)* is survival rate of PBDE-containing products whose age is *d* (*d* years after production)

$$S(i, y) = \sum_{t=1985}^{y} D(i, t) \cdot F(y - t) \qquad \textbf{(Eq.2)}$$

where *S*(*i*, *y*) is the in-use stock of *i* (pentaBDEs, octaBDEs, or decaBDE) in year *y* and *D*(*i*, *t*) is domestic demand of *i* in year *t*.

For the survival function, we assumed a Weibull distribution that is used often to represent the lifetime of products. Due to the lack of information on shape and scale parameters for PBDE-containing products, we performed a scenario analysis using these two parameters (Table 1). The parameter ranges were selected to reflect that the major PBDE usages are flame retarded textiles (e.g., curtains, carpets), electric appliances (e.g., TVs, computers), vehicles (e.g., interior of automobiles), and construction materials (e.g., plastic insulation, composite panels).

Table 1. Scenarios for shape and scale parameters of the Weibull distribution for the survival function.

Scenario	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Shape: m	1.5	2.0	2.5	3.0	4.0	5.0	1.5	2.0	2.5	3.0	4.0	5.0
Scale (year): η	10	10	10	10	10	10	20	20	20	20	20	20

PBDE concentrations in ambient air

We used the atmospheric PBDE monitoring data from the Japanese Ministry of Environment for the period from 2009−2012 (JMOE 2013).

RESULTS AND DISCUSSION

The changes in domestic demand for commercial penta-, octa-, and deca-BDEs are displayed in Fig.1, showing the use of penta- and octa-BDEs ending in 1990 and 1999 respectively, but only a gradual decrease in deca-BDE usage after 1990. Fig.2 reveals the decreasing trends in atmospheric mean concentrations of PBDEs (tetra-, penta-, octa-, and deca-BDEs) in Japan from 2009 to 2012 (non-detect values were replaced by 1/2 limit of detection, LOD). For the quantity information, our previous Tobit regression analysis (Dien et al., 2015) determined that BDE-209 (deca-BDE) decreased slightly (−6%/y; $p=0.065$), whereas BDE-47, -99 (both penta-BDEs), and -183 (octa-BDE) declined −21, −25, and −23%/y, respectively ($p<0.05$).

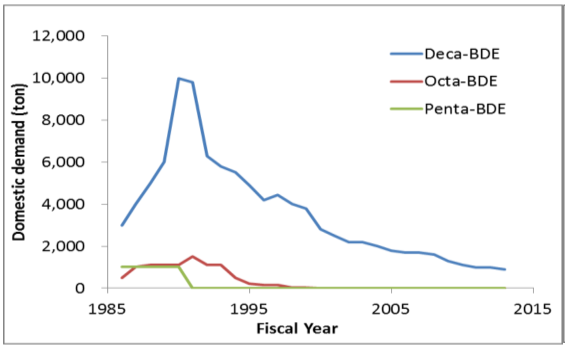

Fig.1 Domestic demand for PBDEs in Japan

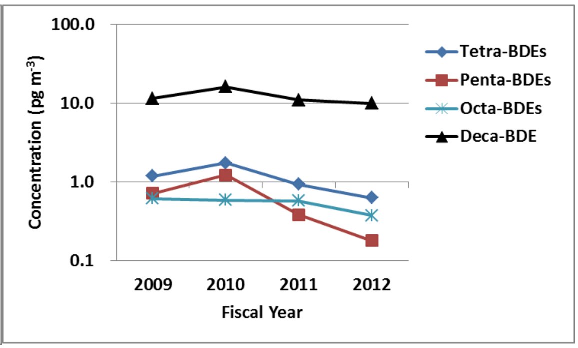

Fig.2 Decreasing trend of PBDEs in air

From these backgrounds, we estimated the survival rate of PBDE-containing products, amount of PBDE stocks in use, and the relatively decreasing rate of PBDE stock in use. Interestingly, the settings for all 12 scenarios produced consistent results. We selected three (Scenarios #1, #6, and #12) of the twelve scenarios for demonstration purposes (Fig.3).

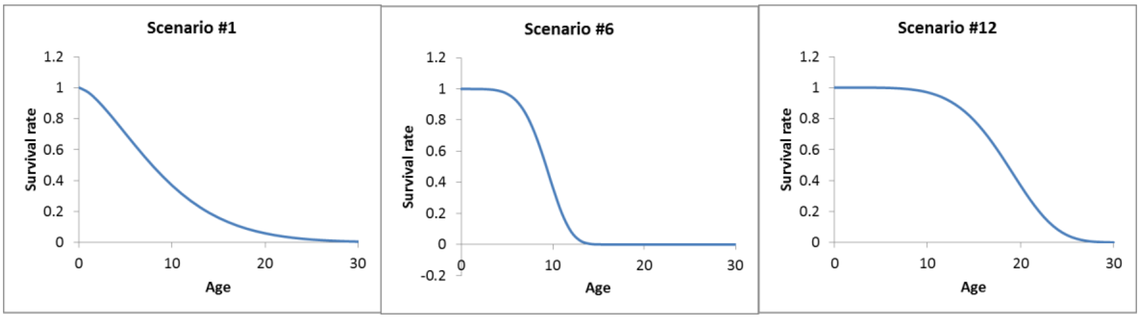

Fig.3 Survival rates of PBDE-containing products for Scenarios #1, #6, and #12

Differently shaped curves of survival rates are presented in Fig.3 for a wide range of product lifespans (8−19 years, calculated values at $F(d)=0.5$ for each scenario). These estimated lifespans are on par with the average lifespan of consumer products in Japan, which is approximately 10−15 years as determined by Murakami et al. (2010). Fig.4 suggests that in-use stocks of deca-BDE persist in society whereas penta- and octa-BDEs may approach undetectable levels in the near future. Fig.5 shows clearly that for a wide range of the two parameters, shape and scale, on survival rate of products, the decreasing speed of penta, octa, and deca-BDEs stocks in use (FY2009=1.0) satisfies the following pattern: penta- > octa- > deca-BDEs, which is consistent with the changes in PBDE levels in ambient air as shown in Fig.2.

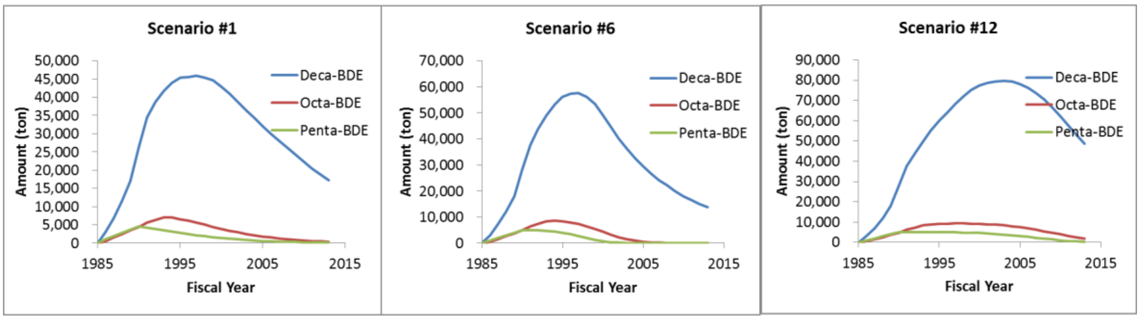

Fig.4 Amount of PBDE stocks in use for Scenarios #1, #6, and #12

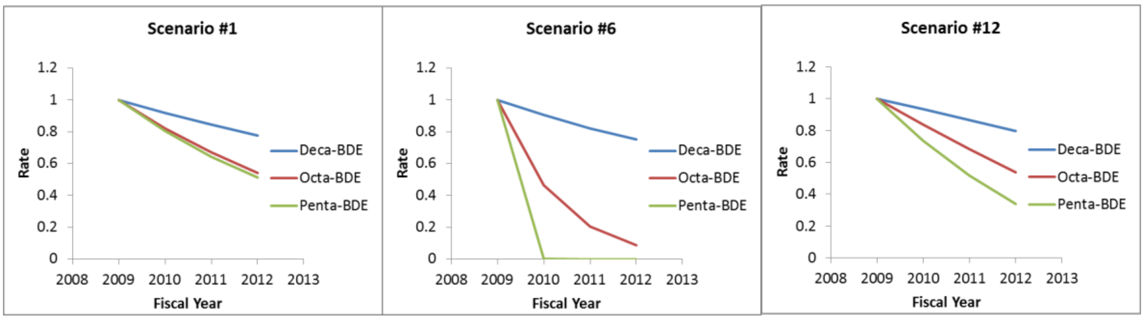

Fig.5 Relatively decreasing speed of in-use PBDE stocks for Scenarios #1, #6, and #12

CONCLUSION

The decreasingly estimated trends of penta-, octa-, and deca-BDEs contained in products in use, based on domestic demand for PBDEs in Japan and product lifespan, were consistent with the declining trends of these compounds in ambient air. The in-use stocks and atmospheric concentrations of PBDEs appear to reflect the control measures on commercial PBDEs that have been implemented in Japan.

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Constructing a New Waste Input-Output Database and Its Application in Environmental Footprint and Hotspot Analysis

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ABSTRACT

Demand for multi-criteria methods of life-cycle assessment has recently been growing, to measure life-cycle environmental performance of products. With this background, we started a research project for the development of methods and databases for environmental hotspot analysis, which is a three-year project for 2014 to 2017 funded by Japan Science and Technology Agency. The project consists of two parts. One is the development of methods for environmental hotspot analysis through case studies of 100 products and services. The other is the development of comprehensive databases for hotspot analysis. Data on disaggregated waste flow like animal and food waste, paper waste, iron and steel scrap, non-ferrous metal scrap, slag and sludge are compiled the waste input-output framework. In this study, we share our experience in developing database and halfway results of the ongoing project.

Keywords: waste input-output (WIO), material flow analysis (MFA), product environmental footprint (PEF), hotspot analysis, life-cycle assessment (LCA)

INTRODUCTION

Demand for multi-criteria methods of life-cycle assessment (LCA) has recently been growing, to measure life-cycle environmental performance of products (Manfredi et al., 2015). In particular, comprehensive databases are desired because they are indispensable to a wide spread use of LCA with multi-criteria methods. With this background, we started a research project for the development of methods and databases for environmental hotspot analysis, which is a three-year project for 2014 to 2017 funded by Japan Science and Technology Agency (JST).

The project consists of two parts. One is the development of methods for environmental hotspot analysis through case studies of 100 products and services. Our method for life-cycle inventory analysis is a hybrid multi-regional input-output analysis (MRIO) (Tukker and Dietzenbacher, 2013) in which the Japanese IO table is in the waste input-output (WIO) framework (Nakamura and Kondo, 2002). The method for life-cycle impact assessment is LIME3, an update and global-scale and multi-regional extension of LIME2 (life cycle impact assessment method based on endpoint modeling) (Itsubo et al., 2012). The other part of this project is the development of comprehensive databases for hotspot analysis. Data on environmental emission are compiled based on IDEA (Inventory Database for Environmental Analysis) (Tahara et al., 2008). Data on disaggregated waste flow like animal and food waste, paper waste, iron and steel scrap, non-ferrous metal scrap, slag and sludge are compiled in the WIO framework.

The results of environmental hotspot analyses of 100 products and services will be used for benchmarking the life-cycle environmental performance of a product. LCA practitioners can focus on the processes and impact categories which are found hotspots in our analyses. This is expected to contribute to reducing time and cost necessary for LCA studies in industry, and thus further promoting green procurement. In this study, we share our experience in developing database and halfway results of the ongoing project.

METHODS

A decreasing rate of material stock accumulation in developed economies will lead to a sizable decrease in the demand for materials recovered from waste products. Thus, an LCA incorporating a constant, predetermined recycling rate of recovered materials, could potentially yield misleading conclusions. The WIO method (Nakamura and Kondo, 2002) is a unique hybrid input-output analysis (IOA) framework, consisting of an accounting system and analytical models. Using WIO, hybrid LCA studies can be conducted using a proper consideration of waste/by-product flow.

Hybrid IOA has been widely utilized in LCA works, and its advantages are well recognized. In particular, a clearly defined economy-wide system boundary can be established in a hybrid LCA (Suh et al., 2004). A key characteristic of WIO is the management of waste/by-products and waste treatment services. In the WIO model, waste recycling and generation are regarded as the supply of, and demand for, waste treatment services, respectively. This is similar to the methodology that has been employed in the Ecoinvent database since the establishment of version 3 (Weidema et al., 2013).

Because the 2011 Japanese benchmark input-output table was recently made available in June 2015, there is a substantial need for updated data for use in hybrid LCAs. Therefore, we are constructing a new WIO database for LCAs, paying special attention to inter-industry waste/by-product flows and a wide range of impact categories. Having developed a new method to identify inter-industry waste flow based on publicly available data sources, we will be able to construct a more reliable database.

The data sources that we used in this study have been reported by establishments generating a lot of industrial waste and made publicly available by the local governments. According to Waste Management and Public Cleansing Act, establishments which generate more industrial waste than one thousand tons per year are obliged to submit their waste management plans and report results to the local governments every year. The local governments are responsible to make establishments' plans and results publicly available. Although one can obtain PDF files of plans and results from the local government through the Internet, those files do not provide numerical data which can be directly used for statistical analysis. Therefore, we downloaded all those PDF files through the Internet and then developed a large database of industrial waste generation by large establishments. The database provides establishment-level information on industrial waste generation by waste types and by industries. We can perform material flow analysis (MFA) of industrial waste based on the database that we developed. Moreover, we can estimate, for example, the distribution of generated industrial waste per output, with which we can carry out an uncertainty analysis for LCA and MFA.

RESULTS

Table 1 shows a summary of the database that we developed, aggregated industrial waste generation by sector. At the meeting we share our experience in developing database and halfway results of the ongoing project, including more detailed summary of the developed database.

Table 1. Industrial waste generation by sector

		# of establish-ments	Waste generation (10^6kg)		Coverage
			Census (A)	Government stats (B)	(A)/(B)
A	Agriculture and forestry	1,183	3,806	85,721	4%
B	Fisheries	0	0	7	0%
C	Mining and quarrying of stone and gravel	58	2,361	9,481	25%
D	Construction	7,378	48,526	74,124	65%
E	Manufacturing	5,461	116,206	108,970	107%
F	Electricity, gas, heat supply and water	1,161	72,272	96,473	75%
G	Information and communications	67	152	110	138%
H	Transport and postal activities	32	160	700	23%
I	Wholesale and retail trade	44	84	1,389	6%
J	Finance and insurance	2	33	0	
K	Real estate agencies and goods rental and leasing	9	23	102	22%
L	Research and professional services, n.e.c.	26	8	65	13%
M	Accommodations, eating and drinking services	1	0	326	0%
N	Living-related and personal services and amusement services	13	51	175	29%
O	Education and learning support	21	17	58	29%
P	Medical services and social welfare	1,032	340	384	88%
Q	Compound services	0	0	24	0%
R	Miscellaneous services, n.e.c.	90	548	962	57%
S	Public administration	24	480	67	714%
T	Activities not elsewhere classified	10	38	0	
Total		16,612	245,105	379,137	65%

Source: (A) Own calculation, (B) Ministry of the Environment, Government of Japan.

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Study on the Role of Informal Sector in Plastic Waste Collecting and Recycling from Municipal Solid Waste Management in Hanoi city

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ABSTRACT

In Vietnam, the informal sectors (including waste pickers, waste diggers, waste collectors, waste dealers, small-sized recycling agents...), have considerably contributed to the solid waste management and waste reclaimation through activities of collecting, sorting, trading and recycling waste. These activities not only provide considerable income sources for part of city residents but also contribute to protect natural and environmental resources.

The above informal system has basic features of simple labor, backward technology, low income, actions without management or support of the Government, usually organized in individual or household sizes. This system have performed the activities of collecting and recycling wastes from the very first stage to the final products. These activities are usually active and flexible, meeting quickly market demands but and greatly affected by fluctuations in economy or policies if any.

Thos paper presents the current situation of material recovery from municipal solid waste through informal sector in Hanoi city and initial steps how to contribute to the increase in the effectiveness of waste collecting and recycling activities toward the sustainability.

Keywords: Solid waste management, waste recycling, informal sector, plastic waste recycling.

INTRODUCTION

In the year of 2009, the Prime Minister of the Vietnamese Government issued Decision No. 2149/QD-TTg approving the National Strategy on general management of solid waste till 2025, vision toward 2050 under the point that general management of solid waste is the social responsibility.

The important solution to reach the mentioned goals is to take precautions against and minimize the arising solid wastes; speed up classification of solid waste at sources; strengthen collection and transportation of solid wastes; increase reuse and recycling of waste...

But, similarly to other developing countries, the infrastructure system and management apparatus in the field of solid wastes in Vietnam still have many shortcomings. Urban environment companies or public service companies at cities have neither currently provided collection services to all households, nor prepared to perform the work of recycling and treating solid waste effectively. Therefore, the informal sector (including waste pickers, waste diggers, waste collectors, waste dealers, small-sized recycling agents...), although formed spontaneously, have considerably contributed to the solid waste management and waste reclaimation through activities of collecting, sorting, trading and recycling waste. These activities not only provide considerable income sources for part of city residents but also contribute to protect natural and environmental resources.

The study was implemented with surveys in order to investigate features of the plastic waste recycling system of Hanoi city. The collected results shall contribute to developing solutions for managing, treating pollution from waste recycling vocational villages in particular, and ensuring the sustainability for waste recycling activities in general.

MATERIALS AND METHODS

To have comprehensive evaluation and collect necessary information regarding to the current status on activities of plastic waste collecting and recycling establishments at Trieu Khuc village, Tan Trieu commune, Thanh tri District, Hanoi City, the research has implemented 2 surveys including preliminary survey and specific survey:

- *Preliminary survey:*The main goals of survey the preliminary survey is to (1) clarify the current status of plastic waste collecting and recycling system in the entire Trieu Khuc village and (2) collect basic information such as working conditions, the quantity of laborers, all kinds of plastic waste bought/sold, applicable selling/buying/ recycling procedures, etc. at all collecting, and recycling establishments in Trieu Khuc village.
- *Specific survey:* The main goals of this survey are to (1) survey and evaluate in details the plastic recycling stages as well as inputs, outputs of the recycling procedure; (2) collect information in order to set up the mass and economic balances of plastic waste collecting and recycling establishments. The result of the specific survey shall be the basis for recommending solutions to protect plastic waste collecting and recycling activities.

The purposes of the study was as follows:

- To evaluate the current status on the activities of plastic waste collecting, buying and recycling establishments in the area of Hanoi city ;
- To clarify the relationship among sectors in the non-official plastic waste collecting and recycling system in Hanoi.
- To clarify factors affecting the sustainability of non-official plastic waste collecting and recycling system in Hanoi.

RESULTS AND DISCUSSION

The result the preliminary survey showed that at Trieu Khuc village there are totally 129 households currently having plastic waste collecting and recycling activities.

The result were shown that waste collecting and recycling establishments at Trieu Khuc village are mainly in household size. About 87% of the establishments have number of labors less than 5 persons, 11% of the establishments have number of labors from 6 to 10 persons. And only 4 of the establishments have number of labors more than10 persons. The Laborers are mainly family members. Only a small number of establishments have sizes of companies or private enterprises, engaging external laborers due to their high demand for production. The activities of collecting and recycling waste at Trieu Khuc can be divided into 2 following groups:

Group 1.Waste collecting dealers: Waste collecting dealers are facilities only having activities of buying/selling or having additional activities of classifying plastic waste by costs, colors meeting demands of buyers without any activities of initial processing or recycling plastic.

Group 2. Recycling facilities: Recycling facilities are facilities with activities of initially processing and/or recycling plastic waste. Depending on kinds of input plastic waste and output plastic products, the principle of plastic initial processing /recycling can include many different phases.

Most of recycled products are sold from Trieu Khuc in plastic form after being crushed into small pieces or plastic pellets with various colors. Only 5 establishments sold products in form of final products (household appliances such as buckets, basins, coat hangers, chairs, etc). Approximately 60% of establishments answered that buyers of their products are dealers or recycling establishments at Trieu Khuc. About 18% of establishments sold to addresses at the inner city of Hanoi. The rest sold to establishments at adjacent provinces.

The result showed that most of plastic waste are used quite popularly currently such as HDPE, PET, LDPE, PP, PVC, PS, etc..of which HDPE plastic has the highest ratio of collecting and recycling (accounting for about 31% of the total plastic waste volume), the nexts are PP plastic (26%), PET plastic (14%), LDPE plastic (8%), PVC plastic (6%). All types of other plastics such as PS, PA, ABS,.. account for an unconsiderable ratio. This result is completely suitable with the fact as HDPE and PP are types of plastic used mainly to produce common plastic products in daily life such as buckets, basins, tables, chairs, cosmetic bottles, children toys, etc..

The incomes per capita of all household groups participating in plastic waste collecting and recycling activities at Trieu Khuc are ranging from 3,356,944 VND/person/month -11,167,327 VND/person/month higher than the announced average income of people in Hanoi in 2011 (3,084,000 VND/person/month). However, the toxicity from emitted air, plastic smells, narrow working environment, no assurance of sanitation has affecting considerably the health of laborers.

CONCLUSION

- The waste in general and plastic waste collecting and recycling system in particular are operated by informal sector. This sector is playing a very important role in collecting and recycling waste from municipal waste tream in Hanoi city.
- The benefit from activities of small-sized collecting and recycling establishments is to decreaes the waste required for treatment by means of recycling waste into useful raw materials. Decrease in waste required for treatment is synonymous with decrease in costs for treating waste, decrease in land areas for dump sites, decrease in nagative effects to environment during waste treatment.
- The waste collecting and recycling through the informal sector has contributed a considerable part to creat jobs and incomes to laborers, especially immigrating laborers, laborers with low qualification, laborers in

rural areas in idle times. However, plastic waste recycling activities have been adversely affecting environment, especially affecting directly the health of communities collecting and recycling areas.

- It's necessary to operate a management model or an organization to connect activities in the field of recycling, playing the bridging role, both supporting the government management authorities to perform and supervise the performance of recycling regulations, and supporting activities of recycling enterprises toward sustainable development in accordance with the laws of Vietnam.

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Poster Program 1

Characteristics of organic wastes for solid refuse fuel(SRF) after fry-drying

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ABSTRACT

In various sludge treatments, drying sludge using typical technology with high water content to a water content of approximately under 10% is always difficult because of adhesive characteristics of sludge in drying. Many methods have been applied, including direct and indirect heat drying, but these approaches of reducing water content to below 40% after drying is very inefficient in energy utilization of drying sludge. In this study, fry-drying technology with a high heat transfer coefficient of approximately 500W/m$^{2}\cdot$℃ was used to dry swine excreta, sewage and industrial sludge. Also waste oil was used in the fry-drying process, and because the oil's boiling point is between 240℃ and 340℃ and the specific heat is approximately 60% of that of water. In the fry-drying system, the sludge is input by molding it into a designated form after heating the waste oil at temperatures between 130℃ and 150℃. At these temperatures, the heated oil rapidly evaporates the water contained in the sludge, leaving the oil itself by buoyancy force of vapor. After approximately 8～10 min, the water content of the sludge was less than 10%, and its heating value surpassed 20,000kJ/kg. Indeed, this makes the organic sludge appropriate for use as a solid fuel. The dried swine excreta, sewage and industrial sludge can be used in an incinerator like low-rank coal or solid fuel.

Keywords: devolatilisation, swine excreta, sludge, fry-drying, solid refuse fuel

INTRODUCTION

Water contained in the sludge is categorized as follows: free water, surface water, interstitial water, and bound water. Free water and surface water are easily evaporated at 100˚C ± 5˚C, but the process of evaporating interstitial water and bound water requires temperatures upwards of 400˚C. Current drying technologies that are widely used include the convection heat transfer method, wherein gas is heated to between 400˚C and 600˚C to dry the sludge, and the heat conduction transfer method, which is an indirect heat transfer method that circulates high temperature steam or gas inside heat transfer equipment while the wet sludge moves on the outside. Indeed, this process is also time-consuming, because as the outer surface of the sludge dry, more time is required (from 40 to 60 min) to decrease the water content to about 40%. Furthermore, as the surface of the sludge becomes hard, the speed of the process becomes remarkably slow. It can be seen that the sludge drying equipment currently used is inefficient with regard to energy and time, and in the end only partially dries the sludge.

The typical drying technologies of sludge have other serious obstacles such as a reduction in surface area, surface carbonation and solidification, fugitive dust, and the offensive odor of the heated gas. Compared to general material drying, sludge drying is a complicated process because the combination of bound water and interstitial water that exists inside the sludge shortens the constant rate drying period and lengthens the falling rate drying period. If dried organic sludge is to be used as a waste-derived solid fuel, its water content should be less than 10 wt.%, and its low heating value should be maintained at more than 12,560 kJ/kg (wet basis). Drying methods can be classified according to the mode of heat transfer: drying by conductive heat transfer (e.g., thin film drying) and drying by convective heat transfer with hot air or a combustion gas. They are generally costly and inefficient owing to the long drying time and low-efficiency energy use; moreover, odorous. Therefore, the present research used evaporative drying by immersion in hot oil (EDIHO), also known as fry-drying, instead of conventional drying methods to transform sludge into fuel. The heat transfer coefficient of the boiling process is upward of 2500 W/m2·˚C, whereas the convective heat transfer coefficient is usually between 75 and 140 W/m2·˚C. EDIHO achieves rapid drying by direct contact between water on the surface of the sludge and oil heated to 130˚C - 150˚C; vapor bubbles form, and boiling heat transfer occurs due to a strong warm current. Moreover, water in the sludge is displaced by oil through strong diffusion in the sludge, even in swine excreta, which has high water content and strong cooking properties. The present research investigated the drying process that occurs in fry-drying of swine excreta, sewage and industrial sludge using a refined waste oil and B-C heavy oil.

EXPERIMENTAL MATERIALS AND METHODS

Figure 1 shows the continuous-type fry-drying apparatus used for the present research. This system is divided into three parts: the first part consists of sludge feeding equipment, which inputs sludge to the evaporative drying tank. The sludge injector, which is operated by a variable-speed motor, pushes the sludge through five holes with 10 mm diameter. The second part is the sludge fry-drying tank where the supplied sludge is dried. The tank is 1.8 m in length, 1.2 m in height, and 1.0 m width, with a waterwheel type drum attached. Inside the drum, a screw feeder controls the fry-drying time of sludge. In order to increase the temperature of the waste oil inside the drying equipment, 10 kW electric coils and a gas burner are attached and a temperature controller is used to adjust the temperature of oil. The third part is the condenser, wherein steam, oil, and volatile organic compounds(VOCs) generated from the drying equipment that separated into condensed liquids and VOCs. The separated oil is recycled as heating oil for fry-drying. The VOCs and odorous gases are burnt after being transported to the burner through a tube by using an I.D. fan. The entire process, from the input of the sludge to the output of the finished product, takes about 10 min, and the equipment can treat 50 to 100 kg of sludge in 1 hour.

The water content of the swine excreta is 78.90% before drying. The percentages of ash, fixed carbon, and volatile matter before drying were 4.76%, 0.23%, and 16.11%, respectively. And water content of the sewage and industrial sludge were 83.49%, 78.56%, respectively. Refined waste oil from engine lubricants, cooling oil, and machine tool oil is produced by removing water, ash, heavy metals, and other foreign substances in order to reuse the waste oil as fuel oil. The waste oil thus treated was further processed into refined fuel oil as follows: the oil was heated at 110˚C - 150˚C by heating a media boiler; water in the heated waste oil was removed by circulating the oil through a heat exchanger, distiller, and classifier; and the remaining ash, and similar contaminants were removed from the resulting waste oil by using a decanter and a centrifuge.

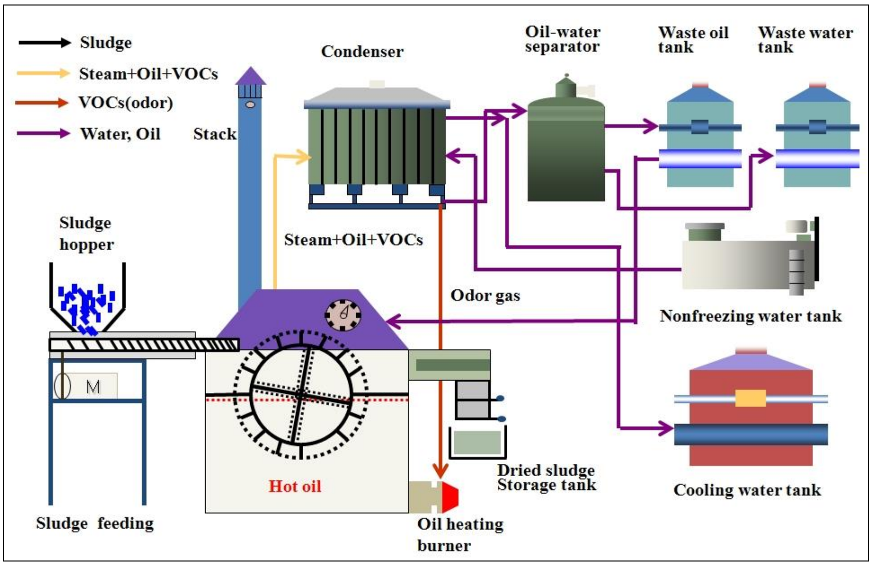

Figure 1 Schematic diagram of continuous–type fry-drying system for organic waste

In this experiment, the refined waste oil has a boiling point of between 240˚C and 340˚C, and a specific heat of between 2.1 kJ/kg·˚C and 2.9 kJ/kg·˚C. Heavy oil is highly cohesive, with a cohesive degree of greater than 50 cSt at 50˚C. Among the heavy oils, BC heavy oil has the strongest cohesive property and is used to fuel large boilers and large, low-speed diesel engines and as a combustor installed with preheating equipment. It is the most widely used heavy oil in Korea. The qualities of heavy oils are classified internationally according to the viscosity range (viscosity at 50˚C), Sulphur content, and other properties. The viscosity and sulphur content increase gradually as the grade changes from A to B to C.

RESULTS AND DISCUSSION

Figure 2 shows the drying curve of sludge with an 83.49% water content that was evaporated in the fry-drying equipment with waste oil heated to 150˚C. In this figure, the constant rate drying period of the sludge lasted from 4 - 5 min. Generally the constant rate drying period is usually short, while the falling rate drying period is generally long when using other drying technologies such as direct and indirect heating system. But conversely the fry-drying process has the constant rate drying period is relatively long and the falling rate drying period is short due to high turbulent heat and mass transfer in the constant rate drying period. The final water content of the sludge dried for 8 min is 2.0%. Fig. 3 shows the results of TGA of swine excreta before and after drying at a heating rate of 10 ˚C/min with air as a carrier gas. As the temperature was increased from room temperature, a dramatic reduction in the swine excreta's weight occurred around 100˚C due to a reduction in their water content. In addition, emission and combustion of the initial volatile matter, carbon residue, and residual volatile matter occurred between 250˚C and 500˚C. Little reduction in the weight of the dried swine excreta appeared around 100˚C because their water content was low. The reaction during drying using B-C heavy oil is believed to occur gradually at temperatures of up to 560˚C because B-C heavy oil has many more components that can react at high temperature than the refined waste oil.

Differential thermo-gravimetric analysis (DTG) was performed by differentiating the TGA curves; the results are shown in Fig. 4. The DTG curves show the speed at which the weight decreased in each sample according to temperature, so combustion features can be determined more clearly. Swine excreta before drying, peaks appeared around 100˚C; these represent moisture that was removed during drying. After fry-drying, the peak around 100˚C did not appear, because fry-drying decreased the water content. The peak around 300˚C was determined to be the result of a devolatilisation reaction.

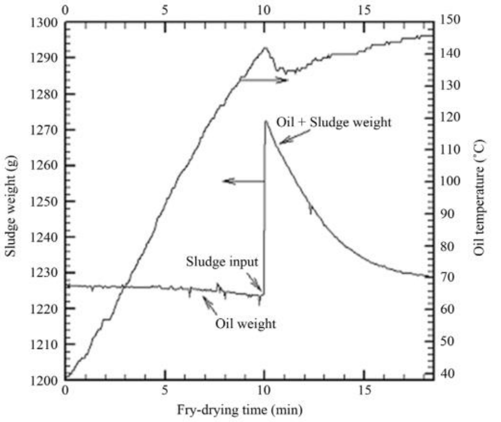

Figure 2 Drying curve of sludge in fry-drying equipment

CONCLUSION

We experimentally investigated the fuel characteristics and drying of swine excreta, sewage and industrial sludge treatment plant using fry-drying technology. We obtained the following results. 1) When swine excreta (water content: 78.90 wt.%) was dried at an oil temperature of 150 ˚ C for 8 min, the resulting water contents were 1.56 wt.% (after drying in refined waste oil) and 1.62 wt.% (after drying in B-C heavy oil). Refined waste oil was slightly more effective at decreasing the water content than B-C heavy oil, but the difference was not significant.

ACKNOWLEDGEMENT

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Factors influencing future intention of municipal organic waste separation at source: The case study in Hoi An city, Vietnam

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ABSTRACT

Most municipal organic waste separation at source (MOW-SAS) programs introduced in developing countries in the past several decades have remained pilot programs and were not developed into a sustainable municipal solid waste (MSW) management strategy. In the same situation, various cities in Vietnam have introduced the MOW SAS programs and almost all of the programs have been stopped after pilot periods. Hoi An city in Quang Nam province of Vietnam has implemented the program from 2012 up to the present. In order to understand the sustainable of MOW SAS program in Hoi An city, the Structural Equation Modeling (SEM) was applied in this study to determine the psychological factors (*i.e.,* attitudes, moral norm) and other factor (*i.e.,* situation factors) influencing residents' MOW SAS behavior and their future intention in Hoi An city. Identifying these factors will contribute to the development of better intervention mechanisms and more sustainable strategies in implementing MOW SAS in Hoi An city.

Keywords: Municipal organic waste, waste separation at source, waste separation behavior, waste separation intention, SEM

INTRODUCTION

Municipal solid waste (MSW) separation at source has been considered as the most effective solution for waste management but relies on the collaboration of the public (Taherzadeh and Rajendran, 2015). In the developing countries such as Vietnam, the residents in some major cities were recommended to sort MSW by municipal organic waste (MOW) and municipal inorganic waste in various programs of waste separation at source. However, almost all of the programs have been stopped after pilot periods (Thuy, 2005).

The extant literature has identified a number of factors influencing the waste separation at source behavior or waste separation at source intention of public participant. Empirical studies addressed a logical outline of the theory of reasoned action (TRA) and theory planned behavior (TPB) suggested that *attitude* toward waste sorting or recycling is the main predictor of public waste management behavior (Zhang et al., 2015; Yuan, 2015; Chu and Chiu, 2003; Valle et al., 2004). Besides, there is no doubt that MOW separation intention likely to contain elements of personal morality and social responsibility, it will be strongly suggested to include *moral norm* as a variable within the model. Examples of this statement can be found in various studies such as Phuong et al.(2015), Yuan (2015) , and Chu and Chiu (2003). Furthermore, residents may have positive attitudes towards sorting waste, however, it does not necessary mean that they will separate the waste. It may be because of inconvenience, skills, resource constrains, or lack of cooperation of family members when the residents practice waste sorting. That is why; the additional factors such as *situational factors* should be involved in the model (Valle et al., 2004; Tonglet et al., 2003).

Hoi An city in Quang Nam province of Vietnam has implemented the MSW separation at source program since the year of 2012. At present, the residents are participating in the second stage of the program and the waste separation at source is one of the most important tasks of their MSW reduction strategies in the city. This study was conduct an empirical study in Hoi An city to identify the factors influencing the residents' behavior and intention of taking part in the MSW sorting program.

METHODOLOGY

Questionnaire Design

The questionnaire for the study was administered in August 2015. This was designed based on previous researches related to waste recycling and waste sorting behavior. Respondents were asked to indicate their agreement with the given statements using a five point Likert scale in which responses could range from 1 as strongly disagreement and 5 as strongly agreement. In total, 357 residents were approached and have been considered as valid respondents.

Measurement Instruments

Structural equation modeling (SEM) deals with theoretical models was applied in this study. SEM has the advantages of both the measurement and structural models (Hair et al., 2010) which can construct latent variables and test the predictive power of various models. One latent variable can be a dependent variable and independent variable. This methodology is most appropriate when the researcher has multiple contructs (Hair et al., 2010). It is reason why recently a lot of empirical behavioral studies have applied SEM such as Yuan (2015), Zhang et al.(2015) , and Mannetti et al.(2004).

Research hypotheses

Regarding MOW separation at source behavior and intention, the hypotheses of this study are investigated below:

H1. Moral norm is a negative predictor of situational factor
H2. Moral norm has positive influence on individual attitude toward MOW separation at source
H3. Situational factor has negative effect on attitude toward MOW separation at source
H4. Attitude is a positive predictor of MOW separation behavior at source
H5. Moral norm has positive effect on MOW separation behavior at source
H6. Situational factor has negative effect on MOW separation behavior at source
H7. Behavior has positive influence on future intention of MOW separation at source
H8. Situational factor has negative influence on future intention of MOW separation at source
H9. Moral norm has positive effect on future intention of MOW separation at source
H10. Attitude is a positive predictor of MOW separation at source future intention

RESULTS AND DISCUSSION

To evaluate the measurement model, construct validity were examined based on factor analysis. An exploratory factor analysis was conducted by computing pattern matrix using SPSS 16.0 software to investigate with 5 constructs namely Future intention, Attitude, Situation factor, Moral norm, and MOW separation behavior.

The maximum likelihood method was used to test SEM. Measures of model fit has shown in table 1. The suggested value was adapted from Hair et al., 2010. The observed values are higher than the suggested value which recommended that the research model fitted the data.

Table 1. Goodness of fit test results

Fit index	**CFI**	**RMSEA**	**IFI**	**NFI**
Suggested value	>0.9	<0.08	>0.9	>0.9
Observed value	0.947	0.074	0.948	0.923
Conclusion	Good fit	Good fit	Good fit	Good fit

Note: *CFI: Comparative fit index, RMSEA: Robustness of mean squared error approximation, IFI: Incremental Fit Index, and NFI: Normed Fit Index*

Figure 1 is structural equation model which was estimated by using AMOS 23 software. The results suggest that future intention of MOW separation at source is affected by the two predictors: MOW separation behavior (0.159) and moral norm (0.139). They are confirmed our hypotheses H7 and H9. Surprisingly, the situational factors predicted positive value of future intention sorting MOW. However, this is not significant. Attitude also has no significant effect on residential future intention sorting MOW. These are opposite with our hypotheses H8 and H10.

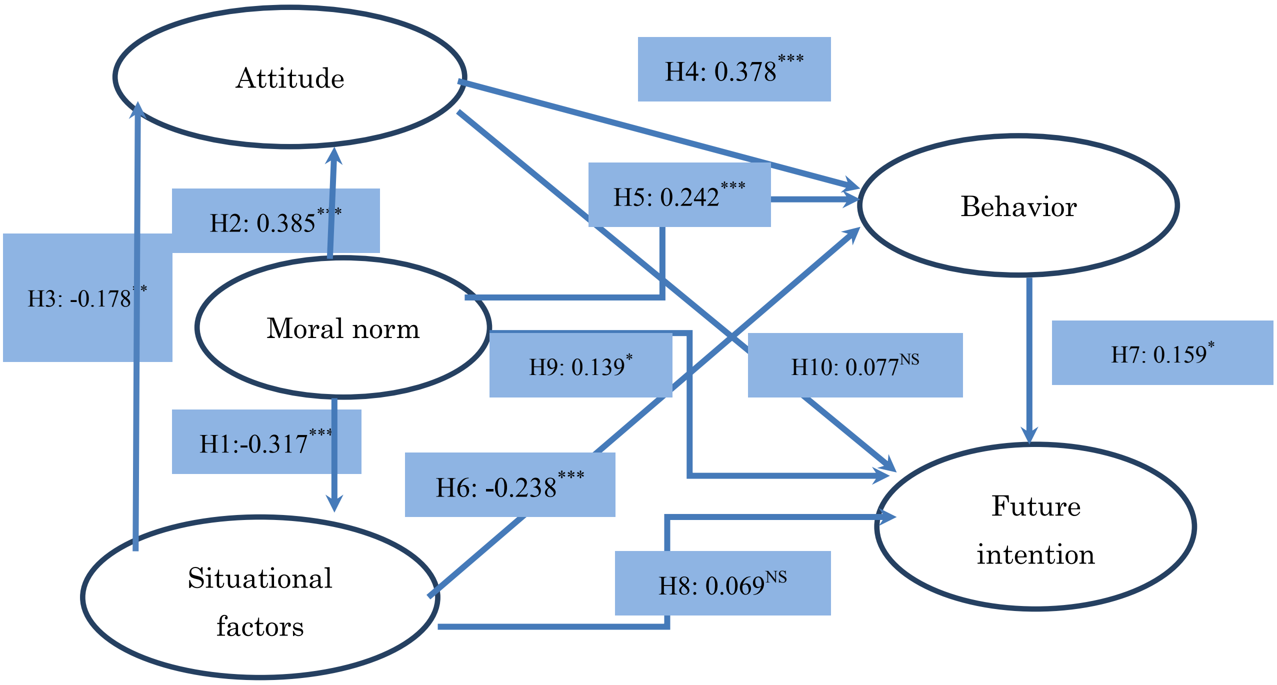

Figure 1. The standardized estimated structural equation model

Note: *** Significant at $p < 0.001$; ** Significant at $p < 0.01$; * Significant at $p < 0.05$. ^{NS} Non significant

Three hypotheses namely H4, H5, and H6 have been confirmed since they are significant effect on MOW separation at source behavior at 1% level (attitude (0.378), moral norm (0.242), and situational factors (-0.238)). Moreover, moral norm can also predict attitude toward MOW separation at source (0.385) and situational factors (-0.317). The participants have higher moral norm will have positive attitude toward MOW sorting and they can perceive the situational factors with less difficulty. These hypotheses H2 and H1 are tested. Finally, the hypothesis (H3) was confirmed. The situational factors have significant negative effect on attitude toward MOW sorting.

CONCLUSION

The study applied SEM provided empirical support for 8 of 10 hypotheses of factors influencing the behavior and future intention of MOW separation at source. The estimated structural equation model shows that moral norm and MOW sorting behavior have significantly influence on the MOW sorting intention in the future. Attitude, moral norm, and situational factors have significant effect on MOW sorting behavior. Enhancing the moral norm of public sectors would be an important task of the local authority strategies. This would not only increase the attitude toward program but also can push the residents perceive situational factors with less difficulty.

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Risk Assessment Based on the Bioaccessibility of Heavy Metals in Cheap Children's Products via Oral Ingestion: Vietnam and Japan Markets

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ABSTRACT

We investigated the levels of heavy metal contamination in cheap children's products and assessed their health risk to children based on bioaccessibility. Sample products were obtained from markets in Vietnam (*n* = 38) and Japan (*n* = 34). Simulated gastric (pH 2.5, 1 h), small intestinal (pH 7.0, 4 h), and colonic (pH 6.5, 8 h) fluids were used for in vitro bioaccessibility tests. We found that the total heavy metal concentrations in many of the metallic jewelry (MJ) items exceeded European Union (EU) standards. We tested the bioaccessibility of seven children's products from Japan (*n* = 3) and Vietnam (*n* = 4). Three items of MJ had leaching concentrations exceeding EU standards. Of note, lead (Pb) and cadmium (Cd) in MJ leached in the stomach and small intestine phases. Accidental oral ingestion of such items could affect a child's health via the leaching of heavy metals, especially Pb, in the stomach and small intestine. Based on these results, bioaccessibility testing of children's products should be expanded at least to the small intestine phase.

Keywords: cheap children products, heavy metals, bioaccessibility, risk assessment

INTRODUCTION

Cheap children's products, such as toys, jewelry, and paint, may contain high levels of toxic heavy metals. For this reason, millions of toys have been recalled in the past few years. Children are very sensitive to exposure to toxic substances. Mouthing or the ingestion of contaminated toys and inexpensive jewelry may confer additional risks. Recently, the European Union (EU) enacted more comprehensive legislation on children's products (EN71-3, Jul 2013) in terms of contaminants and the scientific approach to their evaluation (Guney and Zagury, 2012). This legislation (i) increased the metals tested from 8 to 17 elements (Al, Sb, As, Ba, B, Cd, Cr, Co, Cu, Pb, Mg, Hg, Ni, Se, Sr, Sn, and Zn), (ii) created three product categories [(1) dry/brittle/powder, (2) liquid/sticky, and (3) scraped], and (iii) set migration limits based on a simple bioaccessibility test involving immersion in 0.07 M HCl for 1 hour at 37°C. In the future, this EU legislation might be adopted by other countries.

Children's products in Asian markets have not been surveyed. In this study, we obtained children's products from Vietnam and Japan and assessed the levels of heavy metal contamination and the health risk to children using an in vitro physiologically based extraction test (Ruby et al., 1996; Tilston et al., 2011).

MATERIALS AND METHODS

Children's products were purchased from markets in Vietnam (*n* = 38) and Japan (*n* = 34). The total heavy metal concentrations were measured using a field portable X-ray fluorescence analyzer. We tested the bioaccessibility of several children products based on EU legislation and assessed their health risk to children via oral ingestion. Simulated gastric (pH 2.5, 1 h), small intestinal (pH 7.0, 4 h), and colonic (pH 6.5, 8 h) fluids were used for the bioaccessibility test, which has been reported in detail elsewhere (Ruby et al., 1996; Tilston et al., 2011). Two oral ingestion scenarios were assessed: ingestion of the objects in whole versus in part. The hazard quotient (HQ) was calculated using the formula HQ = CDI/RfD, where CDI is the chemical daily intake (μg kg^{-1} d^{-1}), and RfD is the reference dose (μg kg^{-1} d^{-1}). CDI was calculated assuming one-time exposure to the sample (Guney and Zagury, 2014). The schematic of the experiment is shown in Figure 1.

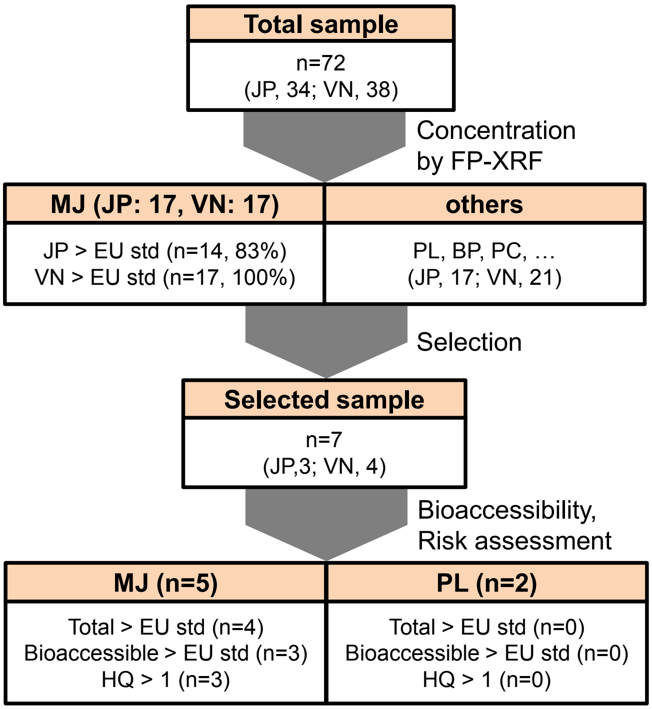

Figure 1 Flowchart of the experiments. MJ, metallic jewelry. PL, plastic toy.

RESULTS AND DISCUSSION

Total concentration

We found that the total heavy metal concentrations in many items of metallic jewelry (MJ) exceeded category 3 of the EU standards. Category 3 is adapted for the major types of children's products. The total exceeded the standard for 14/17 (83%) products from Japan and 17/17 (100%) from Vietnam (Figure 1). Plastic toys, materials with paint or a coating, brittle or pliable toys, and table and cutlery goods also had higher heavy metal concentrations than the EU standards. The total concentrations of copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), and nickel (Ni) in MJ were frequently higher than the EU standards. Figure 2 shows an example of the results for a product from Japan. Although the total heavy metal concentration is

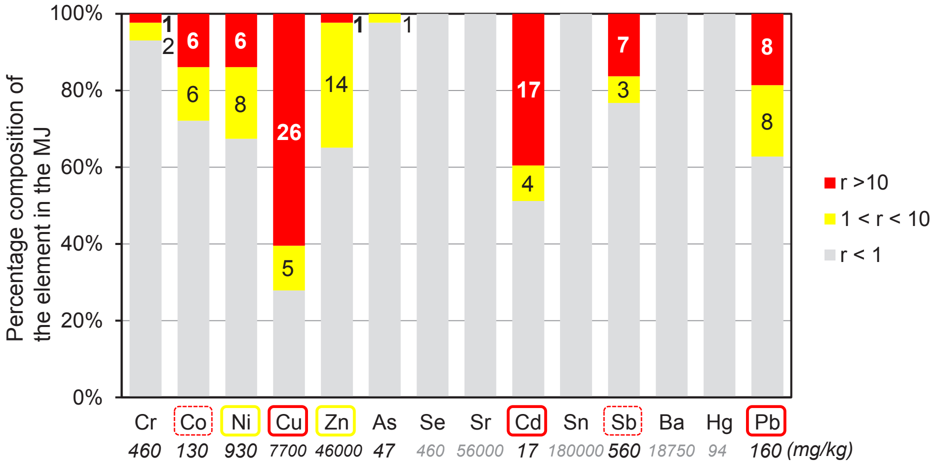

Figure 2 Distribution of heavy metals in metallic jewelry. r is the ratio of the measured value to the EU standard. The number in italics is the EU standard.

useful for screening potentially toxic samples, the bioaccessible concentrations in body fluids are needed to assess health risk properly.

Bioaccessibility test

We tested the bioaccessibility of seven children's products from Japan (*n* = 3) and Vietnam (*n* = 4). The leaching concentrations in simulated body fluids for the plastic toys evaluated did not exceed EU standards. The MJ had a very low leaching ratio of heavy metals (i.e., bioaccessibility), because the chemical states of the heavy metals might be in metallic form. Nevertheless, three MJ samples (MJ04, MJ06, and MJ13) had leaching concentrations exceeding EU standards. Especially, Pb and Cd in MJ leached in the stomach and small intestine phases (Figure 3). MJ containing more than 10% Pb has the potential to release bioaccessible Pb exceeding EU standards.

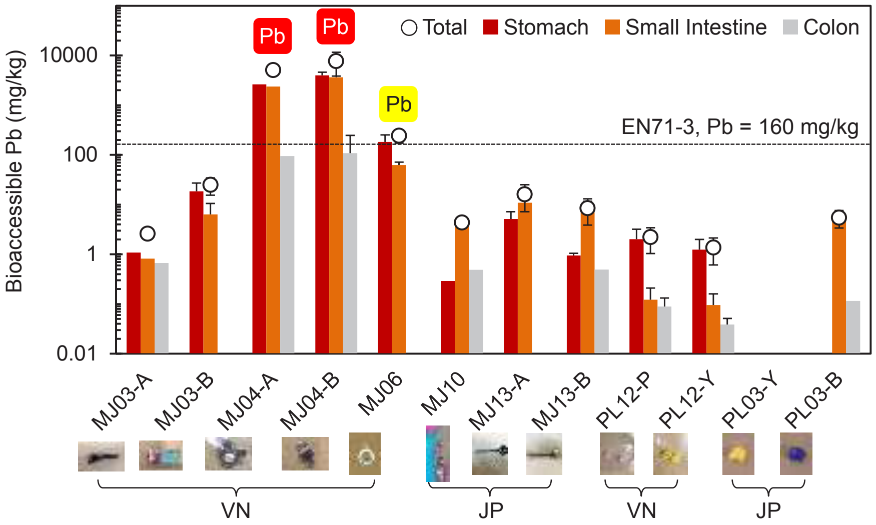

Figure 3 Bioaccessible Pb concentrations in gastric, small intestinal, and colonic fluids.

Risk assessment

We assessed the health risks of oral product ingestion to children aged 6 months to 3 years. One MJ sample had a HQ > 10 for Pb based on the bioaccessible Pb concentrations in the stomach and small intestine phases. In addition, Cd had a cumulative HQ > 1.0 for the case from 6 – 12 months. Therefore, accidental oral ingestion of the product could adversely affect a child's health via the leaching of heavy metals, especially Pb, in the stomach and small intestine.

CONCLUSION

This study investigated the levels of heavy metal contamination in cheap children's products from Vietnam and Japan and assessed their health risk to children based on a bioaccessibility assay. We found that the total heavy metal concentrations in many of the MJ items evaluated exceeded EU standards. Three types of MJ had leaching concentrations exceeding EU standards. Especially, Pb and Cd in MJ leached in the stomach and small intestine phases. Accidental oral ingestion of such an item could adversely affect a child's health via the leaching of heavy metals, especially Pb, in the stomach and small intestine. Based on these results, bioaccessibility testing of children's products should be expanded at least to the small intestine phase.

Frequently, the compositions of the children's products examined were not noted in their descriptions, and it was difficult to identify the factories that produced these products. Therefore, traceability might be important to avoid heavy metal contamination of children's products. In the future, we will examine the relationship between traceability and heavy metal contamination.

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A Method to Calculate Low heating Value of Domestic Industrial Waste Incinerating Facilities

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ABSTRACT

This study established the relationship between heat input and output in a state of equilibrium by using the principle of the conservation of energy and first law of thermodynamics targeting industrial waste incinerating facilities(57 facilities), and calculated the low-heating value of each facility. As a result of an analysis, the low-heating value of integral boiler is averagely 3.777kcal/kg(1,984kcal/kg ~ 6,476kcal/kg), and the low heating value of detachable boiler is averagely 3,787kcal/kg(1,621kcal/kg ~ 8,486kcal/kg).

Keywords : Low heating value, Heat balace, Industry waste incinerators

INTRODUCTION

The low heating value of waste is the basic unit to calculate annual energy included in treated waste, and the reliability of energy gain factor is influenced by the accuracy of low-heating value. In addition, Low heating value is the most important factor that has an impact on parameter related to the efficiency of waste incinerating facilities.

The methods to calculate low heating value are a method to analyze three components(ash, water, and combustibles), elementary analysis(C, H, O, N, S), and a method to analyze a calorimeter, but there are wide variations in caloric value according to the methods to calculated and there is no common standard, so the accuracy of these methods declines1). Therefore, this study desires to deduct a scientific and objective method to calculate low-heating value using a method of heat balance, by reflecting the characteristics of industrial waste incinerating facilities.

MATERIALS AND METHODS

1. Research Subjects and Checklist

On the spot survey and questionnaire study were conducted and used as basic data targeting 57 facilities(14 integral boilers, 43 separate boilers) where are operated at present to prepare a method to calculate low-heating value of industrial waste incinerating facilities adequate for domestic circumstances. Table 1 means the present condition of the facilities.

Table 1. Heat input and flow out heat configuration items according to heat balace method

Division		Incinerator Type	Facilities Number
Industry waste incinerator (57 facilities)	Integral boiler (14 facilities)	Stoker	8
		Rotary kiln	1
		Rotary kiln+ Stoker	5
	Separate boiler (43 facilities)	Stoker	33
		Rotary kiln	2
		Rotary kiln+ Stoker	8

2. Calculation of Low-heating Value

Industrial waste incinerating facility is divided into integral and separate boilers. In addition, shapes(Stoker, Rotary Kilen) and characteristics of furnace are various and a development rate of making waste is not fixed, so it is difficult to apply Net Caloric Value(NCV) for low heating value[2)]. Therefore, low heating value of each facility was calculated by using a heat balance method of land boiler to calculate scientific and objective low heating value[3)]. Table 2 arranged the composition of heat input and output according to a heat balance method, and low heating value calculating formula was showed as (Formula 1).

$$\mathrm{LHV(Low\ heating\ value)} = (Q_{out} - Q_{in\ 2} - Q_{in\ 3} - Q_{in\ 4}) \,/\, m_{waste\ input} \qquad (1)$$

Table 2. Heat input and flow out heat configuration items according to heat balace method

Division	Input (Q_{in})	Output (Q_{out})
Integral Boiler	1) Waste supply heat	1) Steam absorption heat
	2) Primary air for combustion heat	2) Economizer absorption heat
	3) Secondary air for combustion heat	3) Emission gas retention heat
	4) Auxiliary fuel supply heat	4) Incinerators and boilers heat loss
	-	5) Ash exhaust heat
	-	6) Blowdown
	-	7) Ash loss on Ignition
Separate Boiler	1) Waste supply heat	1) Emission gas retention heat
	2) Primary air for combustion heat	2) Incinerators heat loss
	3) Secondary air for combustion heat	3) Incomplete heat loss
	4) Auxiliary fuel supply heat	4) Unburned ash retention heat loss
	-	5) Ash exhaust heat

RESULTS AND DISCUSSION

The study established the relationship between heat input and output in a state of equilibrium by using the principle of the conservation of energy and first law of thermodynamics targeting industrial waste incinerating facilities(57 facilities) operated at present. In case of integral boiler, low-heating value is averagely 3,777kcal/kg(1,984kcal/kg ~ 6,476kcal/kg), and low heating value of separate boiler is averagely 3,787kcal/kg(1,621kcal/kg ~ 8,486 kcal/kg). Table 3 means a result to calculate low heating value.

Table 3. Result of low heating value

Division		Average (kcal/kg)	Error range(kcal/kg)	
			MAX	MIN
Industrial waste (57 facilities)	Integral boiler (14 facilities)	3,777	6,476	1,984
	Separate boiler (43 facilities)	3,787	8,486	1,621

CONCLUSION

The following conclusion was deducted through a result of a method to calculate low heating value targeting domestic industrial waste incinerating facilities(57 facilities) operated at present.

1. Shapes(Stoker, Rotary Kilen) and characteristics of furnace in industrial waste incinerating facilities are various, and the development rate of making waste is not fixed, so it is appropriate to calculate low heating value with a heat balance method of land boiler to calculate scientific and objective low heating value.
2. In case of integral boiler in industrial waste incinerating facilities, low heating value is averagely 3,777kcal/kg(1,984kcal/kg~6,476kcal/kg), and low heating value of separate boiler is averagely 3,787kcal/kg(1,621kcal/kg ~ 8,486 kcal/kg).

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Recovery of Rare Earth Elements from Neodymium Magnets Using Molten Salt Electrolysis

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ABSTRACT

Rare earth elements are used in neodymium magnets, and these elements are critical to the Japanese industry. In this study, we focused on the electric behavior of neodymium magnets for the recovery of rare earth elements using molten salt electrolysis. The influence of the rare earth elemental composition of the neodymium magnets on their anodic polarization behavior was studied. The initial increase in current diminished with the decreasing dysprosium composition in the neodymium magnets. The content of rare earth elements in the molten salt was greater than 99 mass% after the controlled potential electrolysis process.

Keywords: Rare earth elements, neodymium magnet, electrochemistry, molten salt

INTRODUCTION

The separation of rare earth elements using chemical separation methods is difficult. Typically, multistep cycles of solvent extraction are used to isolate each element because of their similar chemical characteristics. Neodymium magnets contain large amounts of neodymium, praseodymium, and dysprosium. Dysprosium, which is more expensive than neodymium and praseodymium, is added to neodymium magnets to increase their heat resistance. Neodymium magnets are used in numerous consumer electronics and electric- and hybrid-powered vehicles. Large amounts of neodymium are wasted each year when products that contain these magnets are discarded. Processes for the recovery of rare earth elements from neodymium magnets have been developed such as hydrometallurgical treatments (J. P. Rabatho, W. Tongamp et al., 2013, T. V. Hoogerstraete, S. Wellens et al., 2013, and Y. Kikuchi, M. Matsumiya et al., 2014), hydrothermal processing (T. Itakura, R. Sasai et al., 2006), molten metal extraction (O. Takeda, T. H. Okabe et al., 2006, T. H. Okabe, O. Takeda et al., 2003, H. Sekimoto, T. Kubo et al., 2014, and H. Hoshi, Y. Miyamoto et al., 2014), molten salt extraction (O. Takeda, K. Nakano et al., 2014), chloride volatility processing (M. Itoh, K. Miura et al., 2009), and glass slag processing (T. Saito, H. Sato et al., 2003). Rare earth oxides are recovered from these processes, and these oxides are subsequently reduced to rare earth metals using molten salt electrolysis. We have reported a recovery process for rare earth elements from neodymium magnets using molten salt electrolysis, where these elements were recovered as alloys (Y. Kamimoto, G. Yoshimura et al., 2015).

In this study, we focus on the differences in the electrical behavior of rare earth elements in neodymium magnets during molten salt electrolysis. We use anodic polarization experiments to determine the optimal electric leaching conditions and observe the leaching behavior of rare earth elements.

MATERIALS AND METHODS

Experimental equipment

The experimental equipment is shown in Fig. 1. The electrolysis potential was controlled using a potentiostat (HZ-5000; Hokuto Denko). The reactor was made of Pyrex glass and purged with Ar gas. A eutectic salt mixture of 59-mol% LiCl and 41-mol% KCl (melting point: 626 K), which melted at 723 K, was used in the electrolysis bath. The cathode electrode was a glassy carbon rod. The anode electrode was a neodymium magnet, a neodymium rod, a dysprosium rod, or an iron wire. The composition of the neodymium magnets used in the experiments is shown in Table I. The reference electrode was Ag/AgCl (0.1 N) in a eutectic composition of LiCl–KCl; this electrode was placed in a mullite tube. The electrolysis bath was maintained at 473 K for 24 h under a vacuum to eliminate water.

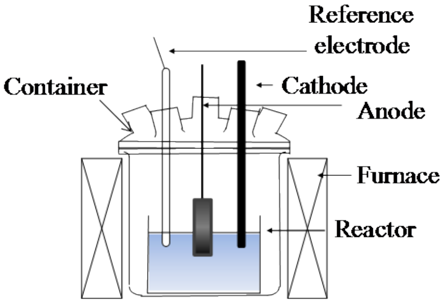

Fig.1 Experimental equipment

Table 1. Composition of the neodymium magnets used in this study

	Nd	Pr	Dy	Fe	B	Al
Magnet (A)	20.0	11.8	1.8	64.9	1.3	0.3
Magnet (B)	18.0	8.0	4.6	67.6	1.2	0.7
Magnet (C)	18.9	6.0	4.7	68.4	1.2	0.7

Analytical method

The compositions of the neodymium magnet, electrolysis bath, cathodic deposits, and anodic residues were analyzed by inductively coupled plasma atomic emission spectrometry (ICP-AES; Optima-3300DV, PerkinElmer).

The current efficiency (C_{eff}) was calculated from the change in composition of the neodymium magnet as detected by ICP-AES using the following equation:

$$C_{eff} = \frac{(Z_{Nd} n_{Nd} F + Z_{Pr} n_{Pr} F + Z_{Dy} n_{Dy} F)}{Q}$$

where Z_X represents the charge of each element X; n_X is the molar amount obtained from the ICP analysis of each element X; F is the Faraday constant; Q is the quantity of electricity; and X represents neodymium, praseodymium, or dysprosium.

The molar amounts were calculated using the following reaction formulas:

$$Nd \rightarrow Nd^{3+} + 3e^{-}$$

$$Pr \rightarrow Pr^{3+} + 3e^{-}$$

$$Dy \rightarrow Dy^{3+} + 2e^{-}$$

RESULTS AND DISCUSSION

Anodic polarization

The scan rate of anodic polarization was 5 mV s^{-1}. The anodic polarization curves of the elements in the neodymium magnet are shown in Fig. 2. The oxidation current of neodymium and dysprosium is generated at approximately −2.2 V, and oxidation potential is the lowest among the elements in the neodymium magnet. The iron oxidation potential was the highest at −0.7 V. Iron is the main component of the neodymium magnet, and the leaching of iron must be avoided in the recovery process. The use of potentiostatic electrolysis enables the selective leaching of rare earth elements from the neodymium magnet, as reported in our previous research.

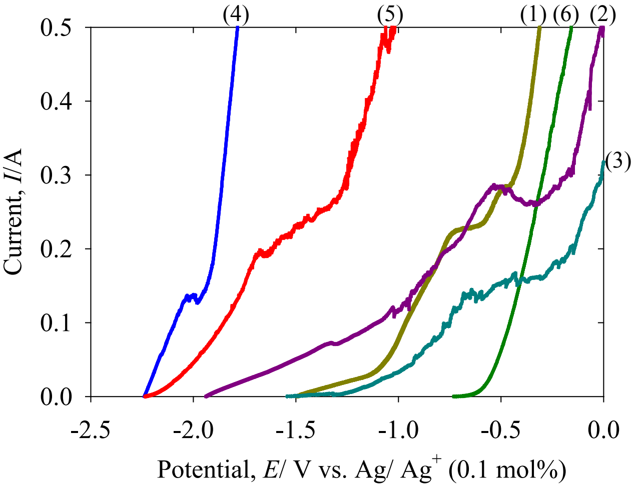

Fig.2 anodic polarization curves at (1) Magnet(A), (2) Magnet(B), (3) Magnet(C), (4) neodymium, (5)dysprosium, and (6) iron

Potentiostatic electrolysis

Rare earth elements were leached from the neodymium magnets using potentiostatic electrolysis. The neodymium magnets were used as the anode, and a carbon rod served as the cathode. The electrolysis potential was −1.0 V, and the quantity of electricity was approximately 1200 C. Table 2 shows the elemental contents of the residual-electrolyzed neodymium magnet and molten salt.

Table 2. Elemental compositions of the residual-electrolyzed neodymium magnet and molten salt

		Nd	Dy	Pr	Fe	B	Al
Residual	Magnet (A)	1.5	1.2	0.2	94.7	2.4	0.2
	Magnet (B)	1.9	1.0	0.4	94.4	1.8	0.5
	Magnet (C)	1.6	0.5	0.4	96.2	1.7	0.5
Molten salt	Magnet (A)	54.9	41.4	3.2	0.4	0.1	0.0
	Magnet (B)	62.4	23.1	13.6	0.9	0.0	0.0
	Magnet (C)	66.9	18.1	14.1	0.9	0.0	0.0

The results in Table 2 show that the residual magnet and molten salt compositions were similar for all three neodymium magnets used in the experiments. The residual iron content increased, and the concentrations of the rare earth elements decreased. The rare earth elements were leached from the neodymium magnet into the molten salt, and the total rare earth content in the molten salt was greater than 99.0 mass%.

CONCLUSION

Rare earth elements were leached from neodymium magnets using electrolysis in a molten eutectic mixture of LiCl and KCl. The oxidation potential of all neodymium magnets was −1.0 V. The oxidation potential of dysprosium was similar to those for neodymium and praseodymium. The content of rare earth elements in the leaching component was greater than 99.0 mass%.

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Simultaneous removing SO_2 and NO by Ammonia-Fe^{II}EDTA Solution Coupled with Fe^{III}EDTA Regeneration by Iron

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ABSTRACT

SO_2 and NOx are the main cause of acid rain, urban smog and greenhouse effect. In this paper, the simultaneous absorption of NO and SO_2 by ammonia- Fe^{II}(EDTA) complex solution in a pilot scale reactor was investigated. Meanwhile, iron regeneration of the used ammonia-Fe^{II}(EDTA) complex solution was proposed. The experimental result demonstrated that the maximum efficiencies of NO and SO_2 were 68.26% and 99%, respectively. It was also found that the denitiration efficiency was continually declined with the reaction time due to the oxidation of Fe^{II}. After the regeneration by iron, the denitration efficiency was improved from 48.83% to 57.12%.

Keywords: Denitration, Desulpherization, Ammonia, Fe^{II}EDTA complex, Iron

INTRODUCTION

SO_2 and NOx are the main cause of acid rain, urban smog and greenhouse effect, which lead to a major environmental pollution due to their hazard effect on human and ecosystem. In 2012, Chinese Iron&Steel industry emitted about 246,000 tonnes SO_2 and 972,000 tonnes NOx(China Statistical Yearbook on Environment, 2013). At the same time, it was also reported that SO_2 and NOx from the sintering flue gas accounted for 90% SO_2 and 48% NOx emitted by the Iron&Steel industry(Liao et al., 2008). Hence, Ministry of Environmental Protection of China issued a new emission standard of air pollutant for sintering and pelletizing of iron and steel industry(GB28662-2012), which required that NOx from the sintering flue gas must be below 300 mg/Nm^3 since 2015. However, the current NOx concentration in sintering flue gas is about 180-400 mg/Nm^3(Chen et al., 2015).

In the recent year, the absorption of NO by the complex such as metal- Ethylenediaminetetraacetic (EDTA) chelates, iron(ii) thiochelate and cobalt ethylenediamine solution has been a hot wave. Sata et al.(1980), Yih et al.(1988) reported that Fe^{2+} (EDTA) could promote the solubility of NO via formation of Fe^{2+}(EDTA)NO. Hence, Fe^{2+}EDTA and sulfites such as Na_2SO_3 or $MgSO_3$ were quite effective in removing NO and SO_2 simultaneously. However, Fe^{2+}EDTA is easily oxidized to Fe^{3+}EDTA that is not capable of binding NO. Many methods had been tried to reduce Fe^{3+} and reuse Fe^{2+}EDTA. Lu et al.(2011) and Gao et al.(2014) found Fe^{3+}EDTA can be effectively reduced to Fe^{2+}EDTA by denitrifying bacteria. Moreover, Ma et al.(2004) proposed iron fillings reduced NO and Fe^{2+}EDTA, and NO removal efficiency reached 90% when O_2 content in flue gas was 10.5%. However, the simultaneously denitration and desulfurization in a reactor has few reported. Especially, most of reaches have been carried out in the laboratory scale reactor. In this paper, a novel process of denitration and desulfurization by ammonia- Fe^{2+}EDTA solution scrubbing combined with iron fillings regeneration was proposed, and the experiment was carried out in a pilot scale reactor to prove the feasibility of the above technology.

MATERIALS AND METHODS

The reactor system was consisted with gas supply system, absorb reactor, regeneration system, iron removing system and gas measure system. The gas supply system was made up by air compressor, SO_2 cylinder, NO cylinder, buffer tank and mass flowmeters. The flow rate was controlled by flowmeters. The absorb reactor was made by stainless steel, its diameter and height were 200 mm and 1000 mm, respectively. At the same time, there was 900 mm plastic pall ring in the absorb reactor. The absorb solution was spayed by three nozzles. The regeneration system was made up by plastic with 200 mm diameter and 1000 mm height. The regeneration reactor was packed by iron scrap and plastic pall ring, the weight of iron filing was about 3.0 Kg. The iron removing system was consisted with a tank adjusting pH, and a centrifugal machine. The inlet and outlet flue gas was recorded by two gas analyzers(Horiba Corp., pg250, Japan).

Before the experiment, 150 L Fe^{2+}EDTA solution was prepared by $FeSO_4$, Na_2EDTA and water, and Fe^{2+}EDTA concentration was 0.05 mol/L. Moreover, $(NH_4)_2SO_4$ was added to the solution to simulated the scrubbing solution in the ammonia desulfurization reactor of a sintering workshop. $(NH_4)_2SO_4$ concentration was 1.5 mol/L. pH was automatically adjusted by adding ammonia and kept at 5.8. During the experiments, SO_2 and NOx concentration in the simulated flue gas were kept at 800 ppm and 400 ppm, respectively. The flow rate of the simulated flue gas was about 40 m^3/h. The scrubbing solution was fed by three nozzles and its flow rate was 300 L/h.

RESULTS AND DISCUSSION

It was well known that ammonia was an excellent reactant of absorbing SO_2 from flue gas, and ammonia desulfurization technology has been widely applied in the coal combustion power plants and the sintering plant. The reaction of ammonia absorbing SO_2 can be described as Eq.1-2.

$$SO_2+H_2O+2NH_3 \longrightarrow 2NH_4^{+}+SO_3^{2-} \quad (1) \qquad SO_2+H_2O+SO_3^{2-} \longrightarrow 2HSO_3^{-} \quad (2)$$

At first, Eq. 1 is the main reaction of absorbing SO_2. However, Eq.2 becomes more important when $(NH_4)SO_4$ concentration is high. Moreover, It was reported that the equilibrium constant of Fe(II)EDTA–NO complex was about 10^7 M^{-1} (25 °C), as Eq. 3. Hence, Fe(II)EDTA solution scrubbing can obtain a high NO removal efficiency. However, Fe(II)EDTA was easily oxidized to Fe(III)EDTA that was not capable of binding NO, as Eq 4.

$$Fe^{II}EDTA+NO \rightarrow Fe^{II}EDTA\left(NO\right) \quad (3) \qquad 4Fe^{II}EDTA + O_2 + 4H^{+} \rightarrow 4Fe^{III}EDTA + 2H_2O \quad (4)$$

Fig.1 showed that ammonia/Fe^{II}EDTA solution scrubbing can achieve about 99% desulfurization efficiency if pH was kept at 5.6-6.0. At the same time, 60% denitration efficiency can be obtained by the ammonia/Fe^{II}EDTA solution scrubbing. However, the denitration efficiency would decrease with the oxidation of Fe^{II}EDTA. The denitration efficiency reached 21% when the reaction time was 55 min. Ma et al.(2004) reported the reaction rate of Eq.2 was $1.09\times10^4\exp(-2.33\times10^4/RT)$. Thus, most of Fe^{II}EDTA was oxidized to FeIIIEDTA when the reaction time was 55 min, which caused the low denitration efficiency, about 21%. In order to improve the denitration efficiency, Fe^{III}EDTA in the scrubbing solution must be reduced. In this experiment, the iron scrap(spiral shape) with a diameter of 15mm and a thickness of 1 mm was used as reactants. The weight of scrap was about 3 Kg. The iron scrap will react with Fe^{III}EDTA and form Fe II EDTA, as Eq.5

$$2Fe^{III}EDTA + Fe \rightarrow 2Fe^{II}EDTA + Fe^{2+} \qquad (5)$$

$$Fe^{III} + 3OH^{-} \rightarrow Fe(OH)_3 \qquad (6)$$

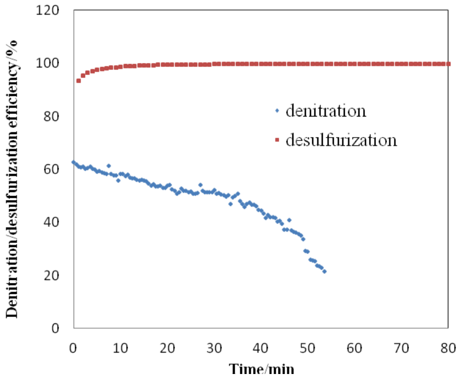

Fig. 1 Ammonia/Fe^{II}EDTA desulfurization and denitration without generation

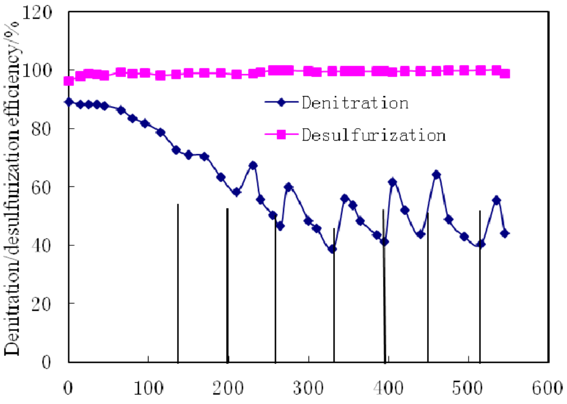

Fig. 2 Ammonia/Fe^{II}EDTA desulfurization and denitration with iron generation

In this test, 30 L scrubbing solution was discharged to the iron removing system each hour. In the iron removing system, pH of the solution was adjusted to 7, then Fe^{III} would form $Fe(OH)_3$. After the precipitation and centrifugal separation, about 60% iron was removed, and the EDTA loss rate was 8.85%. pH of the removed iron solution was adjusted to 5.8 again and re-fed to the absorb system. Fig. 2 demonstrated the denitration and desulfurization efficiency. The desulfurization efficiency was independent with iron ion, and the efficiency was kept at 99%.

As for the denitration, the efficiency would increase the addition of iron removed solution, then the dentration efficiency would decline as the oxidation of Fe^{II}. The minimum denitration efficiency was 48%

and the maximum dentration efficiency was 63%, and the average denitration can keep at 51%. Moreover, the total iron ion in the solution was kept at 0.15 mol/L. At the same time, pH was decreased and sulphuric acid must be added. In the first 180 minutes, the consumption of sulphuric acid(98%) was about 1 Kg, then pH was only stable and without sulphuric acid addition. After the experiment, the iron scrap was weighted. It was discovered that the iron scrap consumption was 108 g/h.

CONCLUSION

In this paper, the simultaneous absorption of NO and SO_2 by ammonia- Fe^{II}(EDTA) complex solution in a pilot scale reactor was investigated. The experimental resulted demonstrated 99% desulfurization efficiency and 55% denitration efficiency can be obtained. Meanwhile, sulfuric acid was consumed at the first 180 minutes, then pH was stable. The consumption of iron scrap was about 108 g/h in our experiment. The EDTA loss was also occurred because of $Fe(OH)_3$ precipitation and centrifugal separation.

ACKNOWLEDGEMENT

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Preliminary micro-characteristics analysis of municipal solid waste incineration fly ash generated in a fluidized bed combustor

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ABSTRACT

Numerous previous researches have studied characteristics of municipal solid waste incineration (MSWI) fly ash with focus on metal distribution and its leachability. However, MSWI fly ash has been regarded as homogeneous fine particles without sufficient micro-analysis. Therefore, this study investigated micro-characteristics of fly ash. According to SEM observation, raw fly ash from a fluidized bed combustor was categorized into two shapes based on morphological characteristics. They are sphere shape and aggregates of small particles. From previous research, raw fly ash from fluidized bed type have almost the same shapes as that from stoker type. Both types of fly ash particles from a fluidized bed combustor consist of the same major elements like Al, Ca, Si, and O as well as those from stoker type combustor. Sphere particles from two combustor types MSWI fly ash have different element basis in the surface. The type of combustor gave no impact on shape formation and major elemental content of fly ash particles.

Keywords: municipal solid waste, fly ash, heavy metal, micro-characteristics

INTRODUCTION

Japan is one of countries that are leading incineration facilities in the world. In 2013 total municipal solid waste (MSW) generated in Japan was about 44.87 million Mg. About 85% of MSW was treated by incineration. Incineration has advantages such as volume reduction about 90% and mass reduction about 70% of municipal solid waste. As a byproduct, incinerators produce residues containing bottom ash and fly ash1). Residue from MSW incinerator, in particular fly ash, contains toxic heavy metals which cause potential hazard to the environment. Therefore, fly ash should be treated before its final disposal in landfill2). The incineration bottom ash was obviously a heterogeneous matrix because of the different nature of municipal solid waste burnt in the incineration system3). In contrast, MSWI fly ash is fine particles and regarded as homogeneous in numerous previous researches. From the previous research of the authors' group, however, it was found that fly ash particles from a stoker type MSW incinerator had mineralogical active surface because the secondary mineral formation on the surface of MSWI fly ash particles4). However, micro-characteristics of MSWI fly ash from a fluidized bed type MSW incinerator is still uncertain. Therefore, the objective of the study is to investigate the micro-characteristics of fly ash a fluidized bed type MSW incinerator to investigate impacts of incinerator type on micro-characteristics of fly ash.

MATERIALS AND METHODS

MSWI Fly Ash

In this study fly ash generated from two types of MSW incinerator, a fluidized bed combustor and a stoker combustor, were analyzed. MSWI fly ash from a fluidized bed combustor was sampled at outlet side of bag filter in a MSWI facility plant. MSWI fly ash from stoker combustor was sampled at inlet side of fabric filter in a MSWI facility plant. All samples were dried under natural condition before experiment and analysis.

Scanning Electron Microscope (SEM)

The morphological surface of MSWI fly ash particles was observed using scanning electron microscope (SEM; JSM-6610LA, JEOL Ltd., Japan). The MSWI fly ash samples were fixed on the carbon tape. It might cause overestimate of carbon content. The samples were observed after Pt sputtering for 90 seconds.

Energy Dispersive X-ray spectroscopy (EDX)

The elemental composition of MSWI fly ash particles was analyzed using energy-dispersive x-ray spectroscopy (EDX) attached to SEM (SEM-EDX JSM-6610 LA, JEOL, Ltd., Japan). Elemental mapping of fly ash particle surfaces was carried out to analyze elemental distribution and correlations among major/minor elements.

RESULTS AND DISCUSSION

Morphological grouping

According to SEM observations, the raw MSWI fly ash particles generated from a fluidized bed combustor could be categorized into two types based on their morphological characteristics, sphere particles and aggregates of small particles. When it was compared with MSWI fly ash generated from a stoker combustor, no significant difference was found among limitedly observed images. Although heating process of MSW in fluidized bed type combustors is much faster than that of stoker type combustor, it seems to give no impact on shape formation of fly ash particles.

Sphere particles

Both of fly ash from two type incinerators have sphere particles (see Figure 1). Sphere particles of stoker type consisted mainly of Al, C, Ca, O, and Si. Sphere particles of stoker types are considered as oxides and/or carbonates of Al, Ca, and Si. On the other hand, sphere particles from fluidized bed type consisted mainly of Al, Na, Si and O. Although sphere particles from fluidized bed type are considered as oxides of Al, Na, and Si, they might also contain carbonates of Al, Na, and Si. SEM-

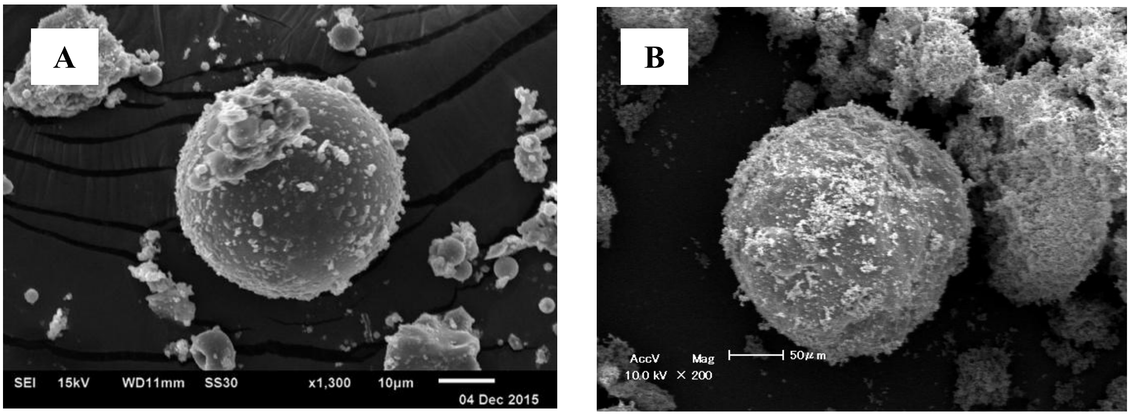

Fig. 1. SEM images of sphere particles of raw MSWI fly ash ([**a**] fluidized bed combustor, [**b**] stoker combustor

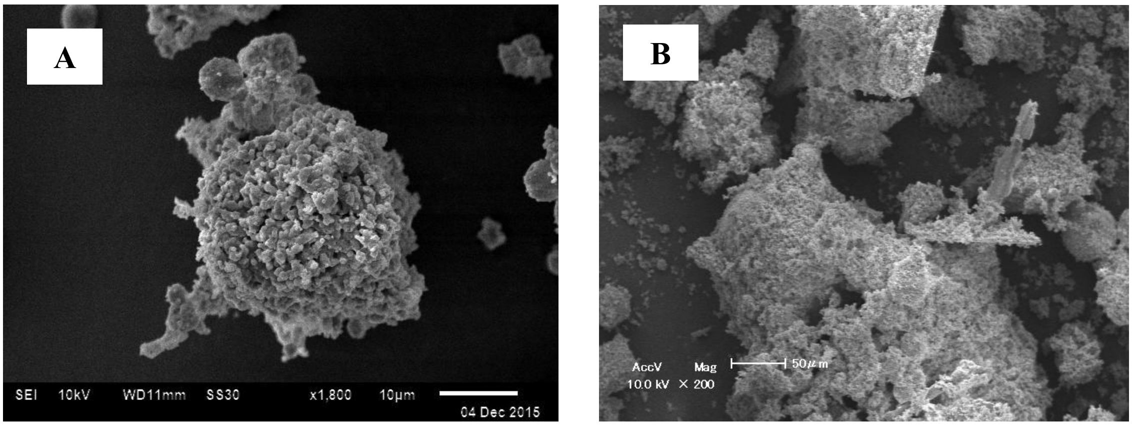

Fig. 2. SEM images of aggregates of small particles of raw MSWI fly ash ([**a**] fluidized bed combustor, [**b**] stoker combustor

EDX used for the analysis of fly ash from fluidized bed type underestimated carbon due to sensor calibration errors. At least, no significant difference of major component element between two type combustor “sphere shape” fly ashes was found in this study.

Aggregates of small particles

As the same as sphere particles, both of fly ash from different type incinerator have aggregates of small shape particles (see Figure 2). Aggregates of small particles from fluidized bed type mainly consisted of Al, Na, Ca, Cl, and O. Aggregates of small particles are considered as oxides and/or chlorides of Ca, Al, and Na. Carbonates of these elements might also be contained. On the other hand, aggregates of small particles generated from stoker type consisted of C, Ca, Cl, K, Na and O. They are also considered as carbonates and/or chlorides of Ca, K, and Na. Therefore, micro-analysis of fly ash in this study suggests no significant difference of major component element between two type combustor “small particle aggregates” fly ashes as well as “sphere type”. These results imply that toxic metals contained in fly ash might also have similar chemical forms regardless of combustor type. Further observation and analysis are planned to investigate the impact of combustor type on major element heterogeneity and toxic metal distribution in MSWI fly ash particles.

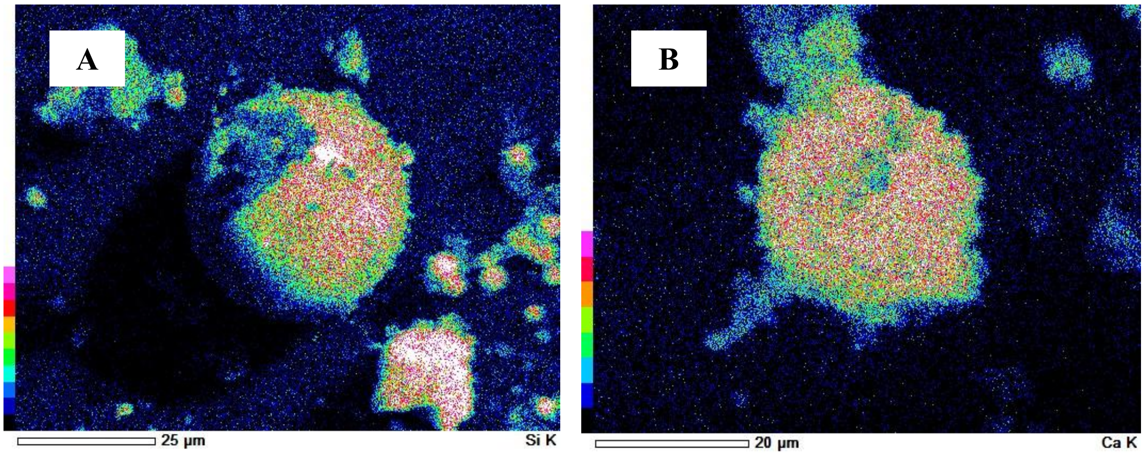

Fig. 3. Elemental distirubtion images of sphere and aggregates of small particles of raw MSWI fly ash ([a] Si, [b] Ca)

CONCLUSION

This preliminary study observed the morphological surface and elemental distribution of MSWI fly ash particles. In this study, the fly ash generated from two MSWIs in Japan were analyzed. The MSWIs have different incineration furnaces, namely fluidized bed and stoker type. Comparing the fly ash generated from two MSWI based on their morphological characteristics, they do not have any differences in terms of particle shapes and elemental distribution of particle surfaces. These results imply that toxic metals contained in fly ash might also have similar chemical forms regardless of combustor type.

ACKNOWLEDMENT

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Identification of Black Plastics Realized with the Aid of Fourier Transform Infrared Radiation and Fuzzy Radial Basis Function Neural Networks Classifier

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ABSTRACT

To overcome the shortage of natural resources, recycling has been seriously studied. Since plastics are one of the most widely used materials in the variety of industrial fields, in general, a large amount of plastics are discharged from households. Therefore, it is necessary to investigate the efficient recycling method for plastics. To recycle the plastic waste, it is the key issue to identify plastics by types such as Polyethylene terephthalate (PET), Polypropylene (PP), Polystyrene (PS), etc. Some researchers used Fourier Transform Infrared Radiation (FT-IR) for identification and separation of plastics. However, for black plastics which contain carbon black, it is unable to identify the black plastics with carbon black by using FT-IR equipment. In the present study, FT-IR with Attenuated Total Reflectance (ATR) is used to qualitative as well as quantitative analysis of black plastics. In addition, in order to enhance the identification of black plastics, intelligent techniques such as fuzzy theory, neural networks and optimization techniques are applied to analyze the obtained data. Especially, Fuzzy Radial Basis Function Neural Networks (FRBFNNs) classifier is considered to inherit the advantages of synthesis technologies of fuzzy theory and neural networks for the identification of black plastics.

Keywords: Fourier Transform Infrared Radiation (FT-IR), Attenuated Total Reflectance (ATR), Black Plastics, Identification, Recycling, Fuzzy Radial Basis Function Neural Networks

INTRODUCTION

Energy depletion problems and environmental problems have afflicted mankind. Waste recycling and reuse are considered as one of the ways to reduce energy depletion pace and solve environmental problem. Therefore, governments all over the world issue on Municipal Solid Waste (MSW) management (Zhung, Y., Wu, S. W. et. al., 2008). Plastic account for large of amounts among various materials of waste that is generated. Therefore, it is necessary to develop the effective plastic recycling and reuse technique due to the amount of plastic waste that is generated in daily life. So far, the various techniques to identify and reuse plastic have been studied.

The key issue to recycle and reuse plastic waste is an identification system to obtain a valuable recovery of plastics. The identification system can classify plastic waste into some categories in terms of materials without any pretreatment of the waste entities (Van Den Broek, W.H.A.M., Derks, E.P.P.A. et. al., 1996). That system should be rapid, accurate, robust, safe, and easy for operators to work with to be applied to the real world.

A technique to identify and separate polyethylene terephthalate (PET) and polyvinyl chloride (PVC) resins from each other was proposed by Scott, D.M. in 1995 (Scott, D.M., 1995). The identification and separation method proposed by Scott used near infrared radiation (NIR) to obtain absorbance spectra of each material. In 2001, Edward and Sommer introduced a method to group and separate PET and PVC from each other (Edward, J., Sommer, J.R., 2001). This system separate the plastic resins based on the NIR transmission spectra of PET and PVC. So far, the methods for identification and separation of plastics are not able to deal with black plastics which contains carbon black because black plastics absorb light with all wave length.

In this study, we use FT-IR with ATR equipment to obtain the transmittance spectra of black plastics. While a general way to identify plastic is to compare some peak points of the obtained spectra of a plastic to the already determined characteristic peak points of each specific plastic, the proposed method uses intelligent algorithms such as fuzzy inference system and neural networks. In order to improve the classification performance, we use an intelligent system named fuzzy Radial Basis Function Neural Networks (RBFNNs) which modifies several fuzzy rules and fuzzy inference algorithm into the structure of neural networks. It is well known that Fuzzy RBFNNs inherits the advantages of synthesis technologies of fuzzy theory and neural networks. Due to the advantages of fuzzy RBFNNs, we anticipate that the fuzzy RBFNNs are able to identify and separate plastics accurately and rapidly.

In order to validate the separation ability of fuzzy RBFNNs with FTIR-ATR equipment, we acquire data sets from black plastics such as PET, PS, and PP by using FTIR-ATR equipment.

IDENTIFICATION AND SEPERATION METHODS OF BLACK PLASTICS USING FTIR-ATR

Fourier Transform Infrared with Attenuated Total Reflectance

Infrared spectroscopy is an extremely reliable and well recognized fingerprinting method. Various materials can be identified by using infrared spectroscopy. One of the strengths of IR spectroscopy is its ability as an analytical technique to obtain spectra from a very wide range of solids, liquids and gases. However, as mentioned before, usual infrared spectroscopy cannot identify black substance. To obtain spectra of black plastic, we apply the technique of attenuated total reflectance. The attenuated total reflectance technique operates by measuring the changes that occur in a totally internally reflected infrared beam when the beam comes into contact with a sample.

Fuzzy C-Means Clustering Algorithm

Fuzzy C-Means (FCM) Clustering algorithm (Bezdek, J. C., Ehrlich, R., et. al., 1984) is the one of the representative clustering algorithms. A brief summary of FCM is outlined below.

Let us consider a finite set of data $\mathrm{X} = \{\mathbf{x}_1, \cdots, \mathbf{x}_N\}$, $\mathbf{x}_k \in \Re^m$, $1 \le k \le N$. The objective function of FCM is as follows.

$$\mathrm{J} = \sum_{i=1}^{c} \sum_{k=1}^{N} (u_{ik})^p \|\mathbf{x}_k - \mathbf{v}_i\|^2 \text{ , subject to } \sum_{i=1}^{c} u_{ik} = 1 \tag{1}$$

Here $\mathbf{v}_j$ is the apex of j-th cluster and $\|\mathbf{x}_k - \mathbf{v}_i\|$ is any distance between the data $\mathbf{x}_k$ and the prototype $\mathbf{v}_i$. The optimization problem to minimize (1) is expressed as follows.

$$\min_{u,v} J \text{ subject to } \sum_{i=1}^{c} u_{ik} = 1 \tag{2}$$

The optimal solution to (2) can be calculated by to iterative update formulas such as (3) and (4).

$$u_{ik} = 1/\sum_{j=1}^{C} \left(\|\mathbf{x}_k - \mathbf{v}_i\| / \|\mathbf{x}_k - \mathbf{v}_j\| \right)^{2/(p-1)} \tag{3}$$

$$\mathbf{v}_i = \sum_{k=1}^{N} (u_{ik})^2 \cdot \mathbf{x}_k / \sum_{k=1}^{N} (u_{ik})^2 \tag{4}$$

Fuzzy Radial Basis Function Neural Networks

We use FCM to analyze the input data patterns and determine the locations of RBFs of fuzzy RBFNNs. The fuzzy rule used in fuzzy RBFNNs is described by (5).

$$Rule\ j : if\ \mathbf{x}\ is\ A_j\ then\ y = f_k(\mathbf{x}) \tag{5}$$

In Figure 1, we show the overall structure of fuzzy RBFNNs.

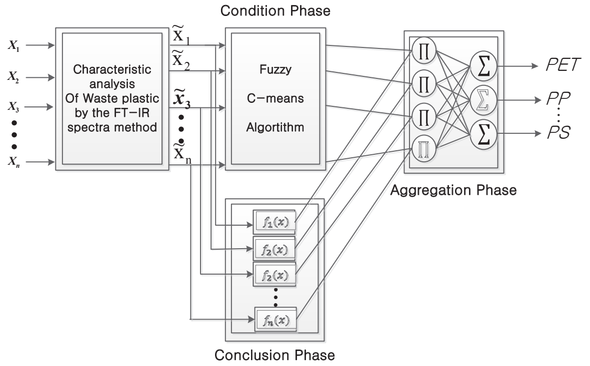


Figure 1. Structure of radial basis function neural networks

RESULTS AND DISCUSSION

Experimental Results

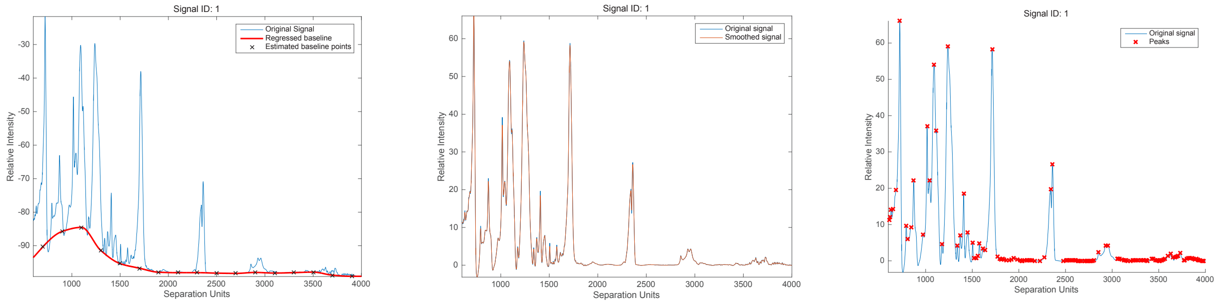
We carried out some experiments with some datasets which are acquired by using FTIR-ATR equipment. In order to validate the proposed plastic identifier, we use 5-fold cross validation technique. We use the pattern classification rate as the identification performance of the proposed identifier for black plastic as (6).

$$Pattern\ Classification\ Rate = \sum_{k=1}^{N} g(y_k, \widehat{y_k}) / N \tag{6-1}$$

$$g(a, b) = \begin{cases} 1, & a = b \\ 0, & a \neq b \end{cases} \tag{6-2}$$

Here, N means the number of data patterns.

Figure 2 shows preprocessing procedure to generate input data based on the acquired spectra of black plastics. Table 1 shows the identification results of fuzzy RBFNNs identifier.



(a) Extraction of Baseline (b) Elimination of Baseline (c) Extraction of Peaks

Figure 2. Preprocessing procedure for input data

Table 1. Identification results of fuzzy RBFNNs

Identification Performance for Training Dataset	Identification Performance for Testing Datasets
98.45±0.41	96.66±3.04

CONCLUSION

In this study, an intelligent identifier named fuzzy RBFNN is proposed to separate black plastic types such as PET, PP, and PS. To obtain spectrum of black plastic, Fourier transform infrared spectroscopy with ATR is considered. From experimental results, we show that the proposed intelligent identifier for black plastics is competitive for recycling black plastic waste.

ACKNOWLEDGEMENTS

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Feasibility Study on Micro-Hydraulic Power Generation from Sewage

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ABSTRACT

This study is concerned with the feasibility study on the power generation from sewage in pipes by using a micro-hydraulic turbine. First, the hydraulic potential of the Toyogawa River-Basin Sewerage in Japan is estimated, and secondly the performance of the micro-hydraulic turbine is investigated. These studies clarify the installation of the micro-hydraulic turbine in the sewage pipes effectively yields electrical power.

Keywords: Power generation, Sewage, Waste to energy, Micro-hydraulic turbine

INTRODUCTION

Sewage has huge energy potential. In Japan, the biogas power generation and the hydraulic power generation are estimated to be 40×10^8 kWh/year and 0.4×10^8 kWh/year respectively, and the sewage heat is evaluated to be 8300 Gcal/h (Webpage of the Ministry of Land, Infrastructure, Transport and Tourism, Japan). Thus, the Japanese government aims to utilize the sewage as energy resources, but the rate of the utilization remains to be extremely low. Sewage facilities are composed of the drainage facilities, the treatment facilities, and the complementary facilities such as pump stations. The estimation of the hydraulic energy of the sewage seems to be restricted to the treated water in the treatment facilities. As the sewage in the drainage facilities flows with higher velocity, it is supposed to have large amount of hydraulic energy.

The authors (Uchiyama et al, 2015) are engaged in the development of a micro-hydraulic turbine, which effectively converts the hydraulic energy in small rivers and channels to electric power. The hydraulic turbine is not blocked with foreign matters such as fallen leaves and refuses included in water flow. The turbine runner has a hollow around the central axis so that the foreign matters can easily pass through the turbine.

This study pays attention to the Toyogawa River-Basin Sewerage in Higashi-Mikawa Distinct of Aichi Prefecture in Japan and searches for the possible power generation by using the hydraulic energy of the sewage in the trunk lines. The above-mentioned hollow micro-hydraulic turbine is installed in the sewage pipes to drive generator. This study is concerned with the feasibility study on such power generation.

TOYOGAWA RIVER-BASIN SEWERAGE AND POWER OUTPUT

The Toyogawa River-Basin Sewerage treats the sewage from four cities, of which population is about two hundred thousand. The trunk lines are composed of the Tobu, Seibu, Mito and Toyohashi lines. The treated sewage from the Toyogawa wastewater treatment plant is discharged to the Mikawa Bay. The sewage treatment capacity is 104,000 m^3 per day. Figure 1 shows the positional relations between the wastewater treatment plant, the trunk lines and the Mikawa Bay.

In Japan, a river-basin sewerage is connected with public sewerage systems managed by local governments. Figure 1 also depicts a connection point (Toyohashi-1) of the Toyohashi trunk line and a connection point (Tobu 11-2) of the Tobu trunk line. The sewage flowrates at the Toyohashi-1 and Tobu 11-2 connection points are 0.17 m^3/s and 0.14 m^3/s, respectively. The photograph of the flow at the Toyohashi-1 connection point is shown in Fig. 2. The sewage does not always flow with occupying the whole cross-section of the pipe. This is because the excessive space is provided against the larger flowrate. The pipe diameter is 1000 mm. If the sewage is assumed to occupy the 10% of the cross-sectional area of the pipe, the theoretical power outputs at the Toyohashi-1 and Tobu 11-2 are estimated to be 421 W and 225 W, respectively. There are twenty-seven connection points in the Toyogawa River-Basin Sewerage. Thus, one can expect that the utilization of the hydraulic energy at all of the connection points yields an output of about 10 kW.

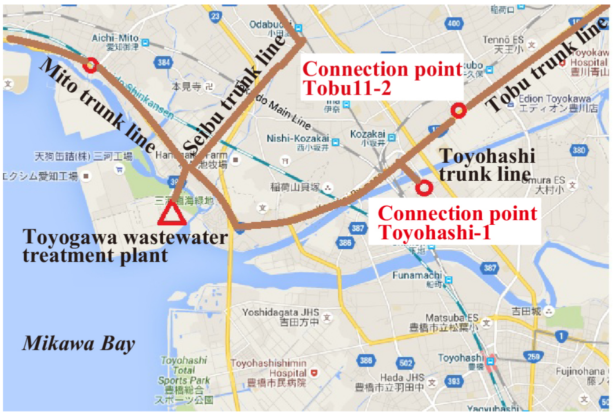


Fig. 1 Toyogawa River-Basin Sewerage

Fig. 2 Sewage at Toyohashi-1

HOLLOW MICRO-HYDRAULIC TURBINE

Figure 3 shows the cross-section of the hollow micro-hydraulic turbine developed by the authors. A runner colored blue is embedded within a pipe hatched with red. The runner and the pipe rotate integrally by the water flowing in the pipe. A guidevane colored green is mounted inside a pipe upstream of the runner.

An example of the runner is shown in Fig. 4. A circular hollow is provided around the rotating (central) axis so that foreign matters in water can pass through the runner. The ratio for the hollow diameter D_2 to the runner diameter D_1 (=80 mm) is defined as the hollow ratio $\varepsilon = D_2/D_1$.

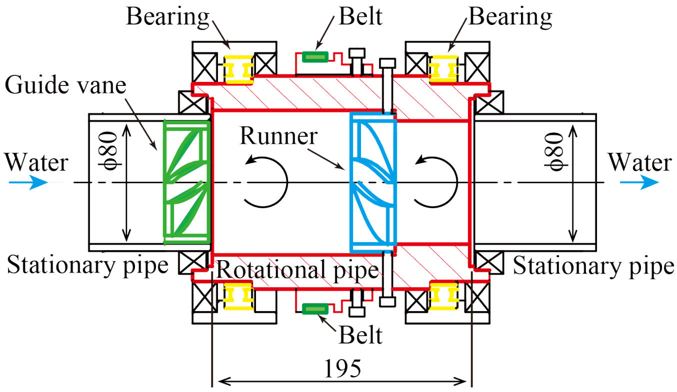


Fig. 3 Cross-section of hollow micro-hydraulic turbine

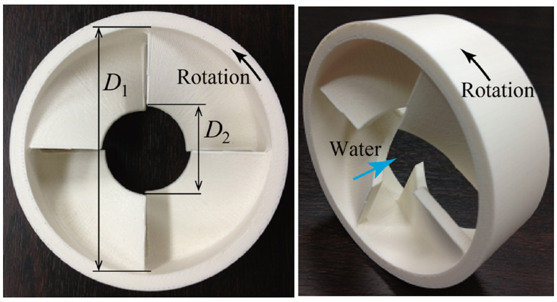


Fig. 4 Runner of ε=0.25

LABORATORY EXPERIMENT ON HOLLOW MICRO-HYDRAULIC TURBINE

Experimental method and conditions

Laboratory experiments are conducted by using a closed-loop test rig shown in Fig. 5. Water in a tank is circulated by a pump. The pressures at two points just upstream and downstream of the turbine, P_1 and P_2 respectively, are measured to calculate the turbine performance η defined by $T\omega/[Q(P_1-P_2)]$, where T, ω and Q are the torque, the angular velocity and the water flowrate respectively. This study investigates the performance of the turbine equipped with the runners and guidevanes of $\varepsilon = 0.25$ at $Q = 0.01$ m^3/s.

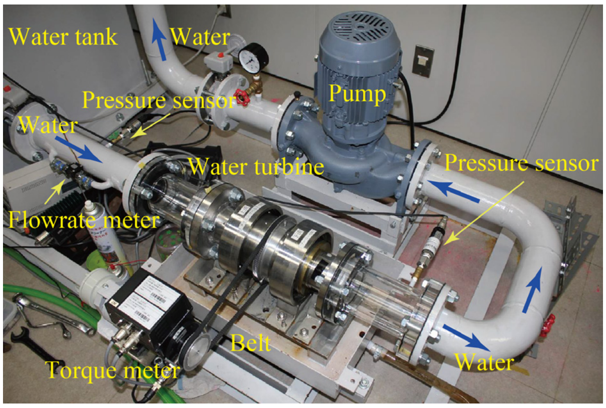
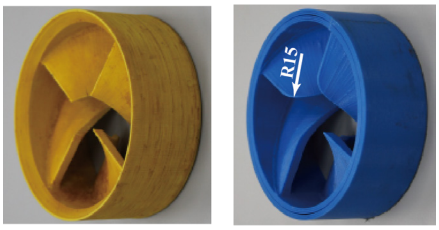


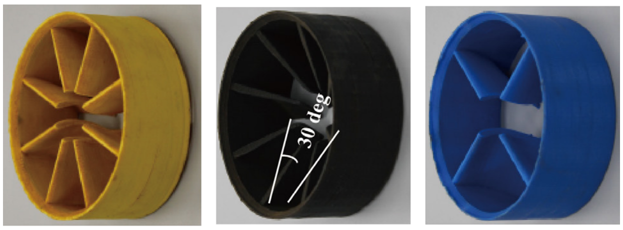
Fig. 5 Closed-loop test rig of laboratory experiment

Figure 6 shows the runners employed in this experiment. Runner 1 is the existing runner. Runner 2 is the revised runner. The blade tip is rounded so that it does not hook foreign matters. The radius is 5 mm. Three guidevanes employed in this study are depicted in Fig. 7. Guidevane 1 is the existing guidevane having eight blades. Guidevane 2 has tapered blades. Guidevane 3 has four blades. This study investigates the turbine performance for four combinations of the runners and the guidevanes as listed in Table 1.



Runner 1 **Runner 2**

Fig. 6 Runner



Guidevane 1 **Guidevane 2** **Guidevane 3**

Fig. 7 Guidevane

Polyester fibers are entrained in the turbine to simulate the entrainment of foreign matters in sewage. The spherically-shaped fibers are presented in Fig. 8, where the diameter is about 20 mm and the total mass is 2 g.

Table 1 Conditions of laboratory experiment

Case 1	Case 2	Case 3	Case 4
Runner 1 x Guidevane 1	Runner 1 x Guidevane 2	Runner 1 x Guidevane 3	Runner 2 x Guidevane 3

Fig. 8 Polyester fibers

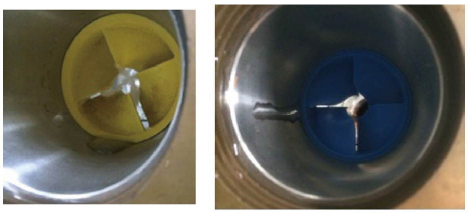
Experimental results and discussion

The photographs of the guidevane for Case 1, 2 and 3 are shown in Fig. 9. They are taken after the experiments of the fiber entrainment. The fibers are attached to the leading edge of the blades in Case 1. Such attachment is reduced in Case 2 because of the effect of the tapered blade. In Case 3, the attachment is still observed, though the number of blades is decreased. The masses of the fibers attached to the guidevane in Case 1, 2 and 3 are 0.312 g, 0.027 g and 0.17 g, respectively. The tapered blade is very effective to make the fibers pass through the guidevane.

The change in the turbine efficiency η due to the entrained fibers is demonstrated in Fig. 10, where η_0 is the efficiency at the fiber-free condition. The guidevane with the tapered blades (Case 2) has the higher efficiency. Because it is excellent in the passage performance of the fibers as shown in Fig. 9.

Case 1 **Case 2** **Case 3**

Fig. 9 Attachment of fibers to guidevane



Case 3 **Case 4**

Fig. 11 Attachment of fibers to runner

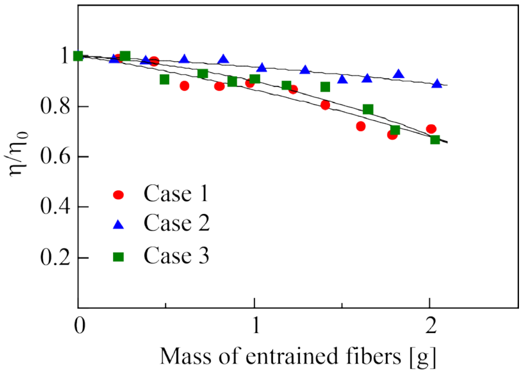


Fig. 10 Change in η due to entrained fibers

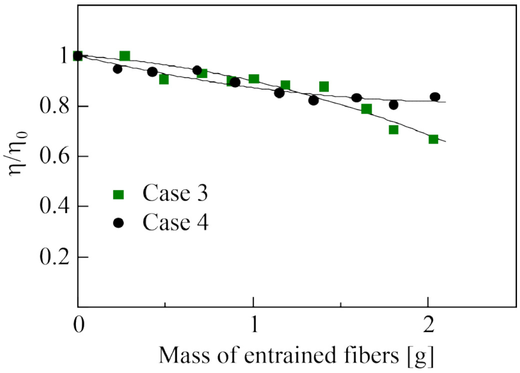


Fig. 12 Change in η due to entrained fibers

The photographs of the runner for Case 3 and 4 are shown in Fig. 11. Some fibers are hooked at the blade tip in Case 3. But there are no fibers on the blades in Case 4. The masses of the fibers attached to the runner in Case 3 and 4 are 0.06 g and 0, respectively. One can find that the rounded blade tip is effective.

The change in η due to the fibers is presented in Fig. 12. When the mass of the fibers is greater than 1.2 g, η for Case 4 is higher. This is because the rounded blade tip hooks no fibers as shown in Fig. 11.

CONCLUSION

This study elucidated that the sewage in the trunk lines of the Toyogawa River-Basin Sewerage in Japan has high hydraulic potential for power generation. To install a hollow micro-hydraulic turbine in the sewage pipes for the power generation, the laboratory experiments on the turbine performance were conducted. The experiments highlighted that the turbine is excellent in foreign matter passage performance, demonstrating the turbine maintains its function without being blocked by the sewage. The abovementioned studies clarified that the installation of the hollow micro-hydraulic turbine in the sewage pipes effectively yields electrical power.

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Technology Development to Reduce Malodor from Food Waste in Korea

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ABSTRACT

Ocean dumping of food waste is being banned worldwide by the regulations according to the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. Therefore, technologies to reduce food waste or recover them as useful resources are being studied and developed, with a few issues in the process. Major issues in the process of food waste disposal are high-concentration organic matter and leachate, as well as malodors which especially have been a sensitive social issue in terms of civil complaints. Technologies applied to reduce malodors are divided into two methods: the masking method that masks the malodors, and the method that removes the causes of the malodors. Among them, the latter can be classified into four technologies. The first is a method using microorganisms, which increases conservative property by making a colony of microorganisms such as Bacillus cereus as beads. The second is a method using catalysts, which coats adsorptive materials such as platinum, palladium and rhodium in a carrier and passes them in high temperature. Recently, technologies with a broader scope of response are being introduced in combination with low-temperature charcoal adsorption process. The third method is a technology using ozone, which improves removal efficiency by using the powerful oxidizing power of ozone in combination with plasma and photocatalyst. Finally, the most advanced technology using electrolysis is a method that reduces malodors by conducting electrolysis on condensate created by heat exchange with exhaust gas. The aforementioned methods are suggested for large-scale disposal equipment, and thus it is necessary to optimize technology applicable to smaller scales such as general residential or commercial complexes.

Keywords: malodor, food waste, microorganism, ozone, catalyst

INTRODUCTION

In 2013, the London Convention banned ocean dumping of food waste, thereby totally banning ocean dumping of all industrial wastes including food waste starting from 2014. According to the Ministry of Environment of Korea, Korea produced considerable amount of food wastes. In 2007, food waste production of Korea was approximately 14,000 metric ton a day, which accounts for 9% of whole organic wastes produced in Korea(The Ministry of Environment of Korea, 2009). Food waste contains a great deal of moisture and is easily decayed. It consists of organic matter and causes leachate in landfill, and may become a source of soil or groundwater pollution. If leachate is leaked to rivers, it may result in severe environmental problems due to various malodors. Incineration of food waste is not easy due to the great quantity of moisture. Due to these pending issues, Korea is making more and more attempts to use food waste for resources such as composts, feedstuffs and fuels. However, the malodors arising from decayed food in the process of turning food waste into resources are particularly rising as an urgent issue to be resolved. Legal regulations in malodors in Korea are enforce in 8 items such as hydrogen sulfide(H_2S), methyl mercaptan(CH_3SH), methyl sulfide($(CH_3)_2S$), dimethyl sulfide($(CH_3)_2S_2$), ammonia(NH_3), trimethylamne($(CH_3)_3N$), acetaldehyde(CH_3CHO), and styrene($C_6H_6CH{=}CH_2$), which are known to give out malodors in low concentration unlike other substances. Civil complaints due to malodors are constantly increasing, and thus the importance of odor management is expected to receive great attention in the future. Meanwhile, facilities that cause malodors include livestock wastewater treatment facilities, food waste disposal facilities, excreta treatment facilities, and landfill sites. Malodors from these facilities do not come from some of the processes but arise from all of them, thereby requiring improvement of process management or facilities as well as installation of preventive equipment to reduce malodors. Offensive odor treatments can be divided into chemical oxidation, enzyme decomposition, and absorption that fundamentally separate or destroy malodorous substances, and the method to simply mask the malodors. The oxidation method decomposes substances that induce malodors, and various technologies have been developed as it can produce an extensive bactericidal effect on pathogenic microorganisms such as bacteria, mold and viruses. Types of oxidants mostly used in chemical oxidation include chlorine dioxide, hypochlorous acid soda, and chlorate from chlorine dioxide. However, since these oxidants contain chorine, they are likely to have harmful effects on human health or livestock. Enzyme decomposition uses extracts from plants to make a deodorant and decomposes odors with it. Absorption removes malodors by absorbing malodorous substances with an absorbent with big specific surface area and excellent absorptive capacity like active carbon. However, when malodorous substances are removed by absorbing them with an absorbent, its absorptive capacity is deteriorated as time passes, thereby requiring regeneration or replacement of the absorbent. The masking method masks malodors by dissolving natural or artificial fragrance with a solvent with strong volatility such as methyl alcohol, and volatilizes the odors in the air. However, while this method can resolve the malodor issues temporarily, it is considered inappropriate as a fundamental solution to malodors. Technologies to remove malodorous substances from food waste are applied suitably to various food waste disposal techniques based on the aforementioned malodor treatment methods. This study will determine the trend of technological development for malodors in food waste disposal, and suggest tasks that must be performed in order to reinforce the food waste malodor treatment technologies.

MALODOR TREATMENT TECHNOLOGY USING MICROORGANISMS

The biological malodor treatment technology is based on the principle of eliminating malodorous substances using microorganism strain, which currently includes *Bacillus cereus*, *Bacillus licheniformis*, *Saccharomyces exiguus*, *Lactobacillus paraplantarum*, etc. Among them, Bacillus cereus is applied to technologies developed for elimination of malodors from livestock wastewater or food waste(Choi, K. and Choi, G., 2012). This technology uses Bacillus cereus by turning it into a microorganism product, and it was made into a bead type in order to remedy the shortcomings such as imbalance of products in the manufacturing process, or deterioration of product performance and conservative property due to decreased activation of microorganism. The beads developed in this technology are made by combining biodegradable polymers such as alginate, pectin, carrageenan or polyaspartic acid and Bacillus cereus culture medium with metallic salt solution including calcium ions, as well as a few additional processes. As a result of reviewing the actual effect in removing malodorous substances from livestock wastewater and food waste using this microorganism product, it was found that the deodorizing effect on dimethyl sulfide and acetaldehyde was low, but that on ammonia, methyl mercaptan, hydrogen sulfide and trimethylamne was high. The experiment was conducted while maintaining the fixed temperature of 37.5℃, and the result implies that it is necessary to establish facilities that can maintain a certain level of temperature when applied to the actual field.

MALODOR TREATMENT TECHNOLOGY USING CATALYSTS

To reduce food waste, 80~90% of which consists of moisture, drying and fermentation processes are being used with heating and microorganism reaction, but this induces high content of moisture and high concentration of malodors. Malodors from food waste consist of a complex mixture of various types, and the ingredients differ according to type of food, period of negligence and processing temperature. The technology using catalysts can treat various types of malodors caused by drying food waste at high and low temperatures. The previous food waste drying method had adopted the single process of catalyst cartridge type coated with catalysts such as platinum, palladium and rhodium. However, in addition to high-temperature catalyst cartridge coated with catalysts such as platinum, palladium and rhodium, there is also a two-step malodor treatment technology that applies low-temperature catalyst cartridge or charcoal absorbent(Kim, H., 2013). This two-step malodor treatment technology has an advantage of being able to broadly respond to malodor types and concentration from food, while it has a disadvantage in terms of initial installation cost and maintenance cost.

MALODOR TREATMENT TECHNOLOGY USING OZONE

Malodor treatment technology using absorbents such as active carbon or zeolite requires relatively low initial investment cost and is easy to operate the system, but has issues such as regular replacement of absorbents and incurrence of wastes accordingly. The deodorization technology using ozone is developed to eliminate such trouble in replacing absorbents and improve efficiency in malodor treatment. Ozone has strong oxidizing power and is thus extremely useful for deodorization and decolorization in wastewater treatment facilities. Recently, a technology using ozone, plasma and photocatalyst was developed as an example of malodor treatment technology using ozone(Kim S., 2008). This technology directly decomposes malodorous substances with ozone molecules, while eliminating malodors that remain without decomposition with plasma and photocatalysts. This technology has excellent malodor treatment efficiency as it uses powerful oxidants like ozone and OH radical, but are also likely to leak harmful substances for human body such as ozone, and thus requires extreme care in operation and management.

MALODOR TREATMENT TECHNOLOGY USING ELECTROLYSIS

Food waste disposal equipment discharges various types of high-temperature and humidity malodorous substances in a short period of time, and thus it may not be easy to effectively treat malodors by merely applying general biological technologies. To remedy the shortcomings of the existing biological deodorization technologies, methods such as absorption and oxidation have been developed, to which active carbon, ozone and photocatalysts are applied. A technology that eliminates exhaust gas from the drying process of food waste with electrolysis is recently developed(Shim, S., Kim, S. et al., 2012). This technology adopts the method of eliminating malodors with electrolysis of condensate created in the process of heat exchange with cooling air from the outside with exhaust gas discharged from the drying equipment. The malodor treatment technology using the heat exchanger and electrolysis requires remarkably less power compared to the previous electrolysis method, thereby having a great effect in reducing operating costs. However, this technology requires complicated facilities and may have high initial costs.

CONCLUSION

This study reviewed the current status of technologies that are being developed and applied as responsive technologies to eliminate malodorous substances occurring in the food waste disposal process. As a result, there are various malodor treatment technologies using microorganisms such as Bacillus, oxidants such as ozone, absorbents such as active carbon, catalysts such as platinum, as well as electrolysis. Most of these technologies are applied to auxiliary facilities of large-scale food waste disposal equipment, eliminating malodors from food waste disposal. Malodor treatment technologies developed thus far have advantages and disadvantages in terms of malodor treatment performance, initial facility costs and maintenance costs. In the future, it is necessary to design and optimize the operation of technologies to be applied to small-scale food waste disposal equipment that can be used in general residential or commercial complexes.

ACKNOWLEDGEMENT

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Design of a Distillation Process for Recovery of Valuable Resources from Waste Photoresist Strippers

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ABSTRACT

For the development of a commercial distillation process to recover MDG (Methyl diglycol) and HEP (1-hydroxyethylpiperazine) from waste photoresist strippers in the TFT-LCD Manufacturing industries, based on the experimental results obtained by using a lab-scale packed-bed distillation column, a thermally coupled distillation and heat pump-assisted distillation sequence was implemented. A comparison was made between the conventional and advanced distillation sequences and the optimal conditions for enhancing recovery were determined. The results indicate that valuable MDG and HEP can be commercially recovered from waste photoresist strippers in an energy efficient manner.

Keywords: waste photoresist stripper, enhanced distillation, thermally coupled distillation, MDG, HEP

INTRODUCTION

Industrial demands for the photoresist stripping solvents are escalating with 15% per annum due to the proliferation of 10X~2X nm DRAM products mainly adopted in the widescreen LCD monitors. Most of the photoresist stripping solvents has been incinerated as a fuel at over 1300 ^{o}C to completely destroy the hazardous gases such as dioxins, NO_x, and SO_x (Chien, 2010). Such fly and bottom ashes from incineration facilities are buried and sometimes have been considered as the valuable materials for cements, blocks, and eco-certified products. Exhaust gases from the incineration facility and high energy costs frequently burden the ecological problems and the time-consuming conflicts to community life and global warming. Hence, the reuse of the high valuable stripping solvents has been recognized as the challenging solver for leveraging competencies of the electronic companies and providing the good benefits for all creatures.

In this work, a packed-bed distillation column was used to recover the valuable components from waste photoresist stripping solvents and evaluate the separation efficiencies with experimental variables. From the feasibility results, several alternative conventional distillation sequences were examined through intensive techno-economic analysis using a rigorous process simulator in order to find an optimal distillation sequence and condition for a commercial purpose.

MATERIALS AND METHODS

The composition of waste photoresist stripper over 6 samples was periodically analyzed with a gas chromatograph (GC, Model Acme 600; column HP-5) and a Coulometric Karl-Fischer titrator (GRS 2000) for moisture content. GC analysis of the waste photoresist strippers (Table 1). It was found that contents of high-boiling solvents over 414 K, HEP and MDG, are more 55 wt% in the waste stripper. Low-boiling solvents including MIPA, IPA, NMF(N-methylformamide), and H_2O are second major components in the photoresist stripper.

Table 1 GC analysis of waste PR strippers retrieved from commercial TFT-LCD process

Sample	MDG	HEP	IPA	MIPA	NMF	H2O	PR	Unknown
1	35	18	2.5	12.5	14	9.8	3	0.8
2	35.2	19	3	12.3	13.8	8.7	3.1	0.5
3	31	25	3.4	12.1	16.7	10.5	3.9	1.3
4	32	24	4	11.5	18	15.2	3.8	0.8
5	33.3	22	3.1	11.5	14.5	14.5	2.6	1.5
6	31.5	18.1	2	12.1	13	13.5	1.7	1.1

RESULTS AND DISCUSSION

Preliminary examination on substances

Table 2 summarizes the physical properties and reactivity of the stripping chemicals to distillation sequences (Kim and Park et al., 2013; Lee and Park et al., 2012). IPA was identified as first flammable chemical distilled from waste stripper. Most compounds are resistant to atmospheric oxidation and acid-base hydrolysis experienced at the distillation process. In explosion-proof facility, anti-oxidants are needed to stop the formation of explosive peroxides when treating with MDG and IPA. CO_2 outflow would be preventive to form the carbonates with MIPA and HEP. HEP and IPA are known to be easily polymerized into insoluble precipitates to block and foul the distillation apparatus.

Table 2 Reactivity and physical properties of stripping solvents

Compounds	HEP	NMF	MDG	MIPA	IPA
Flash point (^oC)	124	111	83	71	12
Atmospheric oxidation at 25 ^oC (half life, $t_{1/2}$)	0.7 h	18.9 h	4.9 h	1.2 h	17.7 h
Hydrolysis or photolysis	-	○	-	-	-
Carbonate formation	○	-	-	○	-
Peroxides	-	-	○	-	○
Polymerization	○	-	-	-	○

Design of distillation sequence

Problem statement: The waste photoresist strippers are consisted of A: isopropyl Alcohol (IPA), B: water (H_2O), C: mono isopropanol amine (MIPA), D: methyl diglycol (MDG), E: N-methyl formamide (NMF), F: 1-piperazne ethanol (HEP), photoresist removal (PR) components and unknown. The PR and unknown as the heaviest components were assumed to be same component as PR in the simulation. Main target materials for recovery were MIPA, MDG, NMF, and HEP. In this design study, all target products for sales purpose were specified to have more than 98 wt.% purity and a water content of less than 0.1 wt.% (Lee and Park, 2012; Kim and Park, 2013). Main design condition and constraints obtained from the experiment for separation feasibility were applied to process simulation to make an appropriate process that qualifies the industrial requirements. To avoid side reactions, all subsequent columns should be operated below 190 °C by using vacuum columns. In particular, the impurity by H_2O needs to be controlled less than 2~3 wt.% in the column sequence because H_2O causes some undesirable side reactions (Ex., side reactions with NMF at above 200 °C, thermal decomposition or deformation of HEP at above 200 °C, resulting in a color change to yellow) (Freeman, 2011). In the feed composition, water has the largest fraction and will cause another problem on the next separation, therefore in the design of the distillation process, water should be removed firstly from the 1st column and using vacuum columns, use of a vacuum should be considered for heat sensitive compounds (King, 1980).

A commercial process simulator (Aspen HYSYS V7.3) was used for rigorous simulations of every distillation process candidate. The non-random two liquid (NRTL) method was used to predict the vapor-liquid equilibrium (VLE) in the simulations. The UNIFAC estimation was used for the missing binary interaction parameters.

Conventional distillation was first optimized in terms of reboiler duty. In this study, the modified direct sequence shown in Fig.1 was chosen as a base case and rigorously optimized for further comparison study (Chaniago et al., 2016). The purpose of this conventional sequence is to recover MIPA, NMF, MDG and HEP where MDG and HEP are main targets.

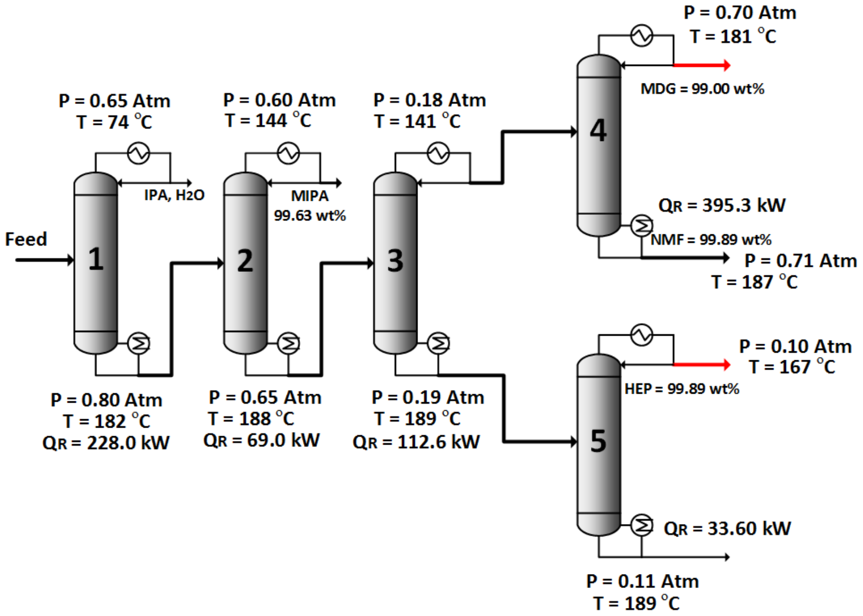

Figure 1 Base case conventional direct sequence of waste solvent separation

Several advanced configurations using the TCD were applied to enhance the energy efficiency. Systematic optimization approach was then tried to find the lowest reboiler duty in each advanced distillation sequence examined. The complex thermally coupled distillation columns could be optimally designed using the response surface methodology based optimization in a simple and effective manner. The proposed advanced distillation configuration achieved a significant energy saving compared to the conventional column sequence case.

CONCLUSIONS

Reusable solvents would be a promising alternative to compensate the chemical losses in the TFT-LCD panel process after assuring the regulations and process qualification. A multi-component distillation system with packed-bed appeared to be successful for the recovery of high-purity solvents discharged from the TFT-LCD stripping process. The purity of the regenerated stripper solvents would be above 99% with less than moisture content <1%. As a result, conventional direct with split sequence configuration was found as an optimal conventional distillation sequence for a commercial purpose in terms of many aspects such as a reboiler duty required, main product purity and recovery, and the lowest operating cost due to low steam and cooling water consumption. The energy efficiency of the waste solvent recovery process could be further improved by utilizing advanced distillation techniques.

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A Study on the Combustion Characteristics of Dried Sewage Sludge for Coal Co-firing in Coal Power Plant

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ABSTRACT

This research studied the basic combustion characteristics of dried sewage sludge using thermal gravimetric analysis technique, in order to mix dried sewage sludge with coal and used it in coal power plants. The basic combustion characteristics of excess sewage sludge and digested sewage sludge that were discharged from D city in Korea were dried and examined to use them as fuel. After, the combustion characteristics of sub-bituminous coal, and wood pellet, which is mixed with coal and used as fuel, in domestic coal power plants were researched to conduct a comparative analysis of them. The fundamental properties of samples were analyzed, and non-isothermal analysis was performed at the heating rates of 10, 15, and 20°C/min using TGA to investigate the basic combustion characteristics. According to the interpretation of non-isothermal analysis results by Friedman method, the activation energy in the section of highest weight loss was 129.85kcal/mol for dried excess sewage sludge, 103.74kcal/mol for dried digested sewage sludge, 48.72kcal/mol for wood pellet, and 32.71kcal/mol for sub-bituminous coal. The combustion reaction order (n) for dried excess sewage sludge, dried digested sewage sludge, wood pellet, sub-bituminous coal was -47.3698, -21.3199, 17.5885, and 9.9193 respectively, and the frequency factor was 3.53×10^{12}, 4.12×10^{11}, 3.62×10^{16}, and 133,453 for each.

Keywords: TGA, Kinetics, Activation energy, Co-Combustion

INTRODUCTION

As a basic research to draw the possibility of co-firing dried sewage sludge with coal, this study will examine the basic combustion characteristics of dried sewage sludge, sub-bituminous coal—which are used in domestic coal power plants—, and wood pellet through thermal gravimetric analysis technique. After, it will report the results on the speed factor of their combustion reaction.

MATERIALS AND METHODS

For dried sewage sludge, excess sludge and digested sludge that were discharged from the sewage plants of D city were collected and dried to be used in this research. Next, wood pellet and coal were supplied by Korea Electric Power Research Institute. All samples were grinded below 250 mesh to experiment their fuel characteristics in the same condition. C, H, O, N, and S were measured using element analyzer in ultimate analysis, proximate analysis was performed in accordance with ASTM D3172, D3174, and D3175, and calorific value was measured using Bomb Calorimeter (SDA CM-IIIb). For the basic combustion characteristics, thermal gravimetric analysis was examined. The thermal gravimetric analysis by non-isothermal combustion reaction was measured in the air atmosphere using TGA, and was performed in the room temperature up to 1400°C at 4 different heating rates of 5°C/min, 10°C/min, 15°C/min, and 20°C/min. Their thermal gravimetric analysis results were interpreted in Friedman model.

RESULTS AND DISCUSSION

The proximate analysis, ultimate analysis, and calorific value analysis results of the physicochemical characteristics of dried excess sewage sludge, dried digested sewage sludge, wood pellet, bituminous coal, and sub-bituminous coal were represented in Table 1.

Table 1. Physicochemical characteristics of materials

Classifications		excess sludge	digested sludge	wood pellet	sub-bituminous coal
Proximate analysis (wt %)	M	81.63	73.28	7.65	10.35
	A	13.59	16.46	2.27	3.32
	VM	2.92	5.13	75.14	9.66
	FC	1.86	5.13	14.94	76.67
Ultimate analysis (wt %, db)	C	36.44	32.22	51.77	63.11
	H	5.95	4.97	6.74	6.44
	O	24.19	20.15	40.11	29.55
	N	6.83	3.96	0.29	1.31
	S	0.19	0.69	0.09	1.14
HHV(Kcal/kg)		3,875	3,399	4,305	5,952

The thermal gravimetric analysis (TGA) curve that represents the weight change of samples by each heating rate was shown on Fig. 1. And Fig. 2 represented the differential thermogravimetric (DTG) curve of each sample.

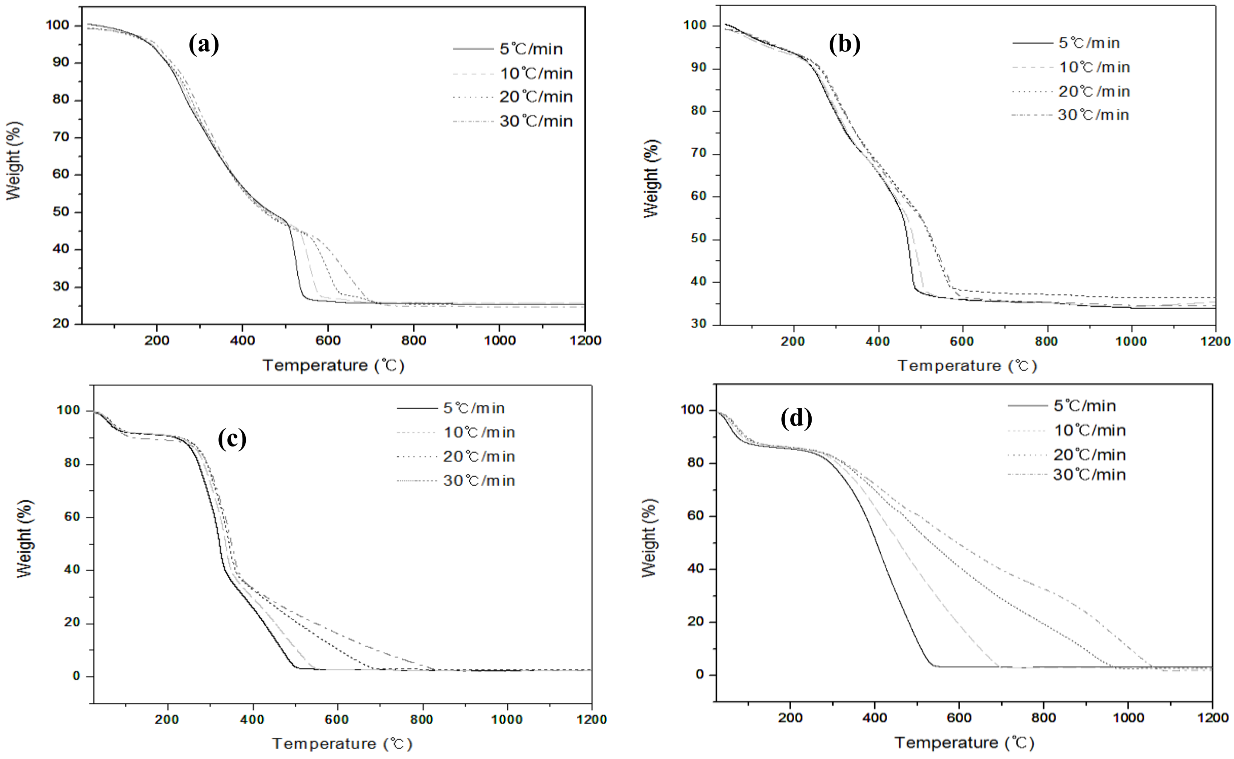

Fig 1. The TGA curve of dried digested sewage sludge (a), dried excess sewage sludge (b), wood-pellet (c) and sub-bituminous coal (d) at various heating rates.

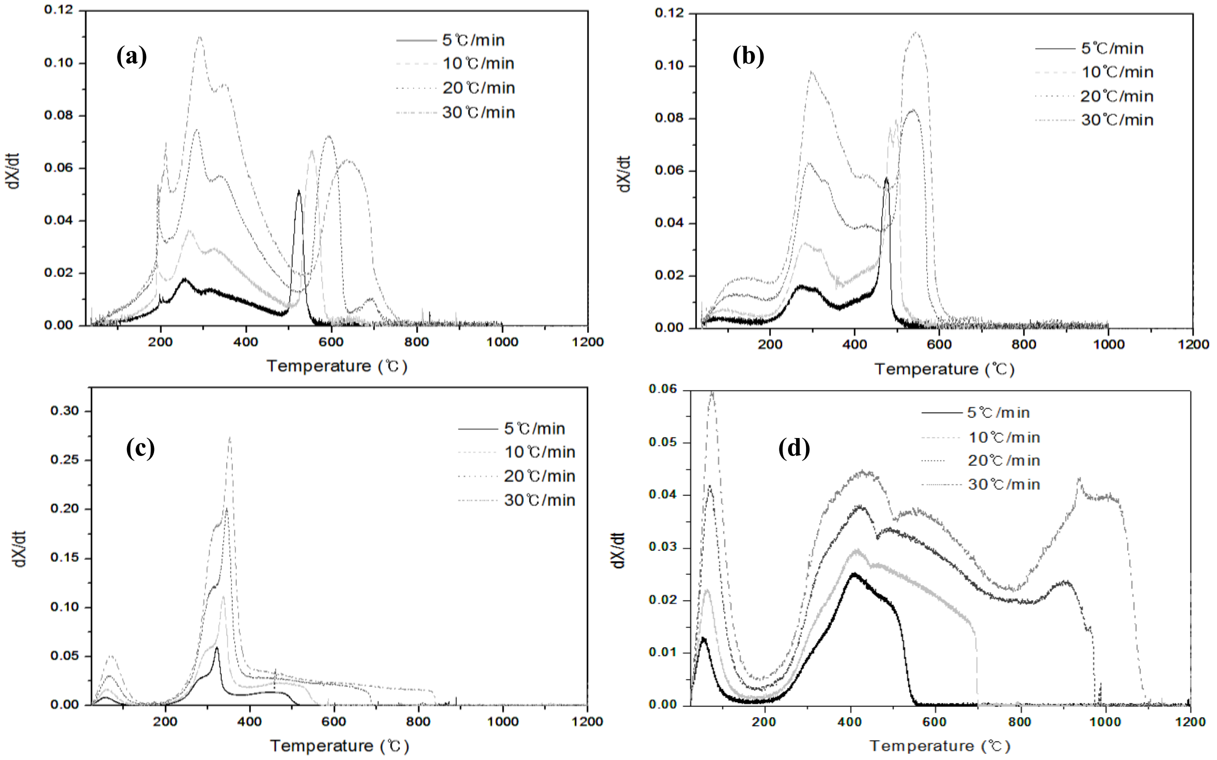

Fig 2. The DTG curve of (a) dried excess sewage sludge, (b) dried digested sewage sludge, (c) wood-pellet and (d)sub-bituminous coal at various heating rates.

By using Friedman method [1], the activation energy needed for the combustion reaction of dried excess sewage sludge, digested sewage sludge, wood pellet, and sub-bituminous coal was obtained and plotted in Fig.3.

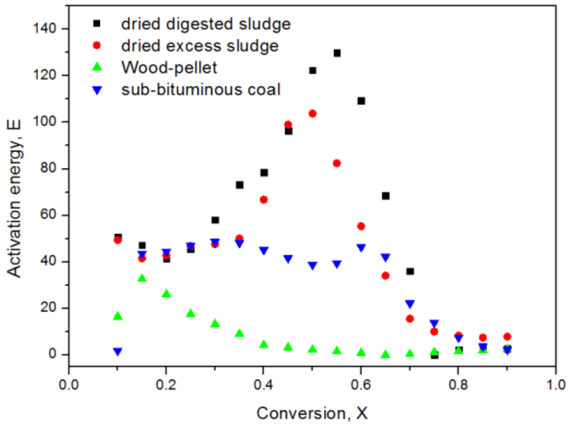

Fig. 3. Activation Energy on conversion level of (a) dried excess sewage sludge, (b) dried digested sewage sludge, (c) wood-pellet and (d) sub-bituminous coal by Friedman method.

The graph of Fig. 4 was drawn to calculate reaction order n and frequency factor A, and reaction order and frequency factor were obtained from the slope and intercept of this graph. Table 3 showed an example for the reaction order and frequency factor of samples obtained by thermal gravimetric analysis at the heating rate of 5℃/min.

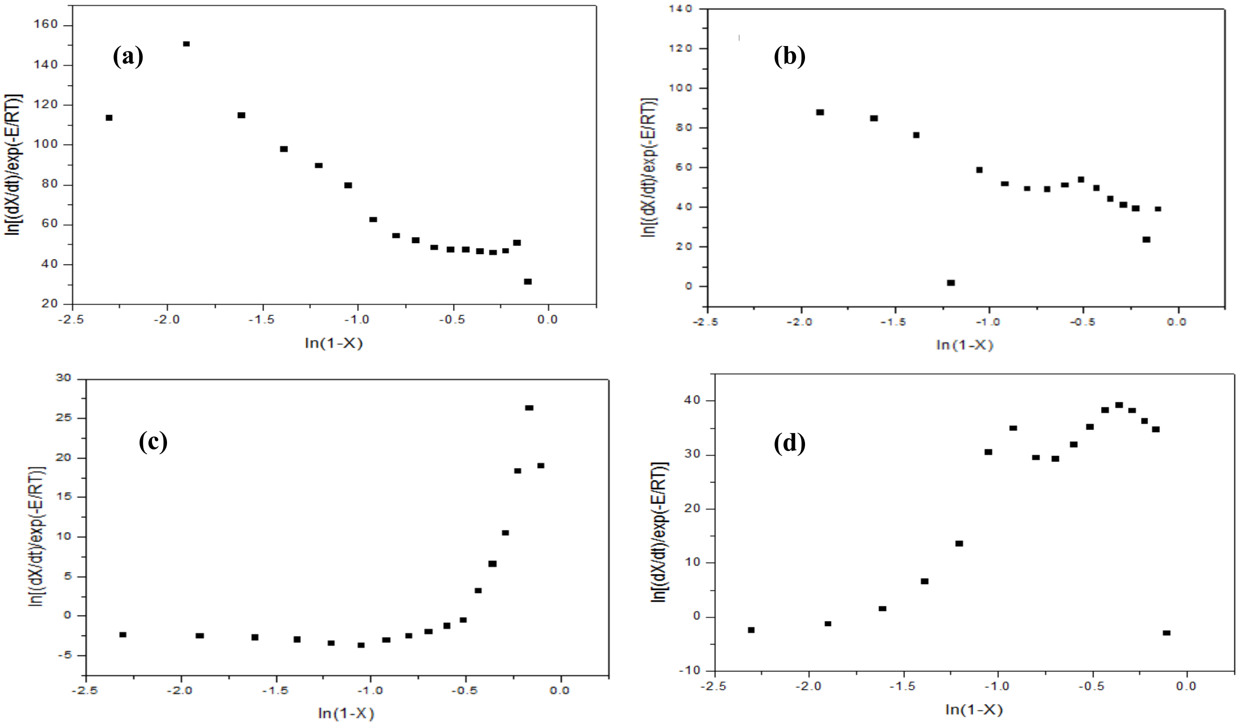

Fig. 4. Kinetic analysis of (a) dried excess sewage sludge, (b) dried digested sewage sludge, (c) wood-pellet and (d) sub-bituminous coal by Friedman method.

Table 3. Reaction order (n) and pre-exponential factor (A) of (a) sub-bituminous coal, (b) wood-pellet, (c) dried digested sewage sludge, (d) dried excess sewage sludge with respect to heating rate 5℃/min

Samples	N (reaction order)	A (pre-exponential factor)
(a) dried excess sludge	-47.3698	3.53×10^{12}
(b) dried digested sludge	-21.3199	4.12×10^{11}
(c) Wood-pellet	17.5885	3.62×10^{16}
(d) sub-bituminous coal	9.9193	133,453.716

CONCLUSION

In order to draw the possibility of co-firing dried sewage sludge with coal, the basic combustion characteristics of dried sewage sludge, sub-bituminous coal—which are used in domestic coal power plants, and wood pellet were investigated through thermal gravimetric analysis technique.

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Estimation of thermal source position in solid waste landfill site based on hot spots' temperature and position on landfill surface

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ABSTRACT

In this study, the model to estimate the position of an internal thermal source in a landfill using hot spots' temperatures and locations on a landfill surface was proposed, and the accuracy of the thermal source positional estimation by the model was verified through results of numerical simulations of heat and gas transport in a simulated landfill which had a thermal source. It was clarified that the thermal source position can be estimated with certain accuracy by the model proposed in this study.

Keywords: solid waste landfill, thermal source, positional estimation

INTRODUCTION

There is a case that a fire occurs inside a solid waste landfill because the heat generated by organic matter decomposition is accumulated and the heat accumulation is developed in a landfill. It is desired that effective measures for a fire extinguishing are carried out after the location of an internal thermal source is specified. There are examples to estimate a thermal source position by vertical temperature distribution in borings and monitoring wells and 1m depth temperature of points (Fujishima et al., 2010, Higuchi, 2011), however, it still has a difficulty to specify the location of thermal source in the landfill a fire occurs.

The spot which shows high temperature locally on a landfill surface, which is called "hot spot" in this study, is focused on. It is thought that a hot spot is the point where the high temperature gas inside landfill, which passes through the large pore continuing from a place around thermal source to landfill surface (gas pathway), is released to the ambient.

In this study, the model to estimate the position of an internal thermal source in a landfill using hot spots' temperatures and locations on a landfill surface was proposed, and the accuracy of the thermal source position estimation by the model was verified through results of numerical simulations of heat and gas transport in the simulated landfill which had a thermal source.

MATERIALS AND METHODS

The model to estimate thermal source position

Figure 1 shows schematic depiction of the landfill which has hot spots on landfill surface. The thermal balance and gaseous mass conservation in the gas pathway were considered. To solve thermal balance equation and gaseous mass conservation equation simultaneously under ideal assumptions, the following Eq. (1) can be obtained.

$$\frac{1}{D_i}\ln\frac{T_*-T_0}{T_i-T_0}=\mathrm{Const.} \qquad (1)$$

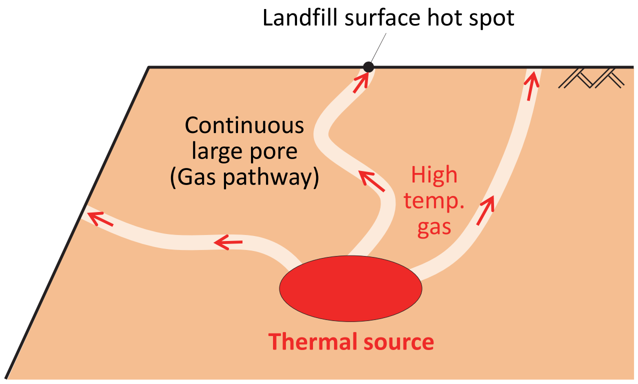
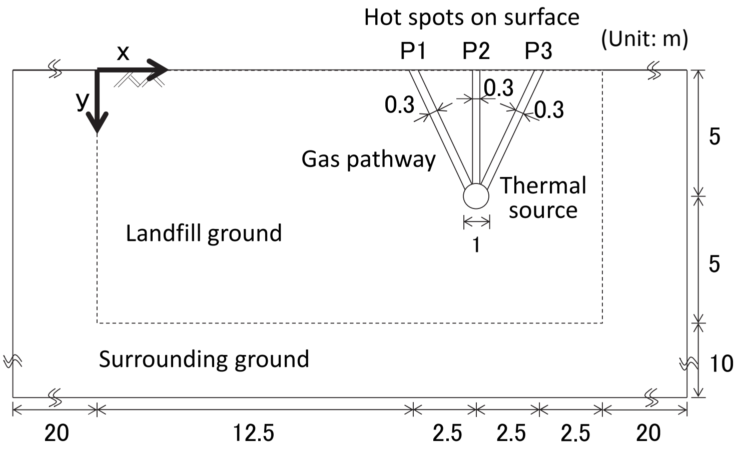


Figure 1. Schematic depiction of the landfill which has hot spots on landfill surface



Case	Coordinate (x, y) (m)		
	P1	P2	P3
Case 1	12.5, 0	15, 0	17.5, 0
Case 2	5, 0	15, 0	17.5, 0
Case 3	5, 0	10, 0	17.5, 0
Case 4	5, 0	10, 0	15, 0

Figure 2. The system of numerical simulation (left) and settings of hot spots' placement (right)

Where, D_i [m] is the distance from a surface hot spot to the internal thermal source, T_* [℃] is the thermal source temperature, T_0 [℃] is the temperature of landfill inside when no internal thermal source exists, T_i [℃] is a surface hot spot temperature. Eq. (1) shows that there is certain relationship among a hot spot's temperature, thermal source temperature and the distance between a hot spot and thermal source. When hot spots are observed multiply on landfill surface, the temperature and location of the hot spots' are measured, and the observed hot spots' temperature and coordinate and assumed values of thermal source temperature and the landfill inside temperature are given to Eq. (1), then thermal source position can be estimated geometrically as the location that the error of the constant value in Eq. (1) is minimal.

Numerical simulation of heat and gas transport

Figure 2 shows the system of numerical simulation and coordinates of hot spots of each of four cases different in gas pathway placement. Eq. (2), (3), (4) and (5) are thermal balance equation, gaseous mass conservation equation, Darcy's law for gas velocity and the boundary condition of landfill surface, respectively.

$$\rho C_p \boldsymbol{u} \nabla T = \nabla \cdot (K_{ep} \nabla T) + Q \qquad (2)$$

$$\nabla \cdot (\rho \boldsymbol{u}) = Q_m \qquad (3)$$

$$\boldsymbol{u} = \frac{k}{\mu}\nabla p \qquad (4)$$

$$-\boldsymbol{n}\cdot(-k\nabla T) = \varepsilon\sigma({T^4}_{amb} - T^4) \qquad (5)$$

Table 1 shows nomenclature and adopted values of parameters and constants in the equations. Boundaries of left side, right side and bottom were set as no thermal and gas flux boundaries. The thermal source was set as constant temperature. Numerical solutions of equations were solved as steady state using COMSOL 4.2a.

RESULTS AND DISCUSSION

Results of numerical simulation

Figure 3 shows distributions of landfill surface and landfill inside temperature of case 1 as an example of numerical simulation results. As expected, hot spots were higher than others in temperature on landfill surface, and the surrounding area of gas pathways was higher than other parts in landfill inside temperature.

Table 1. Adopted values of parameters and constants

Parameter	Symbol	Unit	Value	Reference
Specific heat at constant pressure	C_p	J kg^{-1} K^{-1}	840	Yoshida et al., 1989
Permeability of ground	k	m^2	1.0×10^{-9}	Bear, 1972
Permeability of gas pathway	k	m^2	1.0×10^{-6}	Bear, 1972
Thermal conductivity	K_{ep}	W m^{-1} K^{-1}	4.7	Yoshida et al., 1989
Gas generation rate	Q_m	kg m^{-3} s^{-1}	0.04, 0.08*, 0.12, 0.16	-
Thermal source temperature	T_*	℃	40, 60*, 80, 100, 120	-
Ambient temperature	T_0	℃	15	-
Surface emissivity	ε	-	1.0	-
Viscosity	μ	Pa s	1.8×10^{-5}	-
Solid particle density	ρ	t m^{-3}	2.6	-
Stefan-Boltzmann's constant	σ	W m^{-2} K^{-4}	5.67×10^{-8}	-

*: Standard case

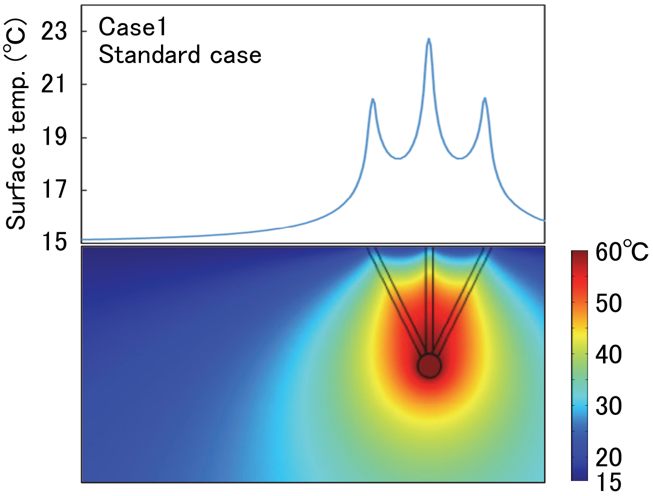
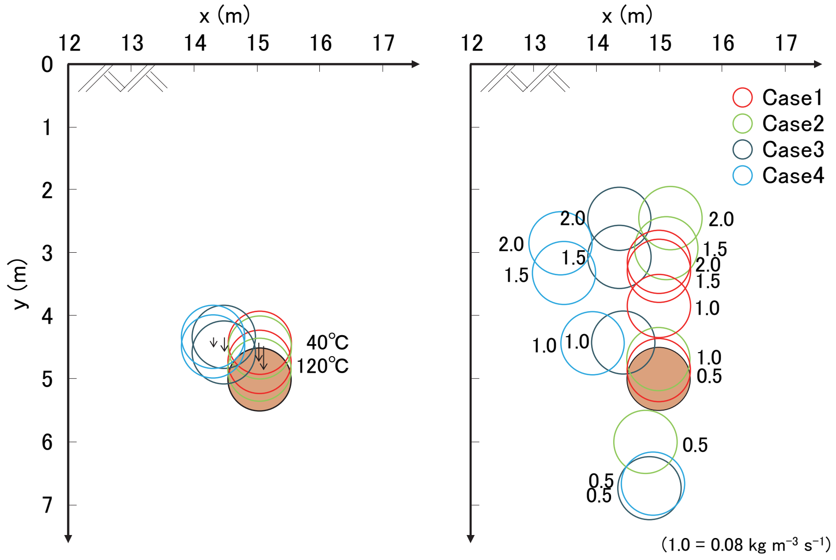


Figure 3. Temperature distributions of landfill surface and inside (case1, standard case)



a) Thermal source temperature **b) Ratio of gas generation rate**

Figure 4. Estimated position of thermal source and influence of factors on the estimation

Accuracy of positional estimation of thermal source

Figure 4 shows the position set in the system and estimated positions of thermal source. Each circle is the estimated position of each condition different in gas pathway placement, thermal source temperature and the gas generation rate at thermal source. There was large positional estimation error in horizontal direction (about 2 m at maximum) in case 4, however positional errors were within 1 m in horizontal direction in other cases. It was clarified that the setting of thermal source temperature had little influence on estimated position. However the estimated position in vertical direction was largely influenced by gas generation rate.

CONCLUSION

It is clarified that the thermal source position can be estimated with certain accuracy by the model proposed in this study.

ACKNOWLEDGEMENT

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Determination of Material Flow of Refrigerant in Automotive Air Conditioners in Korea

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ABSTRACT

Refrigerant performs the cycle of refrigeration cycle and cause cooling action. It is used in various chiller and air conditioning unit, and liquid or gas state. The common types of refrigerants used for today include normally HCFCs and HFCs with the ozone depletion or greenhouse effect. Although environmentally friendly refrigerants are being developed, there are still lack of safety and high cost problems of new refrigerants. This study was to determine the flow of refrigerant from automotive air conditioners. The number of car manufactured, the number of care in use, and waste flow were examined by available statistics and reports. Material flow of refrigerants has been determined by life cycle of car. Based on the results, in 2014, there are approximately 701tons refrigerant introduced from manufacturing stage of car, 397tons refrigerant leaked from stage of use, 69tons refrigerant refilled during use, and 12,213tons refrigerant stored from cars in use. After use stage, there are about 12tons refrigerant waiting for dismantlement of cars, 14tons refrigerant exported by used cars, 13tons refrigerant delivered to companies handling waste gas, and 196tons emitted to the atmosphere during dismantling process. As a result, in South Korea in 2014, total 770tons of refrigerants are used to be introduced and refilled, while total 593tons of refrigerants are estimated to be leaked into the atmosphere from car air conditioners during the stage of use and dismantlement.

Keywords: refrigerant, car air conditioner, HFC, material flow

INTRODUCTION

Refrigerant are used in various devices for air conditioning unit, freezing machine, and others. Most of refrigerants may impact on the environment such as ozone depletion or greenhouse effect. Widely used in refrigerant, HCFCs is ozone depletion and cause greenhouse effect, while HFCs is not ODS(ozone depleting substances), but is one of major six greenhouse gases. Refrigerants used in automobiles are known to be about 25% of current total refrigerants. The rest amounts are used in the supplement of industrial air conditioning unit or home appliances, and many others. Cars in South Korea use HFC-134a as GWP(yr-100) 1370. There is an urgent need for proper collection and management of refrigerants in automotive air conditioners due to minimal collection. Still, there is a lack of applicable laws, inadequate reporting system and monitoring, and treatment facilities. In this study, the material flow of refrigerant in automotive air conditioner has been focused to properly manage it.

MATERIALS AND METHODS

Data collection

In this study, in order to establish the material flow of automotive air conditioning refrigerants, quantitative understanding of car and refrigerant standard unit in the process has been required. The necessary data were obtained from Korea MOE (Ministry of Environment)'s statistical data and to relevant paper and report.

Method and assumption of MFA

The material flow of automotive air conditioner refrigerant was drawn up with mass flow of automobile in lifecycle stage and each contents of refrigerant in automobile. The system boundary included from manufacturing to disposal stage of automotive air conditioner refrigerant in South Korea in 2014. In this study, the amount of air emission was assumed through the gap of refrigerant content in manufacturing stage and disposal stage. Particularly, as the amount of air emission is different in drive speed, it was assumed that all vehicles were driven faster than 100km per hour for 30 minutes every day.1)

RESULTS AND DISCUSSION

Estimation of the amount of air conditioner refrigerant in cars during new introduction and in use

In 2014, new cars of South Korea are registered as 1,155,1282) and total vehicles registered are approximately 20,120,0003). By applying the first injection of 607g4) refrigerant, the refrigerant flow rate from new cars inflows 701tons. Similarly, about 12,213tons as refrigerant of current cars are estimated in use.

Table 1. The register of the status of cars and injection, leakage of using stage

Type	Cars or amount of refrigerant
The number of newly registered cars in 2104	1,075,967
Total number of vehicles registered in 2014	20,120,000
First injection refrigerants in car (g/unit)	607
Leakage of refrigerants in use stage (g/unit·yr)	19.75

Estimation the leakage during use stage and amount of refilled automotive air conditioner refrigerant flow rate

Based on a previous study1), refrigerants leak 0.04~0.07g/hr at high-speed driving (more than 100km/hr) and 6.46~13.37g/yr at parking. In this study, we assumed that high speed drive daily average of 30 minutes, a car leaks refrigerant to 19.75g per year. By estimating vehicles registered to assume the leakage, the amount of leakage of automotive air conditioner refrigerant in 2014 was 397.4tons. Also, using the average life of car of 15 years, the amount of refrigerant leakage on the stage of life cycle per a car is about 296.3g. According to the research, refrigerant residue at scrap car is 313g/car4). Compared the first injection, leakage at life cycle and residue, it can predict that there are about 3.1tons to the whole of refilled refrigerant of automotive air conditioner per year in Korea.

Estimation the leakage of stage of disposal, treatment and handling capacity of automotive air conditioner refrigerant flow rate

According to this research[6)], during a vehicle at disposal, 6% used to be exported abroad, 5% waited to scrap in dissolving, recycling business operator and 89% delivered to dismantlement, recycling business operator in a break up state. By considering the above percentage of the disposal of a vehicle (750,506)[7)] in 2014, there are 44,769 cars from a used vehicle exports, 37,883 cars from standing by dismantling and 668,054 from delivering by dismantlement, recycling business operators. In the case of refrigerant collected by dissolving, recycling business operators were 13tons[7)], business operator handling waste gas reclaimed or destroyed. It was difficult to identify the reclaiming and destruction quantity of the refrigerant transferred to business operators. The leakage at the stage of dismantlement is 196tons from 235tons except for refrigerant of car standing by dismantling, delivering to business operator handling waste gas and refrigerant to export by a used vehicle.

Table 2. The disposal of the status of cars and residue refrigerant

Type	Car, amount of refrigerant
The number of ELVs	750,706
The number of used vehicles exported	44,769
Cars waiting for dismantling (unit)	37,883
Car delivered to disassembly, recycling business operator (unit)	668,054
Residue refrigerant amount in waste car (g/unit)	313

At the stage of disposal, applying average residue refrigerant (313g) to the disposal of the processed 750,706 cars, total residue refrigerant of disused car is 235tons from South Korea in 2014. In 235tons to residue refrigerant at the stage of disposal, 14tons with a used vehicle exports, refrigerant in car waiting by dismantling is 12tons.

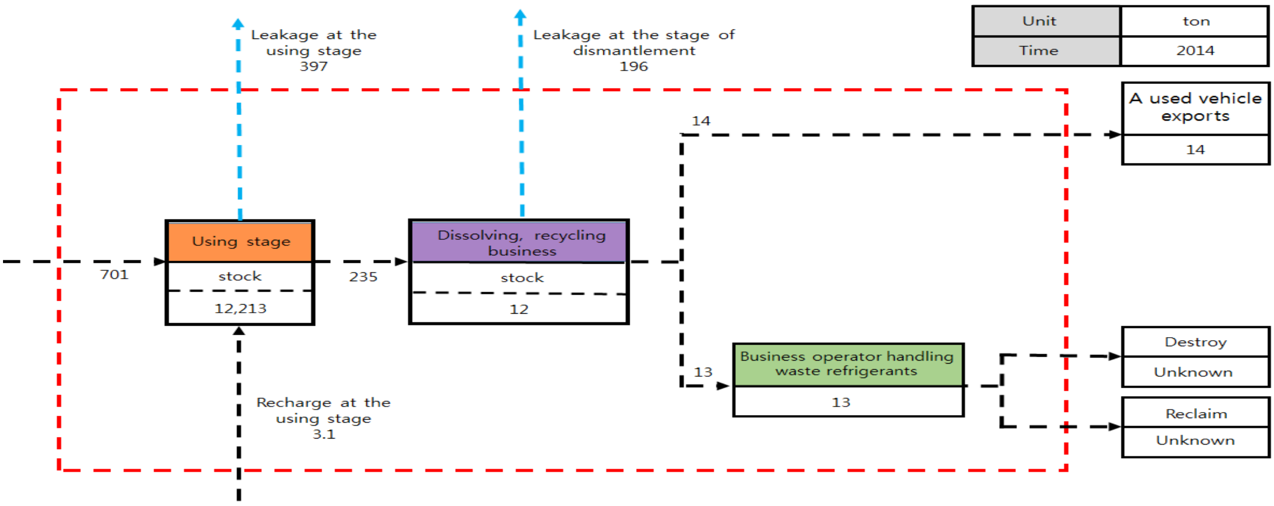

Figure 1. Material flow of automotive air conditioner refrigerant

CONCLUSION

This study investigated a material flow of refrigerant in automotive air conditioner by life cycle. Based on the results, in South Korea, 701tons of refrigerant are newly introduced for automotive air conditioner, 12,213tons of refrigerant used for current cars in use, 397tons leaked during the use stage, and only 3.1tons of refrigerant refilled during the use stage. Approximately 235tons are present in total refrigerant amount in waste car, 12tons refrigerant stored during recycling, 14tons refrigerant exported by used vehicles, only 13tons from delivered to business operators handling waste refrigerants, and 196tons leaked to the atmosphere during the stage of dismantlement. From South Korea in 2014, total leakage of automotive air conditioner refrigerant is estimated to be approximately 593tons during the use and disposal stages.

ACKNOWLEDGEMENT

This work is financially supported by Korea Ministry of Environment (MOE) as Waste to energy recycling Human resource development Project.

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Utilization of Leachate and Sludge generated from the Pre-process of Landfill Gas

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ABSTRACT

With the advent of the era of global warming, the necessity of developing renewable energy source has greatly increased as a countermeasure. Accordingly, as well as the reduction of greenhouse gas emission, waste to energy concept has internationally emerged as leading means of renewable energy currently. In specific, it has been demanded to develop alternative energy through making use of landfill gas to create a plan of economically and environmentally viable.

This study investigated a disposal and recycling technology of high concentration desulfurized sludge and leachate, being produced in the preprocess of landfill gas. After mixing the leachate containing high concentration sulfur and desulfurized sludge respectively with metal plating wastewater, feasibility of removing and recovering heavy metal and sulfur was examined. Heavy metal contained in metal plating wastewater was removed up to about 77% average, showing relatively high yielding rate of possibility of removing heavy metal and sulfur through sulfur- heavy metal interaction.

Keywords: Landfill gas, Desulfurized sludge, Leachate, Metal plating wastewater.

INTRODUCTION

With the advent of the era of global warming, the necessity of developing renewable energy source has greatly increased as a countermeasure. Accordingly, as well as the reduction of greenhouse gas emission, waste energization has internationally emerged as leading means of renewable energy currently. In specific, it has been demanded to develop alternative energy through making use of landfill gas to create a plan of economically and environmentally viable. This study investigated a disposal and recycling procedure of high concentration desulfurized sludge and leachate.

MATERIALS AND METHODS

1. pH Test

As a way of measuring pH, 10g of sample was selected into 50mL beaker, stirred with 25mL of distilled water, left quiescent for 30 minutes, and measured by using supernatant, a test liquid, according to the Korean Standard Method for Waste Analysis.

2. Dissolution of heavy metals and sulfur

A total 1L of leachate, or desulfurized sludge, and metal plating wastewater were mixed in a 2L beaker at the weight ratio of 1:1 and 1:0.5 respectively. Next, a magnetic stirrer was used for complete mixing to achieve enough reaction. An analysis was conducted to examine residual amount of heavy metal and sulfur after stirring and being left quiescent.

RESULTS AND DISCUSSION

This study investigated the disposal and recycling procedure of high concentration desulfurized sludge and leachate, leading to the following results.

1. pH

Figure 1 is the pH results of the leachate, desulfurized sludge, metal plating wastewater, and mixed sample. The average pH of leachate was 6.88 and that of metal plating wastewater was 1.29. Also, the average pH was 5.52 and 3.03 respectively for the mixed of metal plating wastewater and leachate in the case of mixing at the weight ratio of 1:1 and 1:0.5 respectively. The average pH of desulfurized sludge was 6.02 and for the metal plating wastewater, the same sample at the time of previous experiment was used. The average was 4.68 and 2.65 respectively in the case of mixing metal plating wastewater and desulfurized sludge at the weight ratio of 1:1 and 1:0.5 respectively.

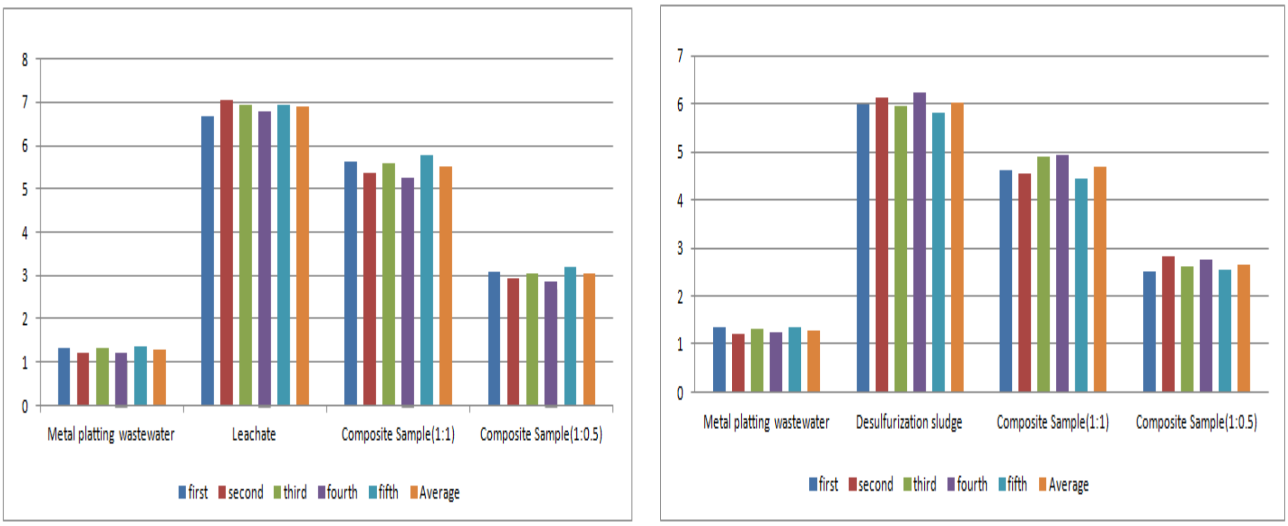

Figure 1. pH measurements

2. Sulfur content(Metal plating wastewater & Leachate)

Figure 2 provides the results of measuring the amounts of sulfur. In particular, the average amount of sulfur in leachate was 15.4mg/L; that in metal plating wastewater and leachate mixed was 2.46mg/L and

5.74mg/L at the weight ratio of 1:1 and 1:0.5 respectively. In addition, the average amount of sulfur in desulfurized sludge was 287.55mg/kg; that in metal plating wastewater and desulfurized sludge mixed was 63.05mg/L and 133.88mg/L at the weight ratio of 1:1 and 1:0.5 respectively.

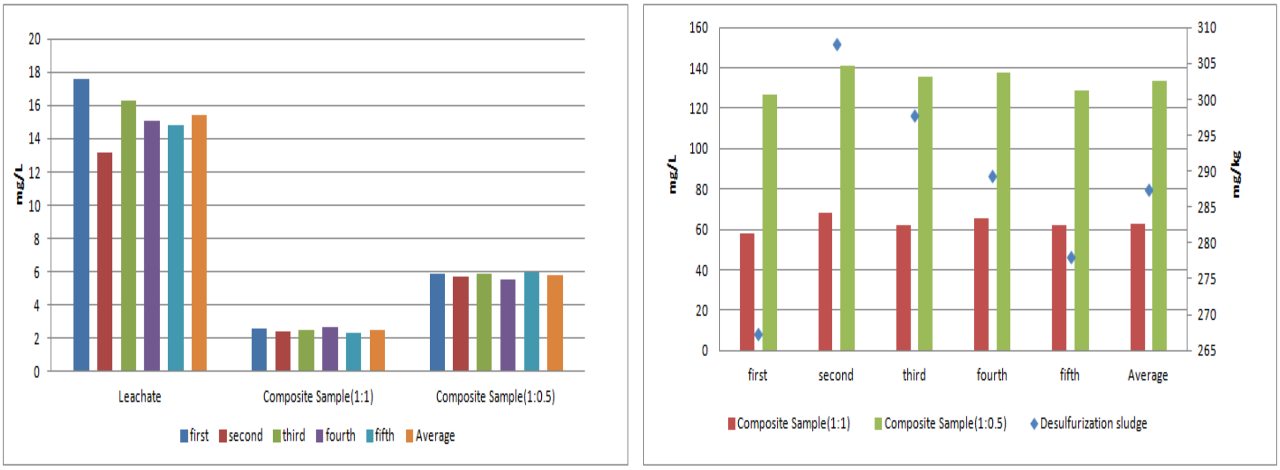

Figure 2 Sulfur content

3. Heavy metal content(Copper concentration)

Figure 3 provides the results of measuring the amounts of heavy metal. As a result of leaching test of heavy metal in metal plating wastewater showed that the highest was Cu, 119.29mg/L, followed by Pb, 23.2mg/L, and Hg, 3.87mg/L. Arsenic(As) and Cadmium(Cd) were not measured. In addition, the result of measuring Copper of leachate and metal plating-wastewater mixed sample showed that the average was 33.41mg/L at the ratio of 1:1; 56.52mg/L at the ratio of 1:0.5. Also, the average of Copper measured for desulfurized sludge and metal plating wastewater mixed sample was 20.76mg/L and 42.54mg/L respectively at the ratio of 1:1 and 1:0.5 respectively.

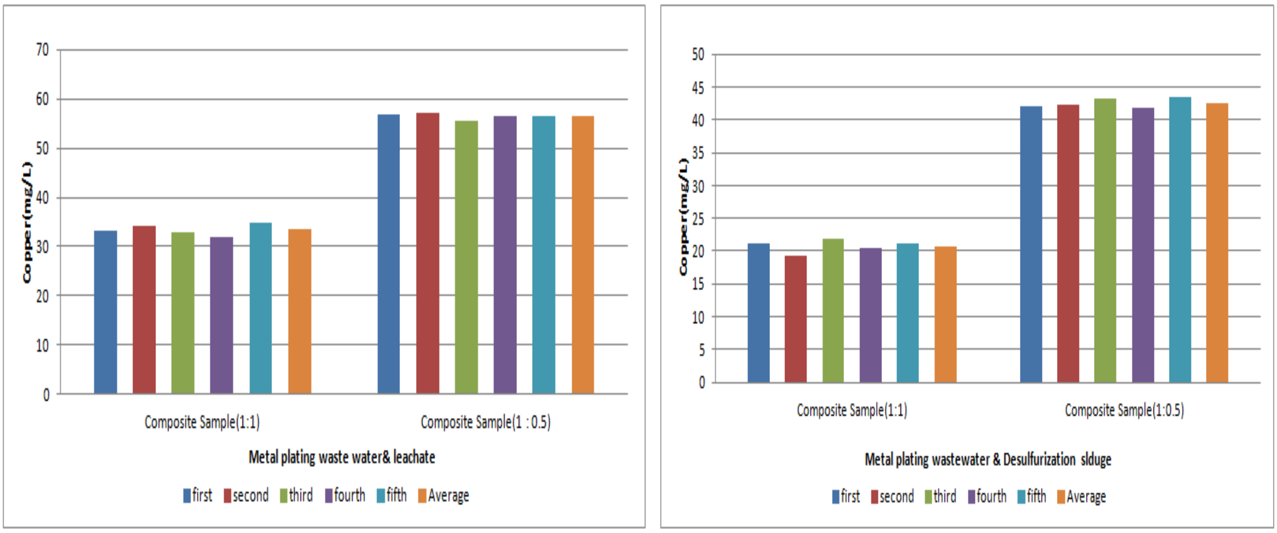

Figure 3 Heavy metal content(Copper Concentration)

CONCLUSION

After mixing the leachate containing high concentration sulfur and desulfurized sludge with metal plating wastewater, feasibility of removing and recovering heavy metal and sulfur was examined. As a result, 84% of sulfur in leachate and 82% of sulfur in desulfurization sludge were eliminated. Heavy metal contained in metal plating wastewater was removed up to about 77% average, showing relatively high yielding rate of possibility of removing heavy metal and sulfur through sulfur and heavy metal interaction.

ACKNOWLEDGEMENT

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Studies on Combustion Characteristics of Low Calorific Waste Generated in SRF Manufactory by Mechanical Biological Treatment (MBT)

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ABSTRACT

In this study, physicochemical characteristics and combustion characteristics of low calorific waste was experimented in a fixed bed reactor. In comparison to other feedstocks (waste residue, solid refuse fuel), low calorific waste has higher carbon content, volatile content and higher heating value. Although the feedstock that used in this experiment was generated in SRF manufactory as residue and later treated by mechanical biological treatment, it shows good combustion characteristics compared with SRF combustion and also satisfied the basis of combustion standard.

Keywords: Low calorific waste, Combustion, Residue, Mechanical biological treatment

INTRODUCTION

It is globally the most interest of securing the renewable energy resource according to the exhaustion of fossil fuels and reduction plans of greenhouse gases. Korean government expect to extend the renewable energy rate of total energy to 10 % for "Plan on the Technology Development and Usage Supply of Renewable Energy" by 2030. Especially, waste is occupied 68 % of renewable energy supply rate depending on 2012 renewable energy statistics, and this rate is represented to be an absolute. In case of waste to energy technologies, there are the heat recovery technology by direct incineration, the manufacturing technology for Solid Refuse Fuel (SRF), pyrolysis technology to produce oil and gasification technology. Now progressing technology for commercializing waste to energy technologies is SRF technology. It has excellent combustibility as separating the combustible waste of high quality, and can be applied to the large scale combustion. It also has eco-friendly disposal, storage and transportation system. Also, it can be maximized to use the energy for having the function of homogeneous high-calorific fuel. So, this technology is drawing attention as the upcoming alternative energy.

However in almost all SRF manufactory, the main purpose is energy recovery rather than landfill minimization. But, during SRF manufacturing process generation of residue is inevitable. And this rate is approaching 40 % of input waste, this disposal cost is occupying 20 % of annual operating cost in some facility. In study, this waste is named Low Calorific Waste Residue (LCWR). After treating this waste by Mechanical Biological Treatment (MBT) process, this waste become ready for thermal treatment. So the waste after all this process is called Low Calorific Waste (LCW), and we studied the physicochemical characteristics and combustion characteristics of LCW in a fixed reactor.

MATERIALS AND METHODS

LCW used in this study is produced by MBT process as mentioned earlier. In case of MT, blow type separator and high-grade combustible equipment was used instead of existing technologies like particle size and wind force separator. This equipment has improved the quality of LCW, as it focuses on separating of the foreign substance and incombustibles. In case of BT, it uses bio-drying technology. This is the technology of fast drying using the aerobic heat of decomposition for the biodegradable microorganism existed within waste. By reducing the moisture within waste, it decreased the viscosity of waste particle and help to maintain good calorific value.

Figure 1 shows the schematic diagram of the lab-scale fixed bed reactor. It is divided into three parts (part 1: Main control box; part 2: Furnace and Inconel column; part 3: Air pollution control devices). The main control box is designed to control the experimental temperature of the furnace, air flow rate, etc. The samples were manually fed into the furnace (two stages and semi-batch mode). In the two-stage manual mode, the samples were placed vertically down by two valves. The air pollution control devices included a cyclone and a scrubber for controlling the gaseous emissions, particularly dust and fly ash in the combustion experiment. The emission gas was analyzed through a gas analysis system at the gas outlet.

The experiment used an air agent at 850 °C. Feedstocks were equally put on 5 g/min with equivalent ratio (ER) 1.3 to determine the flue gas characteristics. When the temperature became stable, gas sampling was performed.

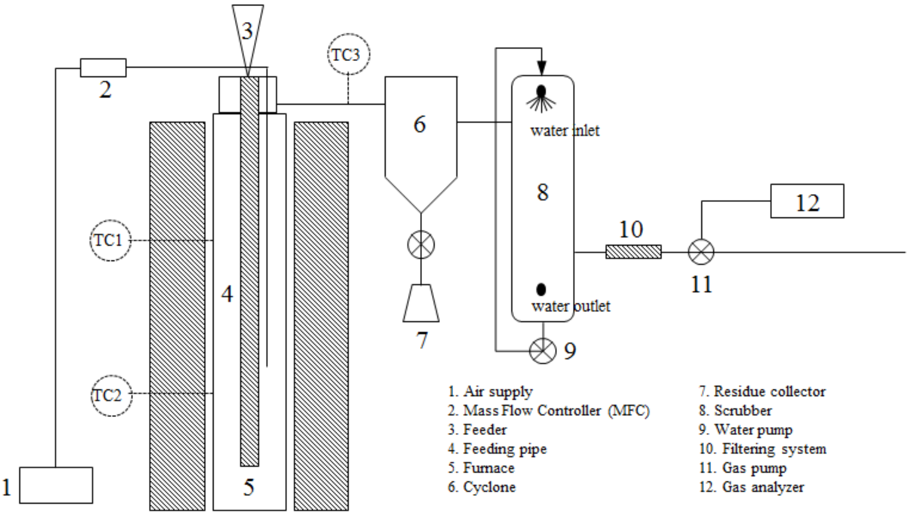

Figure 1. Diagram of the lab-scale fixed reactor

Table 3 showing details of flue gas analysis method. By using gas analyzer (Multi Gas Measuring, KINSCO) we analyzed O_2 (oxygen), CO (carbon monoxide), CO_2 (carbon dioxide) and NO_x (nitrogen oxide). Even if it can analyze sulfur dioxide, we did not find any sulfur dioxide in flue gas. From elementary analysis we already knew that LCW and SRF do not contain sulfur.

Table 1. Flue gas analysis methods

Flue gas	Measuring range	Analysis equipment	Photograph
O_2	~ 21 %	Multi Gas Measuring Hymeth Plus Gas Analyzer	
CO	~ 100 %		
CO_2	~ 10 %		
NO_x	~ 2000 ppm		

RESULTS AND DISCUSSION

Table 1 shows the physicochemical characteristics of LCW and other feedstocks. Although it was the residue generated in SRF manufactory, it has good quality owing to MBT. In comparison to other feedstocks, LCW has higher carbon content, volatile content and Higher Heating Value (HHV). In case of LCWR, it contains many incombustibles such as soil, sand and other residue generated during SRF manufacture. So it has 40 % ash contents, just 3,216 kcal/kg of HHV. In case of LCW, although it has high ash contents, but other compositions are as good as SRF. From Table 1 we can see that the amount of Nitrogen and Sulfur content were decreased using MBT process in LCWR. When we conducted the combustion experiment, sulfur gas pollutants were not detected in flue gas.

Table 2. Physicochemical characteristics

		LCWR	LCW	SRF
Elementary Analysis (wt. %)	C	32.40	43.24	40.49
	H	4.40	6.03	5.81
	N	0.90	0.44	0.61
	O	21.80	41.89	31.53
	S	0.04	ND	ND
Proximate Analysis (wt. %)	Moisture	44.30	3.21	9.63
	Volatile	33.30	73.98	64.95
	Fixed carbon		10.34	19.48
	Ash	40.40	12.48	5.94
HHV (kcal/kg)	Instrument	3,216	5.086	4,212

Figure 2 (a) and 2 (b) show the composition of flue gas and reacting temperature with times, expressed in ppm, vol. % of dry gas and °C. To confirm the combustion test, we compared the combustion characteristics of LCW and SRF. In case of LCW with same ER, O_2 and NO_x concentrations are lower, CO_2 concentration is higher than SRF. From figure 2(a) and 2(b) we found that CO_2 is showing increasing trend whereas O_2 is showing decreasing trend. Again, amount of CO_2 was higher in LCW than SRF, because of higher volatile content in LCW than SRF it reacts faster with oxygen and formed more CO_2. CO was not detected because of higher unit of gas analyzer. We will try to analyze it in future. In case of NO_x generated during combustion process, it can be divided into two types. Firstly fuel NOx from the nitrogen contents of fuel and secondly, thermal NO_x generated from changing temperature. But in this study, we conducted the combustion experiment with one condition (same temperature, same ER). So the NO_x produced during this experiment was fuel NO_x, which means it was generated from the existed nitrogen in the fuel. In case of LCW, NO_x produced during combustion experiment ranged between 15-40 ppm; on the other hand for SRF NO_x ranged between 40-50 ppm. On an average the amount of NO_x from LCW was far below than that of SRF and also it satisfies the emission standard.

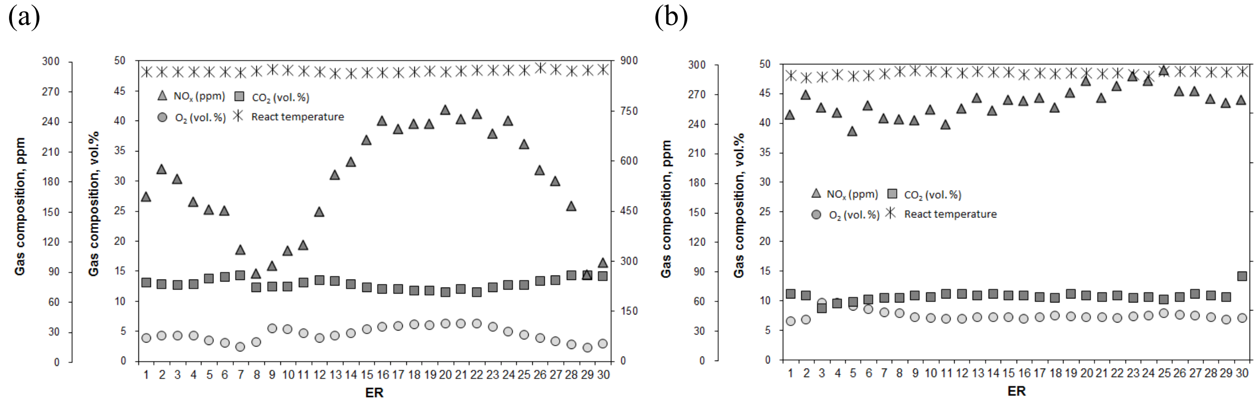

Figure 2. Composition of the flue gas with reacting temperature [(a) LCW, (b) SRF]

CONCLUSION

In conclusion, from the result of physicochemical characteristics it was found that lower calorific waste has higher carbon content, volatile content and higher heating value in comparison to other feedstocks like waste residue, solid refuse fuel. In case of combustion characteristics, it shows good combustion characteristics compared with SRF combustion and also satisfied the basis of combustion standard. In case of NOx generated during combustion process, it was generated from the existed nitrogen in the fuel not from the variation of temperature (as the combustion experiment was conducted on fixed temperature).

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Analysis on Plastic Packaging Waste Segregation Behaviour Taking into Account Inhabitants' Age Groups and Lifestyles

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ABSTRACT

This study discusses the difference in plastic packaging waste segregation behaviours, taking into account inhabitants' age groups and lifestyles. We conducted a survey to investigate respondents' frequency of segregating plastic packaging waste as recyclables in Kobe, Japan. We also asked respondents about the frequency with which they washed their waste, as this step facilitates the recycling process. Based on the survey, we calculated waste segregation rates of respondents taking into account age groups, number of people in households, and so on.

Keywords: Plastic packaging waste, segregation, age group, lifestyle

INTRODUCTION

The population's rate of aging has been increasing in Japan. The Cabinet Office of the Government of Japan (2015) forecasts that the rate will increase up to 26.0% in 2060 from 39.9% in 2014. National and local governments of aging populations might find it very difficult to sustain their administrative services. One of the services that might be affected by this issue is municipal waste collection and treatment. Some papers indicate that the elderly cannot conduct complex garbage segregation because of a decline in their cognitive functions and physical capabilities. Kobe University (2015) conducted a survey on people aged 60 years or older residing in Kobe City, Japan. From this survey, approximately 6.3% of respondents (of a total 1,100 persons) answered that they have difficulty taking out the garbage and segregating incombustibles from combustibles for recycling. Figure 1 shows the ratio of respondents who can segregate garbage and cannot segregate garbage. Based on this figure, we can see that most people 75 years or older cannot sufficiently segregate garbage. Miyamae (2010) also indicates that cities with growing elderly populations are unable to properly satisfy waste segregation

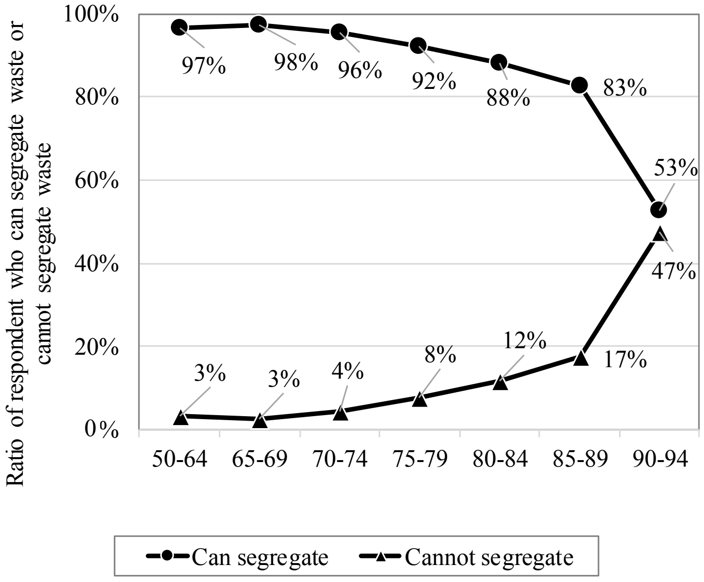

Figure 1 Ratio of respondents who can segregate garbage or cannot segregate garbage (Kobe University, 2015)

requirements.

An even larger elderly population will only increase the amount of collected waste not meeting segregation requirements. This issue can trigger a dynamic change in waste collection and treatment services by local governments. Japanese residents participate in garbage collection and treatment systems through washing and segregating recyclables based on their segregation requirement. However, an aging population might contribute to an increase in the number of residents that cannot sufficiently segregate their garbage. Local governments might be forced to change garbage collection and treatment measures depending on residents' abilities to segregate their own waste.

The overall aim of our study is to analyse environmental and economic impacts of the local government's garbage collection and treatment system, taking into account the increase of elderly people in the population and the resulting change in garbage segregation behaviour. As previously mentioned, this study discusses the different plastic packaging waste segregation behaviours of residents, taking into account age group and lifestyle. A reason that we selected plastic packaging is because residents can easily recognize what is recyclable because of the identification that marks each piece of plastic as part of a program to bolster recycling.

MATERIALS AND METHODS

Questionnaire survey

We administered an online survey made available to qualified respondents living in Kobe City, Japan.

Table 1 Categories of plastic packaging waste and frequency of segregation

	Ratio of composition*	Frequency of segregation** (Mean value)
Cups, food containers and packs	34%	***3.75***
(1) Cups (puddings, yoghurts, ice cream and so on)		3.82
(2) Food containers (boxed lunches, tofu, margarine and so on)		3.58
(3) Packs (eggs, vegetables and so on)		4.14
(4) Packs (hams, sausages, retort foods and so on)		3.46
Packaging of product (excluding aluminum component)	27%	***3.70***
(5) Exterior film (snacks, noodles and so on)		3.68
(6) Bags (clothes, glossaries and so on)		3.54
(7) Plastic bottle labels		3.89
Plastic bottles (excluding polyethylene terephthalate)	17%	***3.62***
(8) Bottles (cooking oil, sauce, dressing and so on)		3.53
(9) Bottles (detergent, bleach, shampoo, cosmetics and so on)		3.72
Plastic bags	9%	***3.29***
(10) Plastic bags		3.29
Aluminum foil compound	8%	***2.72***
(11) Chocolates, gum, ice cream and so on		2.68
(12) Soap, detergents, shampoo and so on		2.76
Packaging of delivery agents	5%	**3.20**
(13) Food wrap (fresh foods, boxed lunches and so on)		*2.98*
(14) Packaging (bread, snacks, vegetables and so on)		3.43

*: Ministry of Environment (2015)

**: Do you segregate these packaging waste as recyclables?

Answer: always segregate (5 points, 100%), almost segregate (4 points, 75%), sometimes segregate(3 points, 50%), rarely segregate (2 points, 25%), not segregate (1 point, 0%)

Italic and bold value indicates total score of each plastic packaging waste.

First, we gathered demographic information, which included gender, number of people in the household, annual income and so on. We then went on to ask if respondents segregated their plastic packaging waste (5 points), washed those materials they segregated for recycling (4 points) and so on. We classified plastic packaging waste into 14 categories (see Table 1) based on those outlined by the Ministry of Environment (2015). A total of 1,304 people responded during the survey period from November 16 to November 24, 2015.

Plastic packaging waste segregation ratio

Regarding the question about segregating plastic packaging, we asked respondents with what frequency they segregated their plastic packaging waste (see Table 1). If they always segregate, we supposed that segregation rate to be 100%. And if they do not segregate, we supposed that segregation rate to be 0% (this means that they throw out their recyclables with their combustibles). We calculated the ratio of plastic packaging waste segregation by multiplying frequency of segregation and composition (Ministry of Environment, 2015).

RESULTS AND DISCUSSION

Table 1 shows the results of our findings based on respondents' answers. One of the survey questions asked about frequency of segregation for each type of plastic packaging waste. Answers were converted to a numeric scale between 1-5 points, enabling us to calculate the score of segregation ratio of each plastic packaging waste category. The higher the score, the more frequent the respondent segregates that waste. As a result, "Cups, food containers and packs" had the highest segregation ratio. On the other hand, the segregation ratio of "Packaging of delivery agents" and "Aluminium foil compound" was lower than other waste groups. The reason for the lower rating is because respondents felt washing these waste containers to be a chore, and they might not identify that these waste containers are recyclable.

Figure 2 shows the result of the segregation ratio of plastic packaging waste for each age group. The ratio was lowest for respondents between 20-29 years old. This ratio increased in accordance with an increase to the group's age. The reason why the highest ratio belongs to respondents falling within the 60-69 year old age group is the following: (1) almost all of them are retired and they therefore have more time, and (2) they segregate their waste out of a highly developed conscientiousness regarding environmental protection. We also found that the segregation ratio in a single-person household was slightly lower than in a multi-person household.

Figure 3 shows the results regarding the ratio of washing plastic packaging waste derived from a boxed lunch. It is required that the plastic packaging waste be washed as it will facilitate recycling. Older respondents (age group 65-69) thoroughly washed "Bottles (detergent, bleach, shampoo, cosmetics and so on)" compared with other age groups. This result supports our understanding that older people are highly conscientious regarding environmental protection. On the other hand, although they also thoroughly washed "Food containers (boxed lunches, tofu, margarine and so on)," the ratio of no segregation was also high. No segregation means that they do not wash the waste and they throw it out with combustibles. Food residues and oils that stick to food containers make them troublesome to wash. Based on this result, we found that some older respondents from this age category would forego washing their waste even though almost all of the older respondents do wash for segregation.

CONCLUSION

Our survey investigated how often residents of Kobe, Japan wash their plastic packaging and segregate it into recycling. We also discussed the different plastic packaging waste segregation behaviours taking into account inhabitants' age groups and lifestyles. Our future research will include conducting the same survey for respondents aged 70 and older to analyse the comparison between the elderly and other people.

ACKNOWLEDGEMENT

This research was supported by the Environmental Research and Technology Development Fund [3K143016] and Mitsui Sumitomo Insurance Welfare Foundation.

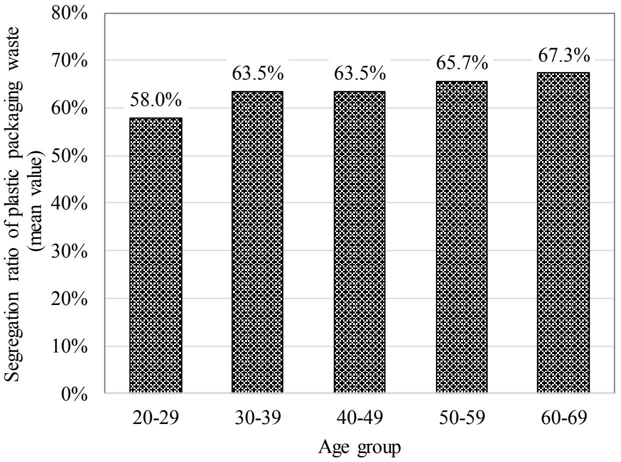

Figure 2 Segregation ratio of plastic packaging waste

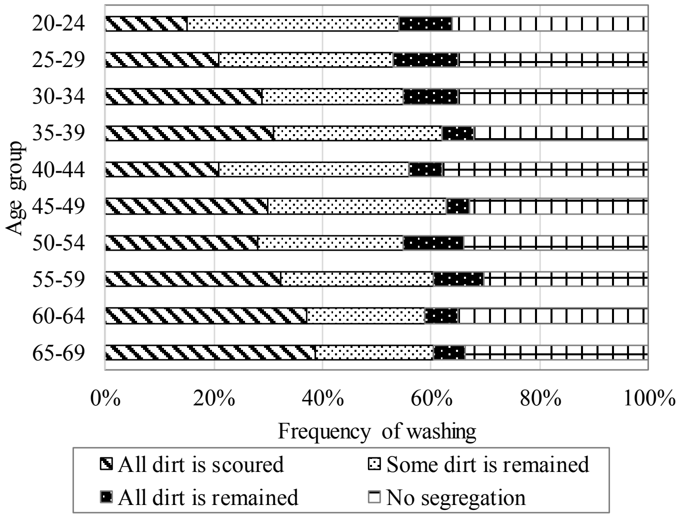

Figure 3 Frequency of washing food containers (boxed lunches, tofu, and margarine)

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Carbon Dioxide Capture and Utilization Using Alkanolamine Type Absorbents and Pretreated Brine Solution

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ABSTRACT

This study deals with the Carbon Capture and Utilization (CCU) technology using alkanolamine absorbents solutions and pretreated brine solution which is produced as wastewater in refined salt production facility. Alkanolamine solutions were saturated by 15 vol% CO_2-N_2 mixed gas which assumed to be industrial flue gas emitted from normal coal-fired power plant. Unlike direct carbon fixation method, all of the experiments were performed under normal temperature range (298.15 – 343.15 K) and ambient pressure (101.325 Pa). Ca^{2+} ions contained in pretreated brine solution is used as metal ion supplying source. 30 wt% of aqueous monoethanolamine (MEA), diethanolamine (DEA), and methyldiethanolamine (MDEA) solutions showed conversion yields of 37.49, 18.69, and 17.95 %, respectively, by forming precipitated calcium carbonate salts. Though Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) analysis, precipitated salts were turned out to be calcite.

Keywords: Carbon Capture and Utilization (CCU), Alkanolamine, Brine solution, Pretreated Calcium Carbonate

INTRODUCTION

Among six types of greenhouse gases, the global warming potential (GWP) of CO_2 towards global warming is not that great compared to others. However, due to its massive amount of emission, contribution level of CO_2 towards global warming is the highest among the greenhouse gases. In order to reduce the amount of its emission to atmosphere, Carbon Capture and Storage (CCS) technologies have been developed and applied to some industrial fields which produced enormous amount of CO_2 such as power plants and cement industries. With this conventional CCS technology, produce carbon dioxide is captured by liquid absorbents at relatively lower temperature and is desorbed at high temperature. Desorbed carbon dioxide gas is compressed at high pressured and disposed at deep ocean and underground. However, some problems occurred in the storage step. When CO_2 is stored at deep ocean, peripheral ecosystem can be acidified and also, leakage can be a problem when it is stored in underground pocket. To prevent these problems, a concept of converting carbon dioxide to stable substances had arisen. One of the technology to achieve CO_2 conversion is to make precipitated calcium carbonate salts by induce chemical reaction between captured carbon dioxide and metal ion, especially for calcium cation. However, it is expected that the source of calcium cation would be depleted considering the amount of carbon dioxide emission. If calcium cation can be obtained from infinite sources or wastes which have to be disposed or post-treated, there would be no concern for securing reactants. Also, produced precipitated calcium carbonate salts can be used in many industries such as cement production, medical research, pharmaceutical medium, and additives in paper industries as well as manufacturing engineering plastics and so on. With this concept, economic feasibility of this Carbon Capture and Utilization (CCU) technology can be greatly improved. In this research, carbon dioxide was captured by using aqueous alkanolamine solution such as MEA (monoethanolamine), DEA (diethanolamine), and MDEA (methyldiethanolamine). These absorbents were selected since their absorption performance are high and they convert captured carbon dioxide into ionic carbon dioxide such as carbonate, bicarbonate and carbamate which can facilitate ionic reaction with high kinetics. Also, metal ions were determined to be supplied from wastewater produced at refined salt production facility (Hanju Salt Corp., Ulsan, Korea). In the salt production process, sodium chloride is separated and remain solution contains relatively concentrated calcium ions. After this process, remaining solution is heated and over-saturated solution is over-saturated. And then, precipitated salt is separated again, and then, remaining solution is used as calcium ion supplying source. With this, carbon dioxide utilization is achieved and precipitated calcium carbonate salt analysis was performed using Scanning Electrom Microscope (SEM) and X-Ray Diffraction (XRD). The detailed methodology to prove the possibility of this process is shown in next section.

MATERIALS AND METHODS

Reagents and Experimental Setup

The composition of pretreated brine solution is suggested in Table 1. Its composition is compared with that of natural seawater.

Table 1. Composition of pretreated brine solution and natural seawater

Metal Cation	Concentration	
	Natural Seawater	Pretreated Brine Solution
Ca^{2+}	402.11	21973.74
Mg^{2+}	1273.03	20830.41
Na^{+}	10551.71	22183.67
Ba^{2+}	0.052.64	0.72

To make absorbent solutions, 30 wt% of aqueous MEA, DEA, and MDEA solutions were used. The reagents were purchased from Sigma-Aldrich. The purities of each reagents were over 99.9 wt%. When preparing aqueous absorbent solutions, precise balance with accuracy of ± 0.001g was used. Also, for absorption and desorption experiments, double jacketed reactor with gas analyzer was used. 15 vol% of CO_2 gas mixed with nitrogen was used. Absorption and desorption experiments were performed under 298.15 K and 343.15 K, respectively. Also, precipitation or conversion of captured carbon dioxide was progressed under ambient pressure and 298.15 K.

RESULTS AND DISCUSSION

CO_2 loading curves and yield of CO_2 conversion

Figure 1 shows the CO_2 loading curve when 30wt% of MEA, DEA, and MDEA were used as absorbent solutions. Unlike conventional CO_2 loading curve in continuous absorption – desorption system, absorption curve and desorption curves are not connected with each other. It is due to the precipitation of calcium carbonate salt right after absorption step. In order to investigate the amount of remaining carbon dioxide captured, desorption experiments were performed. The resulting loading curves are shown in Figure 1 below. The loading for 30 wt% MEA, DEA, and MDEA were 0.4193, 0.3632, and 0.4339, respectively. After absorption step, 100 ml of pretreated brine solution was introduced to the CO_2-saturated absorbents. Absorbed CO_2 is then converted into salts and amount of CO_2 absorbed in the solution was dropped to some extent. After the conversion step, thermal desorption experiments were conducted and the amount of absorbed CO_2 is gradually decreased. Based on the CO_2 loading curve, amounts of calcium carbonate salt formation were **c**alculated and the results were shown in Table 2.

Table 2. The amount of CO_2 converted and conversion yields

Concentration	The amount of pretreated brine solution added	The amount of CO_2 converted into metal carbonate salt [a)]	Conversion yield [b)]
30 wt%			
MEA	**100 vol% pretreated brine solution 100 ml**	0.1572	37.49
DEA		0.0679	18.69
MDEA		0.0779	17.95

a) Amount of CO_2 converted into metal carbonate salts is expressed in mol

b) The conversion yield is expressed in percent (%)

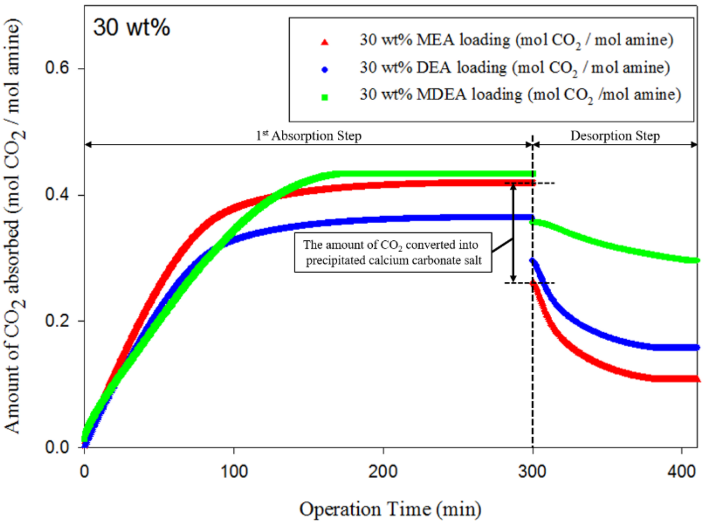

Figure 1. CO_2 loading curves for 30 wt% alkanolamine absorbents.

Judged from Table 2, 0.1572, 0.0679, and 0.0779 mol of absorbed CO_2 was converted to precipitated salts for 30 wt% MEA, DEA, and MDEA, respectively. For each case, conversion yields were 37.49, 18.69, and

17.95 %, respectively. Considering absorption performance and the conversion yield, 30 wt% aqueous MEA solution is thought to be the best alkanolamine absorbents for this CCU process.

Results of Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD) analysis

In order to investigate a component of precipitated salts, SEM images were obtained and XRD analysis were performed. As a result, precipitated salts were proven to be calcium carbonate ($CaCO_3$) as expected1).

By the way, there are three types of crystal structures in calcium carbonate: calcite, vaterite, and aragonite. Each of them are used for some specific purposed in many industrial fields. As shown in Figure 3, the crystal structure of precipitated calcium carbonate salt was calcite which can be used as: reactant for cement production, additives or coating material in paper industry, drug delivery medium in pharmaceutical industry and so on.

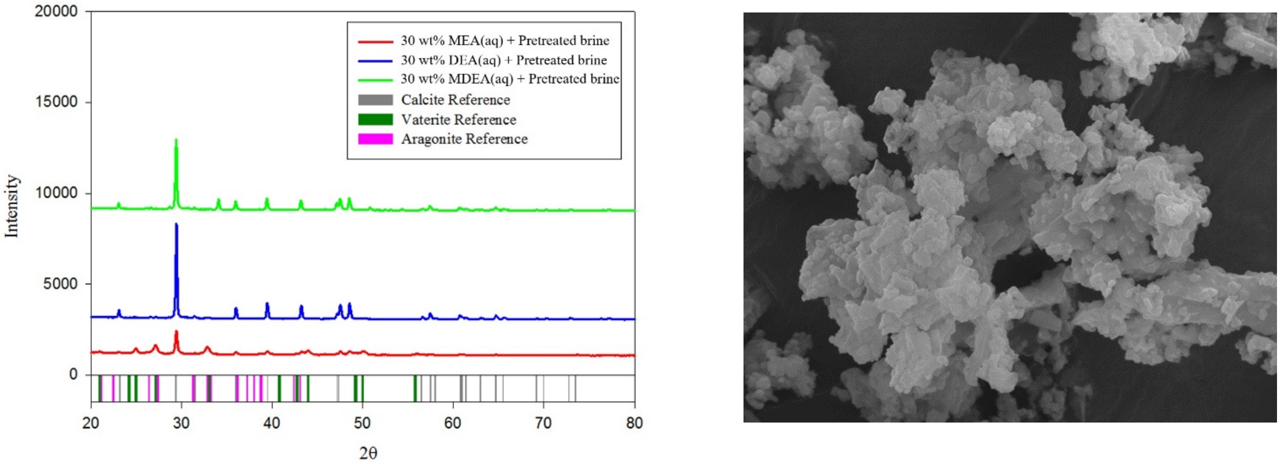

Figure 2. The Results for SEM and XRD analysis. SEM image is for the precipitated salt formed in 30 wt% CO_2-saturated aqueous MEA absorbent solution.

CONCLUSION

The main purpose of this study was to investigate the possibility of CO_2 conversion using wastewater with high concentration of calcium ion. As expected, precipitated calcium carbonate salt formation was possible for all alkanolamine type absorbents. The reaction rate was quite high due to ionic CO_2 produced from reaction between amine and CO_2 molecules. Considering the amount of CO_2 absorption and precipitated salt production, MEA absorbent is thought to be the most adequate absorbents.

ACKNOWLEDGEMENT

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Numerical Study of Heat Transfer Characteristics of Char from Waste Tire Pyrolysis

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ABSTRACT

In order to investigate heat transfer of char from waste tire pyrolysis, the particle cooling of char was simulated by the Computational Fluid Dynamics (CFD). The CFD analysis results were validated by comparing them with experimental results. In the present study, the effects of cooling temperature and mechanical stirring were investigated. As the cooling temperature decreases, the cooling rate of char increases. However, the particle mixing had a great influence on the particle-particle (wall) conductive heat transfer. The cooling rate of char showed larger influence from particle mixing than the influence from cooling temperature. As for the cooling rate of char, mixing condition was 25 to 30% larger than that of the non-mixing condition.

Keywords: Carbon black, CFD, Char, Heat transfer, Waste tire

INTRODUCTION

The disposal of waste tires becomes a serious problem, hence waste tire closely is related with environmental problems. The recycling techniques for the waste tire have been a major challenge to society and the environment. Pyrolysis is one of the major techniques that can convert wastes to energy such as the waste tire. And that has continuously aroused researchers' attention for the past two decades (Mui et al., 2011). Pyrolysis offers an environmentally and economically attractive method for waste tires conversion to useful products and energy. In general, by pyrolyzing waste tire three fractions are obtained: solid residue (around 40 wt. %), liquid fraction (around 50 wt. %) and gas fraction (around 10 wt. %) (Juma et al., 2006). The solid residue contains carbon black, and inorganic matter. It contains carbon black and the mineral matter initially present in the tire. This solid char may be used as reinforcement in the rubber industry, as activated carbon or as smokeless fuel. The temperature of the char that is discharged from the pyrolysis reactor in the pyrolysis process of waste tire is about 400 ℃. Since there is a risk of fire and explosion for storing the high temperature char in a silo, the temperature of char must be cooled down below 100 ℃ in order to store it safely in a silo. The specific heat of char is 1500 J/kg-K and its heat conductivity is very low, as low as 0.1 W/m-K, it takes a long time to cool it down to low temperature. Therefore, what is required to quickly cool down the hot char is to apply the method that can increase the heat transfer rate. However, heat transfer of char has never been studied so far. Therefore, in this study, experiments and CFD analysis were performed in order to study the heat transfer characteristics of the char.

MATERIALS AND METHODS

Figure 1 shows the experimental apparatus used for the cooling experiment of char. The experimental apparatus consisted of a chiller, vessel, thermocouple, and data logger. The temperature of char within the vessel was measured using the k-type thermocouple, while the temperature measurement data were stored every seconds using the digital data logger. Char was heated to 400℃ using an electric furnace, and the temperature of the heated char was measured in a cooling vessel. The experimental conditions are shown in Table 1. The char particle has the density of 926 kg/m^3 and mean diameter of 300 μm. The specific heat of char is 1500 J/kg-K and conductivity is 0.1 W/m-K.

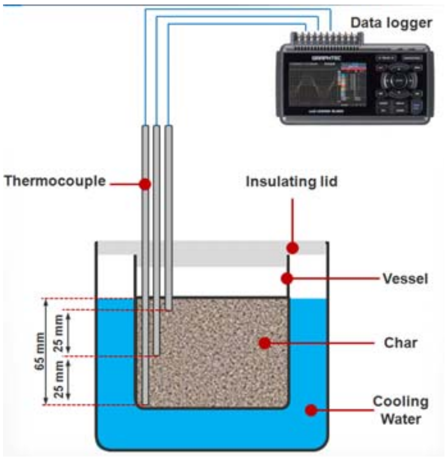

Figure 1. Experimental apparatus

Table 1 Experimental conditions

Initial temperature (℃)	400
Char mass (g)	280
Cooling temperature (℃)	32
Vessel size (mm)	145 × 80 × 65

NUMERICAL PROCEDURE (Choi, 2015)

The governing equations for the present study can be summarized as follows (Syamlal et al., 1993):

- Continuity equations of gas (g) and solid (s) phases:

$$\frac{\partial}{\partial t}\left(\varepsilon_g\rho_g\right)+\nabla\cdot\left(\varepsilon_g\rho_g\mathbf{v}_g\right)=0 \tag{1}$$

$$\frac{\partial}{\partial t}\left(\varepsilon_{sj}\rho_{sj}\right)+\nabla\cdot\left(\varepsilon_{sj}\rho_{sj}\mathbf{v}_{sj}\right)=0 \tag{2}$$

where subscripts g and sj indicate the gas and solid phase. $\mathbf{v}$ represents the velocity vector, and ε is the volume fraction of the gas or solid phase.

- Momentum equations of gas and solid phases:

$$\frac{\partial}{\partial t}\left(\varepsilon_g\rho_g\mathbf{v}_g\right)+\nabla\cdot\left(\varepsilon_g\rho_g\mathbf{v}_g\mathbf{v}_g\right)=-\varepsilon_g\nabla P_g+\nabla\cdot\tau_g+\sum_{j=1}^{n}F_{gsj}\left(\mathbf{v}_{sj}-\mathbf{v}_g\right)+\varepsilon_g\rho_g\mathbf{g} \tag{3}$$

$$\frac{\partial}{\partial t}\left(\varepsilon_{sj}\rho_{sj}\mathbf{v}_{sj}\right)+\nabla\cdot\left(\varepsilon_{sj}\rho_{sj}\mathbf{v}_{sj}\mathbf{v}_{sj}\right)=-\varepsilon_{sj}\nabla P_{g}+\nabla\cdot\mathbf{S}_{sj}-F_{gsj}\left(\mathbf{v}_{sj}-\mathbf{v}_{g}\right)+\sum_{k=1}^{n}F_{sksj}\left(\mathbf{v}_{sk}-\mathbf{v}_{sj}\right)+\varepsilon_{sj}\rho_{sj}\mathbf{g} \quad (4)$$

where τ_g is the stress tensor for the gas phase and $\mathbf{S}_{sj}$ is the j th stress tensor for the solid phase. The F_{gsj} and F_{sksj} are inter-phase drag force coefficients between the gas and solid phases and between the solid phases, respectively. $\mathbf{g}$ is the gravitational acceleration.

- Energy equations of gas and solid phases:

$$\varepsilon_{g}\rho_{g}Cp_{g}\left(\frac{\partial T_{g}}{\partial t}+\mathbf{v}_{g}\cdot\nabla T_{g}\right)=-\nabla\cdot\mathbf{q}_{g}+\sum_{j=1}^{n}\gamma_{gsj}\left(T_{sj}-T_{g}\right) \quad (5)$$

$$\varepsilon_{sj}\rho_{sj}Cp_{sj}\left(\frac{\partial T_{sj}}{\partial t}+\mathbf{v}_{sj}\cdot\nabla T_{sj}\right)=-\nabla\cdot\mathbf{q}_{sj}-\gamma_{gsj}\left(T_{sj}-T_{g}\right) \quad (6)$$

where T represents the temperature of the gas or solid phase, $\mathbf{q}$ is the heat flux from the conduction of the gas and solid phases. γ_{gsj} is the heat transfer coefficient between the gas and solid phases.

In this study, the CFD analysis for the cooling of char was performed using the MFIX code (Syamlal et al., 1993). An Eulerian- Eulerian approach with kinetic theory was applied for the simplicity of the calculation compared to other particle methods considering both the continuum gas and discrete solid phases. The calculation condition of CFD analysis is the same as the experimental condition. The initial temperature of char was 400 ℃ and walls of the vessel is isothermal condition as 32 ℃. An adiabatic condition was applied to the top wall of the vessel. The heat was transferred from the hot char to the vessel wall and air.

RESULTS AND DISCUSSION

Figure 2 shows instantaneous char temperatures in the CFD analysis and experimental results. The char temperature with time in the CFD analysis results agrees well with that of the experimental results. Hence, the computational procedure adopted in the present study is appropriate for the simulation of the cooling of the hot char. Figure 3 shows the effects of the cooling temperature and mixing conditions (stirring of char) on the cooling rate of char. For reference, the mixing condition is that the char is completely mixed after every 20 seconds during cooling considering the pitch of the screw in an auger type cooler. As the cooling temperature decreases from 32℃ to 7℃, the cooling rate of char slightly increases both for mixing and non-mixing conditions. For example, the temperature of char was reduced 5% more at 7℃ than that of 32℃ for non-mixing case. For the mixing conditions at 32℃, the char temperature decreased 25% compared with non-mixing case. In addition, for the mixing condition at 7℃, the char temperature decreased 30% compared to the non-mixing case. This is mainly because the particle-wall or particle-particle convective heat transfer is enhanced by the particle mixing.

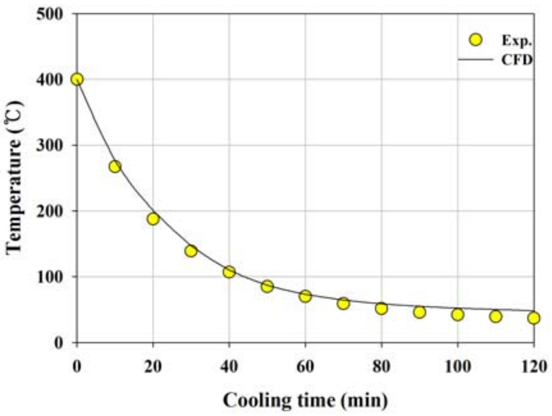

Figure 2. Comparison of char temperature between CFD analysis and experimental results.

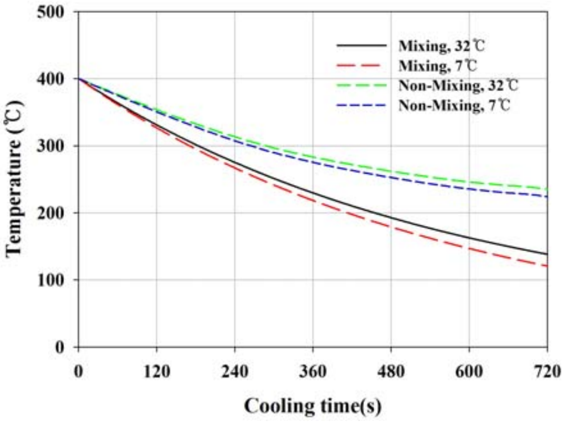

Figure 3. Variation of char temperature by changing cooling conditions.

CONCLUSION

In this study, CFD was applied to investigate the heat transfer characteristics of char particle. As a result of CFD analysis, the cooling rate of char showed a larger influence from particle mixing than from cooling temperature. For the cooling rate of char, the mixing condition showed a larger increase of 25 to 30% than that of non-mixing conditions. The CFD analysis results can be further applied to the design of the screw conveyor cooler.

ACKNOWLEDGEMENT

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Numerical modeling & parametric investigation of renewable CaF2 formation from HF wastewater treatment with fluidized bed reactor
: particle trajectory behavior with particle size

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ABSTRACT

Even though removal of fluoride in HF wastewater using a fluidized bed reactor (FBR) by crystallization process has been widely studied as an efficient alternative to the chemical precipitation method using traditional stirred tank reactor, there have been a couple of serious problems encountered for the optimum design of FBR together with the determination of proper operating conditions. One of those will be the proper formation of the fluidization state of seed as a function of seed particle characteristics such as particle size and density. Since the dynamics in reactor is governed by the forces such the gravity, drag and buoyancy as a function of particle size, particle density, relative velocity together with the flow characteristics, this study carefully examines these effects on the formation of fluidization via theoretical analysis and numerical calculation in fluidized bed reactor in the range of practical design and operation condition. In general, the result of this study shows clearly the overall trend of the motion of particle behavior in terms of particle size and flow condition.

Keywords: CaF2 recovery, HF wastewater, Fluidized Bed Reactor, fluidization, particle size

INTRODUCTION

In various industries, including the production of semiconductors and the thermal incineration of waste refrigerants such as R-134a, a large amount of fluoride containing wastewater with a high fluoride concentration is produced. Crystallization process in a fluidized reactor (FBR), these days, appears as an alternative clean technology to the conventional chemical precipitation process. In the modeling, design and control of a FBR for water treatment it is necessary to study particle behavior in the aspect of fluidization, effluent of fine particles due to homogeneous nucleation and pellet removal by the heterogeneous precipitation at the bottom of the reactor. Since the particle behavior in FBR is governed basically by three forces of gravity, drag and buoyancy as a function of particle size and density together with the flow condition, in this study, a rather systematic investigation has been made using numerical modeling method together with the basic analytic calculation.

MATERIALS AND METHODS

Particle dynamics

Provided that direction of particle settling and direction of force acting on the particle are one-dimensional relation, the forces acting on the settling particle is,

$$\mathrm{m}\frac{dv}{dt} = F_g - F_b - F_d$$

$\frac{dv}{dt}$: $acceleration\ of\ the\ particle, F_g$: $gravitational\ force,\ F_b$: $buoyancy,\ F_d$: $drag\ force, m$: $particle\ mass$

The equation presents drag force is $F_d = {}^{1}/_{2}\, C_d (v_f - v_p)^2 \rho_f A_p$. The drag coefficient($C_d$) exhibit different behaviors in different range of Reynolds number. Roughly, on the spherical object, C_d=24/Re in low Reynolds number and C_d is constantly about 0.4 in $10<Re<10^3$.

Under steady state condition ($dv/dt = 0$), terminal velocity of the spherical particle depending on C_d like below.

① Case 1 (C_d : 24/Re)

$$C_d = \frac{24}{Re}, \qquad Re = \frac{\rho(v_f - v_p)D_p}{\mu}, \qquad \therefore C_d = \frac{24\mu}{\rho(v_f - v_p)D_p}$$

$$v_p = v_f - \frac{g(\rho_p - \rho_f)D_p^2}{18\mu}$$

② Case 2 (C_d : 0.4)

$$C_d = 0.4$$

$$v_p = v_f - \sqrt{\frac{g(\rho_p - \rho_f)D_p}{0.3\rho_f}}$$

Table 1. Terminal velocity depending on particle diameter, drag coefficient and superficial velocity

particle diameter (mm)	terminal velocity of the particle (m/s)					
	drag coefficient(C_d)	24/Re		drag coefficient(C_d)	0.4	
	superficial velocity (m/s)			superficial velocity (m/s)		
	7.37.E-03	3.68.E-02	7.37.E-02	7.37.E-03	3.68.E-02	7.37.E-02
0.01	7.27E-03	3.67E-02	7.36E-02	-1.62.E-02	1.33.E-02	5.01.E-02
0.1	-1.87E-03	2.76E-02	6.44E-02	-6.72.E-02	-3.77.E-02	-8.57.E-04
0.3	-7.58E-02	-4.63E-02	-9.47E-03	-1.22.E-01	-9.22.E-02	-5.54.E-02
0.5	-2.24.E-01	-1.94.E-01	-1.57.E-01	-1.59.E-01	-1.30.E-01	-9.30.E-02
1	-9.16.E-01	-8.87.E-01	-8.50.E-01	-2.28.E-01	-1.99.E-01	-1.62.E-01

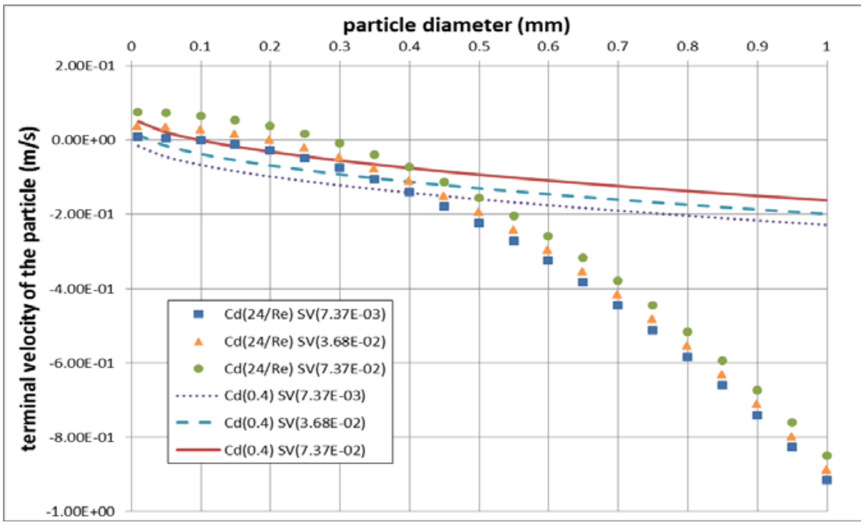


Fig.1. Terminal velocity depending on particle diameter, drag coefficient and superficial velocity

Fig. 1 and Table 1 show terminal velocity of spherical calcite($CaCO_3$) particle as a function of particle diameter and C_d value. From this, it is reasonable to assume that C_d is major factor of determination of terminal velocity in particle settling situation. Since C_d is function of Reynolds number(Re), the flow characteristics, turbulence flow or laminar flow, is necessarily considered to design proper FBR.

RESULTS AND DISCUSSION

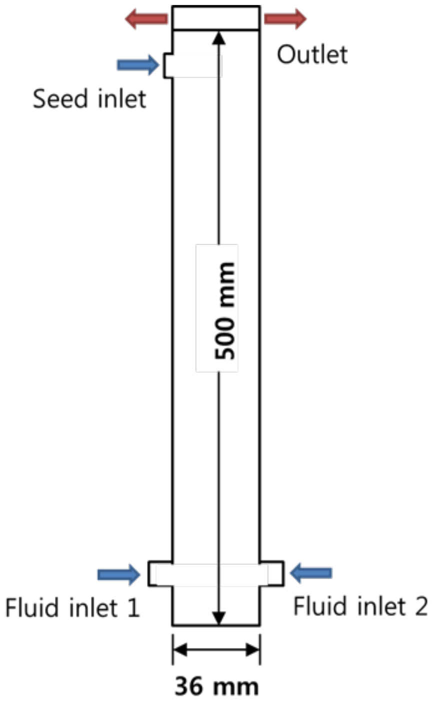


Fig.2. Schematic diagram of fluidized bed reactor(←)

Table 2. Calculation condition of fluid flow rate and particle diameter for two cases.

Flow rate	Fluid inlet 1	409.03 ml/min
	Fluid inlet 2	40.903 ml/min
Particle Diameter	Case 1	2mm($6.813x10^{-3}$ kg/min)
	Case 2	0.2mm($6.813x10^{-6}$ kg/min)

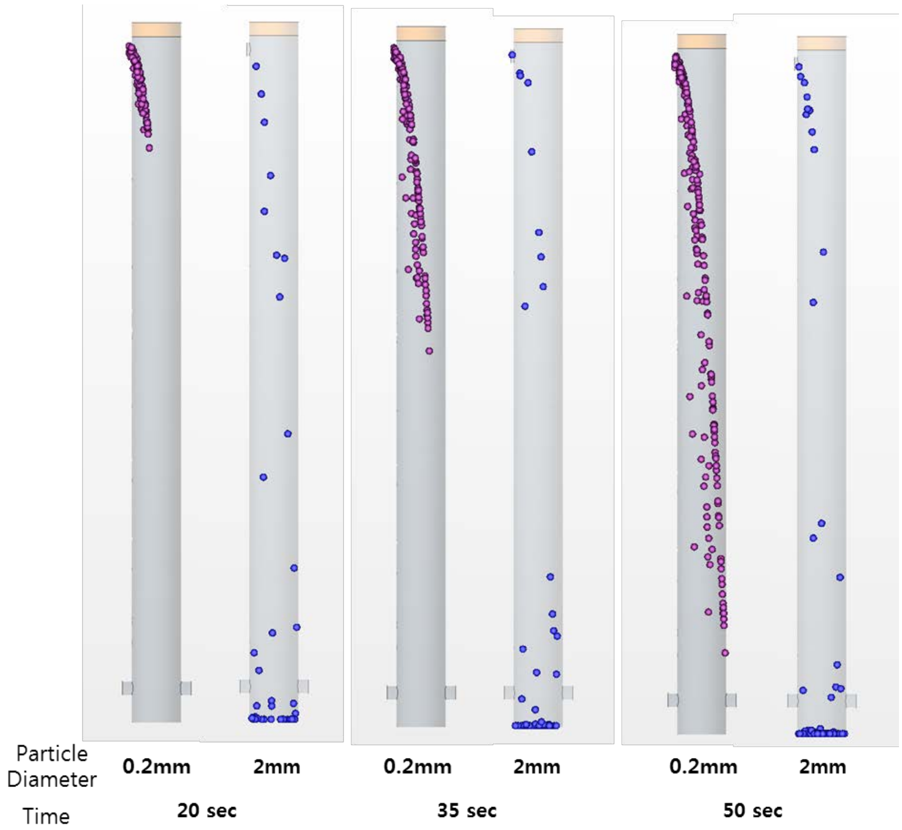
Fig. 2 shows the schematic diagram of fluidized bed reactor employed in this study. And the detailed condition of fluid flow rate and particle diameter of each case was shown in Table 2. Two different particle sizes are employed.

In specific, 0.2mm diameter and 2.0mm diameter calcite($CaCO_3$) particle is injected into the reactor with water feed. The hydrodynamic equilibrium is assumed between particle and water. The calculated results at 20, 35, 50 second from the particle injection has shown in Fig. 3. The results clearly show, as might be expected, that settling behavior of 0.2mm diameter particle is evidently slower than that of 2.0mm diameter particle. From this preliminary study, it is believed to be practicable to make a systematic parametric calculation in order to figure out the fluidization condition as a function of important parameters.

CONCLUSION

A preliminary study has been made for the particle trajectory behavior using analytic method and numerical calculation in order to figure out the fluidization state in a fluidized reactor. The basic calculation of terminal velocity gives a rough idea for the seed particle size and density associated with the superficial velocity and numerical calculation data shows the overall settling trend with time as a function of particle size inside the FBR. In near future, a more detailed calculation will be desirable for the proper formation of fluidized bed.

Fig.3. Calculation results



ACKNOWLEDGEMENT

This work is financially supported by Korea Ministry of Environment(MOE) as Waste to energy recycling Human resource development Project.

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Numerical Modeling & Parametric Investigation of Renewable CaF2 Formation by HF Wastewater Treatment with Fluidized Bed Reactor : Cold Flow Characteristics with Inlet Configuration

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ABSTRACT

Even though removal of fluoride in HF wastewater using a fluidized bed reactor (FBR) by crystallization process has been widely studied as an efficient alternative to the chemical precipitation using traditional stirred tank reactor, there have been a couple of serious problems encountered for the optimum design of FBR together with the determination of proper operating conditions. One of those will be the characteristics of influent flow conditions, which influences and/or determines the optimal hydraulic retention time, fluidization state of seed and the mineral layer abrasion near the inlet stream due to high dissipation action of the flow. In order to resolve this kind of flow problem associated with the inlet flow feature, numerical calculation has been made systematically as a function of inlet flow condition such as shape, dimension and flow rate together with the concentration of HF concentration. By doing this, the flow pattern, turbulence intensity and mixture fraction of HF are investigated with the change of inlet parameters.

Keywords: CaF2 recovery, HF waste water, Fluidized Bed Reactor, Crystallization, inlet condition

INTRODUCTION

Not only the semiconductor industry but also the incineration process of waste refrigerant like R-134a, large volumes of hydrogen fluoride (HF) containing wastewaters needs to be treated properly. In addition, the CaF2(fluorspar) is becoming a more and more precious non-renewable resource. There is a critical demand to develop a reliable technology for recovering fluoride from industrial fluoride-containing wastewater. The commonly used technique for fluoride removal from industrial wastewater involves chemical precipitation by the use of fluidized bed reactor (FBR).

In general, the reactor used for this is a typical cylindrical type FBR filled with calcite sand and waste water containing HF. The suspended sand particle needs to form a fluidizing bed in a reactor and act as seed material for the production of CaF2 crystals by the heterogeneous precipitation on the sand surface by the nucleation of CaF2 via super-saturation process. In this process the HF wastewater (feed) is added as well as well-controlled amount of a proper calcium reagent such as CaCl2. In this process, considering the importance of the inter-coupling of chemistry and fluid dynamic problems, specially designed nozzles are quite necessary for the inlets of HF wastewater and calcium reactant together. For reagent, for example, either CaCl2 or Ca(OH)2 can be used to induce the precipitation of fluoride as CaF2 according to the following reactions;

Ca(OH)2 + 2HF - CaF2 + 2 H2O
CaCl2 + 2 HF – CaF2 + 2 HCl

When $Ca(OH)_2$ is used, it is necessary to feed much more than the stoichiometric amount to work effectively due to its low solubility. As a result, a larger amount of sludge is expected, and the unreacted sparsely soluble $Ca(OH)_2$ particles become the major constituent in the precipitated sludge. On the other hand, $CaCl_2$ with higher solubility is used, and a smaller amount of sludge is generated when $CaCl_2$ is used. However, the very fine CaF_2 particles do not settle readily. Therefore, it becomes necessary to use flocculants, such as PAC or PAM, to help flocculate the fine CaF_2 particles for easier separation from the wastewater. In practice, therefore, many treatment plants use a combination of $Ca(OH)_2$ and $CaCl_2$ to enhance the settlement of CaF_2 precipitates. In this process, the aspect of fluid dynamics such as fluidization state, superficial velocity along the reactor, relative velocity between particle and water, and turbulent intensity and dissipation rate near inlet stream at the reactor bottom become important. These kinds of fluid dynamic parameters are strongly influenced by the inlet stream design. Thus in this study a rather systematic investigation has been made by the use of numerical modeling for the condition of inlet nozzles of FBR.

MATERIALS AND METHODS

Governing equation and Turbulence model

The basic gas phase conservation equations for mass, momentum, energy, turbulent quantities and species concentration can be expressed, in an Eulerian framework, as

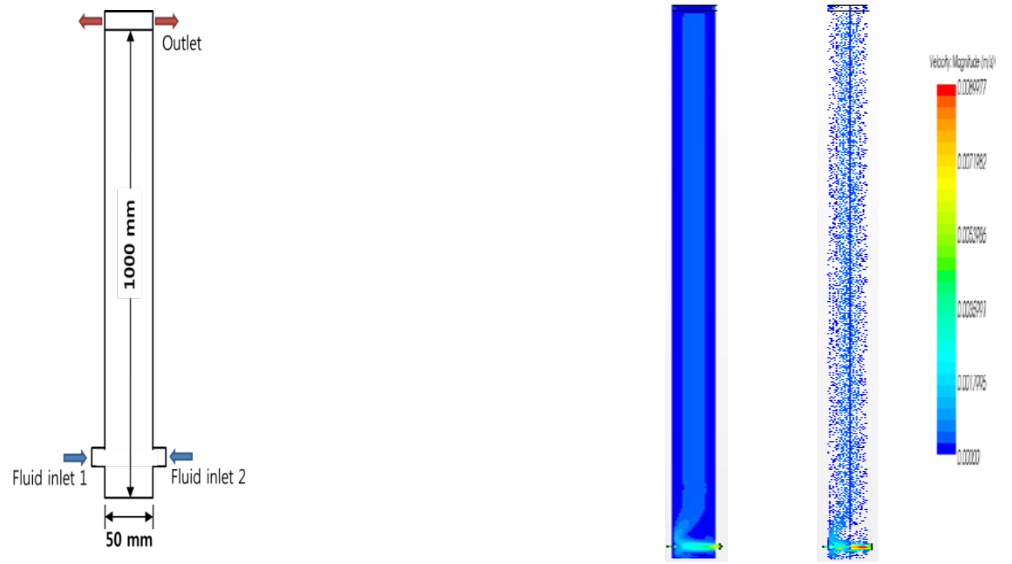
$$\frac{\partial(\rho\phi)}{\partial t} + \nabla\cdot(\rho\vec{u}\phi) = \nabla\cdot\left(\Gamma_\phi\nabla\phi\right) + S_\phi$$

in which φ denotes general dependent variables expressed as a quantity per unit mass. Further ρ, Γ_φ, S_φ stands for density, diffusion, diffusion coefficient and source terms corresponding to φ, respectively. The popular approach is the use of the two equation (k–ε) model by Launder and Spalding, where a Prandtl-Kolmogorov relationship is used to correlate the turbulence viscosity, μ_t to the turbulent kinetic energy and its dissipation rate.

$$\mu_t = C_\mu \rho\, k^2 / \varepsilon$$

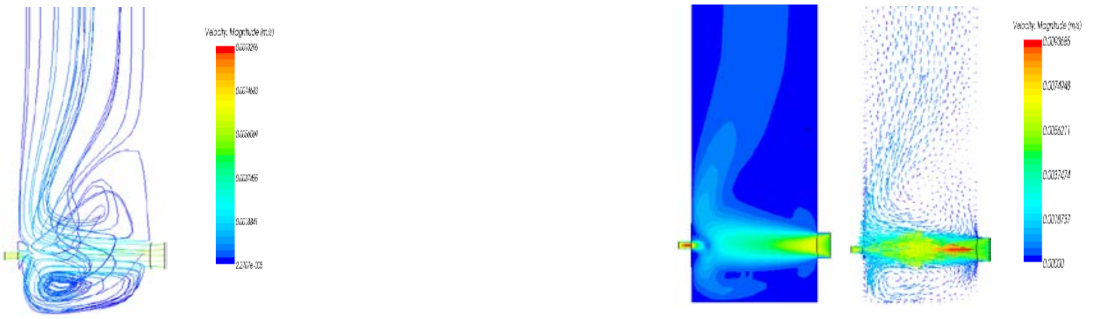
Further the distribution of the mixture fraction of the inlet stream of calcium supply is examined as a study of cold flow.

RESULTS AND DISCUSSION



(a) Schematic diagram of fluidized bed

(b) Overall plot of velocity vector



(c) Overall streamline plot

(d) Near inlet stream vector plot

Fig. 1 Schematic diagram and flow characteristics for the standard condition

Table 1. Input data of standard flow and geometry condition

Flow condition	Fluid inlet 1	
	Flow rate	2.17 ml/min
	Nozzle diameter	10mm
	Injection type	central parallel injection
	Turbulence Intensity	10%
	Dissipation Rate	0.03 of k
	Fluid inlet 2	
	Flow rate	21.7 ml/min
	Nozzle diameter	3mm
	Turbulence Intensity	10%

Fig. 1 shows the schematic diagram of fluidized bed together with the calculation results for the standard condition with parallel employed in this study and the details composition of fluid flow

As mentioned above, in this study, special emphasis is given on the effect of inlet shape and flow rate on the overall flow field and flow characteristics near inlet. The result of the standard condition is given in Fig.1 along with the input data given in Table 1. Further in Fig.2 the inlet flow rate of inlet 2 is increased by 10 fold compared to the standard condition in order to see the change of the flow characteristics such as overall flow pattern together with the turbulence feature near inlet stream, etc.

(a) Flow pattern

(b) turbulent kinetic energy

Fig 2 Comparison of flow pattern at near inlet stream between standard condition with 10 fold flow rate increase

CONCLUSION

Special emphasis has been given on the effect of inlet shape and flow rate on the overall flow pattern and flow characteristics near inlet. Further the mixture fraction of the inlet stream 1 for the supply of calcium species was carefully examined as cold flow study.

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This work is financially supported by Korea Ministry of Environment(MOE) as Waste to energy recycling Human resource development Project.

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Comparison of incineration heat recovery efficiency By change in conditions of facility

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ABSTRACT

Due to economic growth, population growth and rapid growth in industry, Korea has faced many social and economic changes. As a result, the amount of waste generated has increased rapidly and the nature and types become very diverse. In some areas, generated waste included substances harmful to the human body, such as heavy metals, persistent substances. Accordingly, the waste disposal becomes one of biggest environmental problems. Also, higher oil price and global warming issue brought limitable usage of fossil fuels in the world. Thus, it is imperative to find alternative energy sources. In the past, Korea government policy was toward resource consuming but nowaday's policy turned into zero waste and resource recycling society.

As part of this policy, Korea government implements "Comprehensive Plan for Waste-to-Energy" and "a waste to resources and action plan for biomass energy measures". The purpose of these policies is to reduce greenhouse gas emissions by heat energy recycling. Based on the 2011 national household waste generation, 48,934 ton / day, 42.7% of which 20,898 ton / day was incinerated. This process made an increase of about 3% over the previous years, and incineration rate is increasing year by year.

Keywords: Waste-to-energy, Waste heat recovery, Sustainable energy source

INTRODUCTION

Recently, many countries are being interested in waste-to-energy policy and technology due to limit of fossil fuels and global warming issues. As one of the efforts to achieve the sustainable society and maintain low impact of global warming, Korean government has also adopted the policy of 4R that add one policy to original waste policy 3R to convert waste into energy. In this study, analysis of the waste heat recovery was based on the change in incineration condition and the change in the characteristics of waste incinerated.

MATERIALS AND METHODS

1. Analysis using data from treatment facilities

In this study, calorific value, water content, and change of heat generation in household waste in D City were investigated to review the change trend of urban household waste. Also, the change trend of waste heat after changing steam header was investigated for comparative analysis.

2. Analysis of the transition to other energy sources

It is possible to get energy through the reuse of waste heat from incinerator without the use of fossil fuels like petroleum, coal, and liquefied natural gas (LNG). Thus, the amount of LNG equivalent calculated from the waste heat generated is

$$\text{LNG (N}m^3\text{)} = \frac{\text{steam amount supplied(ton)} \times \text{steam enthalpy(Mcal/ton)}}{\text{LNG calorie(Mcal/N}m^3\text{)} \times \text{LNG efficiency(\%)}}$$

*LNG calorie: low heat value 9,393Mcal/Nm^3, LNG efficiency: 93% assumed
Steam enthalpy: steam calorie supplied – calorie supplied

3. Economic Analysis

To analyze the economic feasibility, the market price of LNG equivalent was assessed, which was based on sales revenue each year. In case of LNG, unit cost changes frequently, so the annual average price was taken into account.

RESULTS AND DISCUSSION

1. Changes in physical and chemical components of household waste

Calorific value of waste heat every year shows an increasing trend. Average calorific value of last 3 years was approximately 3,173 kcal / kg. Moisture content was increased by 3% in 2009 compared to that in 2008. But it seems the decreasing trend since then annually. Combustible was reduced till 2010. However, it has bounced back from 2011. Ash content occupied approximately 10%.

Table 1. Annual change in components and heat value of waste incinerated

Year	Analysis of Components			
	Heating Value (Kcal/Kg)	Proximate Analysis (%)		
		Moisture	Combustible	Ash
2008	2,066	30.1	60.2	9.7
2009	2,851	33.8	59.2	7.0
2010	2,949	32.9	58.1	9.0
2011	3,342	25.3	64.2	10.5
2012	3,229	24.8	65.7	9.5

2. Hydrothermal conditions change before and after heat supply compared

The reaction condition of a cogeneration plant was changed from 15ata HDR to 9ata HDR to maximize the use of waste heat in collecting and providing waste heat at the time of incinerating household garbage. The amount of increase of LNG equivalent and annual change of quantity supplied were provided in Table 2.

Table 2. Incinerator operation condition and quantity of LNG equivalent based on heat supply quantity

Year		Incineration Quantity(ton)	Operating Day(day)	Steam supply Quantity(ton)	LNG Equivalent(Nm^3)
Before	2008	98,895	315	241,491	18,544,125
	2009	93,141	312	212,047	16,763,208
	2010	102,587	313	243,518	18,699,778
After	2011	103,227	305	255,394	19,611,738
	2012	104,147	316	259,646	19,938,249

3. Estimate of Energy Sales and Economic Benefit

Table 3 shows the results of sale earnings calculated in case of using the generating waste heat as energy source. Due to fluctuation in unit cost of sales, one year was estimated as an average and maintenance cost was excluded for the calculation. Also, the economic analysis was conducted based on sales profit earned through producing and selling steam.

Table 3. Estimate of energy sales and economic benefit

Year		Steam Supply Quantity(ton)	Annual Unit Cost($/ton)	Annual Total($)	Average($)	Benefit($)
Before	2008	241,491	15,816	3,614,481	3,419,061	1,495,113
	2009	212,047	14,139	2,837,260		
	2010	243,518	16,513	3,805,444		
After	2011	255,394	21,120	5,104,496	4,914,174	
	2012	259,646	19,225	4,723,852		

CONCLUSION

1. Today, less moisture of urban household waste has been brought into the facilities; rather, with more dry waste has been brought into them, available for incineration, and accordingly, resulted in increasing the amount of heat value. Due to the separate garbage collection of food waste and separate garbage collection of organic waste, combustible components have increased, leading to raising heat value; therefore, increasing the value of recycling waste heat in disposal of incinerating waste.

2. The results of comparing the reaction condition before and after 2011 showed that steam quantity supplied was increased by about 10%, up to about 25,000 ton, suggesting that the amount was a meaningful increase to determine it as an alternative energy source.

3. Sales cost using waste heat as alternative energy source was very fluctuating; thus, the average duration was set as one year. Without considering any other costs, the calculated results showed that the sales was 342million dollar before the change of facilities and 491million dollar after the change, increasing about 150million dollar.

ACKNOWLEDGEMENT

This work is financially supported by Korea Ministry of Environment(MOE) as Waste to Energy Recycling Human Resource Development Project.

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A study on the co-firing of pulverized-coal with HHO gas for the reduction of CO_2 and pollutant species emission

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ABSTRACT

These days, the development of various pre- and post-combustion techniques has been pursued in order to reduce the emission of CO2 in the fleet of coal-fired power plants, since it is of great importance to each country's energy production while also being the single largest emitter of CO2. As part of this kind of research efforts, in this study, a novel burning method is tried by the co-burning of the pulverized coal with the stoichiometric mixture of the hydrogen and oxygen (H2+1/2O2) called as HHO. If a certain fraction of coal fuel is, therefore, replaced by HHO, then the CO2 emission will be reduced by that amount, since HHO does not generate any CO2 as combustion product. For the investigation of this idea, the commercial computational code(STAR-CCM+) was used to perform a series of calculation for the IFRF(International Flame Research Foundation) coal-fired boiler (Michel and Payne, 1980). In order to verify the code performance, first of all, the experimental data of IFRF has been successfully compared with the calculation data and a rather systematic investigation has been successfully made to evaluate the potential of HHO as substituted fuel for the reduction of the major greenhouse gas.

Keywords: CO_2 emission in coal combustion, HHO gas, water electrolysis, co-firing with HHO

INTRODUCTION

Coal-fired power plants contribute one of the major supplies of worldwide electricity and thereby account for a significant emission of carbon dioxide (CO_2), the major greenhouse gas associated with global climate change. Post-combustion carbon capture and storage (CCS) such as amine based capture system and membrane methods could play an important role in significantly reducing CO_2 emissions from existing and new coal-fired power plants for mitigating climate change. However, the addition of commercial amine-based capture systems to coal-fired power plants would significantly increase the cost of electricity by 80 percent and lead to about 25 to 40 % energy penalty. In membrane application, on the other hand, to be effective for CO_2 capture, membrane materials should possess a number of features including high CO_2 permeability, high CO_2/N_2 selectivity, thermal and chemical stabilities of membrane material, resistance to aging and plasticization, and so on. There has been a general tradeoff relation between membrane properties like Robeson curve for the system design of practical scale. However, there is no general commercial scale plant using membrane systems probably due to the large pressure drop along the hollow fiber with typical diameter 100 micrometer.

As part of this kind of research efforts, in this study, a novel burning method is tried by the co-burning of the pulverized coal with the stoichiometric mixture of the hydrogen and oxygen (H_2+1/2O_2) called as HHO. The selection of HHO as substituted fuel for the reduction of coal fuel in pulverized coal-fired combustion is in that HHO has the feature of three times high heating potential than that of typical fossil fuels due to the absence of nitrogen comprised in oxidizing air as shown below.

◦Heating value per mole of combustion products for octane(C_8H_8) combustion 79,292 J/mole

$$C_8H_{18} + 12.5\,O_2 + 47\,N_2 \rightarrow 8\,CO_2 + 9H_2O + 47\,N_2 + 5{,}074{,}667\,J$$

◦Heating value per mole of combustion products for methane(CH_4) combustion 76,265 J/mole

$$CH_4 + 2O_2 + 3.76 \times 2N_2 \rightarrow CO_2 + 2H_2O + 3.76 \times 2N_2 + 802{,}303J$$

◦ Heating value per mole of combustion products for H_2 combustion , 24,1827 J/mole

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + 241{,}827\,J$$

If we explain the fuel reduction by the addition of HHO for gasoline fuel as

$$(1-x)C_8H_{18} + (1-x)(12.5\,O_2 + 47N_2) + \frac{21x}{n}\left(H_2 + \frac{1}{2}O_2\right)$$
$$\rightarrow (1-x)(8CO_2 + 9H_2O) + 47(1-x)N_2 + \frac{21x}{n}H_2O$$

where x and n stand for the reduced fraction of fuel and heating potential of HHO over gasoline fuel, respectively. Further the coefficient 21 in above Eqn. expresses the ratio of the heating value of gasoline to HHO, that is 5,116,172J/241,172J ≈21. Similar exercise was done for the fuel of coal as in this study.

MATERIALS AND METHODS

Governing equation

The basic gas phase conservation equations for mass, momentum, energy, turbulent quantities and species concentration can be expressed, in an Eulerian framework, as

$$\frac{\partial(\rho\phi)}{\partial t} + \nabla \cdot (\rho\vec{u}\phi) = \nabla \cdot (\Gamma_\phi \nabla\phi) + S_\phi$$

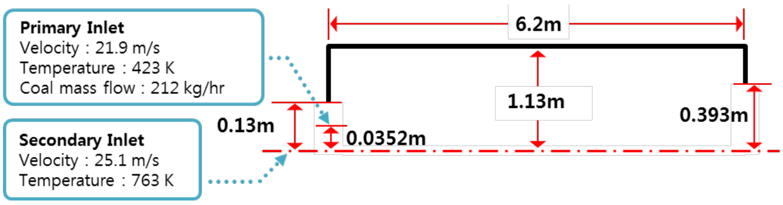
in which φ denotes general dependent variables expressed as a quantity per unit mass. Further ρ, Γ_φ, S_φ stands for density, diffusion, diffusion coefficient and source terms corresponding to φ, respectively.

Turbulence model

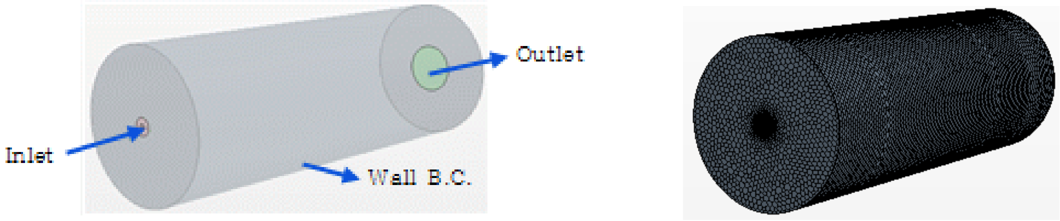
Time averaging of an instantaneous momentum equation causes the unknown correlations of the fluctuating velocity components called Reynolds stress. When incompressible flow is assumed, the Reynolds stress is the only unknown term. The most common practice is to use the Boussinesq hypothesis, in which the Reynolds stress can be replaced by the product of the mean velocity gradient and a quantity termed turbulent viscosity. Therefore the turbulent viscosity is expressed in terms of known or calculated quantities. The popular approach is the use of the two equation (k–ε) model by Launder and Spalding, where a Prandtl-Kolmogorov relationship is used to correlate the turbulence viscosity, μ_t to the turbulent kinetic energy and its dissipation rate

RESULTS AND DISCUSSION

The calculated data employed with pure coal are compared with the co-burning case for the evaluation of the substituted HHO performance. The reduced amount of coal feeding was fixed to be 30% and the added amount of HHO to produce a similar flame temperature with pure coal combustion was considered as 100% case of HHO addition. This value varies from 100 to 90, 80, 60, 50, 0% in order to see the effect of HHO amount on the performance of pulverized coal-fired combustion with the 30 % reduced coal feeding. One of the most important thing found in this study is that the 100% addition of HHO amount shows approximately the same flame shape and temperature with the case of 100% coal combustion, even if the magnitude of the flow velocity differs significantly due to the reduced amount of air oxidizer.



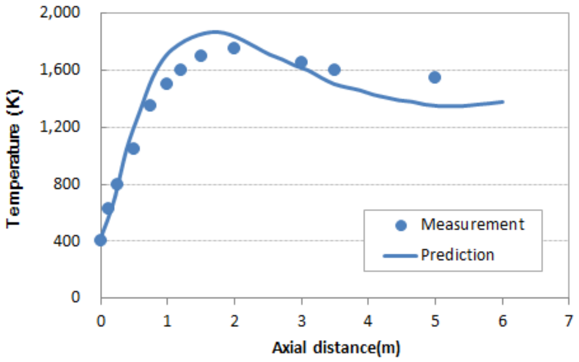
(a)2-D



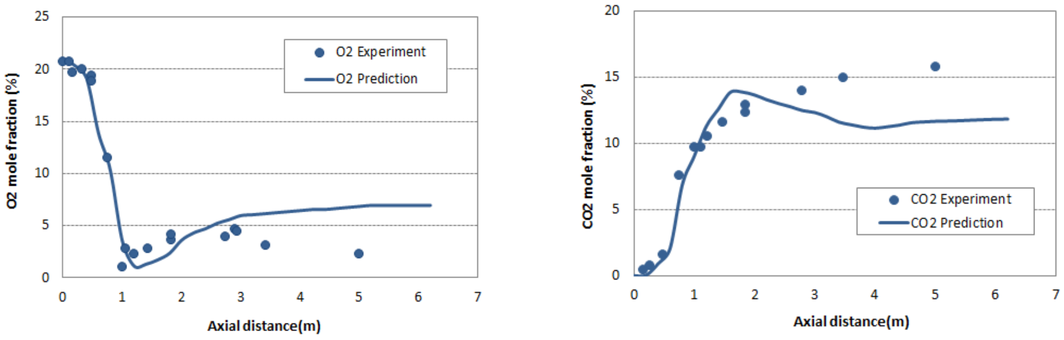
(b)3-D

(c) Grid generation

Fig. 1. Schematic diagram of IFRF boiler & Boundary condition



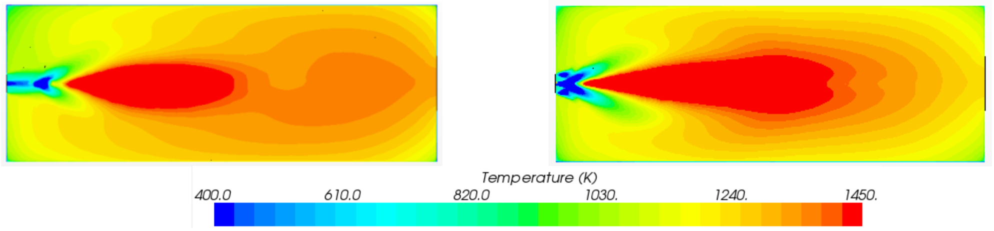
(a) Temperature



(b) O_2 mole (%)

(c) CO_2 mole (%)

Fig. 2. Comparison with experiment and calculation results



(a) Coal 100%

(b) coal 70%+HHO gas 100%

Fig. 3. Comparison of temperature distribution of coal 100% fuel

with the coal fuel modification by the addition of HHO

CONCLUSION

This research suggests the high possibility of the replacement of the coal fuel with HHO in order to reduce the CO_2 emission in pulverized coal-fired power plant. However, an extensive parametric study will be needed in near future, in terms of the reduction amount of coal and HHO addition in order to evaluate the possibility of the HHO replacement for coal in pulverized coal-fired combustion.

ACKNOWLEDGEMENT

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Scavenging informal sector and the recycling production system of craft villages in the Red River Delta

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ABSTRACT

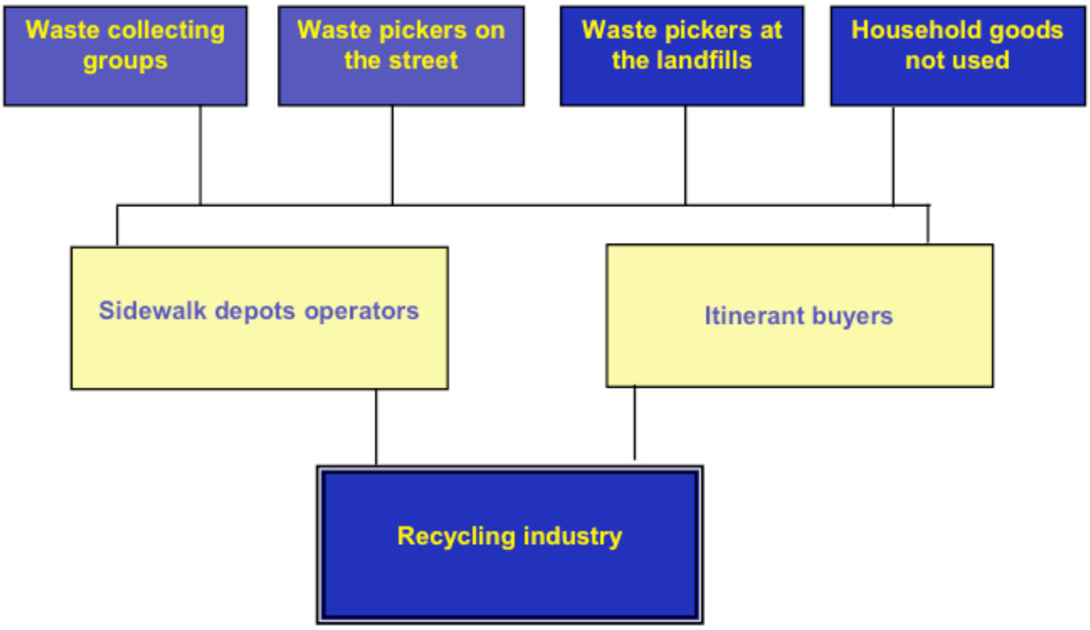
Hanoi solide waste management is a complex organization of collection and recycling of a wide range of items (paper, metal scraps, plastic items, brick and ceramic wastes, organic wastes…). This recycling system, which flourished while Vietnam had a largely self-sufficiency domestic economy that functioned in total isolation from the global market, is now threatened by surging imports of cheap consumer goods and the rapid rates of urbanization (1,3 kg of urban wastes per capita per day in urban areas in 2014, and 62% of solid wastes generated by domestic households).

That system is embedded in the larger peasant social system of the Red River Delta, and of the craft village clusters which recycles scraps of paper, metal, plastic items collects by a large range of scavengers and collectors. As Digregorio (1994) demonstrated, “the structure of peasant participation in the collection of urban wastes in contemporary Hanoi resembles the organization of the hundreds of specialized handicraft industries that characterized the villages of the delta”. For this author, “Scavengers fill a unique place in the life of cities, a place that crosses both the physical boundaries of cities themselves and the disciplinary boundaries of those attempt to interpret their presence in the fabric of urban life”.

Scavenging is an occupation, a labor process and an industry that incorporates a wider range of activities and a larger number of people, named as foragers, scavengers, junk buyers, municipal refuse workers. Most of the actors involved in this activity of scrap collection are from Nam Dinh province. They are organised along a supply chain of exchange and a social network. The scavengers buy scrap to households and then sold to scrap to junk buyers. Then specialised whole sealers buy from them to supply craft villages in paper, scrap metal or plastics items. 10,000 informal collectors are operating in Hanoi in 2014 and fill the gap and deficiencies of formal state organizations of waste refusing fragmented in more than 18 units. The fees they get from the citizens can’t compensate the cost of the daily collect. Scavenging has been promoted as a source of employment, a low coast supply of industrial input and a method of diverting wastes from landfill.

Households routinely separate recyclable wastes such as metals and paper for sale to itinerant buyers, or sell it directly to local depots. Waste pickers are also separating reusable and recyclable wastes. This dynamic recycling market is largely led by the informal sector; in Hanoi, for example, the informal sector recycles 22 percent of all waste produced. “Artisans and workers at many craft villages have been

particularly successful in capitalizing on this opportunity, recycling over 90% of their potentially recyclable waste » (Nguyên TKT, 2010). The recycling of waste paper, plastic and metals in Vietnam is mostly done by private enterprises and craft villages. Although scavenging is an informal activity but this activity was very developed and brings economic benefits to citizen.



Organization of the waste collectors for the recycling industry

These waste collectors are linked to 80-90 villages specialized in recycling and to several hundreds of craft villages producing items with the transformed scraps, as paper, metal and plastic specialized villages. The use of recycled material lowers the cost of production (energy, chemical products…) and the price for consumers.

QUESTIONS

As most recycling technologies used by craft villages are old, out-of-date and seriously polluting ones, what is the future of this recycling process in the context of the craft villages cluster at stake for economic, land and environmental problems linked to the metropolisation of Hanoi?

How the integration of the recycling and collecting sectors can be improved in a context of formalization of enterprises in craft villages?

Does this recycling economy involving numerous poor people and seasonal migrants of the countryside and being place consuming for storage and transport can take part of the project of modernizations of Hanoi? The informal collecting centers of junk buyers are regularly spread over the urban space, either in highly dense and expensive down town, and in urban fringe, how this system of collect can be maintained with the increase of price land? What is the land status of junk buyer centres? The social network created by the scavengers, how does it work? In terme of urban planning, how can it be thinked and presented?

Keywords: recycling processing, solid waste management, scavenging informal, Red River Delta, craft village.

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A Survey and Analysis on Household Solid Waste in Suburban Area of Hanoi

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ABSTRACT

The consideration of the quantity and composition of the domestic household solid waste in a typical suburban area is important for the effective planning of the waste sorting (3R programe) and treatment methods. In this research, we present results of a special survey and analysis on domestic solid waste of 20 households in Tan Xuan hamlet, Xuan Dinh ward, Tu Liem district, Hanoi capital, Vietnam. The solid waste of the households is collected on a daily basis for eight days and it is then analyzed with respect to four indices including the family population, the income, the age, and the education level of the community. The results of the research show that the bulk density is approximately 247 kg/m3, the household waste consists of kitchen waste, paper/cardboard, plastics, diaper/disposablel nappy, textiles, metals, glass and other wastes, and the proportion of the mentioned components is approximately 67.31.3%, 6.25%, 12.42%, 4.69, 2.38%, 2.5%, and 3.31%, respectively. The reseach also suggests a suitable method for the waste sorting and treatment in such the particular area of Hanoi, Vietnam.

Keywords: Household waste, suburban area, sorting, solid waste composition, bulk density

INTRODUCTION

Domestic waste is increasing in Vietnam in terms of volume and complexity of components that has becoming an urgent problem in the management of the urban environment. Hanoi is the capital of Vietnam, newly expanded since 2008; from a municipality with more than 3 million people, it becomes a city of 6 million people. Therefore the management of the urban environment, especially the solid waste management, is even more complex than ever before.

Because of the expension, the city must be re-divided into areas with very different features and properties including the old urban areas, new urban areas and suburban, etc. Thus, there exist dissimilarity in terms of the characteristics and composition of solid waste in such the areas that causes several urgent issues on the waste management and treatment. In particular, in some suburban areas, the disposal of domestic wate of households is usually not at the same time, even at an informal gathering point. Addtionally, the classification of the waste is totally not considered. These possess difficulties and chellenges for the waste processing and treatment via conventional and/or modern methods.

In order to cope with the entire problem arised, a survey and analysis on the component, the characteristics and the properties of the household solid waste needs to be carried out. The expected results of the reseach shall play a particularly significant role for optimizing the further action programmes on the waste management and treatment: the collection, the transportation, the classification, the treatment, etc.

MATERIALS AND METHODS

For the research, 20 households in Xuan Dinh, Tu Liem, Hanoi - a peri-urban area of Hanoi - with the relevant information as the members, the income, the age, and education level of each family member are considered.

Solid waste samples are continuously collected daily for a period of 8 days. The statistical research method is employed to analyze the collected samples of the waste. The sociological characteristics of the households are firstly surveyed and the relevant data is presented in Table 1.

Table 1. Survey household sociological research area

Sociological parameters	Quantity	Percentage (%)
Household size (person)		
1	0	0
2	1	5
3	6	30
4	10	50
5	3	15
Age		
<=18	21	28
19-29	23	30.67
30-49	28	37.33
50-60	1	1.33
=>60	2	2.67
Education level		
Primary – Secondary	21	28
High secondary	36	48
University	18	24
Income (Million Dong)		
< 5		
5–10	14	70
> 10	6	30

The survey is conducted for 8 days continueously, from May 3, 2010 to May 10, 2010. Notice that the households under consideration usually dispose the domestic waste in the late evening at an informal gathering point. In the area, the household waste is not sorting as well as the collection type following hourly gong. The collection of the sampling solid waste for the survey is only performed in the early morning before the waste collecting car coming. The waste of 20 households collected is then shuffled and a random sampling of 20 kg per day is taken into account and classified immediately. Tools and equipments used for the research include a scale a plastic tub with volume of 60 liters, 10 plastic buckets with volume of 6 litters, a shovel, gloves, and plastic sheet, etc.

For every day in the period of the survey, the daily sampling waste is sorted manually. After sorting, each component is weighed and recorded in detail. The statistical result shows that the main compositions of the waste include organic waste (mostly kitchen waste), paper, plastic and plastic bags, metal, glass, wood, cloth, leather, hazardous waste, diapers, and wood. The average proportion of them can be illustrated in Fig.1.

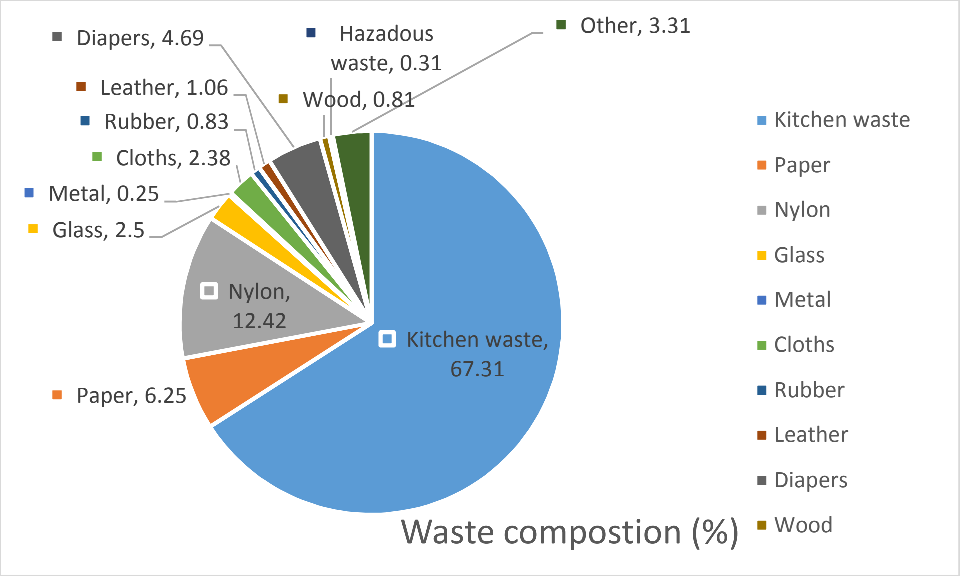

Figure 1: Household waste composition

Beside to the composition analysis as above, the bulk density of the considering waste needs to be analyzed since it is the key indicator necessary to estimate the total weight and volume of waste for the management and treatment planning.

Based on the daily sampling waste collected, its volumne and weight is evaluated and the density is thus determined; the results are depicted in Fig. 2.

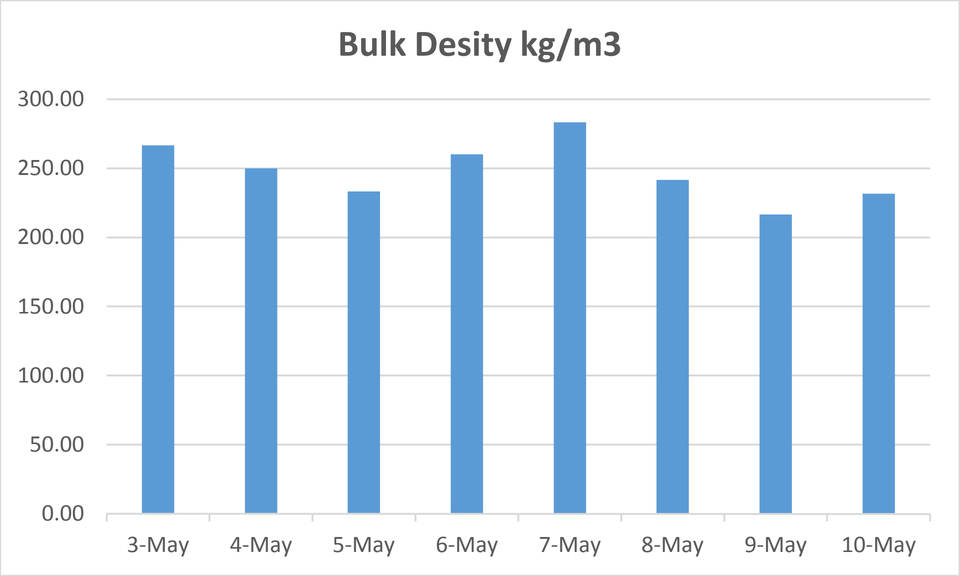

Figure 2: Bulk density of solid waste

Notice that the bulk density of urban waste of the high-income countries is between 100 - 170 kg / m3, the average income countries from 170 to 330kg / m3, and low-income countries from 250 to 500kg / m3 (Holmes, 1984). As can be seen in Fig. 2, the average bulk density is 247,92kg / m3. The result yielded reflects and reveals that the bulk density of solid waste in suburban areas of Hanoi capital city is located in the range of the middle-income countries.

RESULTS AND DISCUSSION

The results of the research on the household solid waste in a specific suburban area in Hanoi, Vietnam show clearly the compositions of the waste. There exist 12 major components, of which the organic component (kitchen waste) is noticebally 67.31% of the total waste. The waste contains a mentionable proportion of nylon and non-recyclable paper (napkins, paper towels absorbent) that are 12.42% and 6.25%, respectively. Besides, the waste consists of a relatively large amount of diapers and sanitary napkins that is about 4.69%. This reflects the young age of the population in the considering area. The waste composition contains the straw used for preserving eggs, but not the straw of agricultural production. The waste also includes both chicken feathers which shows the difference between the household waste in other municipalities with the household waste in peri-urban areas (poultry is slaughtered at home). The bulk density of the waste is 247,92kg / m3 which reveals a reliable and common measure as compared with those of the other the countries in the world (the US is 100 kg / m3, the UK is 150 kg / m3, Singapore is 175 kg / m3, Thailand is 250 kg / m3, Indonesia is 230 kg / m3).

The composition of waste identified during the survey shows that compared with the previous research results on the composition of waste in Hanoi, the amount of organic waste is higher than the general municipal waste. Therefore, we suggest that the implementation of waste separation at the household are strictly required; the waste needs to be collected separately before transporting to recycling plant. Implementing this possible and applicable policy in practice will greatly reduce the amount of landfill, landfill area and environmental risks.

Based on the method of manual waste sorting, the quantity results of research are rich information that could be gathered to build a necessary information database reflecting the resource generation, the waste compositions as well as the relationship between socio-economic conditions, location and components of waste for the whole the city. Therefore, the survey should be carried out several times a year, in the wider area to serve a better waste management strategy of the city.

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Establishment of Regional Mechanism for Centralized Management of Contruction Waste in Viet Nam

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ABSTRACT

Today no effective centralized control system is available for building waste. However, it may be generated through the establishment of special-purpose logistics centers. Depending on the status of development of building waste control systems in specific regions, logistics centers of one of the following two types are to be installed: multi-component logistics centers or information logistics centers. The objective is to develop a mechanism for generation and transfer of information streams in order to compile an effective model of waste management for construction and demolition works. If this mechanism is in place, waste transportation and amount/composition analysis will be streamlined to assure timely information delivery to/from construction organizations, transport companies, waste processing enterprises, and consumers of secondary products

Keywords: construction waste, management, information logistics center, multicomponent logistics center

INTRODUCTION

In recent years, people have been enormously interested in the waste treatment. However, Vietnam has not yet had a solid waste management system that is centrally and effectively built. There is one of measures to build such system that is to implement the project for establishing specialized logistics centers whose main operation shall be directed to the adjustment of construction waste processing.

Depending on the situation of waste control system development built in specific site, logistics centers can be divided into two following types including logistics information center or multi-component logistics center.

Multi-component logistics center should be located in the intersection of major roads and in areas in which construction sector has been strongly developed or in which plans for dismantling of old buildings – that are not met the human demand are planned. For this, it should be discovered the lack of waste treatment facilities, otherwise, new buildings shall not be ensured its standards [Aleksanin A.V., Sborshchikov S.B., 2013].

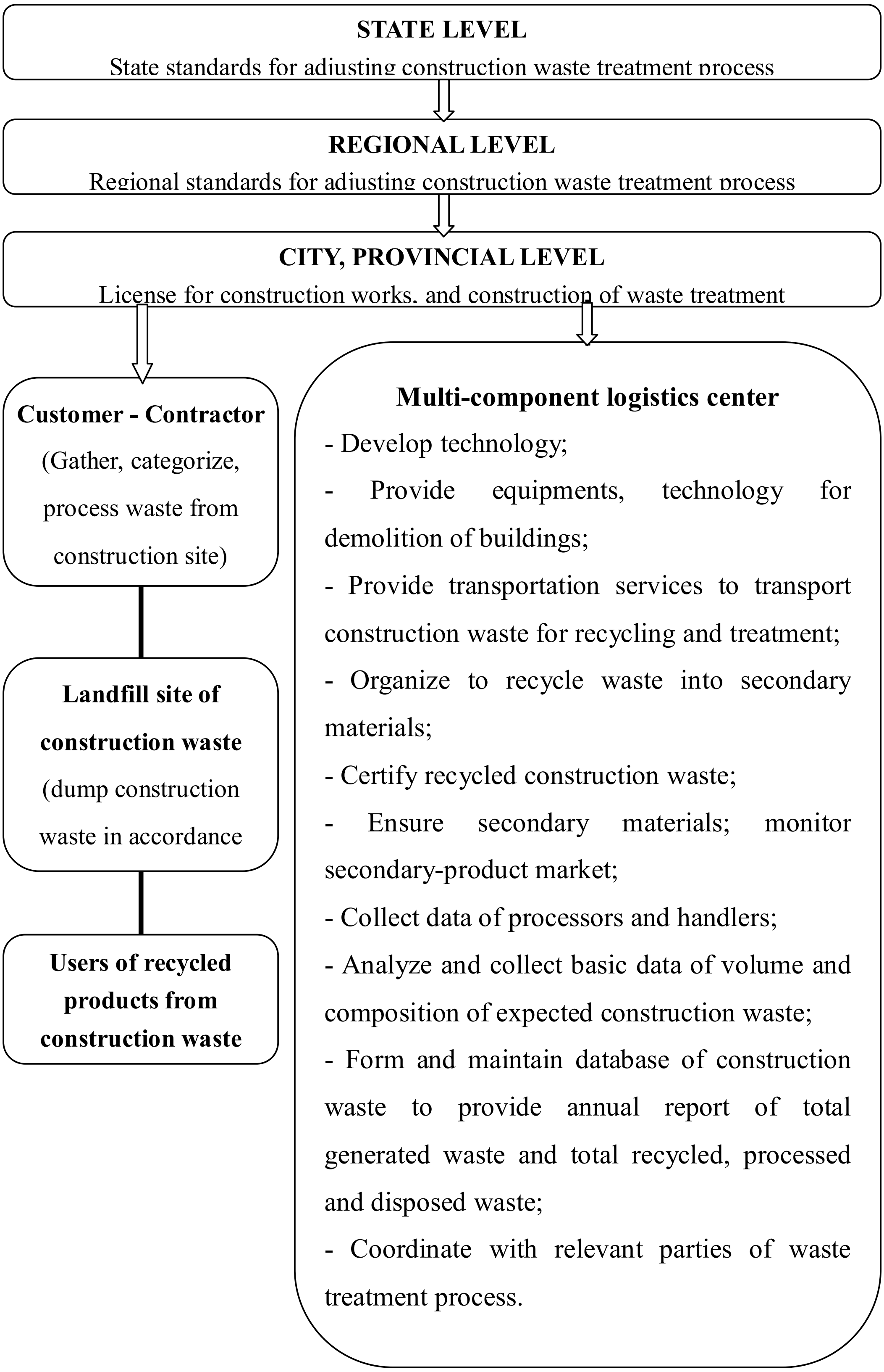
The organization of logistics information center should be established in areas where have full of waste treatment facilities on construction, but lack of interaction between members in the waste treatment process.

For establishing a model with effective waste management during construction or demolition period, it is very necessary to establish a mechanism for the flow of information between members. This shall result in the optimization of transport and highly accurate analysis of construction waste in order to timely provide necessary information to construction and installation companies, transport companies, construction and waste treatment firms, and secondary-product consumers as well.

RESULTS AND DISCUSSION

Model on organizing construction waste treatment in regions includes many members; each member has its own role (Figure 1).

The establishment of logistics information center is to automatically and optimally provide all construction waste management processes in the region. Logistics center should become the nucleus of information in region, in which data shall be accumulated under functional characteristics of the logistics system and the factors that affect them. All information from any organizations that directly participate in waste management process or effect on the system shall be stored into logistics information center (Figure 2).



- Develop technology;
- Provide equipments, technology for demolition of buildings;
- Provide transportation services to transport construction waste for recycling and treatment;
- Organize to recycle waste into secondary materials;
- Certify recycled construction waste;
- Ensure secondary materials; monitor secondary-product market;
- Collect data of processors and handlers;
- Analyze and collect basic data of volume and composition of expected construction waste;
- Form and maintain database of construction waste to provide annual report of total generated waste and total recycled, processed and disposed waste;
- Coordinate with relevant parties of waste treatment process.

Figure 1: Interactive diagram between multi-component logistics center and other components of construction waste management process and their basic functions

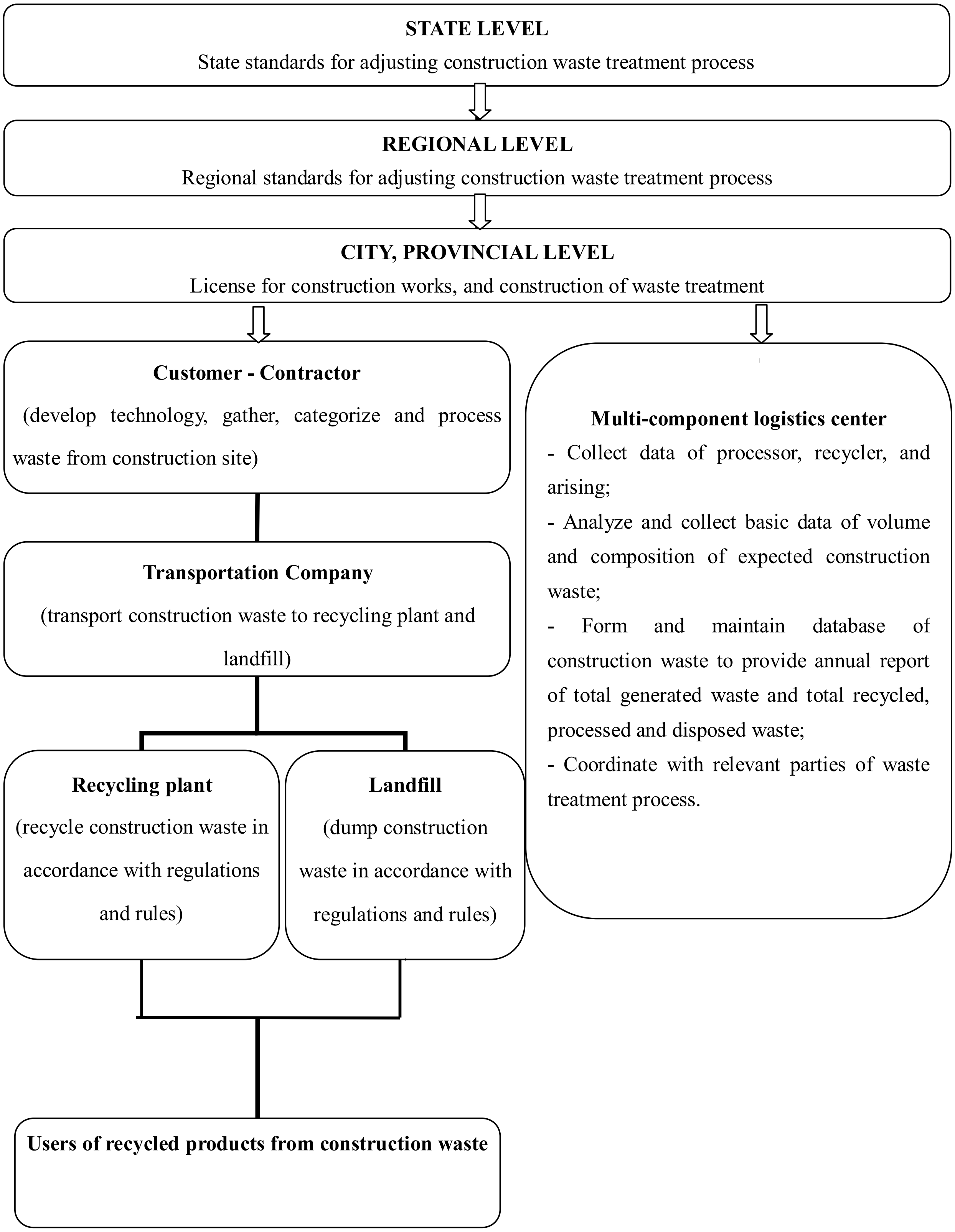


Figure 2: Interactive diagram between logistics center and other components of construction waste management process and their basic functions

Thank to specialization in construction waste management, logistics information center can propose formation of using them to treat pollution and improve certain areas in the region, simultaneously generate the interest in recycling of waste, regularly provide information on the volume of formed, processed and recycled waste in the State's statistics. Up to now, there has not had full actual database to reflect all stages of the cyclical construction waste.

The establishment of logistics information center is easier than establishment of multi-component logistics center because multi-component logistics center is required to provide an empty area with certain safety conditions. Such area should be connected with key transport axis and separated from residential areas.

The formation of quality information flow in regional mechanism for construction waste management plays an important role. For example, the content of information flow that is formed between construction organization and logistics center is the transmission of data on the volume of construction waste and demolition works (works in the area, information of construction, demolition and repaired objects, types of waste). The logistics centers should provide information of existing tax in waste sector; develop a schedule of construction waste removal; and supply equipment, technology for work demolition to construction organizations. It should be formed the statistical information flow about volume of construction and demolition in the area, development of secondary material market and its demand, number of established construction companies, between regional government and logistics center. The opposite direction includes information about the volume of collection, transportation, treatment and recycling of construction waste and demolition works, the data on the operation of the business of recycling and landfill waste garbage, their usage and forecasts in the near future. Creating a professional automated program will significantly simplify the process of information exchange [Aleksanin A.V., Sborshchikov S.B., 2013].

CONCLUSION

The decision on the construction of a logistics center to coordinate the rotation of construction waste and demolition works are very complex process requiring responsibility and details. Members of the logistics center are not only the individuals directly involved in the construction, but also the government agencies and regional government to support.

Before starting the project, it is necessary to determine the type of logistics centers: the logistics center will be multiple components including the waste treatment plant and recycled materials production, or logistics center information whose primary function is to circulate waste of construction industry in the region.

In the development stage of multi-component logistics center project, it needs to calculate the financial resources and budget plans, including not only direct costs in the construction process, but also the development of transportation infrastructure, the purchase of expensive equipment for the processing of construction waste and demolition works. Logistics center has been built in many countries as a system of effective management, the ability to recognize the problems of large-scale region [Eckhardta J., Rantala J., 2012].

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Comparison of Biogas Potentials of Korean Swine Manure from Livestock Farm and in-situ Facilities

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ABSTRACT

This paper examined that methane yields of swine manure were compared from livestock farm and in-situ facilities treating swine manure singly. Theoretical methane yield were determined by the calcuation using element contents and organic constituents of swine manure samples. Theoretical methane yields based on weight of swine manure (ton) from livestock farm were about 3 times higher than those from in-situ facilities. This result implies that it is essential for source management to improve the biogasification efficiency of swine manure.

Keywords: methane yield, swine manure, anaerobic digestion, food waste/food waste leachate

INTRODUCTION

Land filling and ocean dumping of organic waste (food waste, swine manure etc) has been prohibited since 2005 and 2013, respectively (Korean Ministry of Environment; KMOE, 2008). Swine manure produced approximately 173,052 m^3/day in 2012 and 89.3 % of entire livestock farm had recycling such as composting, biogasification, etc (KMOE, 2014, STATISTICS Korea, 2014). Strengthening prohibition on emission of organic waste into the ocean and increasing demand of renewable energy, biogasification was recently regarded as a counterproposal. The government suggested the master plan and execution scheme on animal manure energization (MAFRA, 2013, MAFRA, 2009). 22 of new biogasification facilities are scheduled to construct until 2020 investing 722.5 billion KRW (KMOE, 2007, KMOE, 2012). Nevertheless recent situation, most of biogasification facilities treating swine manure dosen't meet the normal capacity utilization by itself. Especially the average biogas production amount per ton in ongoing biogasification facilities was 9.6 m^3 which were not effective comparing with other organic wastes including food waste (KMOE, 2014). Therefore the purpose of this study was to evaluate and compare the methane yield from livestock farm and in-situ facilities for improving the biogasification efficiency.

MATERIALS AND METHODS

Selection of livestock farm and biogasification facility

The fifteen livestock farm with different type of breeding pig and farm shape were selected for this investigation. Samples were collected from each swine manure storage tanks and last joined slurry liquid fertilizer tank.

Three ongoing biogasification facilities which treating swine manure were chosen as target for this study. Sampling was conducted during the four seasons. Samples were collected from the input storage tank in biogasification facilities. All of samples from livestock farm and in-situ facilities were immediately stored in refrigerator.

Analytical methods

Total solids (TS) and volatile solids (VS) were determined to the Korean Waste Standard Examination (KMOE, 2015). CODcr was analyzed by titration method (5220C) (APHA, 1998). Element contents (C, H, O, N, S) were determined according to elemental analyzer (Leco Co. 628 weries, 2012). Samples were completely dried at 105 °C to remove moisture in the samples and ground into a fine powder less than 0.05 mm. Nutrients (carbohydrate, protein, fat) were determined by Korean Food Standard Codex (MFDS, 2015). Total nitrogen (TN) and ammonium nitrogen (NH_3-N) were analyzed according to oxidation method and UV/visible spectrometry of Official Testing Method with respect to water pollution process (KMOE, 2015). Total phosphorus (TP) and phosphorus-P (PO_4-P) were analyzed according to UV/visible spectrometry and ascorbic acid method of Official Testing Method with respect to water pollution process (KMOE, 2015). Volatile fatty acids (VFAs) were determined according to Standard method 5560 D. gas chromatographic method 4.a. (APHA, 1998). Pre-treatment solution extracted with diethyl ether was analyzed by gas chromatography (GC-FID, Aglient 6890, USA). Gas chromatography used FID detector and DB-FFAP (25 m × 0.32 mm × 0.5 μm) column.

Theoretical methane yield

Organic waste (swine manure) produce biogas consist of methane, carbon dioxide and ammonia gas via anaerobic digestion process. The following equation (1) utilizes elements contents (C, H, O, N) for calculating the theoretical methane yield from organic waste (Tchobanoglous G et al, 1993).

$$C_aH_bO_cN_d + [(4a-b-2c-3d)/4]H_2O \rightarrow [(4a+b-2c-3d)/8]CH_4 + [(4a-b+2c+3d)/8]CO_2 + dNH_4 \quad (1)$$

Equation (2) meaning the theoretical methane yield by elements contents could be computed by reference to above formula (1). In this study, results of elements analysis were applied to the theoretical methane yield. Also, molar ratio of organic constituent such as protein, fat, carbohydrate and methane contents based on molar ratio were used for this study.

$$\text{Theoretical methane gas production (STP L}\cdot\text{CH}_4\text{/g}\cdot\text{VS)} = \frac{22.4(4a+b-2c-3d)/8}{12a+b+16c+14d} \quad (2)$$

RESULTS AND DISCUSSION

Table 1 showed characteristics of swine manure from livestock farm and in-situ facilities handling swine manure only. Most of analysis values tend to decrease when moving from breeding farm to in-situ facilities except only VS/TS ratio. In particular TS and VS of manure from in-situ facilities were reduced by about one-third compared to these from livestock farm.

Table 1 Characteristics of swine manure from livestock farm and in-situ facilities

Samples	TS (%)	VS (%)	VS/TS	VFAs (mg/L)	CODcr (mg/L)	TN (mg/L)	NH_3-N (mg/L)	TP (mg/L)	PO_4-P (mg/L)
Livestock farm (LF)	10.6	7.9	71.8	12,895	151,375	6,804	4,403	2,187	1,383
In-situ facilities (ISF)	3.9	2.8	72.6	6,808	49,133	4,862	2,920	708	442

Characteristics of organic constituents and elements analysis were in Table 2. The average weight of protein, fat and carbohydrate of livestock farm were 2.53 g/100g, 2.74 g/100g and 4.74 g/100g. The average weight of protein, fat and carbohydrate of in-situ facilities were 2.16 g/100g, 1.34 g/100g and 1.62 g/100g. Removal efficiency of fat and carbohydrate were 51.2 % and 65.8 % individually. Among the organic constituents, protein had lowest difference between livestock farm and in-situ facilities.

The average elements contents (%) of in-situ facilities were 38.49 on carbon, 5.41 on hydrogen, 4.05 on nitrogen, 0.95 on sulfur and 23.70 on oxygen. Elements analysis results showed that the bulk of facilities values are lower than livestock farm excepting nitrogen and oxygen. The carbon/nitrogen (C/N) ratio of farm and facilities were 12.17 and 9.50, respectively.

Table 2 Results of organic constituents and elements analysis from livestock farm and in-situ facilities

Samples	Organic constituents (g/100g)			Elements (%)					C/N ratio
	Protein	Fat	Carbohydrate	Carbon	Hydrogen	Nitrogen	Sulfur	Oxygen	
LF	2.53	2.74	4.74	42.14	6.42	3.46	1.07	18.71	12.17
ISF	2.16	1.34	1.62	38.49	5.41	4.05	0.95	23.70	9.50

Table 3 Calculation of methane yield based on organic constituents and element analysis

	Organic constituents		Element contents	
	LF	ISF	LF	ISF
Theoretical methane yield* (Sm^3 CH_4/kg VS)	0.48	0.50	0.41	0.31
Theoretical methane yield* (Sm^3 CH_4/ton)	38.92	13.91	33.43	8.69

* Assume that organic waste (swine manure) was removed 100 %.

Table 3 showed the comparison of theoretical methane yield from farms and facilities based on analysis results of organic composition and elements. All of theoretical methane yield were calculated in condition of 100 % removal efficiency of swine manure. The average theoretical methane yields using organic constituents and element contents were 0.50 Sm^3 CH_4/kg VS_{ISF} and 0.31 Sm^3 CH_4/kg VS_{ISF} in in-situ facilities, respectively. It corresponded to 102.7 % and 74.7 % of livestock farm sources based on VS value. The theoretical methane yields based on weight of swine manure were 13.91 Sm^3 CH_4/ton_{ISF} and 8.69 Sm^3 CH_4/ton_{ISF} in in-situ facilities, respectively. It accounted for 35.7 % and 26.0 % of livestock farm sources based on ton of swine manure. When swine manure moved from livestock farm to biogasification facilities, methane yield based on VS and weight (ton) showed a tendency to decrease in contrast with methane yield of VS based on calculating organic constituents.

CONCLUSION

This study evaluated potential of theoretical methane yield of swine manure which extracted from livestock farm and in-situ facilities. Potential of methane yield based on weight of swine manure showed a declining tendency from livestock farm to in-situ facilities. This tendency was derived from two to six months of manure storage tank and slurry liquid fertilizer tank. In this retention time, more than about one-third of the organic materials is decomposed and converted into a low concentration of swine manure. Accordingly in order to improve the biogasification efficiency of swine manure, it is important to maintain high concentration of organic waste during collection process from livestock farm. It is suggested that a retention time of storage tank in livestock farm could be shortened to prevent the decomposition of swine manure flowed into anaerobic digester.

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Properties of Biochar from Hydrothermal Carbonization of Exhausted Coffee Residue

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ABSTRACT

Due to global energy shortage problem is the rise, the need for renewable energy is increasing. More than 80% of the renewable energy sources have been produced through the waste and biomass.

Accordingly, the aim of this study was to produce renewable energy from a variety of biomass. Therefore, I consider the biomass was exhausted coffee residue. As coffee preference continuously increased, an import coffee bean is increasing sharply. But the amount of coffee that has been used to drink is only about 0.2% of coffee beans and the rest is discarded in the form of exhausted coffee residue. To reuse a large amount of exhausted coffee residue, I used exhausted coffee residue as a biomass. Hydrothermal carbonization is a method of producing an improved fuel by SRF changing the physical and chemical properties in the sample. Biochar was obtained from a variety of reaction temperature conditions during hydrothermal carbonization and analyzed via elemental analysis, industrial analysis, heating value measurement.

Keywords: biomass, biochar, exhausted coffee residue, hyrothermal carbonization, fuel property

INTRODUCTION

The fossil fuel depletion and global warming have become serious problems in the world (Ishigaki T., Yamada M. et al., 2005; José G. and Coelho S.T., 2004). In order to solve these problems, renewable energy from biomass and organic waste has attracted much attention (McKendry P., 2002; Peng W., Wu Q. et al., 2001). Accordingly, the renewable energy from a variety of biomass was focused on an energy resource. Therefore, I consider the biomass was exhausted coffee residue. As coffee preference continuously increased, an import coffee bean is increasing sharply in Korea. However, the amount of coffee that has been used to drink is only about 0.2% of coffee beans and the rest is discarded in the form of exhausted coffee residue. To reuse a large amount of exhausted coffee residue, I considered on reduction and recycling exhausted coffee residue as a biomass.

In this study, the method of the hydrothermal carbonization is used to recover energy from waste biomass as exhausted coffee residue. The hydrothermal treatment process, among the thermo-chemical methods for the conversion of biomass has been under consideration mainly for producing liquid (bio-oil), solid (biochar), and/or gaseous (mainly carbon dioxide) fuels (Daegi K., Pandji P. et al., 2012). This process has generated widespread interest in recent years. Hydrothermal carbonization (HTC) comprises the use of a combination of a high temperature with high-pressure water (subcritical water) that prompted the highest potential among the various short-term methods available for using biomass as an energy source.

Hydrothermal carbonization is a feasible sustainable energy conversion technology for the disposal of biomass. The experiments were conducted at 180°C up to 330°C for 30min holding period. For achieving waste-to-energy, the biochars from exhausted coffee residue as the biomass were conducted. The results of the analysis, it was confirmed that biochar improved fuel nature than raw biomass and the characteristics of biochar was similar with that of the lignite. In addition, the calorific value of biochar increased as the reaction temperature increases so the energy density is raised.

MATERIALS AND METHODS

Materials

A sample of exhausted coffee residue was collected from cafeteria of Konkuk University. The characteristic of exhausted coffee residue showed in Table 1.

Table 1 Characteristics of exhausted coffee residue

	Moisture content (%)	Proximate Analysis (on dry basis, %)				Elemental Analysis (on dry basis, %)				
		Fixed carbon	Volatile matter	Ash	Calorific value (MJ/Kg)	C	H	O	N	S
Exhausted Coffee Residue	56	23.6	74.9	1.5	21.8	48.9	7.9	40.2	1.5	0

Hydrothermal carbonization process

Hydrothermal reactor was used to investigate the effects of HTC on improving fuel properties of the exhausted coffee residue. Experiments were performed using a 1L autoclave reactor consisting of a reactor body, a heater, and a steam condenser which was operated under N_2 gas. A 250g of sample was mixed with an equal amount (250mL) of water and loaded into the reactor. The operating temperatures and pressures ranged from 180°C to 330°C and the reaction time was 30 min in the presence of subcritical water. The components within the reactor were vigorously mixed using an agitator rotating at 200 rpm.

Analytical procedures

The materials and the solid products were evaluated using a PerkinElmer 2400 Series II CHN organic elemental analyzer (PerkinElmer, Waltham, MA, USA) to determine the weight percentage of chemical elements. Proximate analysis used to determine the weight percentage of volatile matter, fixed carbon, and ash were conducted using a SHIMADZU D-50 simultaneous TGA/DTA analyzer. Heating values were determined using IKA Calorimeter System C 5000 according to calorimetric standard method of EPA-Method 5050.

RESULTS AND DISCUSSION

Improvement of fuel properties

The properties of the exhausted coffee residue were improved by HTC with increase of reaction temperature. The chemical properties of the surrogate MSW changed by the hydrothermal treatment. The raw material had high volatile matter content as 68.6 % and oxygen content as 41.6 % similar with normal biomass characteristics. After conduction the HTC, the volatile matter and the oxygen content decreased while the fixed carbon content increased from 23.6 % to 33.9% at 210°C and 48.2% at 300°C. While, volatile matter of the products decreased as the reaction temperature increased with amount of volatile matter being reduced due to chemical dehydration and decarboxylation reactions(Daegi K., Pandji P. et al., 2012; McKendry P., 2002; Daegi, K., Yoshikawa, K. et al., 2015). As a result, an increase of fixed carbon (FC) was obtained by the hydrothermal carbonization reactions. The calorific value of exhausted coffee residue also was improved after HTC as shown in Figure 1. The calorific values of exhausted coffee residue increase from 21.8 MJ/kg to 26.5 MJ/kg at 210°C and 17.2 MJ/kg at 300°C.

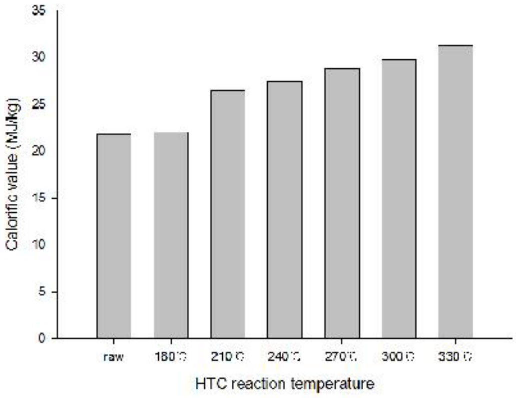

Figure 1 Improving calorific values of biochar by HTC with increase temperature

Improvement of fuel properties Coalification of sludge products

The van Krevelen diagram confirms that the coalification reaction of HTC has a significant effect on the elemental composition of the products. As shown in Figure 2, the atomic H/C and O/C ratios decreased, as the reaction temperature is increased from 180°C to 330°C. The reduced H/C and O/C atomic ratio confirms the significant effect of HTC in upgrading reaction pathways due to dehydration and decarboxylation reactions. The products were improved to become sub-bituminous coal properties as increase of reaction temperature. These results suggest that the hydrothermal treatment can improve the properties of biochar from exhausted coffee residue such that are close to those of coal.

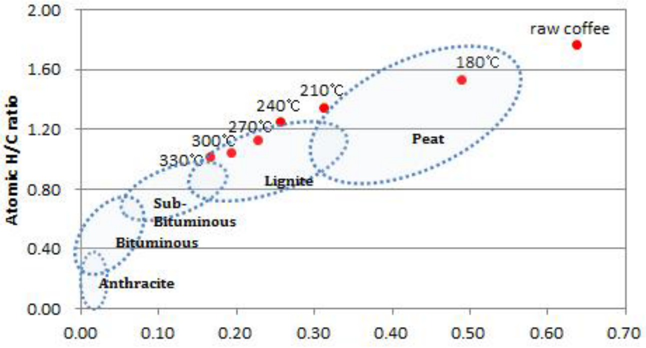

Figure 2 The van Krevelen diagram of biochar by HTC

CONCLUSION

Hydrothermal carbonization was used to convert the waste biomass as exhausted coffee residue into an alternative solid fuel with high energy efficiency. To investigate the effects of reaction temperature on the fuel properties of the biochar by HTC, and the reaction temperatures were varied in the range from 180 °C to 330 °C. After HTC was completed, the biochars exhibited significant increase in carbon content and fixed carbon content with respect to the calorific values due to dehydration and decarboxylation reactions.

Therefore, after HTC, the atomic H/C and O/C ratios decreased which can be referred to as coalification. The treated products should be upgraded sold fuel with the coalification between lignite and sub-bituminous coal.

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Characterization of Carbonation Aggregates for Using Construction Materials

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ABSTRACT

This study was performed to study the properties of the stabilized aggregate for using a construction material. The stabilized aggregate was made by the liquid accelerated carbonation reaction of the industrial by-products such as cyclic aggregate and coal ash. It confirmed the feasibility and the basic physical properties of the modified materials carbonation through basic experiments on constructional materials using a modified industrial by-products. In addition, we conducted the performance evaluation of the stabilized aggregate through a trial product of a pilot scale. It evaluated field applicability test through cement test construction, second concrete product applicability and asphalt admixture used to expand the utilization of calcium carbonate.

Keywords: Carbonation, Industrial by-products, Constructional materials

INTRODUCTION

Domestic aggregate endowment amount is about 20.3 billion m^3, the amount available, such as the economy and the legal limit, is estimated to be about 6.2 billion m^3. The aggregate production is due to problems such as environment and conserve natural resources are expected to be reduced. Meanwhile, the domestic aggregate demand is increasing every year, in order to solve the security and demand aggregate resource issues, scheme to take advantage of construction waste and industrial by-products are emerging. Waste concrete that occupies a considerable proportion of construction waste that occurs, has been re-production and recycling as a circulating bone material, the use of in roadbed material and manure than for concrete material forms a large part there. Domestic concrete for circulation aggregate, KS standards and in the "Law on recycling promotion of construction waste", defines the quality and recycling applications. To take advantage of cyclic aggregate as concrete material is to analyze the characteristics according to the production process of cyclic aggregates, it is necessary to examine the content minute impurities sufficiently.

MATERIALS AND METHODS

This study was performed to study the properties of the stabilized aggregate for using a construction material. The stabilized aggregate was made by the liquid accelerated carbonation reaction of the industrial by-products such as cyclic aggregate and coal ash. For the use of experimental construction materials of mass-produced carbonated reforming industry by-product, is promoting the indoor and field application test, the results were quantitatively evaluated via a test report. It evaluated field applicability test through cement test construction, second concrete product applicability and asphalt admixture used to expand the utilization of calcium carbonate.

Not the standard of carbonation reforming aggregate, circulation aggregate and coal ash fine aggregate, respectively defines the regulations in the "KS F2573- concrete for circulation aggregate" and "KS F4570-precast concrete for the bottom ash aggregate" there. Modifier cyclic aggregate, over dry density than KS standard shows the unexpected value, the absorption rate and the particle size showed results that do not satisfy. However, the natural aggregate, because some substitutions had no significant effect on the overall fine aggregate particle-size granularity. Coal ash showed the value that you are satisfied with the KS standards.

Table 1. The Physical Properties of fine cyclic aggregate and coal ash

	Cyclic Aggregate		Coal Ash	
	KS F 2573	Modified fine aggregate	KS F 4570	Modified fine aggregate
Saturated surface dry Density (g/cm3)	-	2.26	-	2.32
Over dry Density (g/cm3)	more than 2.2	2.05	more tha 1.5	2.2
absorptivity (%)	5 below	10.4	10 below	5.34
0.08mm (%)	7 below	2.9	-	4

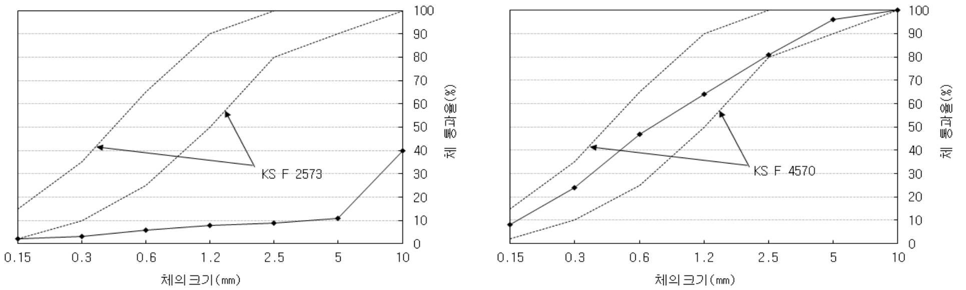

Figure 1 Grain size Distribution

RESULTS AND DISCUSSION

The initial slump of concrete laboratory for use evaluating construction materials carbonation reforming byproduct, the amount of air, and the results at the age of different compressive strength is shown in detail together in Table2.

Table 2. Concrete mix results

Specimen Name	Slump (mm)	Air (%)	Compressive Strength (MPa)				
			1day	3day	7day	28day	56day

	P	112	3.8	16.7	20.7	31.3	35.2	39.4
Part 1	P1-3	105	3.7	15.9	20.6	30.0	33.5	38.0
	P1-5	97	3.5	14.7	19.5	29.2	32.3	35.9
	P1-10	84	3.6	14.2	19.0	28.4	32.0	33.3
	P1-15	77	3.4	13.5	18.4	27.9	30.9	32.4
Part 2	P2-3	109	3.8	15.2	19.6	29.2	33.0	37.5
	P2-5	104	3.4	13.8	18.1	27.2	32.2	35.6
	P2-10	102	3.2	13.0	17.5	25.8	30.1	34.3
	P2-15	97	3.0	12.7	15.4	25.2	29.8	33.2
Part 3	P3-3	119	4.1	14.2	18.3	30.4	33.6	36.7
	P3-5	123	4.2	13.3	17.5	27.8	32.4	35.1
	P3-10	142	4.5	10.2	13.3	24.3	30.9	33.7
	P3-15	148	4.6	9.1	12.1	22.1	29.7	31.8
Part 4	P4-3	108	3.6	16.0	18.1	26.6	32.5	36.8
	P4-5	104	3.3	14.2	16.5	23.1	30.1	34.4
	P4-10	98	2.9	12.5	15.4	21.6	28.3	30.4
	P4-15	92	2.9	10.9	12.4	20.9	26.1	29.5

Immediately after carbonation reforming byproduct concrete mix it showed slump and the impact of the amount of air replacement rate in Fig2~3. Initial slump of concrete that the modified cyclic fine aggregate was used to replace the natural fine aggregate decreases as the replacement rate is increased and decreased as the modified ash fine aggregate also substitution rate increases. The more substitution rate of the reforming fine aggregate increases, fluidity is to lower, it is judged to be due to an imbalance of the high absorption rate and particle size as compared to the natural fine aggregate. Also, cyclic fine aggregate fluidity as compared with the ash fine aggregate was found to be lower with an increase in substitution rate. Ash fine aggregate about two times higher absorption rate of the cyclic fine aggregate compared to the impact on it is determined to be greater.

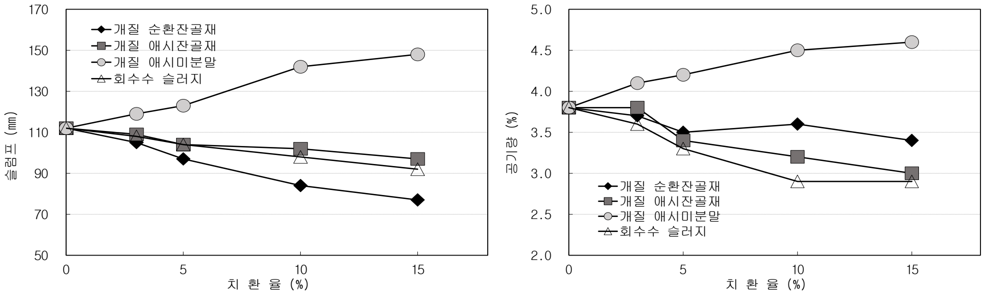

Figure 2 Fluidity in accordance with the replacement ratio of modified material

Fig effects on concrete of material ages compressive strength in accordance with a substitution rate of carbonation reforming byproduct concrete. It was shown to 4-5. Concrete utilizing a modified cyclic fine aggregate, the compressive strength as the standard replacement rate of the age of 28 days increase was reduced. It decreased by approximately 5% as compared with the comparative test piece when it is 3% of the replacement rate. Although standard initial compressive strength material ages 28th appeared low as substitution rate is increased about 90% in the age of seven days, it has been expressed and showed a similar trend regardless replacement rate.

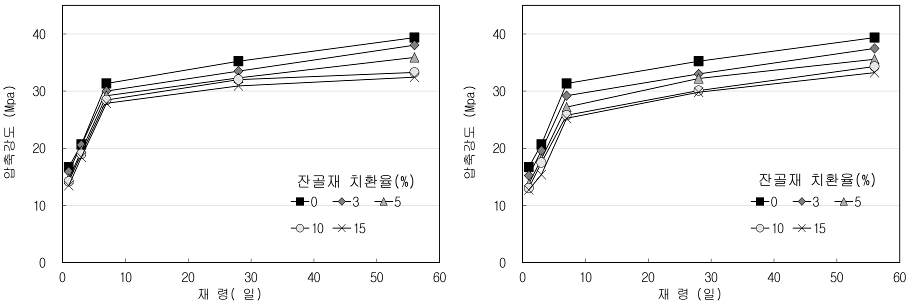

Figure 2 Fluidity in accordance with the replacement ratio of modified material

CONCLUSION

Concrete utilizing the results carbonation reforming cyclic fine aggregate of this study, compressive strength as the standard replacement rate of the age of 28 days increase was reduced. It decreased by approximately 5% as compared with the comparative test piece when it is 3% of the replacement rate. The results of the experiments, the proper substitution rate of carbonation modified example fine aggregate is determined to be 5-10%, but is also 15%, it appears to require careful quality control. For the production of concrete secondary products through the mass replacement of more than 15% should decrease in the rate of increase and the water binding discretion is made.

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Semi-continuous Co-digestion of Waste Activated Sludge with Algal Biomass Residue from Bioethanol

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ABSTRACT

In this study the biogas production from anaerobic co-digestion of organic wastes such as algal biomass residue from bioethanol production (algal biomass residue) and waste activated sludge (WAS) was carried out in order to evaluate biogas production characteristics and microbial communities. The semi-continuous anaerobic digesters were operated three kinds of substrates which were fed with activated sludge as control, raw alga and algal biomass residue mixed waste activated sludge the range of 0.75 ~ 1.25 kg VS/m3 day of Organic loading rate (OLR). All kinds of substrates reactors were stably operated as indicated pH, alkalinity and biogas production until 84 days (HRT: 10 days, OLR: 1kg VS/m3 day). However, pH, alkalinity and biogas production were decreased after 120 days in all of anaerobic reactors. Because the organic acids increased, the organic loading rate increased as 1.25 kg VS/m3 day and the HRT was decreased as 8 days. Evident influence was exhibited at 1.25 kg VS/m3 day and HRT 8 days, which led to slight accumulation of total volatile fatty acids and pH decreasing. When the samples were collected to evaluate the microbial community at the stable operating conditions, which substrates were analyzed according to their DGGE. All bands were affiliated with order *Clostridiales* whose members are frequently found in anaerobic digestion process.

Keywords: Semi-continuous co-digestion, Waste activated sludge, Algal biomass residue, Microbial community.

INTRODUCTION

Anaerobic digestion has been recognized as an efficient technology for treatment of sewage sludge. It has several advantages such as sludge stabilization, sludge volume reduction, and energy production. Especially, biogas production during the anaerobic digestion could be used as renewable energy resource, while at the same time producing biogas that can supply between 40 – 60% of the energy required to run a waste water treatment plant (Silvestre G., Rodrigez-Abalde A. et al., 2011). Different strategies have been proposed to improve biogas production of sewage sludge in anaerobic digestion. One of the strategies is the co-digestion of sewage sludge with other organic matter. Anaerobic co-digestion of sewage sludge and other organic wastes could enhance biogas production and organic matter degradation due to benefits such as diluted inhibitory compounds and a more balanced carbon to nitrogen ration (Labatutet R., Angenent L. et al., 2011).

Various researchers have reported increased biogas production during the co-digestion of sewage sludge with different organic wastes (Silvestre G., Rodrigez-Abalde A. et al., 2011; Serrano A., Siles J. et al., 2014).

The aim of this work was to evaluate the characteristics of semi-continuous co-digestion of WAS with algal biomass and algal biomass residue.

MATERIALS AND METHODS

Semi-continuous co-digestion

Waste activated sludge (WAS) and anaerobic digested sludge (as seed) were collected from the Chungnang municipal wastewater treatment plant in Seoul, Korea. The filamentous alga, *H. reticulatum* and algal biomass residue from bioethanol production (algal biomass residue) were supplied by the Korea Research Institute of Chemical Technology, Daejeon, Korea. Three laboratory-scale continuously stirred tank reactors were operated. The feeding of substrate and discharge of digested sludge were manually conducted every weekday except for holidays. First reactor was only fed with WAS as control reactor to evaluate the biogas converstion of WAS and to compare the performance with second one and third one. All of reactors were operated under mesophilic condition. R_2 and R_3 were fed a mixture of raw *H. reticulatum* and WAS, algal biomass residue and WAS. The mixing ratio of WAS to raw *H. reticulatum* and algal biomass residue was 1:1 on a VS basis, and adjusted 1% VS.

Microbial DNA extraction

The samples of semi-continuous reactors were gathered at the end of first period (85 day) to evaluate microbial communities at the stable operation.

Bactrial and archaeal communities were analyzed via PCR-DGGE using the primer set BAC338F/805R and ARC787F/1059R, respectively, with a GC-clamp as previously described (Kim J., Kim W. et al., 2013). DGGE was conducted at 60 ^{o}C in 1X TAE buffer at 75 V for 13 h on a Dcode system (BioRad Laboratories, CA) on a 8% polyacrylamide gel with 30-60% (M/V) gradient of urea-formamide denaturant. Gels were stained with ethidium bromide and visualized under UV transillumination. Specific gel bands were excised with a sterilized scalpel. Upon confirmation of the excisions as single bands via a secondary DGGE run, the bands were re-amplified, purified with QIAEX II (Qiagen, CA), and sequenced (ABI3730XL DNA analyzer, Applied Biosystems, CA). Sequences were aligned using MEGA 4.0 and analyzed using BLAST.

RESULTS AND DISCUSSION

Semi-continuous reaction of waste activated sludge with raw H. reticulatum and algal biomass residue from bioethanol

Semi-continuously fed anaerobic digestor, laboratory-scale digester at 35 ^{o}C, particulary the effect of hydraulic retention time (HRT) and organic loading rate (OLR) on process performance. The reactor performance in the semi-continuous experiments is summarized in Figure 1.

Figure 1 show the performance data of R_1, R_2 and R_3, which were fed with waste activated sludge as control and raw alga and algal biomass residue from bioethanol production mixed with waste activated sludge the range 0.75 ~ 1.25 kg VS/m^3 day of OLR. In the first 37 days, each reactor was operated at an OLR of 0.75 kg VS/m^3 d, which indicated stable operation at low OLR and high HRT. As OLR increasing to 1 kg VS/m^3 d, biogas production of each reactor showed increasing trend.

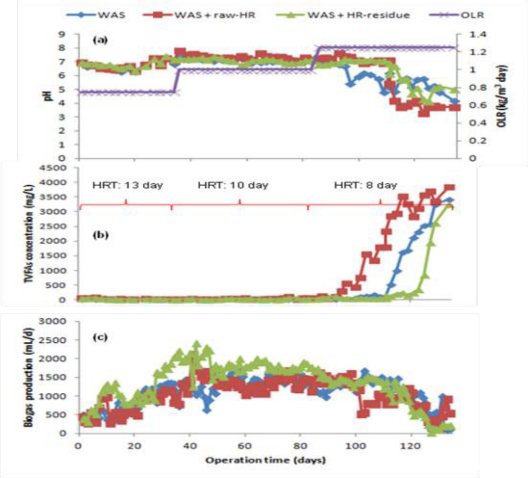

Figure 1 Variation in the pH, volatile fatty acids and biogas production with the different OLR and HRT on semi-continuous reaction

All of reactors (R_1, R_2 and R_3) were stably operated as indicated by pH, alkalinity and biogas production until 84 days (HRT: 10 days and OLR: 1 kg VS/m^3 day). The average biogas production on OLR of 0.75 kg VS/m^3 day and 13 days HRT were 768 ± 323, 706 ± 291 and 1026 ± 388 mL/day on the R_1, R_2 and R_3, respectively. At the OLR of 1 kg VS/m^3 day and 10 days HRT, The average biogas production were 1351 ± 211, 1330 ± 238 and 1853 ± 207 mL/day on the R_1, R_2 and R_3, respectively. Especially, waste activated sludge and algal biomass residue mixed substrate was highest biogas production.

The accumulation of organic acids can lead to the deterioration of anaerobic digestion (Wang et al., 2014). In all of reactors, pH, alkalinity and biogas production were decreased after 120 days of anaerobic digestion reaction. Because the organic acid increased, the organic loading increased as 1.25 kg VS/m^3 day and the HRT was decreased as 8 days. Evident influence was exhibited at 1.25 kg VS/m^3 d and HRT 8 days, which led to slight accumulation of total volatile fatty acids (TVFAs) and pH (a) decreasing. Significant inhibition occurred with accumulation of TVFAs (b), leading to decrease pH, alkalinity and dramatic drop of biogas production on all of reactors.

Microbial community

Archeal and bacterial communities in semi-continous anaerobic digesters treating the three kinds of substrates were analyzed according to their DGGE results (Figure 2).

Among the various bands, from A to P were detected in all samples and were affiliated with the order *Clostridiales* whose members are frequently found in anaerobic digestion processes. Metabolically, *Clostridiales* is a highly versatile group capable of producing lipase and degrading long-chain fatty acids (Vos P., Garrity G. et al., 2009). *Clostridium ultunense* which produces acetate as its main fermentation product is syntrophically associated with a hydrogenotrophic methanogenic bacterium.

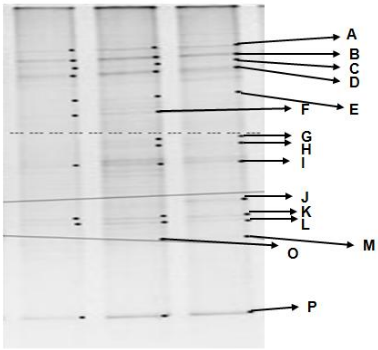

Figure 2 Analysis of microbial profiles analyzed from raw *H. reticulatum*, only WAS and algal biomass residue mixed samples on semi-continuous anaerobic digester

CONCLUSION

The aim of this work was to evaluate the characteristics of semi-continuous co-digestion of WAS with algal biomass and algal biomass residue.

At the all of semi-continuous reactors, the pH and biogas production were decreased after 120 days of anaerobic digestion. Because of the volatile fatty acids increased, the organic loading rate increased as 1.25 kg VS/m^3 day and the HRT 8 days.

Archeal and bacterial communities in semi-continuous anaerobic digestors treating the three kinds of substrates were analyzed according to their DGGE results. All bands were affiliated with order *Clostridiales* whose members are frequently found in anaerobic digestion process.

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End-of-life NiMH and Li-ion battery generation from next-generation vehicles

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ABSTRACT

Recently, attention has increased toward the reuse and recycling of end-of-life (EoL) batteries from next-generation vehicles. In order to contribute to the development of a scaled vehicle-battery reuse-and-recycling system, it is necessary to estimate the future generation of EoL batteries. This study is focused on nickel-metal hydride (NiMH) and lithium-ion (Li-ion) batteries. Based on statistics, the generation of EoL hybrid electric vehicles (HEVs) and electric vehicles (EVs) was estimated by a population balance model through the Weibull distribution. Additionally, the replacement probabilities of batteries during vehicles' lifespans were estimated using normal (Gaussian) distribution. The number of EoL batteries was estimated by summing the batteries discarded with EoL vehicles and batteries replaced from vehicles. The results suggest that the number of EoL batteries will reach to 3.6 million in 2030, of which 27% are discarded and 73% are replaced. Meanwhile, 18%, 46% and 36% of the totals are NiMH batteries, Li-ion batteries for hybrid electric vehicles, and Li-ion batteries electric vehicles, respectively.

Keywords: End-of-life vehicle, next-generation vehicle, NiMH battery, Li-ion battery

INTRODUCTION

The rapid commercialization of next-generation vehicles including HEVs and EVs by major manufacturers is underway, owing to the advance of battery technologies combined with a regulatory push for low- and zero-emission vehicles. Japan is one of the biggest markets for next-generation vehicles. Approximately 4 million HEVs and 0.4 million EVs were domestically in use during 2014 (NeV, 2013). The official government target suggests that the share of first-registered HEVs and EVs will increase from the current percentage of approximately 20% to 50–70% in 2030 (METI, 2010). The NiMH battery has been used in HEVs for many years, and the Li-ion battery has been applied to EVs in recent years. Generally, EoL batteries retain considerable energy capacity (about 80% of their initial capacity) and contain valuable metals (e.g., Ni, Co and rare earth elements). Thus, the development of a reuse-and-recycling system for EoL batteries has gained increasing attention. At the end of 2015, Toyota started to equip the fourth-generation Prius, which is the most popular HEV in the world, with Li-ion batteries. Although Prius buyers can still choose a NiMH battery (at a different price), this change is likely to trigger the future wide replacement of NiMH batteries with Li-ion batteries in HEVs. In addition, it was predicted that the share of Li-ion batteries in HEVs will grow and finally surpass NiMH batteries between 2018–2025 (Richa K., Babbitt C. et al., 2014).

Our previous study estimated the future EoL batteries from HEVs (Yano J., Muroi T. et al., 2015). However, Li-ion batteries used in EVs and potentially in HEVs were not included. This study focuses on both NiMH and Li-ion batteries installed in next-generation vehicles. The objective is to provide a quantified generation of EoL batteries from next-generation vehicles.

MATERIALS AND METHODS

The primary data sources for this study were official government statistics and annual reports from automotive associations. The time boundary for estimation was set from 1997 (HEVs and EVs were primarily commercialized from 1997 to 2009) to 2030 (the government target was set for 2030). Additionally, this study was comprised of three major stages, which are outlined in the following sections.

Estimating EoL HEVs and EVs

HEVs and EVs in Japan were considered in this study. The targeted shares of first-registered HEVs and EVs to the total number of vehicles were set as 30–40% (minimum-maximum situation) and 20–30% in 2030, respectively. The median values of the target (35% and 25% for HEVs and EVs, respectively) were applied for estimation. By using a population balance model, EoL HEV and EV generation were estimated. The remaining rates for the first registration year were considered following the Weibull distribution. For HEVs, the first, second, third, and fourth generations (from 1997 to 2030) were included, and for EVs only one generation (from 2009 to 2030) was considered. The shape parameter m and scale parameter η of HEVs were estimated by the least squares method, while the shape parameter m and scale parameter η of EVs were determined as 2.20 and 20.47 based on assumptions. The remaining rate function is shown in Eq. 1, where $F(t)$ is the remaining rate of first-registered vehicles in FY y, y is the first-registered year (= FY 1997, 1998,…, 2030), t is the vehicle age, m is the shape parameter, and η is the scale parameter.

$$F(y,t) = exp\left\{-\left(\frac{t+0.5}{\eta}\right)^{m}\right\} \qquad \text{Eq. 1}$$

$$N_{use}(y,t) = N_{1st\_reg.}(y,0) \times F(y,t) \qquad \text{Eq. 2}$$

$$N_{EoL\_CPV}(y,t) = N_{use}(y,t) - N_{use}(y,t+1) \qquad \text{Eq. 3}$$

$$Total_{N_{EoL\_CPV}(Y)} = \sum_{Y=FY1997}^{Y} N_{EoL\_CPV}\,(y,t=Y-y) \qquad \text{Eq. 4}$$

Moreover, the estimation of EoL vehicles followed Eq. 2, Eq. 3, and Eq. 4, in order. In these formulae, Y is the counted fiscal year (= FY 2010, 2011,…, 2030), $N_{use}(y,t)$ is the annual number of vehicles in use that were first registered in FY y of vehicle age t, $N1st\_reg.$ is the annual number of vehicles that were first registered in FY y [= $N_{use}(y,0)$], $N_{EoL\_CPV}(y,t)$ is the annual number of vehicles that were first registered in FY y of vehicle age t, and $Total\_N_{EoL\_CPV}(Y)$ is the annual total number of vehicles in Y.

Estimating replaced NiMH and Li-ion batteries

The EoL batteries are of two types: 1) batteries discarded with EoL vehicles and 2) batteries replaced from vehicles. The replacement (50% probability) of a NiMH battery was estimated to occur in the 13th year by an internet survey of HEV owners. On the other hand, the replacement of a Li-ion battery was determined to occur in the 8th year according to major manufacturers' warranty items, which expired after eight years (Nissan, 2016).

Statistics on historical battery replacement times for EVs are currently unavailable. Therefore, assumptions were made to estimate future replaced battery flows. In reality, the replacement probability of batteries depends on various factors including 1) deep depth of discharge, 2) excessive charge rates, 3) temperatures, and 4) consumers' operational habits (e.g., driving range, acceleration, and other vehicle performance characteristics). Because of high uncertainty caused by these factors, we assume the distribution of the replacement probability is similar to a random case. Thus, a normal distribution was used to estimate the number of replaced batteries. Batteries were assumed to be replaced a maximum of three times during the lifespan of an HEV or EV. The replacement probability function is shown in Eq. 5, where *F(x)* is the replacement probability of first-registered batteries in previous year x, x is the previous year (= 1, 2, 3,…) after first input, μ is the mean of the distribution, and σ is the standard deviation.

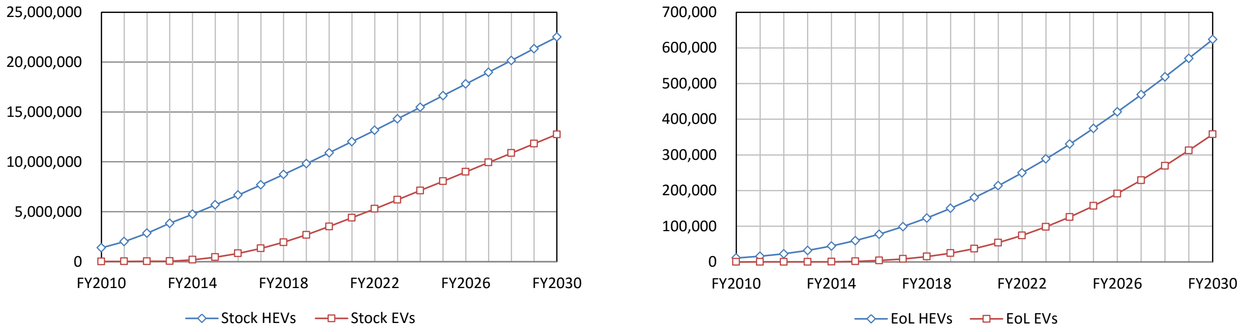
$$F(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left\{-\frac{(x-\mu)^2}{2\sigma^2}\right\} \qquad \text{Eq. 5}$$

Regarding first-time replacement, the mean and standard deviation for a NiMH battery were estimated as 12.5 and 3.91, while the estimated mean and standard deviation for a Li-ion battery were 7.5 and 2.61. These were calculated by assuming the replacement probability as 3.13–12.50% (6.25% was determined for estimation) at one-fourth of the lifespan. Assuming the replacement probability is independent, the first, second, and third replacements of batteries were estimated.

Estimating EoL batteries

The future situation of installing Li-ion batteries in HEVs was assumed. In addition to the Prius (from 2016), other HEVs produced by Toyota were equipped with Li-ion beginning in 2018, and all HEVs produced in Japan will be equipped with the Li-ion battery beginning in 2020. The number of EoL batteries was estimated by summing the number of batteries discarded with EoL vehicles (equals to the number of EoL vehicles) and batteries replaced from vehicles.

RESULTS AND DISCUSSION



a) Stock of HEVs and EVs   b) Generation of EoL HEVs and EVs

Figure 1: Stock and generation of EoL HEVs and EVs

Results are shown in Figure 1. The stock of HEVs and EVs is shown in Figure 1a), where the number of HEVs and EVs in use will reach 23 million and 13 million in 2030, respectively. As Figure 1b) illustrated, the number of EoL EVs will increase from less than 10 to approximately 0.4 million in 2010–2030. The share of EoL EVs will be 36% of the total in 2030, while the number of EoL HEVs will reach over 0.6 million.

Figure 2 shows the generation of EoL batteries. In 2030, more than 3.6 million EoL batteries will be generated from vehicles. With regard to output routes, 1.0 million batteries are discarded with EoL vehicles, and the number of replaced batteries from vehicles is nearly three times higher. Moreover, with regard to battery types, 18%, 46% and 36% of the total number of EoL batteries are NiMH batteries, Li-ion batteries for HEVs, and Li-ion batteries for EVs, respectively.

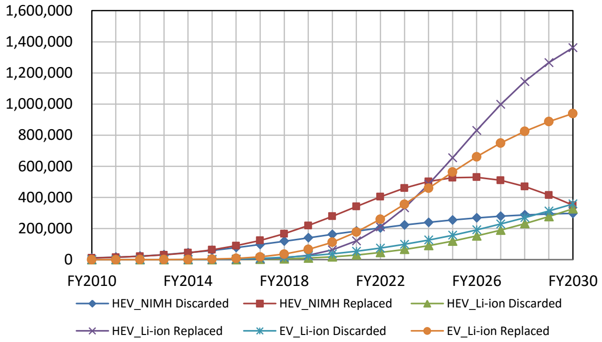


Figure 2: Generation of EoL batteries

CONCLUSION

In 2030, over 3.6 million EoL batteries will be generated from vehicles.

- With regard to output routes, the number of replaced batteries from vehicles is nearly three times higher than the number of discarded batteries from EoL vehicles. Thus, the collection of replaced batteries outside dismantling sites is significant for further reuse and recycling.
- With regard to battery types, 0.6 million, 1.7 million and 1.3 million are NiMH batteries, Li-ion batteries for hybrid electric vehicles, and Li-ion batteries for electric vehicles, respectively. These three types of batteries differ in terms of size, capacity, and so on. Therefore, appropriate reuse and/or recycling plans for these batteries need to be developed.

In total, the estimated 3.6 million EoL batteries that will be generated from EVs by 2030 provides support for policies to expand facilities for the a) collection, b) reuse, and c) recovery of these batteries. However, to support a future scaled reuse-and-recycling system, further studies on the chemical and physical characteristics of the batteries and their potential for reuse and recycling need to be conducted.

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Developing a strategic framework for E- waste in Mongolia

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ABSTRACT

In the last decade the Government of Mongolia has completed a rapid transition to a market economy, and to a democratic structure of government. Over the past few years, Mongolia has experienced trends towards increasing solid waste output, mainly due to concentration of the population in urban areas, increased consumption and changes to economic structure. There is no proper e- waste management practice in Mongolia yet. Therefore inadequate waste disposal system creates huge problems on the environment and human health. Mongolia faces number of issues in waste management. This paper highlights survey results on WEEE of Mongolia and current situation of e-waste in Mongolia and proposed strategies to address this emerging problem in Mongolia.

Keywords : e –waste, Mongolia, solid waste

INTRODUCTION

Rapid development of technology in today’s society, electrical and electronic equipment (EEE) have become indispensable to all aspects of people’s daily lives. It is estimated that more than 660 types of electronic appliances are currently sold in the global marketplace (Huisman et al., 2012). The quantity of e-waste has been increasing exponentially, with a global annual growth rate of 4 percent, due to fast technological development and ever-shortening product lifespans (Lundgren, 2012). E-waste is generally defined as waste or end-of-life electrical and electronic equipment (EEE), which has ceased to be of any value to its original owner and has been discarded (Widmer et al., 2005). E-waste encompasses a broad and growing range of electronic devices as well as embedded components and substances (OECD, 2001; Puckett et al., 2002). In Mongolia. waste management framework is not adequate yet, however there are number of laws and national programs are in place . These are the Basel Convention on the Control of Trans-boundary Movement of Hazardous Wastes” in 1996, "Rotterdam Convention on Trade in Hazardous Chemicals and Pesticides" in 2001, “The Stockholm convention on persistent organic pollutants” in 2004, National program on Reduction waste 1999 and a New Law on “Waste management” approved by the Parliament introducing 3R concepts in 2012.

The Law on "Environmental Protection" and Government National Plan on "Waste reduction management" were enacted by the Mongolian Parliament in 1995 and 1999 respectively. Several national policies have been developed and approved by the Government such as National Policy on Ecology in 2000. In spring 2012, the Parliament of Mongolia adopted a "New Law on Waste" combining the Law on Household and Industrial Waste and Law on Hazardous and Toxic Chemicals. The new Law has introduced 3R principles. In addition a Waste Reduction Action Plan was approved by the Government. A number rules and procedures have been enacted at Ministerial levels such as Regulation on classification, collection, temporary storage, transportation, treatment of hazardous wastes (2002),"Regulation and procedures on disposal and landfill of hazardous waste of business entities, and requirements on waste containers and waste disposal sites"(2006), Methodology for calculating waste norms"(2006), Payment calculation methodology for hazardous waste"(2006), Classification and characteristics and hazard level of waste" with joint order No. 324/318/336 of Ministers for Environment, Health, and Education, Culture and Science (2006), Regulation on labeling hazardous waste"(2006), Regulation on national reporting and inventory of hazardous waste(2009).

In 2010 JICA implemented Technical Cooperation Project for Strengthening the Capacity for Solid Waste Management in Ulaanbaatar City in Mongolia. In this survey conducted waste of electrical and electronic equipment (WEEE) generated in UB. WEEEs and the Scope of the Survey 5 types of EEEs (TV set, refrigerator, washing machine, PC and mobile phone) were initially selected as target EEEs, the mobile phone was deselected since its imported quantities can not be obtained and it is impossible to clarify waste flow in UB city.

Current Condition of WEEE Recycling System

According to the interviews, the methods of WEEE recycling in UB are almost similar for all types of target WEEEs. The majority of the most common recyclables are metal-containing parts. Generally, metal containing parts are recycled regardless of their functionality as non-functional ones can be sold as metal after segregation. Among non-metal or mixed small parts, any of the functional ones can be used in maintenance as spare parts.

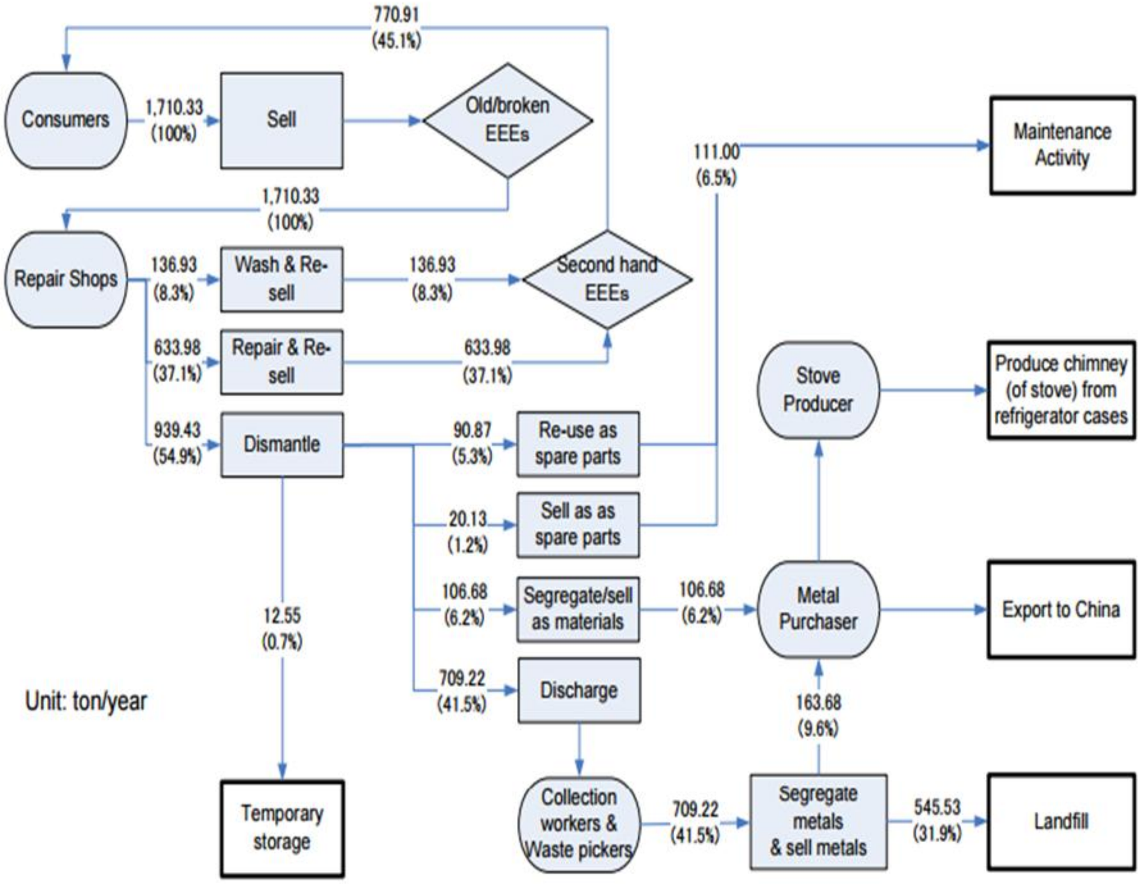
WEEE Recycling Processes

The WEEEs generated in UB are re-used since most of second hand EEEs purchased by recyclers are resold and repaired/resold back to consumers. Only those that cannot be repaired are dismantled and some of their parts are recycled. All the metals (copper, iron, aluminum and alloys) segregated from WEEE parts, except iron cases of refrigerators, are exported to China. As iron cases of refrigerators are used as raw material for chimneys of ger stoves, most refrigerator cases are purchased by ger stove producers.

WEEE Recyclers

The WEEE recyclers in UB are repair shops or individual repairmen, collection workers, waste pickers and metal purchasers. The repair shops and the repairmen play the main role in WEEE recycling since they purchase old and broken EEEs from consumers, repair most of the purchased EEEs, resell them to residents and dismantle other EEEs that are impossible to repair.

Figure 1. WEEE Recycling Cycle and WEEE Flow in Ulaanbaatar



RESULTS AND DISCUSSION

WEEE Recycling Cycle and WEEE Flow in Ulaanbaatar city.

From this survey 45.1% in the total WEEEs is re-used, 23.0% is recycled (including stored spare parts) and 31.9% is disposed. Re-use rate of each type of WEEEs is usually high (ranging from 66.9% to 80.2%) except PC. As for PC, the indicator is only 28.6% since CRT monitors that occupy the major part in the weights of TV sets, are usually impossible to re-use. The total disposed amount occupies 31.9% in the total (545.53 tons). As the amount is estimated by weights of the disposed parts, the majority of the total disposed waste has been resulted from disposed CRTs of PCs and TV sets.

CONCLUSION

To summarize, e-waste is a very complex and heterogeneous waste stream, containing numerous types of products, components and materials. This study aimed to introduce current situation of e – waste of Mongolia. All the CRTs of PC cannot be sold and around 80% of those of TV sets are disposed; and a CRT weights more than 10 kg occupying the majority in the weights of TV sets and PCs, according to survey results. Therefore, the sum of disposed amounts of CRTs from TVs and PCs occupy 94% in the total landfill amount

CRTs contain heavy metals such as mercury that cause serious health problems to human beings, the major attention should be paid to their disposal. A separate disposal site where hazardous wastes are disposed in safe manner is required to be constructed in order to prevent the negative impacts on surrounding environment. Until such hazardous waste disposal site is ready, these hazardous wastes should be stored in dry places away from the sun light. There are no manufacturers of the target EEEs in Mongolia; as the result, all of these EEEs are imported from abroad. Therefore, encouraging imports of EEEs that do not contain hazardous substances is needed. The re-use and the recycle of WEEEs are conducted mainly by individual recyclers. Thus, it is necessary to promote and develop these individuals as formal recyclers by supporting their status such as accommodating low interest rate loans after achieving a complete control on their activities by registering the recyclers, identifying the amounts and the flows of parts dismantled by them and preventing possible illegal dumping.

From this proposed solutions can be:

- Urgent need to introduce e- waste management system in Mongolia
- Ban on total imports of e- waste.
- To introduce regulations related to e –waste
- Need to address safe disposal of e- waste.
- Link up activities of informal sector with formal sector
- To learn e - waste management best practices of developed and developing countries

ACKNOWLEDGEMENT

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Community - based Solid Waste Management: Case Study of Sai Son Commune, Quoc Oai District, Hanoi Capital

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MA. Ngo Thanh Mai

1. Introduction

In Vietnam, solid waste (SW) - especially municipal solid waste - is a matter of urgency in the context of urbanization and industrialization. According Vietnam Environmental Status Report (2011), about 26 million tonnes of waste is discharged annully, of which municipal solid waste accounts for 60-70 %. In urban areas, where about 30% of the national population, each year nearly 13 million tons of SW has been generated. Large volumes of municipal solid waste are posing many challenges for management system in Vietnam. It also has pointed out two key problems existing in the system of solid waste management (SWM) in Vietnam today. *Firstly*, it is the overload of waste collection services in urban areas. The proportion of domestic waste collection in whole nation reached only 60-70%. Uncollected waste can go into rivers, lakes and the empty land, causing a negative impact on the environment and human health. *Secondly*, SWM system not to promote the role of the community, especially families. The involvement of families in activities of SW classification, collection, reuse and recycling of waste has been limited.

Aware of such shortcomings, Vietnamese government has set out the priorities to enhance community participation in SWM are particularly interested. The key issue is the community should be given the opportunity to self-organizing activities of SWM. When the Government is facing many difficulties in providing SW services due to its limitation of human resources and finance, the Community-based SWM is considered as a suitable direction. This approach will reduce the burden on the government sector, while also mobilizing financial resources and human resources available in the community to ensure SWM activities toward sustainability.

2. Overview of Community-based Solid Waste Management

Community-based solid waste management (CBSWM) is a process which encourage all community members in active management and taking responsibility for planning, operating and controlling of elements in waste system. The nature of community-based QLCTRSH CBSWM is that its community members or their representatives are responsible, have the power to do something and decide how implementation, direct and perform management operations, maintenance SW services (including collection, transportation, recycling) in order to bring benefits to the members of the community. This is a new management approach which is consistent with the "socialization" and empowering trend in Vietnam. This approach also creats co-benefits for local community and authority.

Main benefits of Community-based Solid Waste Management:

- Improve efficiency, reduce management costs: in the long run, the cost of government will decrease due to the sharing management responsibilities, the contribution of the community resources.
- Reduce the difficulty for authorities and bodies of local environmental management, contributing to building relationships and trust with local communities.
- Raising awareness of the community and the authorities about the situation and the influence/impact of SW through learning, sharing knowledge and experience as well as working methods and exchange of information .

3. Community - bases solid waste management: case study of Sai Son commune, Quoc Oai district, Hanoi capital

3.1. Study area profile and History of CBSWM model

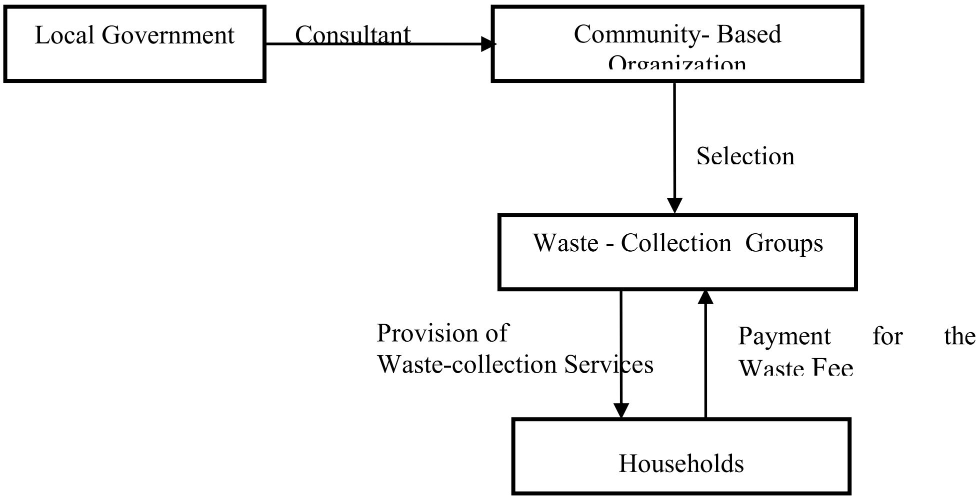
Sai Son commune, belonging to Quoc Oai district, former HaTay province, is a suburban commune located in the southwest of Hanoi capital. Its natural land covers more than 10 kilometer square. Over past years, Sai Son has gained considerable economic achievements. The economic growth rate in the period of 2006 – 2010 is about 10.6%/year, annually income per capita is VND 11,450,000. Population of Sai Son is 18,718 people divided into 4,200 households.

Prior to 1995, there was no system of waste collection, transportation and other activities related to SWM in Sai Son. Most households burned, buried or threw their waste into streets surrounding fields or even anywhere they can. The local environment was quite polluted with many plastic bags in the community's pond and littered throughout the streets.

Year of 2005 is a turning point in SWM system of Sai Son. There was a pilot model of CBSWM which is self-established, self-financed and self-managed by community. Three hamlets in Sai Son were selected to be experimental places for applying this model. In a short time, the implementation of CBSWM model in Sai Son commune have exerted considerable positive effects such as raising society's awareness of the environmental sanitation, creating more jobs for its residents, eliminating the rubbish dumps. From this success, this model was continuously applied in other hamlets since 2007.

3.3. Structure of CMSWM model

Figure 1 points out the stakeholders and mechanism of model's operation.



(Source: The authors compiled from field survey)

(1) *Community-based organization* (CBO): This is an organization which is elected by the community and has 03 responsiblities. *Firstly*, the most important role is to choose a suitable provider of SW services in community *Secondly*, CBO makes a decision on waste collection fees. It is not easy task because fee is a sensitive problem. In Sai Son, CBO discuss with local government, consult households' opinions and make a final decision of fee level. *Thirdly*, CBO has responsibility to create a forum in which service users can express their ideas and complains about the quality of service in the community.

- (2) *Households*: Residential households have rights to reflect the quality of waste collection services to CBO if they do not satisfy; and have responsibility to pay about VND 2500 /capita/month for waste collection service.

- (3) *Providers of SW service*: Provider of SW service mainly supplies a garbage-collection service. Collectors are responsible for gathering waste discharged by households and filled collected waste at some ponds. They can earn about 1,100,000VND (equivalent $50 USD) per month to their livelihoods.

- (4) *Local government*: In Sai Son, local government plays a minor role in model of CBSWM. It does not have enough technical as well as financial assistance for community and for waste collectors. Local government has consulted and introduced some members of CBO which are voted by the community. Besides, it has a role to encourage household as well as whole community to participate and obey all CBO's decision related to SWM.

3.3. Discussion of community - based solid waste management in Sai Son commune, Quoc Oai

district, Hanoi capital.

Basing on information collected from fieldwork and survey of 70 households in Sai Son, some results of CBSWM models in Sai Son have been examined and analyzed as follows:

**** Environmental perspectives:***

- *High rate of collected waste*: The socio-economic report in Sai Son indicates that that environment is cleaner sinces its application of CBSWM in here. It is shown that SW collection rate increased gradually, reaching 86.8% in 2012. This rate is fairly high as compared to this rate in urban areas (80%), and the whole nation (65%). Results from depth interview local government and households in locality show that uncollected waste which mainly remains along the river side and pond sides in the ward has decrease considerably, leading to a reduction of waste, air and land pollution and creation of good scenery in the community.

- *Increase of waste recycle rate*: the socio-economic report in Sai Son implies that recycle rate is 28.3%, much more higher than average recycle rate of 18% in Hanoi. In Sai Son commune, nearly 30% of household participate in activity of reuse and recycle. From the depth interviews, some households said that they can earn from VND 50,000 to VND 100,000 per month from reuse/recycle activity. The incremental income is not so high as compared with their general income in Hanoi (about VND 4,000,000/capita/month); however it also creates an incentive for households to implement activity of reuse and recycle.

**** Social perspective***:

- *Job creation for local residents*: The model in Sai Son has created a considerable number of jobs for local residents. Among 21 garbage collectors, 18 local labors are employed. Workers are contracted temporary workers with Chairman or leader of CBO. It is expected that generation of job will be higher in near future when requirement of waste collection/transportation/reuse increases.

**** Economic perspective:***

- *Cost recovery problem*: Cost recovery problems refer to a lack of funds to cover capital and recurrent costs of SW activities (Anschütz, 1996:64). The waste collection fee in Sai Son is VND 2500/capita/month. On average, each collector can get about VND 1,100,000/month. Because they do not invest to buy equipment and transportation vehicles (this expenditure is financed by commune's fund), this rate may be acceptable to sustain collection service. According to opinions of waste collectors, this level of fee is so low and not suitable with condition of high inflation at this time. The collection fee should be changed year by year in order to match with increasing price in the economy. Actually, cost recovery in Sai Son is about 106.8%. In long term , if the collection fee is not adjusted, the revenue are not enough to offset the cost. Thus , the ability of financial sustainability in Sai Son commune model is still a problem which is not answered in coming time.

**** Managerial perspective:***

- *Accountability and legality to the community:* In Sai Son, accountability of SWM model is not clearly defined. There is not a contract which lists all rights, responsibility among CBO, garbage collectors and households. Between CBO and waste collectors, they only discuss and talk each other about time, frequency and route to gather waste. Between CBO and households, there is every 3 month community meeting, in which CBO inform and getting household's opinions about collection fee and garbage collection service. The household's responsibility to participate and pay collection fee are not prescribed. Consequently, 15% household surveyed express that they do not have responsibility to take part in and pay for SW collection service.

- *Monitoring mechanism* is not performed in this model. No one is responsible for overseeing day to day collection activities of the waste collectors. It is not confirmed that collectors complete their tasks along the prearranged routes and within the predetermined time. Consequently, quality of garbage collection service is not controlled and ensured.

4. Recommendations

**** Solutions of finance:***

During the analysis, one weakness of CBSWM is not sustainable in term of finance respective. The bottom line is that the cost and benefit flows are not balanced in the model. Therefore, the solutions should be offered as follows:

Forming mechanism of financial support of the central government/local government for CBSWM. Financial support should be made at an early stage when designing newly established models, especially in communities in rural areas with low incomes. Amount of funding should be limited by the cost of investment and will be repeated after a period of use (3-5 years).

The fees collected should be implemented in a flexible way depending on different socio - economic conditions of various communities. The collection fees should also be made to facilitate the direction of management, but also to strengthen the autonomy of the service providers in setting fees. This means that the city Government should take 'floor' of charge, but specific charges will be made basing on the consensus between providers and users of waste services.

**** Awareness raising:***

Raising awareness of community needs and the solution is particularly important to achieve success for the model CBSWM. Raising awareness to the community can be made through the communication program, advocacy and campaigning on the media, organized environmental programs or the establishment of environmental clubs. Raising awareness is not a temporary solution, or short-term; moreover, this solution needs to be recognized, evaluation and design implementation on a large scale and long term.

**** Solutions of management****:*

The local authority should formulate a regulation which requires to sign a contract among CBO, SW service providers and households. Its objective is to control and ensure all stakeholder of the management model to implement their rights and responsibilities.

Trainings should be organized to improve management capacity for members.

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Comparative kinetic study of biogas production from the co-digestion of differential biomass waste

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ABSTRACT

Greenhouse gas mitigation by anaerobic digestion technology had been gained public concern due to their economical and environmental benefits. Domestic and agricultural biomass wastes are the large emission sources of green house gas and according to IPCC's estimation, solid waste management sector contribute 5% to the global GHG budget (Bogner et at., 2008). In this research, differential biomass sources such as domestic organic waste, vegetable waste and animal waste has been investigated in 15 anaerobic digesters in 40 days at 35^0C with the ratios of substrates to inoculums (S/I) and 13% TS substrates. Biogas yields from differential biomass waste types were comparative.

Keywords: anaerobic digestion of biomass waste, greenhouse gas, mitigation, water hyacinth, cabbage, domestic organic waste (3-5 keywords should be appeared)

INTRODUCTION

Recent researches on digestion of water hyacinth or cabbage caused the low methane content and longer starting up time of anaerobic digestion system. According to J. Gao 2013, methane content of water hyacinth is from 126 to 190 ml CH_4/gVS in case of single digestion of water hyacinth [3,4,5]. The co-digestion helps to increase methane yields to become more economically feasible. Besides, co-digestion can provide a better nutrient balance, higher biogas yield [6,7]. Co-digestion of cow dung and water hyacinth (Jagadish H Patil, 2011) caused 380 ml biogas/gVS or 247ml CH_4/gVS [8]. Co-digestion of cow dung and grass has methane yield of 190-210 ml CH_4/gVS, methane yield is 260 ml CH_4/gVS if water hyacinth is co-digested with cow dung. The shortest lag phase was exhibited by co-digestion samples is from 6.625 days to 15.28 days. In this paper, compare biogas production among biomass wastes, between mono-digestion and co-digestion of cow dung, other biomass waste as well as calculate their kinetic parameters by modified Gompertz equation.

MATERIALS AND METHODS

Substrate and inoculums

Water hyacinth and waste cabbage, cow dung was taken from Cat Que - Hoai Duc district, Hanoi city. Domestic organic waste was taken and separated at 4 households during 10 days. Samples were removed root, sand and grinded into 0.5 -1 cm in size and dried at 60^oC then stored at 4^oC; cow dung was accounted 20% of input substrates. Characteristics of cabbage, water hyacinth, organic domestic waste and cow dung were displayed in Table 1. Inoculum was taken at AD system of INPC donated by NEDO- Japan with OLR design 2.8 kg VSS/$m^3_{reactor}$.day, biogas production rate 0.83 $m^3/m^3_{reactor}$.day, CH_4 concentration 55%, total alkalinity 4300 mg$CaCO_3$/l, pH 7.12 and were centrifuged to get TS 8%, VS 2.5%.

Method of Setup experiment and kinetic study

15 anaerobic digester 1500ml (1 blank samples, 2single waste samples at S/I of 2 and co-digestion waste samples at S/I ratios 2 were double), HRT 30-40 days. Each anaerobic tank was put 200g inoculum, blow 2liter N_2 gas/min, put substrates, stirred, supplied N_2 gas during 5 minutes. The S/I ratios of co-digestion waste ($VS_{substrate}$ and $VS_{inoculum}$) ranged from 0.5 – 4. Finally, AD were added 5ml solution including NH_4Cl, K_2HPO_4, $MgCl_2.6H_2O$, $CaCl_2.2H_2O$, $FeCl_2.4H_2O$, H_3BO_3, $ZnCl_2$, $MnCl_2.4H_2O$, Na_2MoO_4, $CoCl_2.6H_2O$, sealed by rubber lid and silicon gel. The modified Gompertz equation, that gives cumulative biogas production from batch digesters assuming that biogas production is a function of bacterial growth. The modified Gompertz equation is given as following [14,15].

Table 1. Characteristics of cabbage, water hyacinth, organic domestic waste and cow dung

Items	Water hyacinth	Cabbage	Organic Domestic waste	Cow dung
Total solid,%	8-11	7-8	33.66	
Lignin (% of TS)	4.37	0.95		
Hemi-cellulose (% of TS)	32.69	1.91		
Cellulose (% of TS)	19.2	2.01		
Extractives, %	85-88	93-95		
Volatile Solid -VS (% of TS)*	57.1	65.1	31.65	14.6
TOC, % of TS*	44.6	43.87	36.28	11.5
TKN, % of TS*	0.76	2.06	0.229	

*:based on dry matter.

$$M = P \times \exp\left\{-\exp\left[\frac{R_m \times e}{P}(\lambda - t) + 1\right]\right\}$$

in which M was cumulative biogas production (l/gVS) at production time t, P was biogas potential yield (l/gVS), R_m was maximum biogas production rate (l/gVS/day), λ : duration of lag phase, d (days), t wasresponding digestion time, d (days). Kinetic studies and regression analysis between biogas production experimental data and Gompertz model was determined P, Rm, and λ for samples at each S/I ratio.

Analysis methods: Samples Total solid (TS), Volatile solid (VS) were determined according to standard method APHA (APHA, 1998) [13]. Biogas volume and CH_4 concentration were checked once every three days by liquid displacement and analyzed by GC/FID 2010 Shimadzu.

RESULTS AND DISCUSSION

Biogas yields from differential biomass waste

Figure 1 showed that biogas generation process is very quick in the start of digestion and very slow at the end of digestion. Biogas volume reaches the maximum value at the first week and gradually decreases in the third and second week. Week 4th, 5th and 6th biogas generation reduced remarkably. Table 2 showed that biogas was in the order of Sample M5 (478.2 mL/g VS) > Sample M4 (458.4 mL/g VS) > Sample M6 (418.8 mL/g VS) > sample M1 (365.7 mL/g VS) > Sample M2 (361.8 ml/gVS)> Sample M3 (344.9

ml/gVS)> Sample M7 (350.2 ml/gVS). Biogas yield of mono-digestion of cabbage was also fractionally more than water hyacinth with respective biogas yields were 362 ml/gVS and 345 ml/gVS.

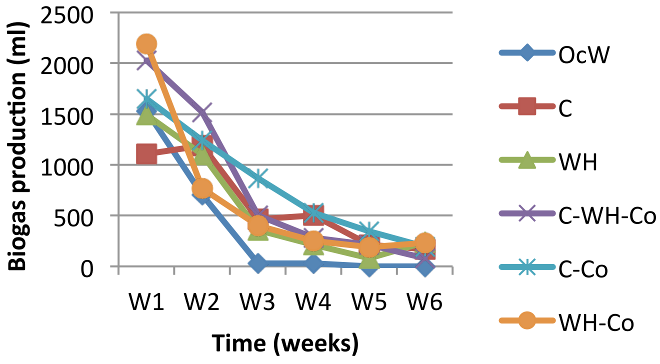

Figure 1: Biogas production trend by weeks

Table 2. Biogas and methane yields and cumulative biogas of biomass wastes

Samples	M7	M1	M2 -R	M3-B	M4(RPB)	M5(RP)	M6(BP)
Biogas yield (ml biogas/gVS)	350.2	365.7	361.8	344.9	458.4	478.2	418.8
Methane yield (ml CH4/g VS)	203.116	224.98	157.4	142.5	319.5	335.2	291

Additionally, co-digestion yield of cow dung and cabbage is 1.32 times higher than the mono-digestion of cabbage only. And the biogas yield of cow dung and water hyacinth is 1.21 times higher than the mono digestion of water hyacinth only. Domestic organic waste had the lowest biogas yield than other biomass waste in this research. Besides, with the good inoculums, mono digestion and co-digestion process created the higher biogas yield. In the figure 2: co- digestion processes of cow dung with cabbage or WH was quickly responded, created high biogas production rate as soon as inputting the raw substrates. For instance, after three days of digestion, the maximum biogas production rate is 0.37L/gVS/day when cabbage and cow dung are co-digested. WH, cow dung created maximum biogas production rate of 0.33 L/gVS/day after 6 digested days (Figure 2). In the first three days, WH has a lower biogas generation rate than in cabbage meaning that the longer start up time in water hyacinth than in cabbage, Table 1.

Figure 2 showed the biogas production rate of differential biomass wastes.

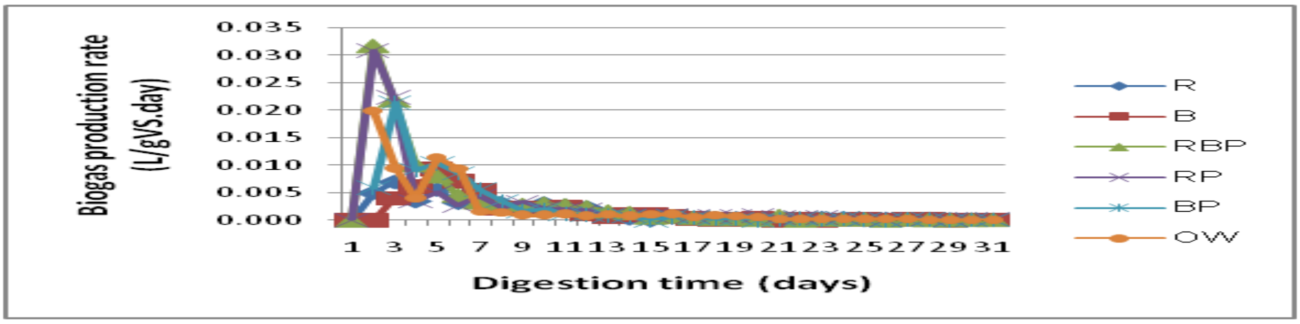

Fig 2: Biogas production rate (ml biogas/gVS/day).

Kinetic study of biogas production based on Gompzert equation

The lag phase, Biogas max, biogas generation per 1gVS per day of kinetic equation presented in Table 3.

Table 3.Values of kinetic data

Samples	R^2	rmsd	Pmax, l/gVS	Rm, l/gVS/day	λ ngay^{-1}	Biogas, ml/gVS	Methane, ml/gVS
		Advanced Gomperzt value (model)					
OCW-M7	0.981	0.007	0.365	0.02	1.23	365.7	225.0
R-M2	0.986	0.008	0.351	0.017	0.71	361.8	157.4
B-M3	0.987	0.006	0.323	0.023	1.12	344.9	142.5
RBP-M4	0.992	0.005	0.445	0.029	0.26	458.4	319.5
RP-M5	0.993	0.006	0.472	0.021	0.23	478.2	335.2
BP-M6	0.972	0.012	0.388	0.027	0.29	418.8	291.0

CONCLUSION

In this research, differential biomass sources such as domestic organic waste, vegetable waste and animal waste has been investigated. The maximum biogas production rate or Rm (lit biogas/gVS/day) values among RP, BP, RBP, R, B2 samples, it showed that water hyacinth performed higher Rm values than in cabbage. RP2, BP2, RBP2 samples has the increasing Rm values from 0.02, 0.027 to 0.029 respectively. R2 maximum biogas production rate is also higher than B2 one within their values are 0.017 and 0.022 respectively. It means that water hyacinth has the higher maximum biogas production rate than in cabbage. However, average biogas yield (ml/gVS) after 47 digestion days displayed those values of RP2 and BP2 are 478 ml biogas/gVS and 418 ml/gVS.

ACKNOWLEDGEMENT

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Pollution prevention by energy recovery from biomass waste at lab, pilot scale for dissemination

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ABSTRACT

The baseline studies on biomass resource to energy assessment, Biomethane potential (BMP), specific methane activity (SMA) assessment of anaerobic digestion (AD) of organic municipal solid waste (OW), water hyacinth (WH), vegetable wastes (VW), sludge (cassava residue CSR). The BMP of studied biomass ranged from 156-420mlCH_4/gVS, SMA varied from 0,044 – 0,207 gVS/gVS_{ad}/day showed high potential on energy recovery. The technical parameters used for designing 12m^3 pilot digester could generate 11-13m^3CH_4/day supplied over 110kWh as alternative energy. Our studies at lab and pilot scale could use for further dissemination of biomass waste to energy at large scale.

Keywords: biomass waste, methane BMP, green house gas reduction

INTRODUCTION

Preventing all forms of pollution, including reduce GHG and other pollutants emitted into environment especially from biomass waste as path way for resource utilization, energy recovery from biomass source is key tool to avoid this waste stream to landfill and related pollution (Chi, 2011). The National Strategy on Green Growth issued by QĐ1993/2012 targeted the resource utilization to reduce climate change 8-10% by the year 2020, as well as reduce energy consumption 1 -1,5 1.5% per GDP annually. We conducted baseline studies on biomass wastes: vegetable waste, water hyacinth, organic municipal waste, cassava residues, pig manure, cow dung and other sludge due to its local availability. The series of Bio Methane Potential test, Specific Methane Activity assessments, fuel tests carried out to get the data and kinetic parameters on biomass AD at lab scale to assist the technical design and operation pilot and dissemination.

MATERIALS AND METHODS

2.1 Materials: Water hyacinth, agricultural vegetable waste, organic municipal waste separated from household, cassava residues of Minh Dương factory, pig manure, cow dung, anaerobic sludge collected in Hoai duc district – Hanoi. Waste characteristics analysed and presented in Table 1.

2.2. Experiments: 1) *BMP* and *SMA* test conducted by series of anerobic lab digester 1500ml by using the anaerobic inoculum of 24,7g/l of volatile solid (VS). The feeding ratio of substrate, inoculum (S/I) varied from 0,5; 1; 2; 4 to determinate optimal S/I rate. The digestion was conducted at 35,5^{0}C± 0,3^{o}C. In case of CSR, the S/I varied 1,6; 2; 2,5 or 2,33, 2,79; 3,49gCOD/l *2) Kinetic studies on semi-continuous anaerobic digestion (AD) batch* by mixing used feeding pump. 3) Same studies at AD pilot digester of 12m^3 to get biogas and slurry treatment by the decanter and waste water treatment JKS-25 (12m^3) presented in Fig 1a. Biomass fuel replaced convention DO testing at Kobuta dual fuel generator 13,8KVA in Fig 1b.

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Fig : Organic waste to energy, waste water treatment pilot plant, Cat Que Village- Hanoi, 2012[7]

2.3. Analytical methods: The pH, COD, TS, VS, VSS, NH_4, VFA, alkalinity were tested by APHA, 1998. The biogas tested by GC/FID 2010 Shimadzu.

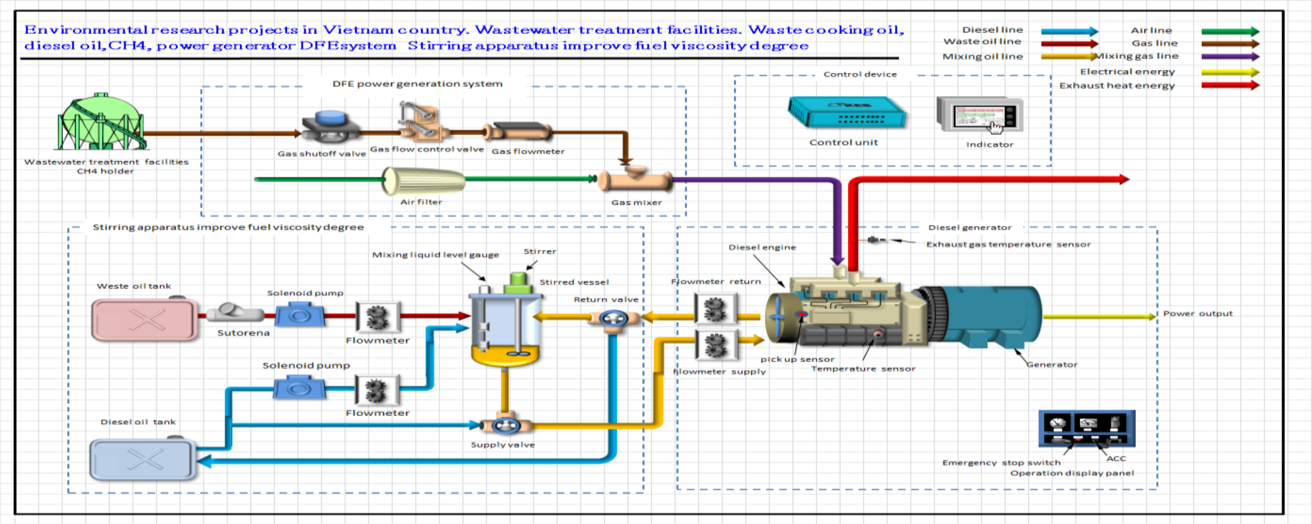


Fig 1b: System for testing biomass fuel at dual fuel generator, INPC pilot.

III RESULTS AND DISCUSSION

3.1 Waste characteristics - Bio methane potential and specific methane activity assessment of AD.

Biomass waste composition presented in Table 1.

Table 1. Characteristics of studied biomass source for study (% dry matter)

Sample	TS	VS	OC	T-N	T-P	Celulose	Hemicellulose	Lignin	Extractive	Others	VS/TS	BMP,mlCH4/gVS
WH	9,21	72,96	15,3	0,59	-	20,26	30,86	5,92	10,45	7,41	0,73	142
VW	8,7	75	43,78	2,06	0,1	3,4	3,1	1,5	21,7	15,66	0,75	335*
OW	16,4	74,23	51,63	1,41	0,3	1,3	1,1		14	14,26	0,742	389*
CSR	10,24	76,74	93	0,4	0,1					6,1	0,76	420

** Organic waste OW, Vegetable waste VW, Water hyacinth WH, Cassava residue CSR, Codigestion cow, pig manure _C, _P,*

The result of BMP, SMA tests presented in Fig 1c and Fig 2 below.

The feed rate S/I varied 0,5, 1, 2, 4. The results showed that the highest BMP obtained at S/I equal 2, high feeding rate up to S/I equal 4 reduced the gas production. The vegetable waste, water hyacinth without co digestion (sample VW, WH) generated less biogas volume (only 362 ml biogas/1gVS and 345 ml biogas/1gVS) compared to co digestion with cow dung or pig manure. The co digestion with cow dung produced less biogas than co digestion samples with pig manure.

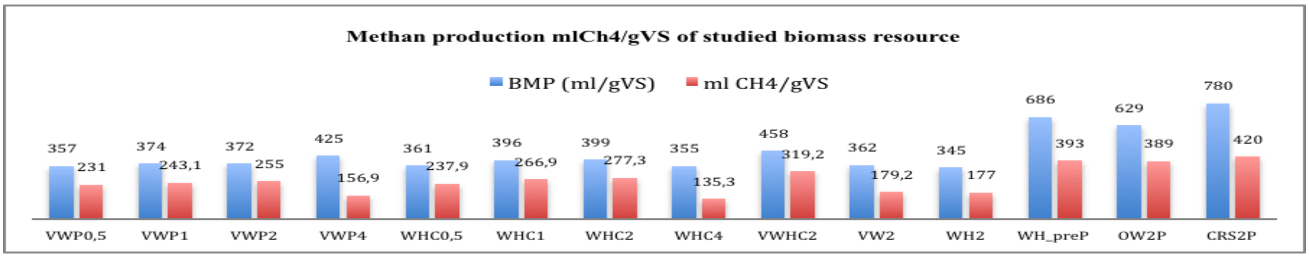


Fig 1c: Comparative study on BMP of studied biomass in the AD with different loading rate S/I

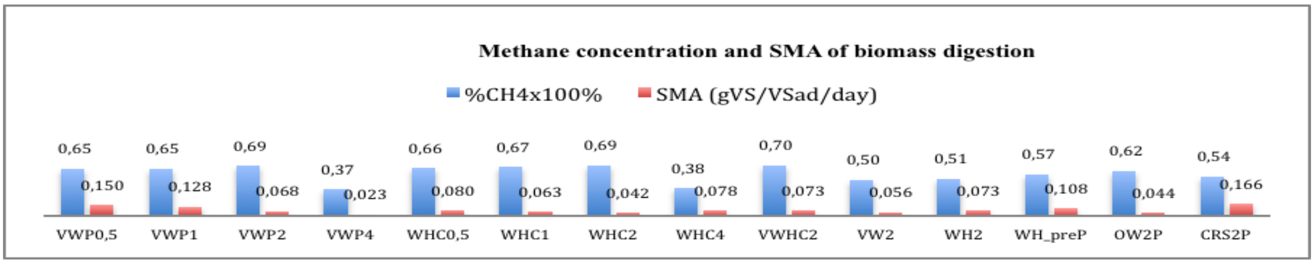
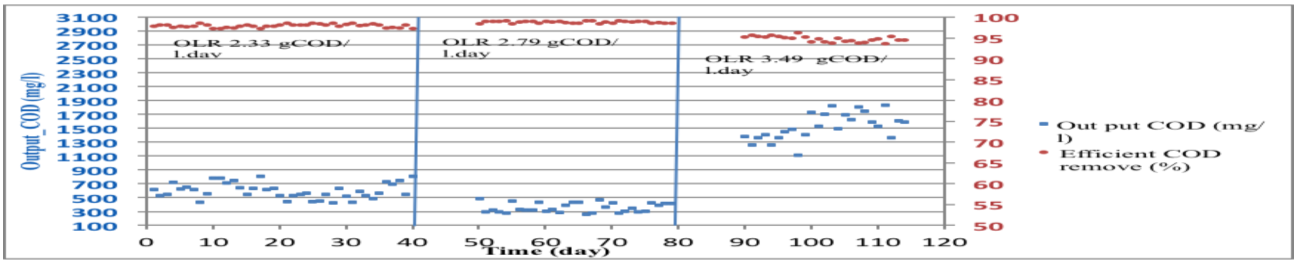


Fig 2: Comparative study on methane concentration and SMA of studied biomass AD

The co digestion cassava residue with pig manure CSR2P generated 780ml biogas/1gVS or 420ml CH_4/gVS, following pretreatment water hyacinth with pig manure $WH_{pre}P$ was 686mlbiogas/ gVS or 393ml$CH_{4/}$1gVS, organic solid waste OW2P with 629 mlbiogas/ gVS or 389 ml$CH_{4/}$1gVS, vegetable waste 458 mlbiogas/ gVS or 319mlCH_4 /1gVS, WHC2 was 399mlbiogas or 277,3mlCH_4/1gVS. The BMP of studied biomass varied from 156-420mlCH_4/gVS, different content of methane and SMA values in which the methane production yield from co digestion cassava residue, organic waste and water hyacinth with pig manure ranged 389-420ml CH_4/1gVS, Fig 1b, Fig 2.

3.2) Building up pilot digester, biogas collected and slurry treatment

The cassava residue AD tests with S/I varied from 1,6, 2, 2,5 or organic loading rate (OLR) was 2,33; 2,79; 3,49 gCOD/l.day were tested. Input flow of 800 l/day was pumped and collected biogas, purified and conducted to generator. The COD removal and methane production efficient yield presented in Fig 3, Fig 4. The digested slurry after decanter had COD ranged 380-800mg/l, TS was 230-310mg/l, T-N was 204-230mg/l, T-P was 6 -7,2mg/l and TDS was 700-780mg/l. The solid sludge reached good organic materials for soil improvement with organic content (OC) was 28-35%, ash was 5,1-5,8%, T-N less than 0,03% and did not content any hazardous matters. Also, liquid from decanter treated by the wastewater treatment model JKS-25 ($12m^3$) to meet QCVN 39. The collected biogas with 52-54,8%CH_4 supplied to dual fuel generator Kubota 13,8KVA to generate over 110kWh daily.



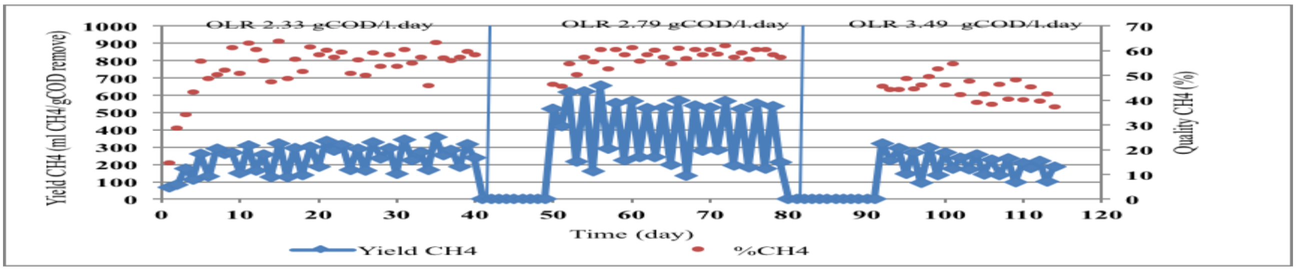


Fig 3, Fig 4: COD removal and Methane production yield from AD of cassava residue

3.3) Comparative study on biogas energy and calculation GHG reduction

Biogas could replaced 75% of convention DO consumption. The ratio of biogas/DO of 75:25 the system produced 7,9KWh with 0,7 l of DO/h and 1,1 m^3 biogas/h, compared to the case 100%DO (2,86l DO/h) generated same power of 7,9kW. Knowing that 3kg CO$_2$ emmision/1litre DO, DO replaced by bio methane reduced 69,7% CO$_2$ emision compared to the case of using 100%DO at the same electric generator. The emission was (0,7l / h × 3kg) + (1,1m^3 / h × 0,8 × 0,57Kg) = 2,6kg or 0,329kgCO$_2$/kWh and could be significantly reduced emission from existing 0,43-0,52 kgCO$_2$/kWh (Chi, 2013).

CONCLUSION

Biomass waste to energy could help in pollution prevention, reducing GHG. The BMP of studied biomass varied from 156-420mlCH$_4$/gVS, SMA was 0,207 - 0,044gVS/VS$_{ad}$/day. The feeding rate S/I was 2 considered was optimal for AD. Kinetics studies at lab, pilot scale to design, monitor and evaluate AD system. Co digestion cassava residue, organic waste and water hyacinth with pig manure the methane production yield ranged from 389-420ml CH$_4$/1gVS and high efficiency on COD removal. The R-D on biomass conversion to energy at pilot scale provided useful tool for solid waste management and should be disseminated using local biomass resource and setting up suitable integrated AD system for waste treatment using local materials to contribute for resource utilization and GHG emission reduction.

ACKNOWLEDGEMENT

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Research on sorbent synthesis for hydrogen sulfide treatment at the high temperature

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ABSTRACT

Solid waste burning is one of the large emission sources of green house gas. Exhaust gas emission control from waste burning incinerator had been gained public concern in the world but still limited in Vietnam. This study had synthesis metal sorbents based on kaolin for hydrogen sulfide treatment at high temperature. Results showed that proper ratios of Fe/kaolin; Zn/Fe, Fe and Zn/kaolin are 2.11; 0.40 and 2.38 with calcination temperature are 350^0C in 3 hours. This synthesis conditions created 2/9 samples has the highest surface areas as 31.3 and 37.2 m^2/g and the smallest nano sizes from 5-20 nm. The optimum conditions for hydrogen sulfide treatment are at 350^0C, 2 cm of reaction length (1g media mass), 17 ml/min input gas velocity at 2 hour of reaction.

Keywords: pollution emission control, hydrogen sulfide treatment, sorbent synthesis.

INTRODUCTION

In Vietnam, it has been well recognized that waste burning incinerators without proper gas treatment systems are major emission sources. Exhaust gas from coal and biomass co-firing contains many impurities such as fly ash, tar, especially hydrogen sulfide, COS, nitrogen and heavy metal like Pb, Cd. These gases must be removed before discharge to atmosphere especially when application on engine operation. Due to the low material cost then mixed metal sorbents based on natural and mineral sources such as biochar and dolomite/kaolin are more concerned recently (M.Mureddu, 2012) (S.S. Tamhanker, 1981). Mayumi Tsukada published the research on hydrogen sulfide removal by sorbets at high temperature (Mayumi Tsukada, 2010). In the initial research, we carry out the research on synthesis condition of hydrogen sulfide sorbent such as Zn/Fe (at ratios 0.13; 0.40; 0.27; 0.53.) Fe/kaolin (1.21; 1.41; 1.7; 2.11 và 2.51) Fe,Zn mixed metal/kaolin (1.93; 2.16; 2.38 và 2.61) at differential temperature conditions (3 hour at 300^0C, 3 hour at 350^0C, 3 hour at 400^0C, 3 hour at 350^0C and 2 hour at 450^0C). Besides, we carried out the influence of sorption temperature, media mass, gas velocity and reaction time on hydrogen sulfide treatment.

MATERIALS AND METHODS

Materials: sorbent synthesis

Kaolin Phu Tho was selected for sorbent synthesis. Each bottle of $Fe(NO_3)_3$ or mixture of $Fe(NO_3)_3$,Zn $(NO_3)_2$ was stirred at 500 rpm at 313K and NH_3 was add into each of them over 5 min and stirred at 800 rpm for 10 min and ripened for 10 days at 100°C in a capped bottle. The collected slurry was then wash by distilled water and separated from the solution by centrifugation. Washing and centrifugation separation were repeated thrice and the purified slurry was dried at 80^0C for 24h to and grinding to obtain the final powdery products. The prepared sorbents were observed by SEM and specific surface area was measured by BET.

Desulfurization model

Fig. 1 shows the desulfurization test apparatus. The reactor was made by using coaxial quartz glass tubes with inner diameters of 8 mm and 9 mm for the outer and inner tubes, respectively. A sorbent sample of 0.5-1g was set on a ceramic filter made of cordierite. After the furnace temperature reached the certain temperature, the gas was switched to a mixed gas with a composition of 0.5% H_2S and balance N_2, and then monitoring the hydrogen sulfide reduction yield by FT-IR.

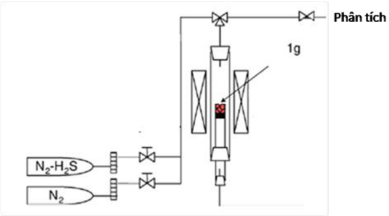


Figure 1: hydrogen sulfide test apparatus

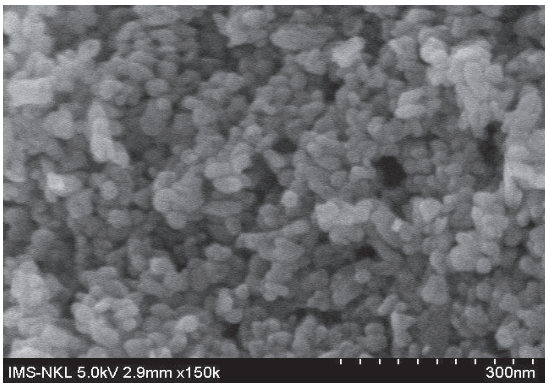
Research methods

Influence of ratios of Zn/Fe; Fe/kaolin; Zn, Fe/kaolin and calcinations temperature on H_2S sorbents.

Survey the influence of absorbed temperature, media bed, gas velocity, reaction time on hydrogen sulfide treatment efficiency.

RESULTS AND DISCUSSION

Result on material synthesis



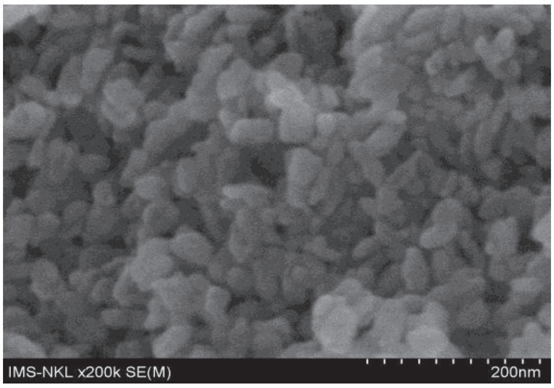


Image 1: SEM image of sample MC7 (BET: 31.3 m^2/g)

Image 2: SEM image of sample MC6 (BET: 37.2 m^2/g)

Sorbents (MC7 and MC6) were created at the optimum coditions in which ratios of Fe/kaolin; Zn/Fe, Fe and Zn/kaolin were 2.11; 0.40 and 2.38 respectivley and calcination temperature were 350^0C in 3 hours.

Influence of temperature on hydrogen sulfide treatment

Our result research showed that 350^0C is the most suitable for hydrogen sulfide treatment. The higher temperature could reduce the mass of sorbent then reducing the treatment efficiency. Its lower temperature could not be enough for the treatment process.

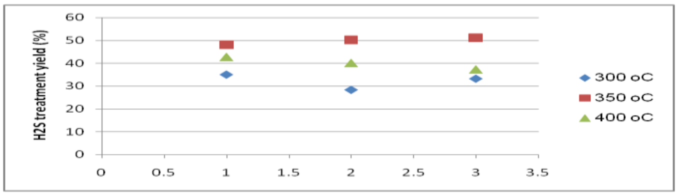


Figure 2: Influence of temperature on hydrogen sulfide treatment

Influence of media bed on hydrogen sulfide treatment yield

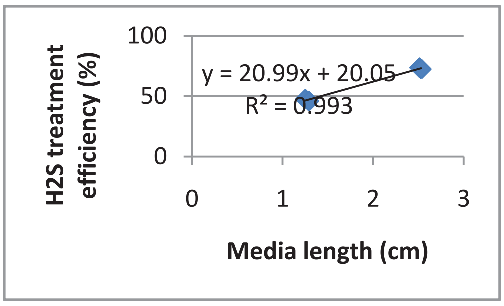


Figure 3: Influence of media bed on hydrogen sulfide treatment efficiency

A full bed with media length of 2.5cm had an average mass of approximately 1 g, and a half bed had approximately half of that mass. Figure 3 shows that the amount of H2S removed from the biogas was dependent on the mass and volume of sorbent present. The change in removal capacity in the half bed may have been due to a decrease in the contact time, and therefore, related to the adsorption reaction time.

Influence of gas velocity on hydrogen sulfide treatment efficiency

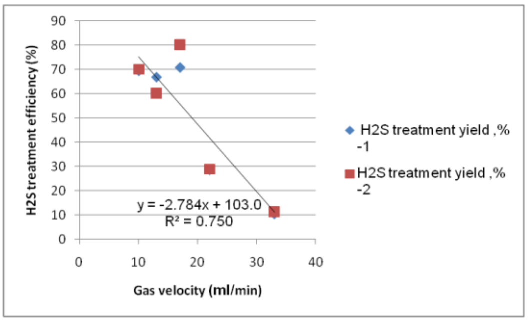


Figure 4: Influence of gas velocity on H2S treatment efficiency

Research showed that gas velocity influence on hydrogen sulfide treatment yield, as high velocity as lower treatment yields. The most suitable treatment velocity gas was 17 ml/min which has the highest hydrogen sulfide treatment yield of 78%.

Influence of absorbent time on hydrogen sulfide treatment efficiency

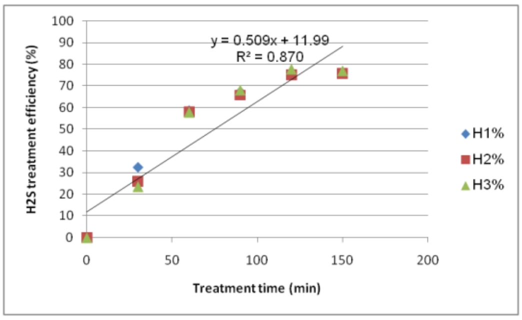


Figure 5: Influence of absorbent time on hydrogen sulfide treatment yield

Research showed that the longer reaction time was, the higher hydrogen sulfide treatment yield was but from 120 min to 150 min the treatment yield was not more changeable then 120 min was the best time for H2S treatment efficiency.

CONCLUSION

This research initially published the result on hydrogen sulfide treatment at the high temperature, research created 11 sorbents in which 2 sorbent (MC6, MC7) has the best structure with nano size from 5-20 nm and surface areas are 37.2 and 31.3 m^2/g. And after 2 hour of reaction, 2.5 cm of media bed, 17 ml/min of gas velocity at 350^0C.

ACKNOWLEDGEMENT

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Study of biogas production from organic municipal solid waste

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ABSTRACT

The biogas production yield from organic municipal solid waste impacted by anaerobic digestion has been studied. The co digestion of organic waste and cow dung was conducted during 30days at 35oC and S/I ratio of 2 based pre – examination. Semi continuous anaerobic digestion (AD) with mixing at mesophilic condition was conducted for organic waste having % TS from 13% - 22%. It showed that the sample of TS 13% had biogas production yield of 365,7ml/gVS, CH4 varied 53,12% - 61,52%, or obtained 224,98 mlCH4/gVS. Total solid removal efficiency was 53,40%, and 50,22% for volatile solid (VS) removal.

Keywords: Organic municipal solid waste OMSW, biogas, total solid (TS), volatile solid (VS)

1. INTRODUCTION

The MSW directly related to human activity and the generation rate was approximately 0,35-0,7 kg/head/day depended on living standard. The total municipal solid waste volume was about 42000 tones per day in the year 2015 [1] and caused pollution. However, organic solid waste (OW) was abundant biomass resource for anaerobic digestion (AD), especially for the alternative energy. This purposes, we conducted studies on investigation of biogas production from organic MSW at lab to get the baseline data on anaerobic digestion of organic municipal solid waste.

2. METHODS

Organic municipal solid waste was collected from 4 households during 1 week, cow dung and AD seed (inoculum) was taken from AD pilot Cat Que – Hoai Duc – Hanoi. 05 anaerobic digesters 2000ml (01: Bank sample, 01 sample organic municipal solid waste with TS 13% (RHC.TS15), 01 sample organic municipal solid waste with TS 15% (RHC.TS15) and 01 sample with TS 22% (RHC. TS22) and 01 sample vegetable waste rau.TS15%, working volume was 1500ml, condition of 35,0 ^{o}C ± 0,3^{o}C. Anaerobic digestion was connected to gas volume measurer and GC/FID. AD operation has been set up by putting 86ml inoculum, N2 was blew 2l/minute, OW was added and N2 was blew during next 5 minutes. Ratio off S/I (VS substrate / VS inoculum) was 2. pH, TS, VS measured by APHA methods, CO_2 by titration method and H_2S - ASTM 4084 – 94.

3. RESULTS

3.1. Daily methane production yield

Waste composition: The moisture of OW was 66,34%, total solid was 13%, volatile solid was 31,65%, total nitrogen T-N was 0,229%, total organic matter was 36,28%. Moisture of cow dung was 81,48%, TS was 18,52%, VS was 15,65%. Fig. 1 was presented daily biogas production yield. The volume was increased quickly, obtained maximum value at first week and reduced at the second and third week. Sample RHC.TS13% obtained highest volume of 313,5 ml Biogas/ gVS/day, higher than other samples.

Sample of vegetable waste Rau.TS15% was reached 231,73 mlCH_4/gVS due to high CH_4 concentration compared to RHC.TS13%.

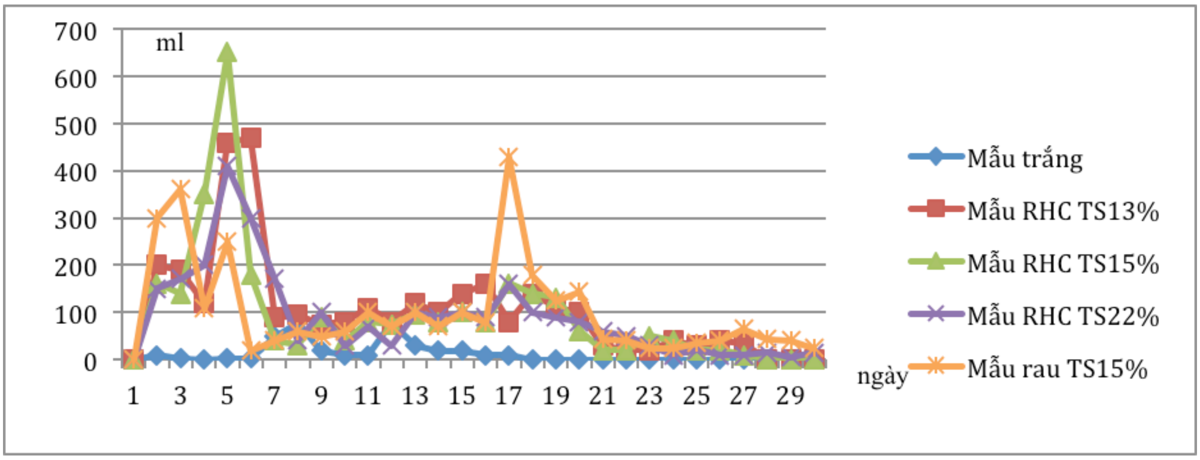

Fig 1: Biogas production yield of studied samples (ml Biogas/ gVS/day)

Table 1: Biogas production yield (ml Biogas/ gVS)

Sample	**Blank**	**RHC.TS13%**	**RHC.TS15%**	**RHC.TS22%**	**Rau.TS15%**
%CH_4	15.56%	61,52%	55,86%	53,20%	62.52%
Yield (mlCH_4/gVS)	-	**224,98**	186,35	167,85	**231,73**

3.2.Total solid and volatile solid in anaerobic digesters.

Total solid removal percentage was higher and efficiently by anaerobic digestion process with sample Rau TS15% achieved 59,94%, sample RHC.TS13% of 53,40% and was less efficiently with sample RHC.TS22% of 39,41% due to its high organic loading. Fig 4 was presented CO_2 percentage of biogas from digested samples, the maximum percentage of CO_2 obtained at 4th days and reduced at the following days until the 16th day and reached the lowest value. After that, percentage of CO2 was increased from 20th day to 30th day. Sample Rau.TS15% had percentage CO_2 was 37,39% higher than sample RHC.TS13% of 38,29%, or sample RHC.TS15% was 43,86% and RHC.TS22% was 50,62%. Fig 5 was presented sample Rau.TS15% having percentage of CH_4 was maximized at 12th day to 16th day varied from 57,78% - 62,52%. RHC.TS13% was obtained CH_4 percentage of 61,52%. The percentage of total solid TS% was 13% provided good condition for the anaerobic digestion, produced flammable gas with good flare.

Table 2: Total solid removal of AD system

Sample	Blank	RHC TS13%	RHC TS15%	RHC TS22%	Rau TS15%

Removal TS%	37,98	53,40	46,14	39,41	59,94
Removal VS%	35,14	50,22	44,94	38,04	55,54

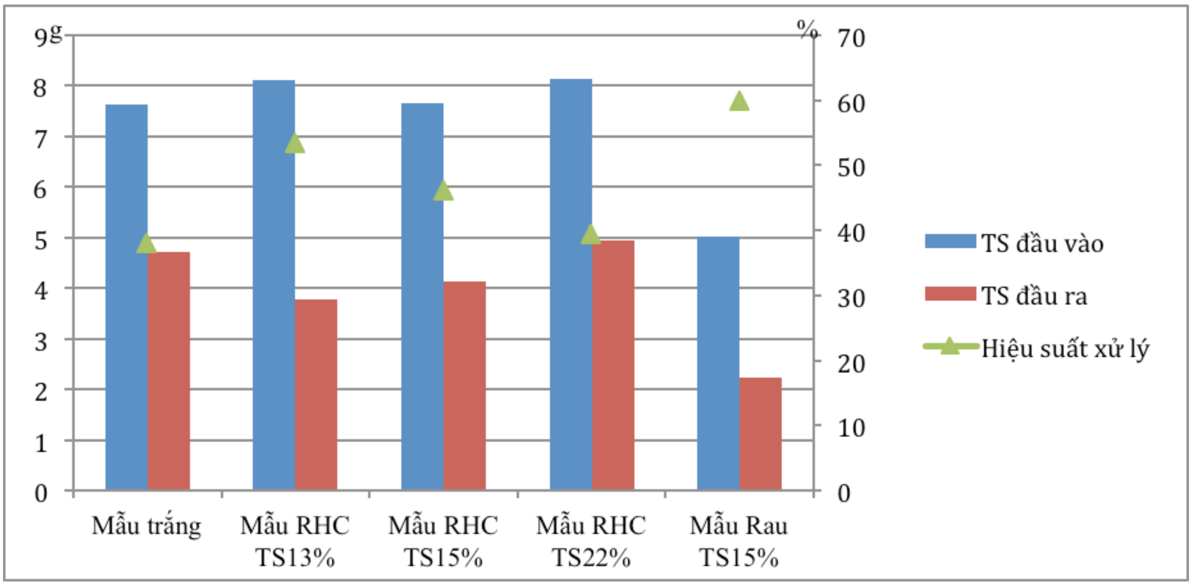

Fig 2: TS removal

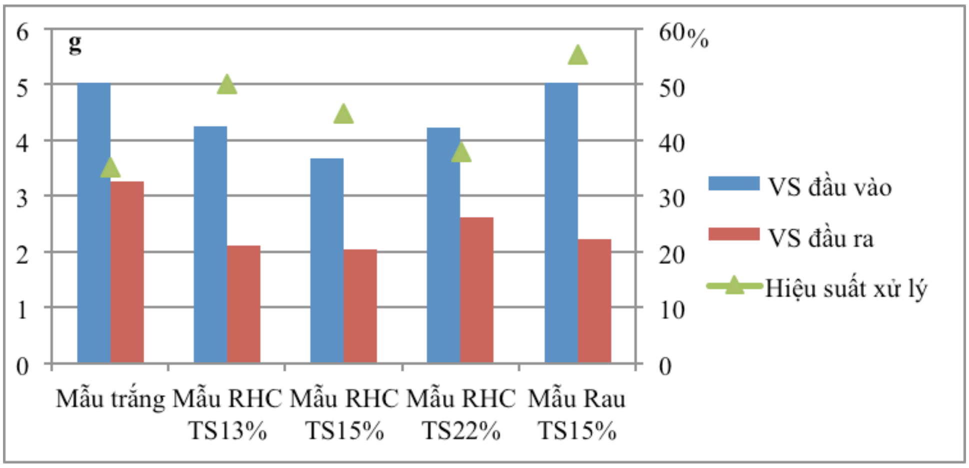

Fig 3: VS removal

3.3. CO_2

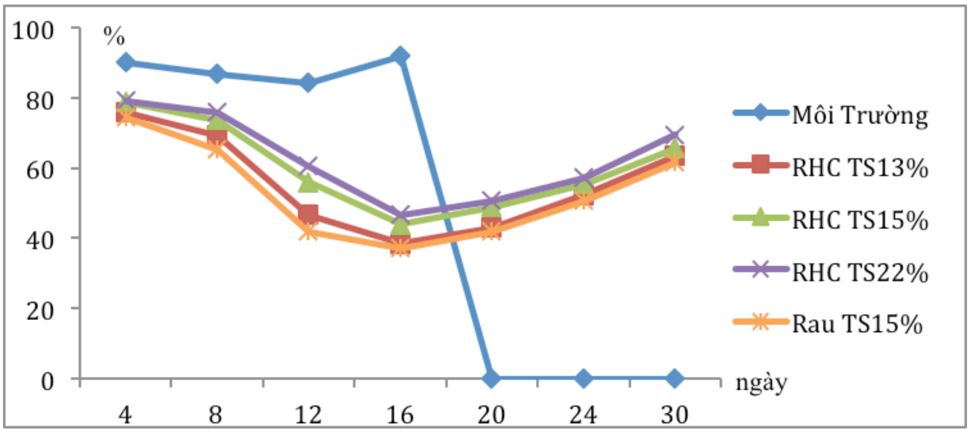

Fig 4: *CO_2 (%) in biogas samples*

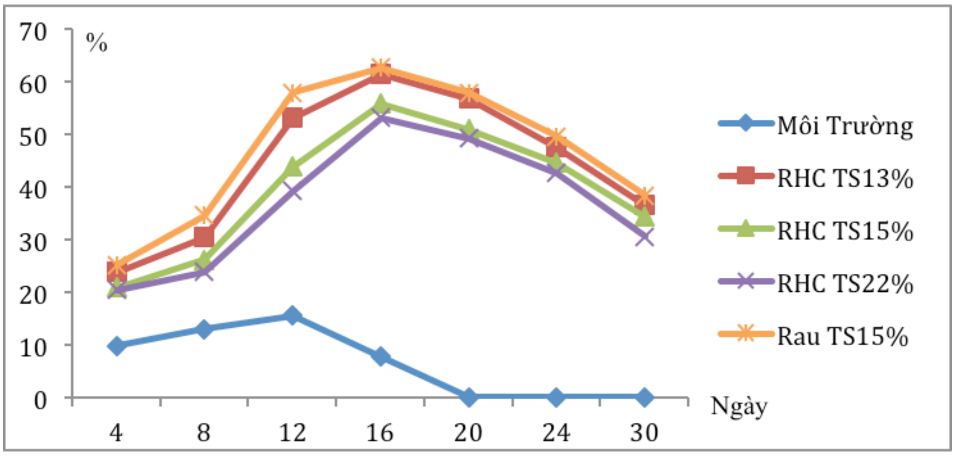

Fig 5: *CH_4 (%) in biogas*

4. CONCLUSION

Organic municipal solid waste could generate good quality biogas in wet anaerobic co digestion system of total solid content of 13%. After 30 days examination, the results showed that the methane production yield of sample RHC.TS13% was obtained 224,98 mlCH_4/gVS higher than other samples. The percentage of CH_4 was 53,12% to 61,52%, created good flammable.

ACKNOWLEDGEMENT

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Semi-continuous Co-digestion of Waste Activated Sludge with Algal Biomass Residue from Bioethanol

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ABSTRACT

In this study the biogas production from anaerobic co-digestion of organic wastes such as algal biomass residue from bioethanol production (algal biomass residue) and waste activated sludge (WAS) was carried out in order to evaluate biogas production characteristics and microbial communities. The semi-continuous anaerobic digesters were operated three kinds of substrates which were fed with activated sludge as control, raw alga and algal biomass residue mixed waste activated sludge the range of 0.75 ~ 1.25 kg VS/m3 day of Organic loading rate (OLR). All kinds of substrates reactors were stably operated as indicated pH, alkalinity and biogas production until 84 days (HRT: 10 days, OLR: 1kg VS/m3 day). However, pH, alkalinity and biogas production were decreased after 120 days in all of anaerobic reactors. Because the organic acids increased, the organic loading rate increased as 1.25 kg VS/m3 day and the HRT was decreased as 8 days. Evident influence was exhibited at 1.25 kg VS/m3 day and HRT 8 days, which led to slight accumulation of total volatile fatty acids and pH decreasing. When the samples were collected to evaluate the microbial community at the stable operating conditions, which substrates were analyzed according to their DGGE. All bands were affiliated with order *Clostridiales* whose members are frequently found in anaerobic digestion process.

Keywords: Semi-continuous co-digestion, Waste activated sludge, Algal biomass residue, Microbial community.

INTRODUCTION

Anaerobic digestion has been recognized as an efficient technology for treatment of sewage sludge. It has several advantages such as sludge stabilization, sludge volume reduction, and energy production. Especially, biogas production during the anaerobic digestion could be used as renewable energy resource, while at the same time producing biogas that can supply between 40 – 60% of the energy required to run a waste water treatment plant (Silvestre G., Rodrigez-Abalde A. et al., 2011). Different strategies have been proposed to improve biogas production of sewage sludge in anaerobic digestion. One of the strategies is the co-digestion of sewage sludge with other organic matter. Anaerobic co-digestion of sewage sludge and other organic wastes could enhance biogas production and organic matter degradation due to benefits such as diluted inhibitory compounds and a more balanced carbon to nitrogen ration (Labatutet R., Angenent L. et al., 2011).

Various researchers have reported increased biogas production during the co-digestion of sewage sludge with different organic wastes (Silvestre G., Rodrigez-Abalde A. et al., 2011; Serrano A., Siles J. et al., 2014).

The aim of this work was to evaluate the characteristics of semi-continuous co-digestion of WAS with algal biomass and algal biomass residue.

MATERIALS AND METHODS

Semi-continuous co-digestion

Waste activated sludge (WAS) and anaerobic digested sludge (as seed) were collected from the Chungnang municipal wastewater treatment plant in Seoul, Korea. The filamentous alga, *H. reticulatum* and algal biomass residue from bioethanol production (algal biomass residue) were supplied by the Korea Research Institute of Chemical Technology, Daejeon, Korea. Three laboratory-scale continuously stirred tank reactors were operated. The feeding of substrate and discharge of digested sludge were manually conducted every weekday except for holidays. First reactor was only fed with WAS as control reactor to evaluate the biogas converstion of WAS and to compare the performance with second one and third one. All of reactors were operated under mesophilic condition. R_2 and R_3 were fed a mixture of raw *H. reticulatum* and WAS, algal biomass residue and WAS. The mixing ratio of WAS to raw *H. reticulatum* and algal biomass residue was 1:1 on a VS basis, and adjusted 1% VS.

Microbial DNA extraction

The samples of semi-continuous reactors were gathered at the end of first period (85 day) to evaluate microbial communities at the stable operation.

Bactrial and archaeal communities were analyzed via PCR-DGGE using the primer set BAC338F/805R and ARC787F/1059R, respectively, with a GC-clamp as previously described (Kim J., Kim W. et al., 2013). DGGE was conducted at 60 ^{o}C in 1X TAE buffer at 75 V for 13 h on a Dcode system (BioRad Laboratories, CA) on a 8% polyacrylamide gel with 30-60% (M/V) gradient of urea-formamide denaturant. Gels were stained with ethidium bromide and visualized under UV transillumination. Specific gel bands were excised with a sterilized scalpel. Upon confirmation of the excisions as single bands via a secondary DGGE run, the bands were re-amplified, purified with QIAEX II (Qiagen, CA), and sequenced (ABI3730XL DNA analyzer, Applied Biosystems, CA). Sequences were aligned using MEGA 4.0 and analyzed using BLAST.

RESULTS AND DISCUSSION

Semi-continuous reaction of waste activated sludge with raw H. reticulatum and algal biomass residue from bioethanol

Semi-continuously fed anaerobic digestor, laboratory-scale digester at 35 ^{o}C, particulary the effect of hydraulic retention time (HRT) and organic loading rate (OLR) on process performance. The reactor performance in the semi-continuous experiments is summarized in Figure 1.

Figure 1 show the performance data of R_1, R_2 and R_3, which were fed with waste activated sludge as control and raw alga and algal biomass residue from bioethanol production mixed with waste activated sludge the range 0.75 ~ 1.25 kg VS/m^3 day of OLR. In the first 37 days, each reactor was operated at an OLR of 0.75 kg VS/m^3 d, which indicated stable operation at low OLR and high HRT. As OLR increasing to 1 kg VS/m^3 d, biogas production of each reactor showed increasing trend.

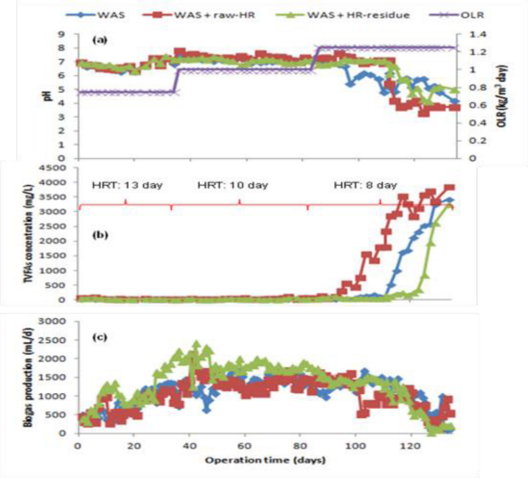

Figure 1 Variation in the pH, volatile fatty acids and biogas production with the different OLR and HRT on semi-continuous reaction

All of reactors (R_1, R_2 and R_3) were stably operated as indicated by pH, alkalinity and biogas production until 84 days (HRT: 10 days and OLR: 1 kg VS/m^3 day). The average biogas production on OLR of 0.75 kg VS/m^3 day and 13 days HRT were 768 ± 323, 706 ± 291 and 1026 ± 388 mL/day on the R_1, R_2 and R_3, respectively. At the OLR of 1 kg VS/m^3 day and 10 days HRT, The average biogas production were 1351 ± 211, 1330 ± 238 and 1853 ± 207 mL/day on the R_1, R_2 and R_3, respectively. Especially, waste activated sludge and algal biomass residue mixed substrate was highest biogas production.

The accumulation of organic acids can lead to the deterioration of anaerobic digestion (Wang et al., 2014). In all of reactors, pH, alkalinity and biogas production were decreased after 120 days of anaerobic digestion reaction. Because the organic acid increased, the organic loading increased as 1.25 kg VS/m^3 day and the HRT was decreased as 8 days. Evident influence was exhibited at 1.25 kg VS/m^3 d and HRT 8 days, which led to slight accumulation of total volatile fatty acids (TVFAs) and pH (a) decreasing. Significant inhibition occurred with accumulation of TVFAs (b), leading to decrease pH, alkalinity and dramatic drop of biogas production on all of reactors.

Microbial community

Archeal and bacterial communities in semi-continous anaerobic digesters treating the three kinds of substrates were analyzed according to their DGGE results (Figure 2).

Among the various bands, from A to P were detected in all samples and were affiliated with the order *Clostridiales* whose members are frequently found in anaerobic digestion processes. Metabolically, *Clostridiales* is a highly versatile group capable of producing lipase and degrading long-chain fatty acids (Vos P., Garrity G. et al., 2009). *Clostridium ultunense* which produces acetate as its main fermentation product is syntrophically associated with a hydrogenotrophic methanogenic bacterium.

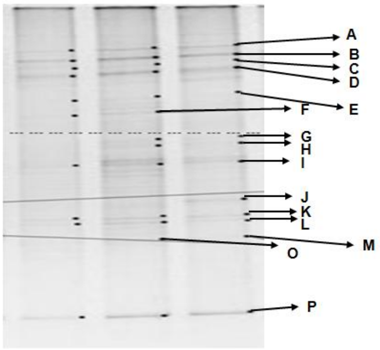

Figure 2 Analysis of microbial profiles analyzed from raw *H. reticulatum*, only WAS and algal biomass residue mixed samples on semi-continuous anaerobic digester

CONCLUSION

The aim of this work was to evaluate the characteristics of semi-continuous co-digestion of WAS with algal biomass and algal biomass residue.

At the all of semi-continuous reactors, the pH and biogas production were decreased after 120 days of anaerobic digestion. Because of the volatile fatty acids increased, the organic loading rate increased as 1.25 kg VS/m^3 day and the HRT 8 days.

Archeal and bacterial communities in semi-continuous anaerobic digestors treating the three kinds of substrates were analyzed according to their DGGE results. All bands were affiliated with order *Clostridiales* whose members are frequently found in anaerobic digestion process.

ACKNOWLEDGEMENT

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Properties of Biochar from Hydrothermal Carbonization of Exhausted Coffee Residue

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ABSTRACT

Due to global energy shortage problem is the rise, the need for renewable energy is increasing. More than 80% of the renewable energy sources have been produced through the waste and biomass.

Accordingly, the aim of this study was to produce renewable energy from a variety of biomass. Therefore, I consider the biomass was exhausted coffee residue. As coffee preference continuously increased, an import coffee bean is increasing sharply. But the amount of coffee that has been used to drink is only about 0.2% of coffee beans and the rest is discarded in the form of exhausted coffee residue. To reuse a large amount of exhausted coffee residue, I used exhausted coffee residue as a biomass. Hydrothermal carbonization is a method of producing an improved fuel by SRF changing the physical and chemical properties in the sample. Biochar was obtained from a variety of reaction temperature conditions during hydrothermal carbonization and analyzed via elemental analysis, industrial analysis, heating value measurement.

Keywords: biomass, biochar, exhausted coffee residue, hyrothermal carbonization, fuel property

INTRODUCTION

The fossil fuel depletion and global warming have become serious problems in the world (Ishigaki T., Yamada M. et al., 2005; José G. and Coelho S.T., 2004). In order to solve these problems, renewable energy from biomass and organic waste has attracted much attention (McKendry P., 2002; Peng W., Wu Q. et al., 2001). Accordingly, the renewable energy from a variety of biomass was focused on an energy resource. Therefore, I consider the biomass was exhausted coffee residue. As coffee preference continuously increased, an import coffee bean is increasing sharply in Korea. However, the amount of coffee that has been used to drink is only about 0.2% of coffee beans and the rest is discarded in the form of exhausted coffee residue. To reuse a large amount of exhausted coffee residue, I considered on reduction and recycling exhausted coffee residue as a biomass.

In this study, the method of the hydrothermal carbonization is used to recover energy from waste biomass as exhausted coffee residue. The hydrothermal treatment process, among the thermo-chemical methods for the conversion of biomass has been under consideration mainly for producing liquid (bio-oil), solid (biochar), and/or gaseous (mainly carbon dioxide) fuels (Daegi K., Pandji P. et al., 2012). This process has generated widespread interest in recent years. Hydrothermal carbonization (HTC) comprises the use of a combination of a high temperature with high-pressure water (subcritical water) that prompted the highest potential among the various short-term methods available for using biomass as an energy source.

Hydrothermal carbonization is a feasible sustainable energy conversion technology for the disposal of biomass. The experiments were conducted at 180°C up to 330°C for 30min holding period. For achieving waste-to-energy, the biochars from exhausted coffee residue as the biomass were conducted. The results of the analysis, it was confirmed that biochar improved fuel nature than raw biomass and the characteristics of biochar was similar with that of the lignite. In addition, the calorific value of biochar increased as the reaction temperature increases so the energy density is raised.

MATERIALS AND METHODS

Materials

A sample of exhausted coffee residue was collected from cafeteria of Konkuk University. The characteristic of exhausted coffee residue showed in Table 1.

Table 1 Characteristics of exhausted coffee residue

	Moisture content (%)	Proximate Analysis (on dry basis, %)				Elemental Analysis (on dry basis, %)				
		Fixed carbon	Volatile matter	Ash	Calorific value (MJ/Kg)	C	H	O	N	S
Exhausted Coffee Residue	56	23.6	74.9	1.5	21.8	48.9	7.9	40.2	1.5	0

Hydrothermal carbonization process

Hydrothermal reactor was used to investigate the effects of HTC on improving fuel properties of the exhausted coffee residue. Experiments were performed using a 1L autoclave reactor consisting of a reactor body, a heater, and a steam condenser which was operated under N_2 gas. A 250g of sample was mixed with an equal amount (250mL) of water and loaded into the reactor. The operating temperatures and pressures ranged from 180°C to 330°C and the reaction time was 30 min in the presence of subcritical water. The components within the reactor were vigorously mixed using an agitator rotating at 200 rpm.

Analytical procedures

The materials and the solid products were evaluated using a PerkinElmer 2400 Series II CHN organic elemental analyzer (PerkinElmer, Waltham, MA, USA) to determine the weight percentage of chemical elements. Proximate analysis used to determine the weight percentage of volatile matter, fixed carbon, and ash were conducted using a SHIMADZU D-50 simultaneous TGA/DTA analyzer. Heating values were determined using IKA Calorimeter System C 5000 according to calorimetric standard method of EPA-Method 5050.

RESULTS AND DISCUSSION

Improvement of fuel properties

The properties of the exhausted coffee residue were improved by HTC with increase of reaction temperature. The chemical properties of the surrogate MSW changed by the hydrothermal treatment. The raw material had high volatile matter content as 68.6 % and oxygen content as 41.6 % similar with normal biomass characteristics. After conduction the HTC, the volatile matter and the oxygen content decreased while the fixed carbon content increased from 23.6 % to 33.9% at 210°C and 48.2% at 300°C. While, volatile matter of the products decreased as the reaction temperature increased with amount of volatile matter being reduced due to chemical dehydration and decarboxylation reactions(Daegi K., Pandji P. et al., 2012; McKendry P., 2002; Daegi, K., Yoshikawa, K. et al., 2015). As a result, an increase of fixed carbon (FC) was obtained by the hydrothermal carbonization reactions. The calorific value of exhausted coffee residue also was improved after HTC as shown in Figure 1. The calorific values of exhausted coffee residue increase from 21.8 MJ/kg to 26.5 MJ/kg at 210°C and 17.2 MJ/kg at 300°C.

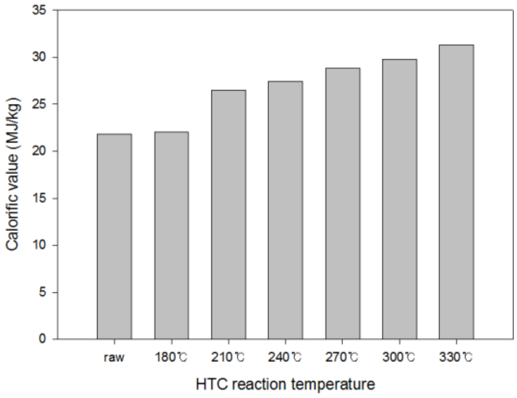

Figure 1 Improving calorific values of biochar by HTC with increase temperature

Improvement of fuel properties Coalification of sludge products

The van Krevelen diagram confirms that the coalification reaction of HTC has a significant effect on the elemental composition of the products. As shown in Figure 2, the atomic H/C and O/C ratios decreased, as the reaction temperature is increased from 180°C to 330°C. The reduced H/C and O/C atomic ratio confirms the significant effect of HTC in upgrading reaction pathways due to dehydration and decarboxylation reactions. The products were improved to become sub-bituminous coal properties as increase of reaction temperature. These results suggest that the hydrothermal treatment can improve the properties of biochar from exhausted coffee residue such that are close to those of coal.

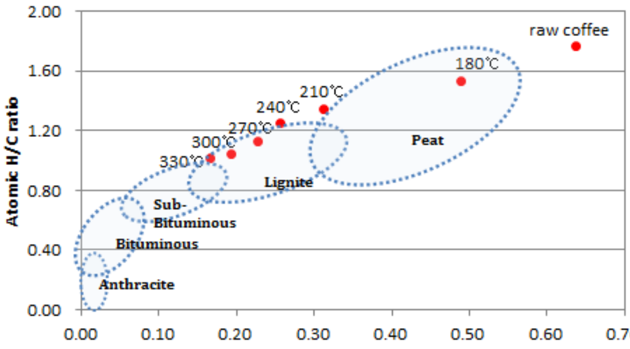

Figure 2 The van Krevelen diagram of biochar by HTC

CONCLUSION

Hydrothermal carbonization was used to convert the waste biomass as exhausted coffee residue into an alternative solid fuel with high energy efficiency. To investigate the effects of reaction temperature on the fuel properties of the biochar by HTC, and the reaction temperatures were varied in the range from 180 °C to 330 °C. After HTC was completed, the biochars exhibited significant increase in carbon content and fixed carbon content with respect to the calorific values due to dehydration and decarboxylation reactions.

Therefore, after HTC, the atomic H/C and O/C ratios decreased which can be referred to as coalification. The treated products should be upgraded sold fuel with the coalification between lignite and sub-bituminous coal.

ACKNOWLEDGEMENT

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Poster Program 2

A Study on the Drying Characteristics of the Carbonation Product from the Slurry of Waste CMB Catalyst

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ABSTRACT

The waste Co-Mn-Br (CMB) catalyst can be used as high-value cobalt resources through a carbonation product from the slurry of waste CMB catalyst. Cobalt can be recovered from the waste catalyst by solvent extraction or supercritical fluid extraction. Since the waste CMB catalyst has large moisture contents, and a drying process is essential prior to the cobalt collection process. In this study, fundamental properties of the waste CMB catalyst are investigated by proximate and elemental analysis. The drying characteristics are also compared at various temperature conditions. From the proximate analysis, the waste CMB catalyst contains 65.9 wt% water content, 6.76 wt% volatile, and 28.4 wt% ash. Drying characteristics are investigated by the moisture evaporation rate using a moisture analyzer balance at the temperatures of 100°C, 120°C, 140°C, 160°C, 180°C, and 200°C. It was found that the evaporation rate increases almost linearly with drying temperature.

Keywords: waste CMB catalyst, carbonation product, drying process

INTRODUCTION

Cobalt catalyst is widely used for the production of TPA (terephthalic acid) which is a raw material for polyester fiber, PET (polyethylene terephthalate) bottle, film, paint, and tire cord, etc. TPA is produced from the oxidation of para-xylene in Co-Mn-Br (CMB) catalyst conditions. CMB catalysts which are used for TPA production are disposed in the form of cake. The waste CMB catalyst in Korea contains about 132 tons of cobalt, thus a sustainable supply of high-value cobalt resources is possible when the waste CMB catalyst is properly treated. The metal can be recovered from the waste by solvent extraction or supercritical fluid extraction (Zhu, Z., Zhang, W. et al. 2012; Joo and Shin, 2015). The carbonation product from the slurry of waste CMB catalyst for collecting cobalt contains a large amount of moisture, therefore drying process is essential before the main cobalt collection process. In the present study, fundamental properties of the carbonation product from the slurry of waste CMB catalyst are investigated together with its drying characteristics, which could be used for the development of an efficient drying process.

MATERIALS AND METHODS

Carbonation product from the slurry of waste CMB catalyst

The carbonation product from the slurry of waste CMB catalyst (waste CMB hereafter) is received from a chemical processing company in Korea. The received waste CMB sample is shown in Fig. 1.

Figure 1 Waste CMB sample

Proximate analysis of waste CMB was carried out by thermo-gravimetric analysis (TGA) using a TGA 701 LECO in accordance with ASTM D5142. The sample material was put into a ceramic crucible in the TGA instrument, and the sample was heated be nitrogen gas from 30°C to 950°C at a heating rate of 5°C/min. The elemental analysis of the sample was performed using a Flash EA 1112 series elemental analyzer in accordance with ASTM D3176. Table 1 shows the results of proximate analysis of waste CMB in wet basis. It was found that the water content, volatile, and ash are 65.88 wt%, 6.76 wt%, and 28.41 wt%, respectively.

Table 1 Proximate analysis of waste CMB (dry basis)

Water content [wt%]	Volatile [wt%]	Ash [wt%]	Fixed carbon [wt%]
65.88	6.76	28.41	-

Table 2 shows the results of elemental analysis of waste CMB in dry basis. The carbon, hydrogen, and oxygen contents are measured to be 8.66 wt%, 0.82 wt%, and 9.75 wt%, respectively. We note that the organic compounds in waste CMB can obstruct electroextraction process and can reduce the cobalt recovery, thus the removal of the organic compounds is also important in the cobalt collection process.

Table 2 Elemental analysis of waste CMB (wet basis)

C (wt%)	H (wt%)	O[a] (wt%)	N (wt%)	S (wt%)
8.66	0.82	9.75	0	0

Experimental methods

The moisture evaporation rate of waste CMB was measured by a moisture analyzer balance (AND ML-50). It employs a heating method where moisture content is rendered by the weight of water evaporated from the samples after heating the sample for a period of time (Bradley, 2003). Weight loss ratchets up as samples get heated and finally converge on a certain value, and the moisture content is determined by that weight loss. The moisture analyzer balance utilizes halogen lamp as heating source to heat sample on an electric balance that weights the sample before and after the heating to determine the moisture loss. Thus the moisture evaporating rate can be also determined as a function of time together with the total moisture content of the sample.

RESULTS AND DISCUSSION

Moisture evaporating rate

The moisture evaporating rates were measured at various temperatures of 100°C, 120°C, 140°C, 160°C, 180°C, and 200°C. The initial mass of the sample on the balance was kept consistent at 5g for all temperature cases. The ratio of the evaporated moisture to the initial sample mass is calculated as follows:

$$\text{Evaporation }(\%) = \frac{m_{init} - m_t}{m_{init}} \times 100$$

Here, m_{init} and m_t denote the initial weight (5g) and the intermediate weight during evaporation, respectively. Since m_t decreases during evaporation, the value of $\text{Evaporation }(\%)$ increases with time and its final value becomes the total moisture content of the sample. The evaporating rates at various drying temperatures are compared in Fig. 2.

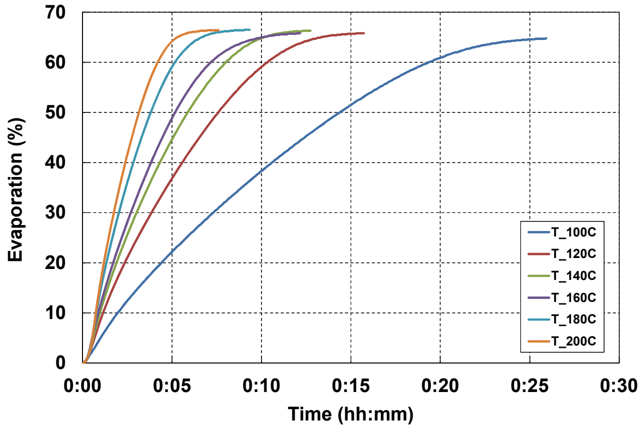

Figure 2 Moisture evaporation with time at various drying temperatures

The final values of evaporation ratios at various drying temperatures are averaged to be 65.9 wt%, which is identical to the result of proximate analysis (65.88 wt%) in Table 1. Although the moisture evaporations at all temperature cases ultimately reach almost same values, the evaporating rate with time varies for different drying temperatures. It was found that the moisture evaporates faster at higher drying temperature. To compare the evaporating rate with time quantitatively, the average evaporating rates (g/s) were calculated by the ratio of the weight of evaporated moisture (g) to the total evaporation time (s).

$$\text{Average evaporation rate }(g/s) = \frac{Weight\ of\ evaporated\ water\ (g)}{Total\ evaporation\ time\ (s)}$$

But in this method, the calculation includes the initial stage of drying where the moisture evaporates very quickly and the final stage where the rate of evaporation becomes quite smaller with time. Thus the average evaporation rate is also determined in the range where Evaporation (%) is between 5% and 60% in Fig. 2, which could be more reasonable. Figure 3 shows the evaporation rates with drying temperature using both methods. It was found that the average evaporation rate increases almost linearly with drying temperature.

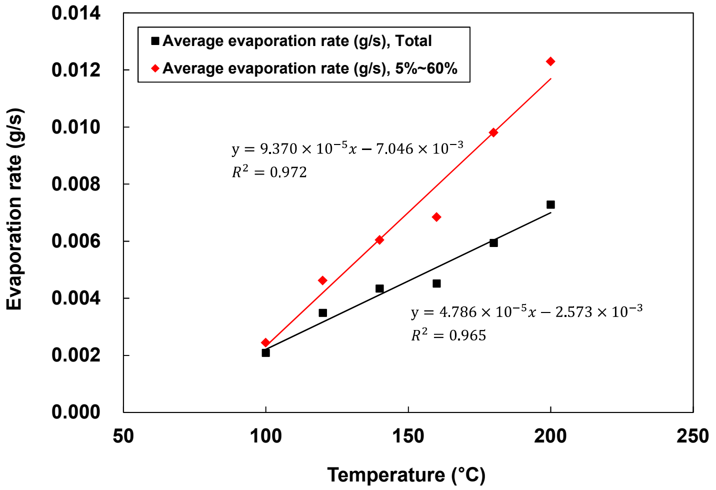

Figure 3 Average evaporation rate as a function of drying temperature

CONCLUSION

The fundamental properties of carbonation product from the slurry of waste CMB catalyst were investigated by proximate analysis and elemental analysis. The moisture content of waste CMB was found to be 65.9 wt%. The drying characteristics were studied at various drying temperatures using a moisture analyzer balance. The moisture evaporating rates are compared by calculating the ratio of the weight of evaporated moisture to the evaporation time, and it was found that the average evaporation rate increases almost linearly with temperature. The results in the present study could be used in developing an efficient drying process of waste CMB catalyst.

ACKNOWLEDGEMENT

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Cyanide uptake tested by raw and iron-doped zeolite

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ABSTRACT

Production of cyanide containing wastewater from mining industry has been increasing since the introduction of cyanidation for gold and silver recovery. Raw and synthetic zeolite modified by iron doping were used as adsorbents for simple cyanide removal to study the effectiveness of iron-doped zeolite for cyanide adsorption process. The structure of zeolite was examined by SEM observation and cyanide uptake experiments were conducted by batch technique at room temperature with concern on the contact time between cyanide and zeolite at fix adsorbent dose and agitation speed. The results showed that iron-doped zeolite increased the cyanide removal within shorten time for all initial cyanide concentration which were used in the present study.

Keywords: cyanide uptake, zeolite, iron-doping, contact time, adsorption

INTRODUCTION

Cyanide is a chemical compound that has been commonly used in several industrial processes as well as gold and silver recovery. The use of gold cyanidation, which was established as MacArthur-Forrest process in 1887, has been applied as the main and most economic technique for gold extraction due to the high effectiveness of cyanide as the leaching agents (Eisele J.A., Hunt A.H. et al., 1988). However, the prospect of using cyanidation technique for extracting gold from the ores is in doubt owing to potential great risk of cyanide toxicity to the environment (Laitos, 2013).

Several options for removing cyanide from effluents in gold mining have been proposed based on chemical, physical, biological, and adsorption techniques (Kuyucak and Akcil, 2013). Adsorption process has received more interests for cyanide removal since there are many candidate materials that could be potentially developed as adsorbent for eliminating cyanide. Researchers have investigated some adsorbent materials including plain and iron impregnated activated carbon (Depci, 2012), modified natural zeolite (Noroozifar, M., Khorasani-Motlagh, M. et al, 2009), ion-exchange resin (Torre, M., Bachiller, D. et al, 2006), and bioadsorbent material (Dwivedi, N., Balomajumder, C. et al, 2014).

Despite the cyanide adsorption by activated carbon has been largely practiced in most mining industries, the method still has some lacks especially on the recovery of cyanide and the low degree of carbon regeneration during the process which led to high operating costs (Sagar, S.D.V., Singh, D.P. et al, 2004). On the other hand, ion-exchange material, such as synthetic zeolite, has been proved to overcome the cyanide recovery problem (Bachiller, D., Torre, M. et al, 2004) because synthetic zeolite has high volume of empty spaces, is possible to be regenerated, and has good flexibility to be modified with metal, especially iron which has high affinity with cyanide. Iron-zeolite likely to have more potential to be implemented for removal of cyanide from the waste effluents. Therefore, this study aims to investigate and evaluate the effectiveness of iron-zeolite for cyanide removal compared with raw synthetic zeolite.

MATERIALS AND METHODS

Iron doping

ZSM-5 synthetic zeolite (purchased from Zeolyst International) with SiO_2/Al_2O_3 ratio of 23 and surface area of 425 m^2/g was used as raw material. Iron-doped zeolite was prepared by modifying raw zeolite with 300 ml of aqueous solution containing 18 g $FeCl_2.4H_2O$ (supplied by Wako Chemicals) and agitated for 24 h at 40 ^oC. Then, the suspension was filtered and the solid part was calcined in a muffle oven at 500 ^oC for 6 h in the presence of air.

SEM observation

SEM observation was conducted using Analytical Scanning Electron Microscope JEOL JSM-6610LA to study the surface and structure of raw and iron-doped zeolite.

Cyanide uptake experiment

Cyanide solutions with three different initial concentration (50, 100, and 200 mg/l) were prepared prior to conduct cyanide uptake experiment. In this study, simple cyanide solution was made by adding certain amount of sodium cyanide (NaCN) in 100 ml of ultra-pure water in the presence of sodium hydroxide (NaOH) to keep the pH in between 10.5 - 11. The adsorbent dose used for all experiments was fixed at 10 g/l. Experiments were carried out by batch technique at room temperature with agitation speed of 200 rpm in 250 ml Erlenmeyer flask. The cyanide adsorption was investigated for 72 h. Effectiveness of raw and iron-doped zeolite for cyanide removal was compared by calculating the measured carbon and nitrogen content before and after treatment using TOC/TN analyzer (TOC-L, Shimadzu Co.).

RESULTS AND DISCUSSION

SEM Observation

Figure 1 shows the SEM images of raw and modified ‘iron-doped’ zeolite. As observed in figure 1, no significant difference on the morphology of raw and iron-doped zeolite was found since there was no chemical etching applied. Calcination process that was done to the zeolite worked to increase the porosity by

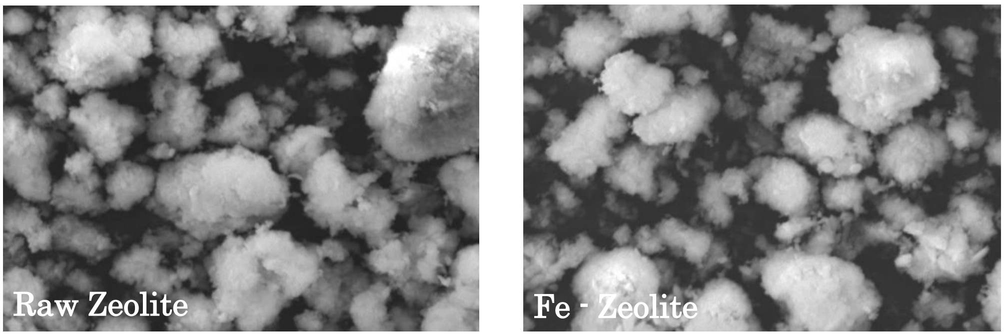

Figure 1 SEM images of Raw (left) and Iron-doped Zeolite (right) at magnification of 4000X

evaporation of H_2O trapped inside the pores. The active site of iron-zeolite was obtained after thermal decomposition during the calcination. The uniform spherical structure of both raw and iron-zeolite confirmed high surface areas which was good for adsorption selectivity (Tao, Y., Kanoh, H. et al, 2006).

Cyanide uptake by raw and iron-doped zeolite

The ability to perform ion-exchange and high volume of porous structure were considered as the basic important criteria of zeolite in adsorbing cyanide compounds as well as providing iron ions-exchange. As depicted in figure 2, cyanide removal reached almost 100% for all initial cyanide concentration even on raw zeolite after 24 h contacting time. The cyanide uptake on the zeolite surface is related with anion adsorption theory through complexation mechanism (Kuyucak and Akcil, 2013).

While in figure 3, the data obtained showed that the existence of Fe ions in the zeolite could increase removal percentage of cyanide more than 20% from less than 50% up to 80% within 6 h of contact time. This result was supported by the evidence at pH value around 10.5, cyanide compounds could be eliminated by iron-cyanide bonding to form iron cyanide complexes, $[Fe(CN)_6]^{3-}$ or $[Fe(CN)_6]^{4-}$ which are more stable than free cyanide (Noroozifar, M., Khorasani-Motlagh, M. et al, 2009). Thus, modifying zeolite with iron has been proved in upgrading synthetic zeolite as adsorbent material for cyanide removal effectively.

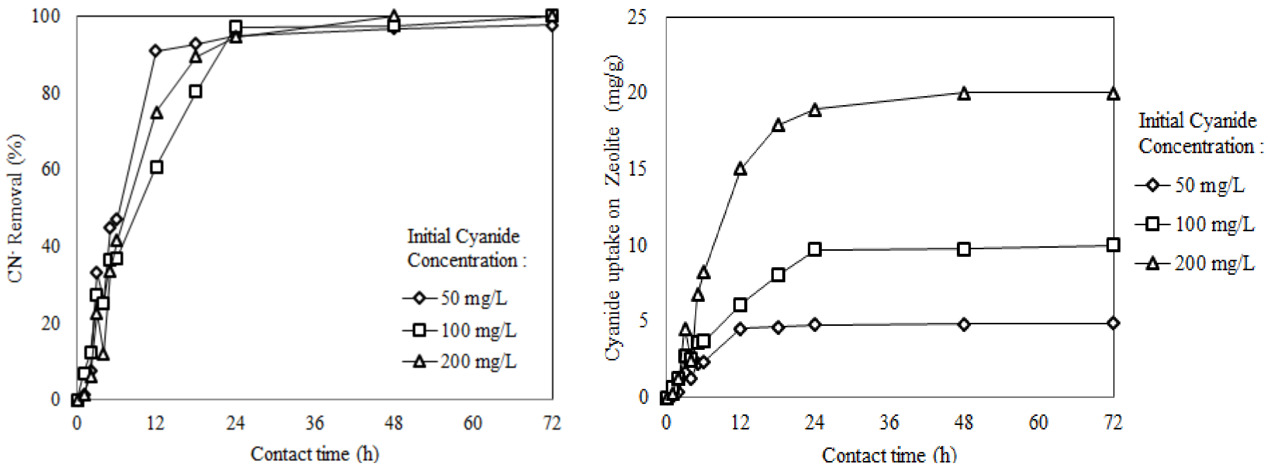

Figure 2 Effect of contact time on cyanide removal and uptake on raw zeolite

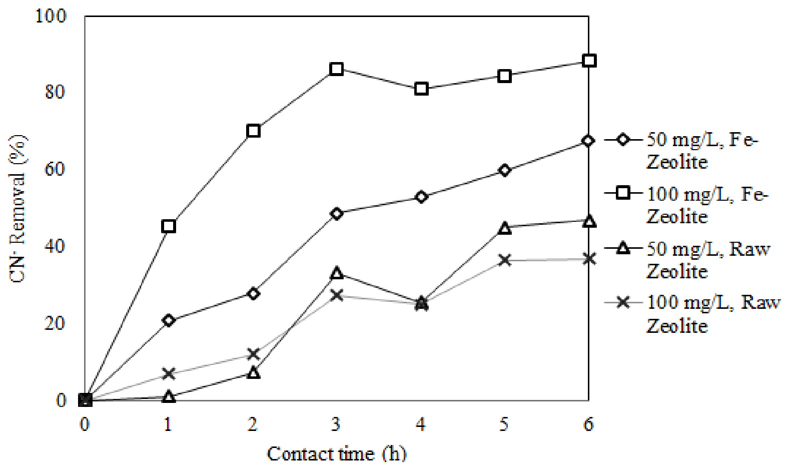

Figure 3 Cyanide uptake on raw and iron-zeolite within several different contact times

CONCLUSION

This study revealed that iron-doped zeolite had higher effectiveness in removing cyanide compound than raw zeolite. The presence of iron in the zeolite was supposed to have a significant effect for eliminating cyanide from the solution since iron has high affinity with cyanide. Therefore, the use of iron-doped zeolite is predicted to be very potential. Further studies will be organized to know the best parameters and condition for cyanide removal using iron-doped zeolite in terms of temperature, agitation speed, adsorbent dose, and iron concentration in the zeolite.

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Mixotrophic growth of *Chlorella Sorokiniana* for simultaneous organic and inorganic removal

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Abstract

Statistical optimization on mixotrophic growth of *Chlorella Sorokiniana* was conducted for tertiary treatment of livestock wastewater. Among various design of experiment (DOE) techniques, a central composite design (CCD) was applied to perform a series of batch optimization experiments. Results indicate that the simultaneous control of light intensity (LI) and temperature were the keys to accelerate the mixotrophic growth. Within the ranges of light and temperature tested, we confirmed high LI (>150 μmol E/m^2/s) and temperature (>30 °C) were favorable to enhanced organic and nitrogen removals. Moreover, it was revealed that the temperature had more significant impact on the mixotrophic metabolism than light. Within 36 hrs, chemical oxygen demand (COD) removal efficiency could be as high as 87.5% at the optimum operating condition, and corresponding COD removal rate was estimated as 105 mg/L/day. Maximum ammonia removal rate was 0.393 d^{-1} at 200 μmol E/m^2/s and 40°C. These results indicate that the potential of mixotrophic microalgal growth is a viable option to meet the effluent quality of livestock wastewater treatment.

Keywords: *Chlorella Sorokiniana*, livestock wastewater, mixotrophic growth

Introduction

Microalgae have gained much attention in these days and have been utilized for various applications including wastewater treatment, CO_2 mitigation, feedstock for biofuel production and so on (Ji et al. 2015). In most cases, mass-production of microalgae biomass have been performed via autotrophic cultivation in a photobioreactor by using light as a sole energy for fixing CO_2 (Deschênes et al. 2015). Microalgae-based biodiesel production has advantages over crops in productivity due to algae's greater solar energy-conversion efficiency (Li et al. 2014). Since sunlight is naturally abundant and renewable, photosynthesis has great potential to generate a sustainable source of biomass that can be converted to renewable energy such as biodiesel (Kim et al. 2011). However, little attention have been paid to the utilization of mixotrophic microalgal growth. Exploring the mass production of mixotrophic microalgae is promising because it contributes to sustainable development by utilizing both sunlight and organics resolving environmental issues (Kumar et al. 2014). In this study, a series of mixotrophic batch experiments was conducted using the *Chlorella Sorokiniana* to find the optimum growth conditions using statistical/mathematical approach. To evaluate overall mass balance on biomass production and ammonia removal under mixotrophic condition, regression results for exponential biomass growth and ammonia decay were further analyzed by adapting response surface methodology.

Material and Methods

Mother culture and growth medium

As a mother culture, *Chlorella Sorokiniana* has been cultivated in a 1-L glass bottle with modify BG-11 medium which contains various ingredients (unit: g/L): EDTA 0.1, $C_6H_5O_7Na_3{\cdot}2H_2O$ 0.6, $C_6H_8O_7{\cdot}H_2O$ 0.6, $CaCl_2{\cdot}2H_2O$ 3.6, $MgSO_4{\cdot}7H_2O$ 7.5, K_2HPO_4 12, H_3BO_3 2.86, $MnCl_2{\cdot}4H_2O$ 1.81, $ZnSO_4{\cdot}7H_2O$ 0.222, $CuSO_4{\cdot}5H_2O$ 0.079, $COCl_2{\cdot}6H_2O$ 0.050, $NaMoO_4{\cdot}2H_2O$ 0.391, Na_2CO_3 0.04, $NaNO_3$ 0.5.

Batch experiments

Temperature and agitation were controlled automatically by using a shaking incubator (DAIHAN ThermoStable IS-10RL, Korea). Tested range of temperature was 16℃~44℃, and we fixed the agitation as 100rpm constantly. Applied light intensity ranges between 80 and 220 μmol E/m^2/s by using a controllable LED light device (Yuyao Lishuai Film & Televiosion Equipment Co.,Ltd., China). We set a light-dark cycle as 12hr-12hr, which is equivalent to equinox light irradiance. The 20 ml of mother culture, which was grown with the same modified BG-11 medium, was inoculated directly into each reactor containing 380 ml of secondary effluent from a livestock wastewater treatment system. This creates a photobioreactor with the 400ml of working volume. Light path was 5 cm wide.

RSM (Response surface methodology)

Following the design of experiment (DOE) strategy, we used central composite design (CCD) to establish a data collection plan. Independent parameters for mixotrophic growth were selected as temperature and light. Corresponding dependent variables were biomass growth rate, nitrogen removal rate, and COD removal efficiency, which create each response surface. All the experimental points were tested in duplicate and its reference point was a center point (C point) of the experimental design. Five center reactors were operated to guarantee accuracy of the data.

Analytical procedures

All the chemical and physical analyses including total suspended solid (TSS), NH_3-N, COD were determined based on standard methods (Method 5220B and Method 4500-NH_3 F) (Rand et al. 2005). pH was measured with a pH Meter (HORIBA F-74BW, Japan). For TSS analysis, we build a relationship between TSS and optical density at 730nm (OD_{730nm}) (Kim et al. 2011) and then calibrated measured OD_{730nm} into TSS concentration. The OD was determined by using a UV spectrophotometer. (HACH DR3900, USA)

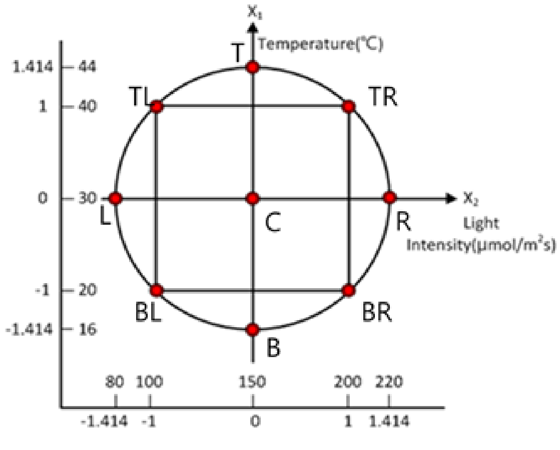

Fig 1 Design of experiment using a central composite design according to light intensity and temperature: C= center, T=top, B=bottom, L=left, R=right.

RESULTS AND DISCUSSION

Biomass growth rate

To determine optimal operating condition for the mixotrophic growth of *Chlorella Sorokiniana*, applied RSM designed to temperature and light effectively reduced the number of batch experiments. Table 1 summarizes all the regression results based on each exponential growth data set. Results indicate that operating condition of B, BL, and BR significantly limit the growth thus specific growth rates were estimated as almost zero. However, the specific growth rate of TR points presented the fastest value with a rapid ammonia removal rate. For TR, TSS concentration was increased from 127 to 1,057 mg TSS/L for 3 days. Corresponding ammonia removal rate reached up to 0.6 h^{-1}. The optimum temperature and light irradiance were found to be 40°C and 200 μmol E/m^2/s based on a statistical analysis of all the experimental results.

Table 1. Biomass growth and ammonia removal kinetic parameters of *Chlorella Sorokiniana* according to experimental design

RUN	Time (hr)	Biomass growth					Ammonia removal	
		R^2	Specific growth rate, k (h^{-1})	Number of generation, n	Generation time, g (h)	Division rate, v (h^{-1})	R^2	Ammonia removal rate, k (h^{-1})
C1	120	0.92	0.013	2.1	55.0	0.018	0.10	-0.004
C2	120	0.95	0.012	2.1	57.3	0.017	0.02	-0.002
C3	120	0.86	0.012	2.0	60.3	0.017	0.58	-0.082
C4	120	0.93	0.012	2.1	57.8	0.017	0.69	-0.264
C5	120	0.95	0.012	2.1	57.3	0.017	0.76	-0.088
L1	120	0.95	0.009	1.5	77.9	0.013	0.72	-0.030
L2	120	0.97	0.010	1.7	70.7	0.014	0.92	-0.042
R1	72	0.95	0.013	1.3	55.0	0.018	0.99	-0.046
R2	72	0.90	0.015	1.6	46.2	0.022	0.98	-0.048
TL1	72	0.89	0.013	1.3	54.2	0.018	0.93	-0.077
TL2	72	0.95	0.015	1.5	47.2	0.021	0.99	-0.086
TR1	72	0.80	0.020	2.1	34.1	0.029	0.97	-0.393
TR2	72	0.95	0.022	2.3	30.9	0.032	0.93	-0.777
BL1	72	N.A.	N.A.	N.A.	N.A.	N.A.	0.99	-0.022
BL2	72	N.A.	N.A.	N.A.	N.A.	N.A.	0.97	-0.015
BR1	72	0.03	0.000	0.0	1732.9	0.001	0.78	-0.018
BR2	72	0.01	0.000	0.0	6931.5	0.000	0.99	-0.016
T1	72	0.65	0.005	0.5	154.0	0.006	0.10	-0.102
T2	72	0.91	0.010	1.1	67.3	0.015	0.99	-0.100
B1	72	0.00	0.000	0.0	1732.9	0.001	0.03	-0.002
B2	72	0.00	0.000	0.0	1732.9	0.001	0.14	-0.002

Nutrient removal rate

We found that the COD removal efficiency and removal rate of the mixotrophic *Chlorella Sorokiniana* in TR1 were as high as 77.1% and 97.5 mg/L/day, respectively. As shown in Table 1, nitrogen removal rate was relatively high in T (0.100~0.102 h^{-1}), TR (0.393~0.777 h^{-1}), and TL (0.077~0.086 h^{-1}), which indicates that the high temperature is more strongly related with the nitrogen removal mechanism in mixotrophic growth rather than light irradiance. Better performance might be achievable with the further optimization. Throughout the experiment, *Chlorella Sorokiniana* could meet the effluent quality of nitrogen in most cases. TR presented the shortest generation time, the most rapid division rate, and the highest specific growth rate, which present 1.5-fold better performance than those of point C.

CONCLUSION

In this study, results explains how higher temperature and light irradiance are related and preferable for the mixotrophic growth of *Chlorella Sorokiniana*. Temperature was the most important key to control mixotrophic biomass production as well as organic removal. Low temperature limits mixotrophic growth significantly while the impact of light was negligible if the temperature is high enough. Within the ranges of two factors tested in this study, optimal condition for *Chlorella Sorokiniana* were revealed as: temperature > 30 °C and light intensity > 150 μmol $E/m^2/s$. These conditions guarantee shorter generation time and higher division rate, which leads to better organic removal.

ACKNOWLEDGEMENT

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Influential factors on solid-liquid separation of wastewater from food waste disposer

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ABSTRACT

The use of food waste disposers can be an attractive option to integrate the management of municipal wastewaters and household organic wastes. This device can be introduced to resolve the inconvenience of separating food wastes and satisfy the policy for converting food wastes into resources. However, the use of disposer has been prohibited in Korea unless the total solid recovery rate is greater than 80% (by dry wt.). It is important to separate solid portions from food wastewater as much as possible to meet the regulations. The objective of this study is to examine the influential factors such as sieve-mesh size of screen, coagulants, centrifuge, etc., on solid-liquid separation of wastewater generated from food waste disposers. The result revealed that the use of sieve less than 0.3 mm could meet the total solid recovery rate of 80% (by dry wt.). Also, the filtrate recirculation precipitated by a coagulant, PAC, also improved the solid recovery rate of 11.0% (by dry wt.) in using the sieve of 0.6 mm. This led to the total solid recovery rate of 79.3% (by dry wt.). Although RPM variation of solid-liquid separator hardly influences the total solid recovery rate, it could benefit the means of compost and feedstock for animals by reducing the moisture content of the filtered materials.

Keywords: Food waste disposer, Total solid recovery rate, Solid-liquid separation, Filtrate precipitation

INTRODUCTION

Since 2005, disposal of food wastes into the landfill has been prohibited according to the Ban on Direct Landfill of Food Wastes, and this has become the main issue which requires an immediate solution. For that reason, the government of Korea has strictly implemented the separated-collection policy for food wastes and many environmental policies related to recycling. However, there are not a lot of markets regarding the products originated from food wastes, and people have felt inconvenience of separating garbage collection. Due to these problems, introduction of more convenient means such as food waste disposer is needed.

Food waste disposer is a machine which grinds food wastes and discharges to sewage treatment plant through plumbing (Marashlian and El-Fadel, 2005). The use of disposer has been prohibited by the Ministry of Environment in Korea because it could cause bad effects to sewage system such as the deposits in the sewer, sudden loads on sewage treatment plant, and bad odor unless the total solid recovery rate is above 80% (by dry wt.). Since the value of total solid recovery rate falls short of optimum level, research on the factors capable of increasing solid recovery rate is needed. The objective of this study was to investigate how to improve the solid recovery rate of food wastes when using food waste disposer. In this study, sieve mesh sizes, filtrate precipitation, and RPM of centrifuge were chosen as influential factors.

MATERIALS AND METHODS

Standard food waste

Standard food waste was prepared as suggested by Korea Environmental Industry Technology Institute (Ministry of Environment, 2012). The amount of 250g (by dry wt.) was used at an experiment.

Batch-feed disposer

Batch-feed disposer with edge rounded knife and two hammers was used.

Centrifuge

Centrifuge was used to imitate the actual on-site solid-liquid separator. Since RCF value of solid-liquid separator which has 900 rpm and diameter of 20 cm is 90.6 (×g), the RPM of centrifuge which has diameter of 14 cm was set in 1,213 rpm for 30 minutes to match the RCF derived from relative centrifugal force equation.

RESULTS AND DISCUSSION

Grain-size distribution of recovered solid filtered by sieves

In this experiment, 8 different of sieves were used : 5.6, 4.0, 2.0, 1.0, 0.6, 0.425, 0.3, and 0.2 mm. Water supply velocity was 6 L/min and shredding time was 60 sec. RPM of centrifuge was 1,213 rpm and was operated for 30 min.

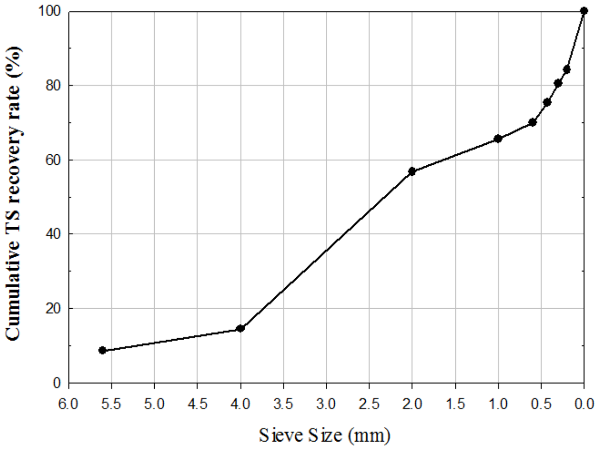

Figure 1 Grain-size distribution of shredded solid

Figure 1 represents the grain-size distribution of shredded solid filtered by sieves. The amount of solids between 2.0 and 4.0 mm was the most occupying 42.2% (by dry wt.), and in the other experimental ranges, the recovery rate was less than 10% (by dry wt.). This figure shows that the minimum sieve mesh size necessary to satisfy the total solid recovery rate of 80% (by dry wt.) is 0.3 mm and the total solid recovery rate of 84.1% (by dry wt.) can be recovered at 0.2 mm. Therefore, in order to satisfy the standard that solid recovery rate should be over 80% (by dry wt.), we could use the sieve whose mesh size is less than 0.3 mm even if it might cause deposits at the sieve.

Filtrate precipitation and recirculation

The second factor for improving the total solid recovery rate is using PAC (Poly Aluminum Chloride) as a coagulant for filtrate precipitation. After filtrate is precipitated by PAC, condensed matters return to the solid-liquid separator to recover total solid. In this experiment, three sieves whose mesh sizes are 2.0, 1.0, and 0.6 mm were used to monitor how much solid recovery rate could be increased.

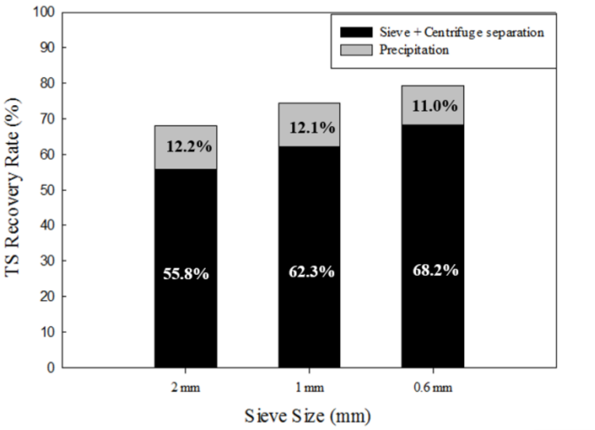

Figure 2 Total solid recovery rate after precipitated filtrate recirculation

Figure 2 represents that if precipitation process is added, total solid recovery rate can be improved by 12.2, 12.1, and 11.0% (by dry wt.) when using 2.0, 1.0, and 0.6 mm sieves, respectively. As a result, under the condition of using 0.6 mm sieve and PAC as a coagulant, the total solid recovery rate of 79.3% (by dry wt.) can be attained and this value is extremely to close the standard level of 80.0% (by dry wt.).

Influence by RPM variation of centrifuge

In order to investigate the influence of centrifuge RPM on solid recovery rate in solid-liquid separation, RPM of centrifuge was set at 1,213, 1,800, and 2,400 rpm.

Table 1 Total solid recovery rate according to RPM variation of centrifuge

TS (g)	RPM of centrifuge		
	1,213	1,800	2,400
Standard Food Waste (g) (A)	46.8	46.8	46.8
5.6 mm sieve (g)	4.3	4.4	4.5
4.0 mm sieve (g)	2.5	2.5	2.7
2.0 mm sieve (g)	18.7	18.7	18.8
1.0 mm sieve (g)	3.8	4.3	4.3
0.6 mm sieve (g)	2.3	2.5	2.5

Total (g) (B)	31.6	32.4	32.8
TS recovery rate (%) (By dry wt.) (B/A x 100)	68.1	70.1	70.9

Although 2,400 rpm is almost twice more than 1,213 rpm, TS recovery rate hardly increased compared to the rate of increase in RPM (Table 1). This is probably because TS recovery rate is influenced by sieve mesh size more than RPM of centrifuge. Rather, increased RPM of centrifuge influences on moisture reduction effect due to the increase of total solid content. Furthermore, increased RPM of centrifuge causes to improve the effectiveness of separation suggested by Worrell and Rietema at all cases. It is highly important for recovered solid to reduce moisture content in converting organic wastes to resources such as compost and feedstock for animals (Aja and Al-Kayiem, 2014).

CONCLUSION

This study aimed to investigate the influential factors on solid-liquid separation of wastewater from food waste disposer to reach the purpose of recovering total solid above 80% (by dry wt.). In case of adjusting sieve mesh size, the standard could be satisfied in the sieve mesh size less than 0.3mm. Using PAC as a coagulant for filtrate precipitation also improved the total solid recovery rate by 79.3% (by dry wt.) under the condition of 0.6 mm sieve mesh size. Finally, RPM variation hardly had any impact on total solid recovery rate, nevertheless, its increase had a good effect on moisture reduction of filtered food waste. Since the required total solid recovery is 80% (by dry wt.) in Korea, the results tested in this study did not meet the regulations except when adjusting sieve size. Therefore, further research on improving the effectiveness of precipitation and adjusting size of the shredded materials is required to increase the total solid recovery rate.

ACKNOWLEDGEMENT

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Pipe Flow Analysis of an Automated Vacuum Waste Collection System Installed in Korea

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ABSTRACT

This paper describes the pipe flow in the automated vacuum waste collection system (AVWCS) installed at Cheong-ra in Korea. Analysis of the pipe flow has been performed through the flow measurement of pressure and air velocity inside a circular duct along the pipelines. Pressure at each local position is measured and evaluated using a static pressure tab installed on the circular duct. Local air velocity inside a circular duct is obtained by Pitot tube at three measuring positions, and controlled by the number of the blowers operated. Throughout the experimental measurements, it is noted that optimal air velocity inside the pipeline of an AVWCS is needed to transport waste effectively from a waste inlet to a waste collection station. Suction pressure along the pipeline increases linearly from the air intake valve to the blowers with the increase of air velocity. The increase of air velocity comes from the compressibility of air due to the high suction pressure.

Keywords: automated vacuum waste collection system, pressure, velocity, piping system

INTRODUCTION

In recent years, an increasing number of automated vacuum waste collection systems (AVWCS) have been installed in new urban residential areas in Korea. Waste collection and transportation through a pipeline can be an environment-friendly solution for urban development. (Alfonso and German, 2013)

An AVWCS mainly consists of a waste inlet, piping lines for transportation and a waste collection station. In the waste collection station, a blower system, deodorization device and cyclones for separating transported waste are installed. A pipeline has many different duct shapes: straight, curved, bended, inclined and Y-shaped ducts. (Jang, 2009) The suction pressure required for waste transportation is controlled by the blower system, which has several turbo blowers connected in series. Proper air velocity inside the pipeline enables effective waste transportation without waste accumulation inside the pipeline or damage to the walls of the pipeline (Ong, Goh et al, 1990). It is noted that the energy to operate the blower system to maintain the proper air velocity for waste transportation represents almost 90 percent of the total energy consumption of an AVWCS.

In the present study, pipe flow in an automated vacuum waste collection system installed at Cheong-ra in Korea has been analyzed through experimental measurements of internal air velocity and surface pressure in the pipeline. Internal pipeline conditions are also investigated using a camera loaded on a remotely-controlled vehicle to check the waste accumulation. Pressure and velocity along the pipeline are measured and compared under different suction flow conditions from the blower system.

EXPERIMENTAL METHODS

Pipeline of an AVWCS at Chongra

In Korea, about 30 large-scale AVWCSs had been constructed in so-called “new town” districts since the first was installed in 1990. The number of households for each large-scale AVWCS systems is between 5,000 and 50,000. The AVWCS installed at Cheong-ra new town is introduced to analyze pipe flow in the present study. (LH, 2007) The system is designed to serve 30,000 households, and the pipeline layout is shown in Fig. 1. The total length of the pipeline is 44.5 km, and there are 5 waste collection stations (WCS). Two different pipe diameters are selected considering the maximum waste transportation distance. A 600 mm pipeline is used when the maximum length of the pipeline is greater than 2,000 m.

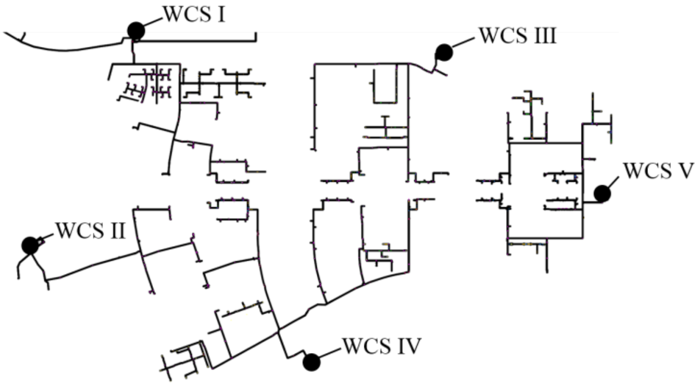


Figure 1 Pipeline of AVWCS at Cheong-ra in Korea

Measuring methods for analyzing the internal flow of a pipeline

To measure the air velocity and pressure along the pipeline, Pitot tube and pressure transducer are used, as shown in Fig. 2. The position at which the stagnation and static pressure is measured using Pitot tube is 200 mm below the top of the circular duct. The inner diameter of the circular duct is 480 mm. Air velocity is determined by the dynamic pressure obtained from the Pitot tube through a micro manometer (model: Furness FC012). Considering the high pressure measured, a micro manometer having a maximum pressure of 130 kPa (model: Yokogawa MT210) is used.

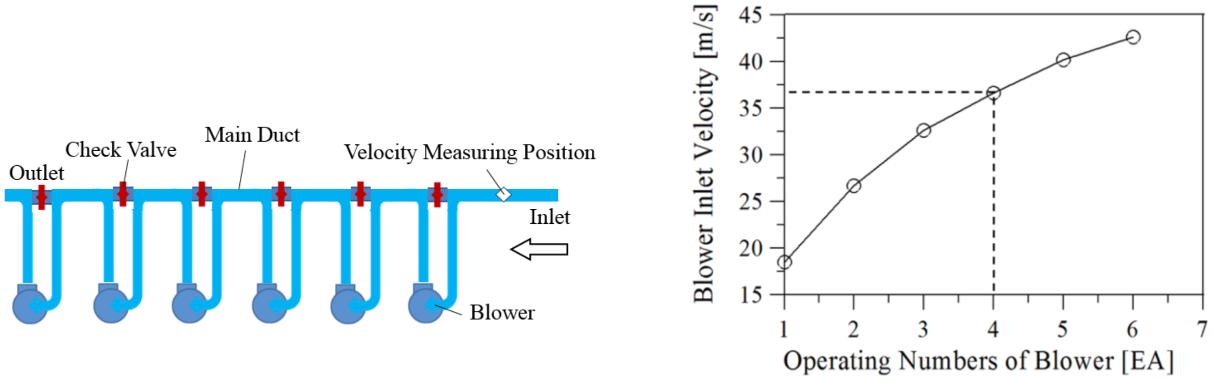
(a) hole for Pitot tube (b) pressure tab (c) camera loaded on a remotely-controlled vehicle

Figure 2 Experimental equipment (Jang and Lee, 2015)

RESULTS AND DISCUSSION

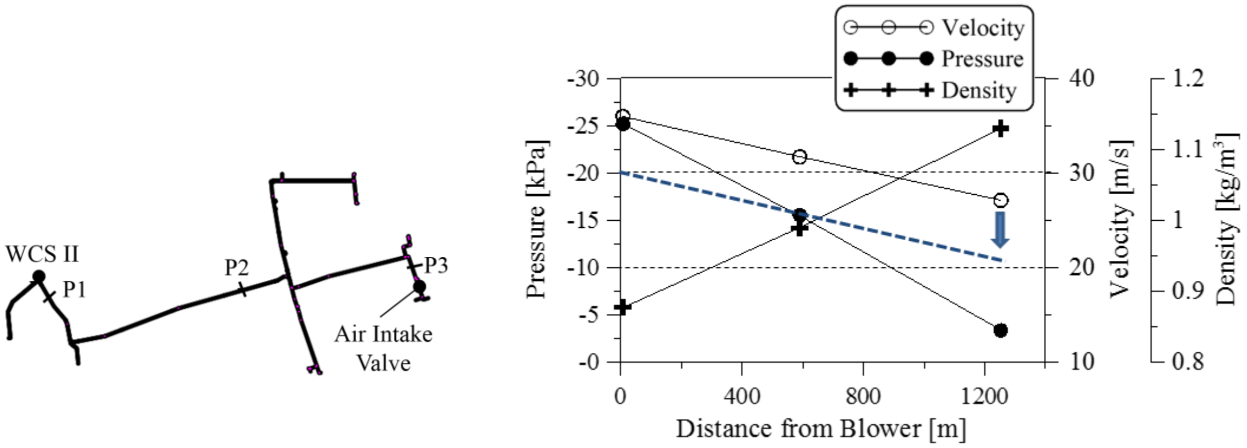
Figure 3 shows the blower inlet velocity with respect to the number of blowers operated at the waste collection station II (WCS II). The inlet velocity is measured at the upstream of the first blower. As shown in the figure, inlet velocity increases as the number of blowers operated increases. Blower inlet velocity for four operating blowers is 36.6 m/s.

Figure 4 shows pressure, velocity and density along the pipeline at the WCS II. The distance between the first blower and first measuring position (P1 in Fig. 4(a)) is 6.5 m, and the number of blowers operating is four. Data measured at three positions as shown in Fig. 4(a) are compared. In Fig. 4(b), suction (minus) pressure increases linearly from the air intake valve to the blower. Pressure increase per unit length is 17.5 Pa. It is known that air velocity should be maintained between 20 and 30 m/s to transport waste without waste accumulation inside pipeline. The measured air velocity increases from 27.1 m/s to 36 m/s while air density decreases from 1.13 to 0.88 kg/m^3. It is noted that the increase of air velocity comes from compressibility of air due to the high suction pressure. Considering the proper air velocity inside the pipeline, it is recommendable to reduce blower inlet velocity from 36 m/s to 30 m/s by decreasing the rotational frequency of the blower, as shown with the dashed line in Fig. 4(b).



(a) measurement position (b) inlet velocity

Figure 3 Blower inlet velocity with respect to the number of blowers in operation



(a) measuring positions (b) pressure, velocity and density

Figure 4 Pressure, velocity and density along the pipeline

Figure 5 Accumulated waste inside pipeline

An excessive increase of air velocity inside the pipeline induces abrasion and defects on the pipeline's surface, as well as higher energy consumption by the blower system. On the other hand, transported waste is apt to accumulate inside the pipeline when the air velocity is lower than the proper velocity range.

Figure 5 shows accumulated waste inside pipeline when the air velocity is below 20 m/s. Transported waste is accumulated inside the pipeline near the bended, curved and inclined duct region due to the locally decreased air velocity.

CONCLUSION

This study aimed to understand the pipe flow of an automated vacuum waste collection system installed at Cheong-ra in Korea. Experimental measurements have been performed to analyze the distributions of pressure and air velocity along the pipeline. Suction pressure increases linearly from the air intake valve to the blowers. Pressure increase per unit length is 17.5 Pa during the operation of four blowers. The increase of air velocity comes from the compressibility of air due to the high suction pressure. Based on the experimental measurements, waste transported along the pipeline is accumulated when air velocity is less than 20 m/s.

ACKNOWLEDGEMENT

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Recycling Wastewater from Biodiesel Fuel Production Process to Liquid Fertilizer for Hydroponics

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ABSTRACT

Wastewater discharged from a washing process in a biodiesel fuel (BDF) production process using an alkaline catalyst was recycled to a liquid fertilizer for hydroponics by the addition of insufficient components for plant growth. The effects of the liquid fertilizer prepared from the BDF wastewater on plant growth were investigated. The liquid fertilizer containing a smaller amount of the BDF wastewater showed a tendency to grow plants similarly to the standard nutrient solution. This result reveals that the BDF wastewater can be recycled to the liquid fertilizer for hydroponics. Moreover, it is indicated that sterilization of the BDF wastewater is necessary to recycle the BDF wastewater as much as possible to liquid fertilizer and that the frequent pH adjustment is necessary when the BDF wastewater is included in the liquid fertilizer.

Keywords: biodiesel fuel, plant factory, hydroponics, liquid fertilizer, recycling

INTRODUCTION

Biomass is promising as an alternative energy source because it is reusable and eco-friendly. Biodiesel fuel (BDF) produced from edible oil or its waste and alcohol is one of the bioenergies, and it can solve not only energy but environmental problems such as water and air pollutions caused by waste oil and exhaust gas from diesel engines, respectively. Although BDF is mainly produced with alkaline catalysts such as KOH, a glycerol by-product containing potassium, methanol and oil is produced in methanolysis reaction. Moreover, alkaline wastewater containing oil, glycerol, methanol and potassium is discharged from a multistep water washing process. As the recycling of the BDF production wastes, the hydrogen and ethanol production (Ito T., Nakashimada Y. et al., 2005) and the compost fermentation (Sadano Y., Toshimitsu R. et al., 2010) using the glycerol by-product have been studied. Whereas it has been studied that the biological treatment of the BDF wastewater (Suehara K., Kawamoto Y. et al., 2005), there are few attempts to recycle the BDF wastewater.

Plant factories can constantly produce fruits and vegetables with controlling environmental conditions such as light, temperature, humidity, and fertilizer and CO_2 concentrations artificially, regardless of season or location. One of the advantages of plant factories is that the variation in the quality of products is small. Another is that products are edible without washing because they are pesticide-free and because the number of bacteria adhering to products is extremely low. Meanwhile, plant factories using artificial light sources have the disadvantage in costs for equipment investment and electricity charges, and hence it is necessary to reduce costs of the liquid fertilizer for hydroponics used in a plant factory.

In this study, in order to elucidate the recycling of the BDF wastewater to the liquid fertilizer, the effects on plant growth of the liquid fertilizer prepared from the BDF wastewater were investigated.

MATERIALS AND METHODS

Preparation of liquid fertilizer from BDF wastewater

BDF wastewater discharged from a BDF production process was gifted from the nonprofit organization, INE OASA. Potassium concentration in the BDF wastewater was measured with atomic absorption spectrometry. The pH of the filtrated BDF wastewater was adjusted at 2.0 by adding 2 M HNO_3. After standing for 5 d to separate oil and water layers, 1 M KOH was added to the oil-removed BDF wastewater to adjust its pH around 5.0. Potassium nitrate, $NH_4H_2PO_4$, NH_4NO_3 and $MgSO_4 \cdot 7H_2O$ were added to the pH-adjusted BDF wastewater, their concentrations followed the 50-fold concentration of the Enshi Standard Nutrient Solution (ESNS, NO_3-N 400, PO_4-P 200, K 400, Mg 200 mEq L^{-1}). Calcium nitrate tetrahydrate was dissolved in distilled water so that Ca and NO_3-N concentrations would be 400 mEq L^{-1}. Before hydroponics, these solutions were diluted into deionized water, this liquid fertilizer containing a smaller amount of the BDF wastewater was referred to as the low-BDF liquid fertilizer. Furthermore, K and NO_3-N concentrations in the pH-adjusted BDF wastewater were calculated by the amounts of added 1 M KOH and 2 M HNO_3, respectively, this BDF wastewater was diluted into deionized water so that K concentration would be 4.0 mEq L^{-1}. And then, other elements except for K were added so as to be 1/2 strength of ESNS. This liquid fertilizer containing a larger amount of the BDF wastewater was referred to as the high-BDF liquid fertilizer relative to the low-BDF liquid fertilizer. The amounts of the added pH-adjusted BDF wastewater to prepare the low-BDF and high-BDF liquid fertilizers were 10 mL and 207.3 mL on average, respectively. ESNS prepared with distilled water instead of the BDF wastewater was used as a control. Trace elements (Fe, Mg, Mn, B, Zn, Cu, and Mo) were added, and then, the pH of the liquid fertilizer was adjusted around 6.0 by adding 1 M KOH.

Hydroponics of komatsuna

Komatsuna (*Brassica rapa* var. *perviridis*) was used as a plant in this study. Plants were grown at 22.5℃ in 16 h of light/8 h of dark, and the averaged photosynthetic photon flux density (PPFD) of 106 μmol m^{-2} s^{-1} with fluorescent lamps in a growth chamber. Seeds were sowed into polyurethane foam soaked into tap water in a plastic pot, and were germinated for 3 d. Raising seedling was performed by exchanging tap water for the liquid fertilizer from 4 to 7 d after seeding. The concentration of the liquid fertilizers was 1/2 strength ESNS (NO_3-N 8.0, PO_4-P 2.0, K 4.0, Ca 4.0, Mg 2.0 mEq L^{-1}). At 7 d after seeding, the polyurethane foam was planted into a Styrofoam board putting over a polypropylene container (inner volume 1.6 L). Hydroponics was carried out in 1 L of the liquid fertilizer aerated with an air pump to which a valve was attached in order to avoid overflow. The pH and electric conductivity of the liquid fertilizer were measured with pH and conductivity meters, respectively. When pH was not within a range of 5.5-6.5, the pH was adjusted to the range of 5.0-7.0 by adding 1 M KOH or 2 M HNO_3. After 21 d planting, the fresh weight of an above-ground part of harvested plants and its dry weight after drying with a circulation dryer at 75℃ more than 24 h were measured.

RESULTS AND DISCUSSION

Preparation of liquid fertilizer from BDF wastewater

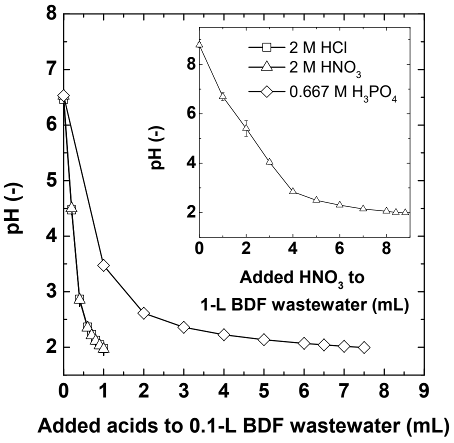

Figure 1 pH change of the BDF wastewater by acid addition

Although the BDF wastewater was originally discharged at an alkaline pH, its pH was around 8.8 (inner graph in Fig. 1) and 6.5 (outer graph in Fig. 1) after about 4.5 and 14 months from its discharge, respectively. This is because carbon dioxide in the atmosphere would be absorbed into the BDF wastewater during storage in a polyethylene tank. Taking into account the utilization as a fertilizer, HNO_3 was added to decrease the pH of the BDF wastewater in this study, its pH change is shown in the inner graph in Fig. 1. The outer graph in Fig. 1 shows the pH change by the addition of 2 M HCl, 2 M HNO_3 or 0.667 M H_3PO_4 to 0.1 L of the BDF wastewater. Initial pH of the BDF wastewater did not affect extremely the relative amount of HNO_3 added to the BDF wastewater (triangles in both graphs in Fig. 1). The amount of added H_3PO_4 to adjust at pH 2.0 was larger than that of HNO_3, whereas the amount of added HCl was similar to that of HNO_3. These results indicate that phosphoric acid can be also available to decrease the pH of the BDF wastewater instead of nitric acid because phosphoric acid can be consumed as a fertilizer component and handled more safely than nitric acid. Although potassium hydroxide and ammonia water can be used for increasing the pH of the oil-removed BDF wastewater, it is known that higher NH_4^+ concentration will cause the growth inhibition of plants. Therefore, KOH was used in this study. Potassium phosphate could increase the pH of the oil-removed BDF wastewater (data not shown), so K_3PO_4 can be also available instead of KOH.

Hydroponics of komatsuna

Table 1 The fresh and dry weights of an above-ground part of harvested plants

	Fresh weight (g)			Dry weight (g)		
	Min	Mean±SD	Max	Min	Mean±SD	Max
ESNS	10.17	15.13±3.86	20.95	0.76	1.01±0.22	1.32
Low-BDF	8.29	16.44±4.03	21.36	0.62	1.11±0.26	1.46
High-BDF	1.39	5.41±3.98	11.28	0.12	0.41±0.26	0.81

Two heads of plants were cultivated on one board. The hydroponics was carried out 4 times.

Table 1 shows the fresh and dry weights of an above-ground part of harvested plants. Although komatsuna was able to grow with all three kinds of liquid fertilizers, plants grown with the high-BDF liquid fertilizer were smaller than those grown with ESNS and the low-BDF liquid fertilizer. Plants grown with these two liquid fertilizers had similar size. The high-BDF liquid fertilizer got turbid and markedly foaming around 7 d after planting. The optical density at 600 nm (OD_{600}) after shaking the non-sterilized liquid fertilizers in a shake flask increased drastically as an amount of the BDF wastewater was increased (data not shown). On the other hand, the OD_{600} of the sterilized liquid fertilizers was not changed regardless of the amount of the BDF wastewater (data not shown). The high-BDF liquid fertilizer contains a larger amount of glycerol as a carbon source, and hence its C/N ratio seemed to be suitable for microbial growth. It has been reported that *Rhodotolura mucilaginosa* could grow in the nutrient-supplied BDF wastewater (Suehara K., Kawamoto Y. et al., 2005). Therefore, these results suggest that the BDF wastewater used in this study has been contaminated by microorganisms, and they could grow by the addition of nitrogen sources and aeration. From these results, it is considered that plant growth was slow because essential components for the plant growth would be consumed by microorganisms, and because the aeration amount limited to avoid foaming would be insufficient for plant growth. When the BDF wastewater is used as much as possible, BDF wastewater should be sterilized. Figure 2 shows the time courses of pH (a) and electric conductivity (EC) (b) of the liquid fertilizer. When the BDF wastewater was included in the liquid fertilizer, their pHs were immediately changed after planting and their pH changes became rapid from 10 d after planting. In contrast, a pH of ESNS gently changed between pH 5.5 and 6.5 until 14 d after planting, and then its pH rapidly changed from 14 d after planting. Although the EC of the high-BDF liquid fertilizer did not decrease until 20 d after planting, those of the low-BDF liquid fertilizer and ESNS gradually decreased with similar curves during hydroponics. These results indicate that the BDF wastewater affected the pH change of the liquid fertilizer and that too much BDF wastewater affected the plant growth, and thereby EC did not change.

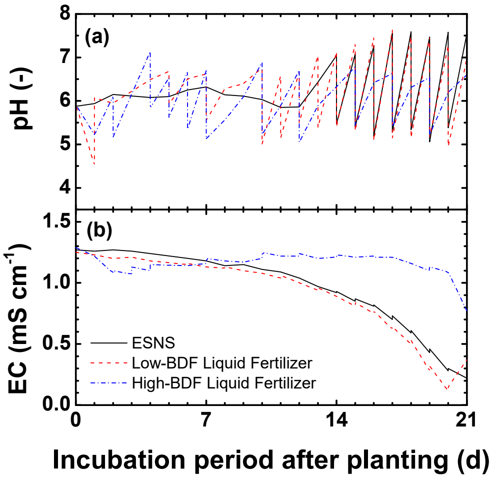

Figure 2 Time courses of pH (a) and electric conductivity (b) of liquid fertilizers

CONCLUSION

BDF wastewater can be available as the liquid fertilizer for hydroponics. Moreover, it is indicated that sterilization of the BDF wastewater is necessary to recycle it as much as possible to liquid fertilizer and that the frequent pH adjustment is necessary when the BDF wastewater is included in the liquid fertilizer. In the future, the components of the liquid fertilizer so that its pH change would be small should be investigated.

ACKNOWLEDGEMENT

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Micro-characteristics of refuse plastic fuel combustion fly ash generated in a fluidized bed combustor

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ABSTRACT

This study investigated micro-characteristics of refuse plastic fuel (RPF) combustion fly ash particles generated in a fluidized bed combustor in Korea. 50 fly ash particles were observed and analyzed by SEM and SEM-EDX. , elemental mapping indicates what elements fly ash particles contain. RPF combustion Fly ash particles can be divided by constituent elements. There are two types in this study. And elemental mapping indicates many of fly ash particles seem homogeneous. But, line analysis indicates it is non-homogeneous.

Keywords: refuse plastic fuel, fly ash, fluidized bed combustor, heterogeneity

INTRODUCTION

Waste management is a social problem anywhere. In general, municipal solid waste (MSW) has high calorific value owing to plastic fractions. Therefore, MSW recycle as alternative solid fuel, called refuse derived fuel (RDF), is attractive in terms of waste management and fossil fuel saving. However, RDF has many problems owing to highly heterogeneous quality. On the other hand, refuse plastic fuel (RPF), produced from only waste plastic, has less heterogeneous properties and thus easy to control the quality. In Korea, waste plastics are segregated, collected, and manufactured to PRF with controlled sufficient quality like chlorine content. PRF is used in cement kilns and power generation plants. RPF combustion in a fluidized bed combustor produces fly ash. Although MSW incineration fly ash has been investigated anywhere[1-5], characteristics of PRF combustion fly ash, in particular its micro-properties, are still uncertain. Therefore, this study investigated micro-characteristics of RPF combustion fly ash particles.

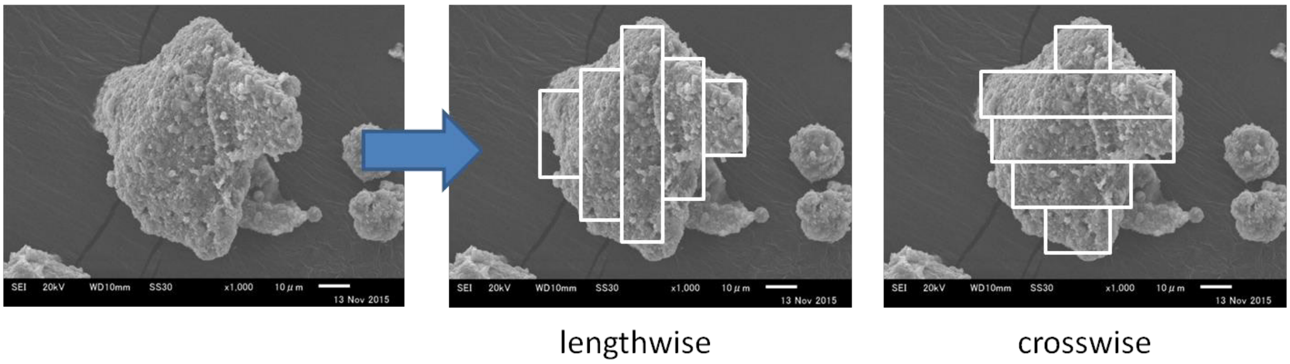

Figure 1. Fly ash particle scission for elemental heterogeneity analysis

MATERIALS AND METHODS

Sample observation and analysis

RPF combustion fly ash were sampled in a fluidized bed combustor for electric power generation in Korea. Fly ash particles were modified by Pt sputtering for 90 seconds before scanning electron microscope (SEM) observation. Surface morphology of RPF combustion fly ash particles were observed by SEM (JSM-6610LA, JEOL Ltd., Japan). The number of observed fly ash particles is 50. Elemental distribution on fly ash particle surfaces were analyzed by Energy Dispersive X-ray Spectroscope equipped in SEM (SEM-EDX: EX-94300S4L1Q, JEOL Ltd., Japan).

Micro-characteristics analysis

To analyze micro-characteristics of fly ash particles, each fly ash particle was divided to 5 parts lengthwise and crosswise (see Figure 1). Elemental content data of each part were extracted from elemental distribution data measured by SEM-EDX. Elemental content variation across the distance were plotted to visualize elemental heterogeneity inside fly ash particle body and used for correlation analysis of major and minor elements.

RESULTS AND DISCUSSION

Microphotograph, surface elemental distribution, and elemental content variation across horizontal distance of two fly ash particles are shown in Figure 2 and 3, respectively. According to elemental content analysis, around 90% of RPF combustion fly ash particles contain Al, Ca, Cl, K, Na, O, S, and Si. Major elements

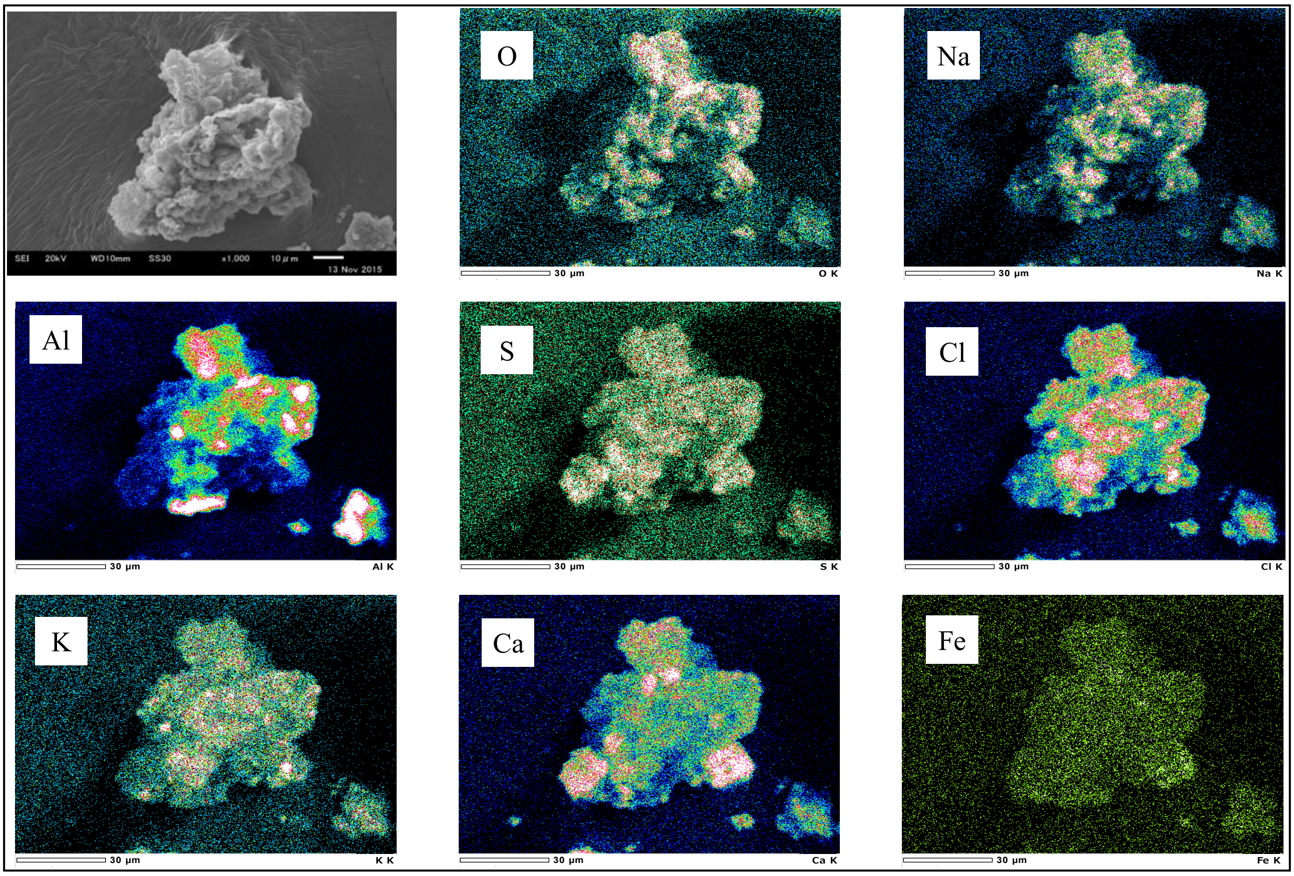

Figure 2. SEM photograph and elemental content distribution on the surface of a RPF combustion fly ash particle

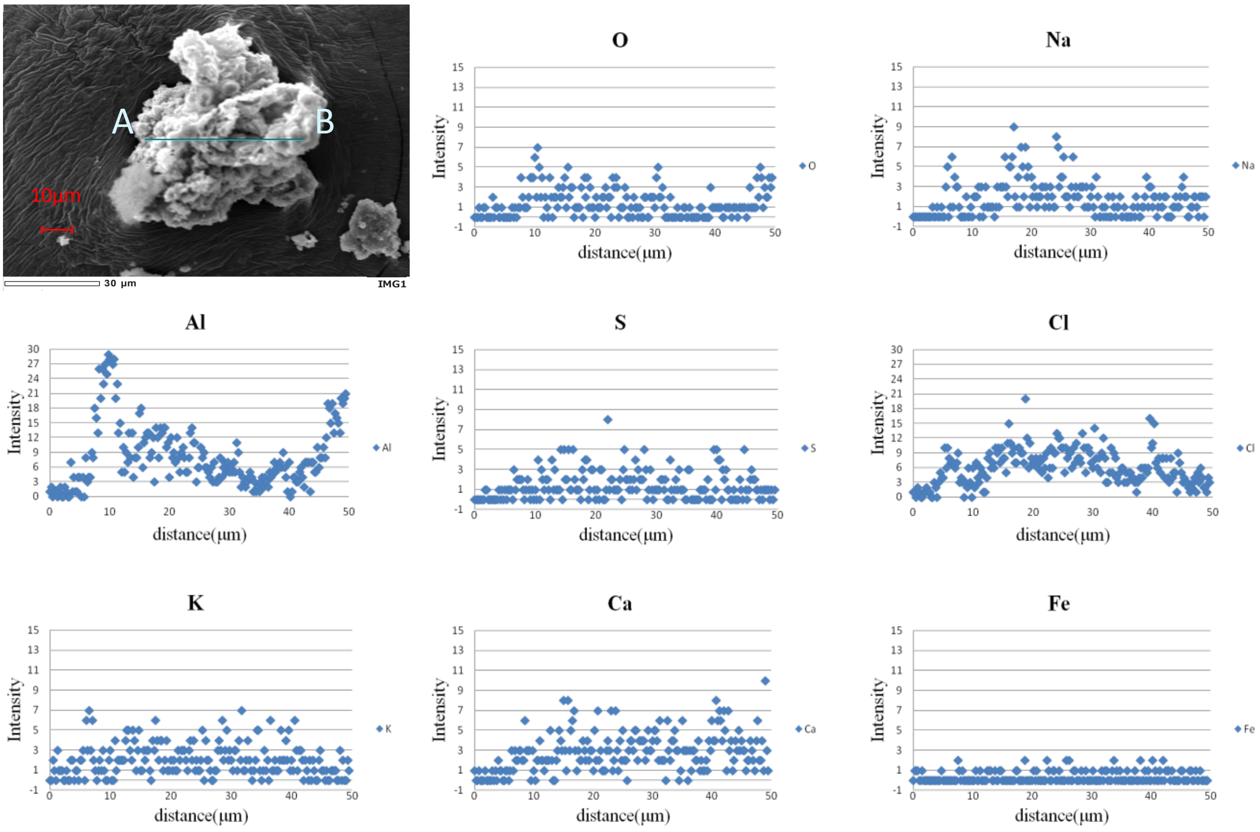

Figure 3. Elemental content variations across the distance inside a RPF combustion fly ash particle

consisting of RPF combustion fly ash are the same with MSW incineration fly ash. In addition, about 40% of combustion fly ash contain Mg, Ti and Fe. Although other heavy metals like Cr were also detected for some fly ash particles, these concentrations were very low. Some of plastics contain fire-retardant material like Sb. Therefore, Sb was expected to concentrate in combustion fly ash. However, Sb was note detected in this observation. Sb magnification in fly ash seems to be negligible for RPF combustion fly ash. Figure 3 clearly shows large variation of all element content across the distance. This means that elemental distribution of one fly ash particle surface is heterogeneous. Because Ca, Cl, K, Na and O have similar variations, Na and K seems to be mainly chloride salt and Ca seems to be oxide or carbonate salt for this observed fly ash particle. On the other hand, Al variation pattern is different from other elements. In particular, a large peak of Al at 10 μm is specific. This seems to be derived from Al metal phase at that point. If so, metallic Al will react with water and generate hydrogen gas. RPF combustion gas might have non-negligible potential of hydrogen gas generation and fire accident cause by hydrogen gas ignition. According to element correlation analysis for 50 elemental line profiles (10 fly ash particles with 500 times magnification observations), Al has low correlation coefficient with Si (less than 0.20), high correlation with O (0.61), and negative correlation with Ca (-0.23). This means that Al is mainly oxide, not aluminosilicate form. Ca has relatively high correlations with Si (0.40) and S (0.40). This implies calcium silicate and calcium sulfate as major forms. Although correlation between Ca and O is not high (only 0.27), this is because oxygen combines with not only Ca but also other elements like Al as oxide form. Na and K have high correlation with Cl (more than 0.70). This supports NaCl and KCl on fly ash particle surfaces.

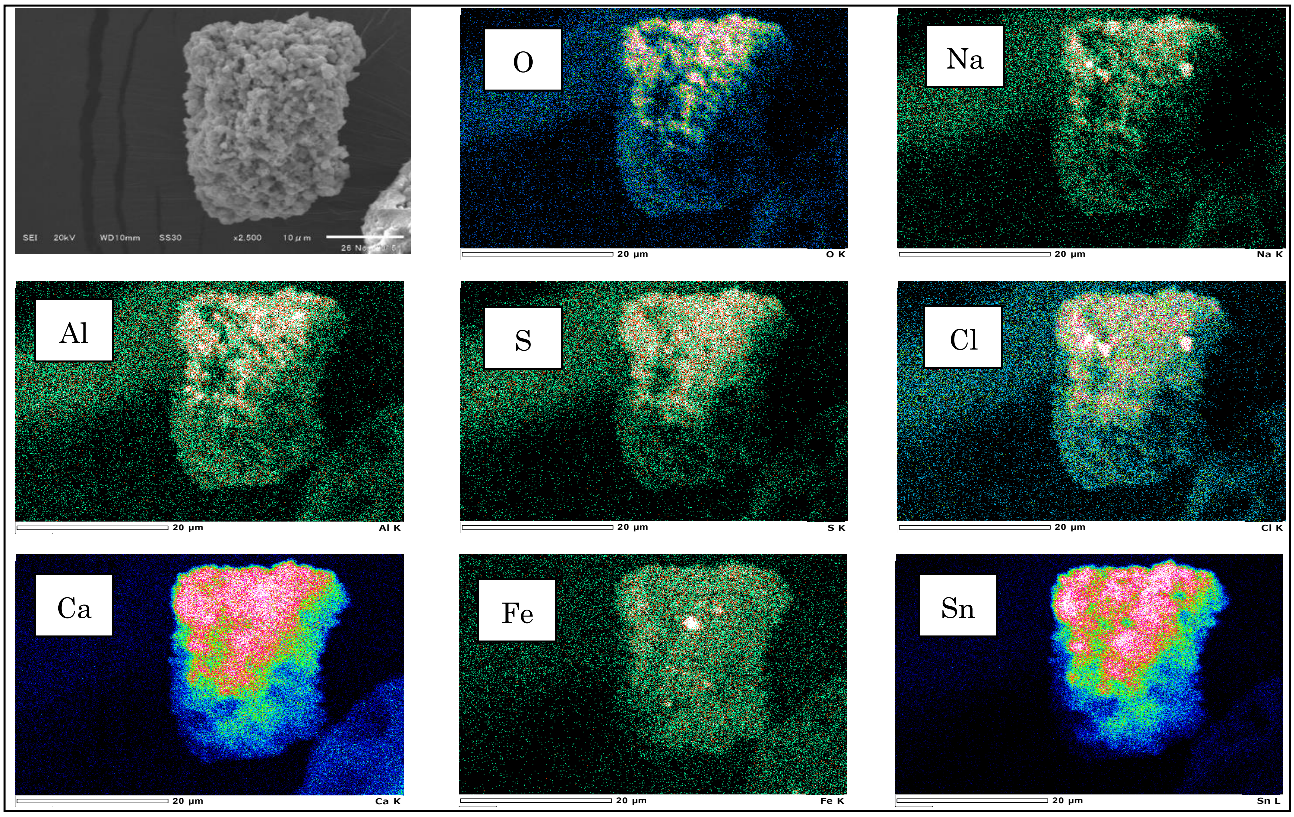

Figure 4. SEM photograph and elemental content distribution on the surface of a RPF combustion fly ash particle (different from a fly ash particle shown in Figure 2.)

CONCLUSION

Micro-characteristics of RPF combustion fly ash particles were investigated. Fly ash particles consist of mainly Al, Ca, Cl, K, Na O, and Si. Major component elements are the same with those of MSW incineration fly ash. Elemental surface content analysis across the distance shows large variation of elemental content on one fly ash particle surface. This means that RPF combustion fly ash particles have heterogeneous elemental distribution.

ACKNOWLEDGEMENT

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Development on the generation unit of flood debris in South Korea

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ABSTRACT

After natural disasters, significant amount of disaster waste is generated and it takes time to recover social infrastructure. The amount of flood debris depends on the characteristic of disaster and the built environment. Estimation of flood debris generation is necessary for emergency response and fast recovery. The objectives of this study are to establish the factors that affect the flood debris generation, to verify present generation unit of flood debris, and to propose more accurate generation unit. The Ministry of Environment suggested 1.7 ton/buildings generation unit which cannot reflect generation unit of total flood debris and special disaster area. Correlation coefficients show that population density, number of damaged households, complete collapse and flooded buildings reached statistical significance ($p < 0.05$). After categorizing the samples and using linear model, 8.8 ton/buildings ($R^2 = 0.600$) generation unit in flood hazard zone is suggested. This value indicate that flood debris generation in special disaster area can be predicted from the damaged buildings.

Keywords: disaster waste, flood debris, generation unit

INTRODUCTION

Flood debris causes several problems to society. First, the quantity of waste in short period of time is huge (Jeong and Kim, 2012). If people don't treat this waste in a limited time, it can cause infectious diseases, environmental pollution and congestion of urban management system. Additionally, the disaster waste depends on the type of disaster and the built environment impacted (Brown et al, 2011). The amount of waste from large scale of disaster cannot be predicted.

Some researchers studied the estimation method of flood debris. First, using statistical method of correlation and regression, researchers suggested per unit generation unit of flood debris or the linear models (Chen et al., 2007; Kang et al., 2015). The U.S. Army Corps of Engineers (USACE) model provided 30% of accuracy and considered five factors: number of households, vegetation density factor, commercial density factor, storm wind intensity, and rainfall intensity (US EPA, 2008). Second, the researches utilizing GIS software or natural hazard map have been implemented (US EPA, 2008; Hirayama et al., 2010). Yeo et al. (2008) investigated the types of flooded buildings and distribution of vulnerable underground house by using inundation trace map.

The objective of this study is to distinguish generation unit of flood debris from the Ministry of Environment and suggest more precise generation unit. Also, it indicates the relationship with factors and flood debris generation for the prediction of flood debris.

MATERIALS AND METHODS

Factors and flood debris generation

Damaged buildings and flood debris generation were collected from annual report on natural disasters 2008-2014. Damaged buildings are included in complete collapse, half collapse and flooded buildings. Each sample was in special disaster area where the disaster damage exceeded over 2.5 times of the government subsidy. Generation unit of flood debris is the flood debris generation per number of damaged buildings.

This study selected 9 factors in literature: population density, complete collapse, half collapse, flooded buildings, number of detached houses, maximum accumulated rainfall, preceding rainfall, number of damaged households. Population density and number of detached houses were collected from population in the 2010 Population and Housing Census (Statistic Korea, 2010) and local area in the Cadastral statistical annual report (Ministry of land, infrastructure and transport, 2014). Maximum accumulated rainfall and preceding rainfall were calculated from Korea Meteorological Administration (KMA). Maximum accumulated rainfall was calculated during natural disaster period and preceding rainfall was calculated from 4 days to 1 day before natural disaster period. Number of damaged households were collected from annual report on natural disasters 2008-2014.

Statistical method

To compare the flood debris generation unit from ministry of environment and special disaster area in 2008-2014, the box-and-whisker plot was shown by using Sigmaplot 12.5 (Sistat Software Inc, 2013). This study calculated Spearman rank order correlation coefficient using software Sigmaplot 12.5 from factors in literature and flood debris generation to find relationship with flood debris generation. The linear regression was implemented with natural hazard zone such as flood hazard zone, debris flow hazard zone, and no hazard zone by using software Microsoft Excel 2013 (Microsoft, 2012).

RESULTS AND DISCUSSION

Comparison of per unit generation

Figure 1 shows the box-and whisker plot of generation unit for flood debris. Generation unit of total flood debris was 242.5 ± 897.8 ton/buildings from 71 samples and generation unit of special disaster area was 32.7 ± 51.6 ton/buildings from 48 samples. Generation unit of the Ministry of Environment was 1.7 ton/buildings. This value was the mean of flood debris generation per flooded house in 2009-2011 special disaster area. The 5-6 times of 1.7 ton/buildings was similar to the median of total flood debris and special disaster area.

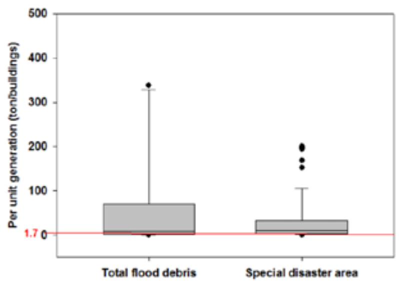

Figure 1 Box-and-whisker plot of generation unit

Correlation with factors and flood debris generation

The correlation was conducted to reveal relationship of flood debris generation and factors (Table 1). The results indicated that the parameters such as population density, number of damaged households, complete collapse, and flooded buildings show positive correlation coefficient and reach statistical significance ($p < 0.05$). However, other parameter such as half collapse, maximum accumulated rainfall, preceding rainfall and number of detached house do not reach statistical significance ($p > 0.05$).

Table 1 Correlation results of factors and flood debris generation

Factors	Population density	Number of damaged households	Complete collapse	Half collapse
Coefficient	0.390	0.478	0.380	0.155
P value	p < 0.01	p < 0.01	p < 0.01	0.290
Factors	Flooded buildings	Maximum accumulated rainfall	Preceding rainfall	Number of detached house
Coefficient	0.507	0.203	0.038	0.085
P value	p < 0.01	0.166	0.795	0.567

Suggestion of generation unit for flood debris

After grouping the samples in special disaster area, the regression for linear model was conducted. Figure 2 shows the linear regression of 3 groups including flood hazard zone (N = 35), flow debris hazard zone (N = 8) and no hazard zone (N = 5). Generation unit of flood hazard zone, flow debris hazard zone and no hazard zone was respectively 8.8 ton/buildings ($R^2 = 0.600$), 2.4 ton/buildings ($R^2 = 0.116$) and 5.8 ton/buildings ($R^2 = 0.668$). Generation unit of flood hazard zone can be suggested for prediction of flood debris generation. The R^2 value for flood hazard zone was greater than 0.5 and the percentage of its samples was 35 (72.9%).

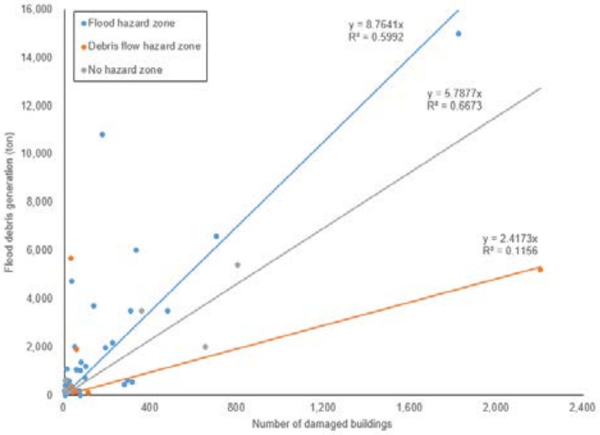

Figure 2 Linear regression of natural hazard zone

CONCLUSION

This study calculated more accurate generation unit of flood debris and explained the factors for flood debris generation. Present generation unit (1.7 ton/buildings) of flood debris does not reflect the value of total inland debris and special disaster area. The parameters such as population density, number of damaged households, complete collapse, and flooded buildings show positive correlation coefficient and reaches statistical significance ($p < 0.05$). 8.8 ton/buildings ($R^2 = 0.600$) generation unit of flood debris is suggested. This value indicate that flood debris generation in special disaster area can be predicted from the damaged buildings. Further research of applying these parameters for prediction of flood debris is recommended.

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Food Waste Generation and Treatment in the Food Supply Chain in Japan

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ABSTRACT

Food waste is indeed a critical issue in Japan, due to a low food self-sufficiency rate as well as a shortage of final landfill sites of waste management. To further mitigate and prevent food waste in Japan, we analyzed the status of food waste in Japan's food supply chain, and provided further policy recommendations based on the recent official published data and reports on food waste. The results of the study indicate that among total food waste in the food supply chain in 2011, 43% (16.34 million tons) is recycled or dehydrated. Another 21.52 million tons could be potentially recycled or reduced by further efforts, both downstream and upstream: 9.52 million tons by households; 4.24 by food businesses; 3.95 million tons at the stage of storage and transportation, and 3.81 million tons during agricultural production. Although the Food Recycling Act and related initiatives since 2001 have made progress supporting recycling food waste among food business industries, further efforts to systematically reduce and recycle food waste remain a challenge, not only for food businesses, but also at other stages in the food supply chain, especially the consumption in downstream of food supply chain.

Keywords: Food waste, Food Supply Chain, Food Waste Recycling Act, Waste management, Japan

INTRODUCTION

According to FAO, roughly one third of the food produced in the world for human consumption is lost or wasted throughout the whole food supply chain every year, which is about 1.3 billion tons per year (FAO, 2011). Reducing lost and wasted food is attracting growing public attention at the international, regional, and national levels, and is widely acknowledged to contribute to abating interlinked sustainability challenges such as food security, climate change, and natural resource shortages (FAO, 2013; 2014). However, the pattern and scale of food waste throughout the food supply chain (FSC) remains poorly understood, despite growing media coverage and public concerns in recent years (Bagherzadeh et al., 2014).

Food waste is indeed a critical issue in Japan, due to a low food self-sufficiency rate as well as a shortage of final landfill sites of waste management. Japan's Food Recycling Law was enacted in 2001 and revised in 2007 in order to promote the reutilization of food resources. It encourages food-related businesses to reduce the generation of food waste during production in order to implement recycling methods (e.g. animal feed, fertilizer, methane), and to promote heat recovery and weight reduction (i.e. dehydration). Since the issue of food waste entered the political agenda, some studies on food waste have been generated to tackle this issue. For example, Parry et al. (2015) overviewed the food waste policy practices in Japan and the United Kingdom. Marra (2014) studied on national policy and waste stream logistics in relation to Japan's social and cultural history. Takata et al. (2012) assess the environmental and economic efficiency of the food recycling facilities that are involved in the recycling loop. However the whole view of food waste occurs in the FSC is fragmented and unclear.

To analyze food waste issue and improve management on mitigation and prevention of food waste, we chose Japan as a case study, which has reliable published official data, and many practices on fighting food waste in recent years. By using official published data and reports on food production, consumption and food waste in Japan, we analyzed the status of food waste in Japan's FSC, and provided further policy recommendations.

RESEARCH SCOPE, MATERIALS AND METHODS

There are no agreed definitions of "food loss", "food waste" and "food wastage". In order to prevent the food waste and to improve its management in Japan, food waste in this paper refers to any food that was meant for human consumption, together with any unavoidable waste, but which gets out of the human food supply chain.

This study relies primarily on official statistics and research reports released by government organizations, such as the Ministry of Agriculture, Forestry and Fisheries (MAFF), the Ministry of Environment (MOE) and the Consumer Affairs Agency (CAA).

Based on the accessible official statistical data, we have differentiated five main life cycle stages in which food waste is found: the agricultural production stage (food waste on farms), the storage and transportation stage (including food waste during post-harvest handling, storage and transportation before processing), the food businesses stage (including food waste at food processing and manufacturing industries, as well as food waste at wholesale, retail, catering and restaurant), the household consumption stage (food waste at household preparation and cooking), and the end-of-management stage (including recycling use as feed, compost, energy recovery, and incineration and landfill treatment). Note this is only a conceptual visualization of the food supply chain. Therefore it may not represent a strict step-by-step flow of food. Furthermore, we only consider the food waste in Japan, excluding the food waste happened at farm in other exporting countries, as well as during the storage and transportations processes before entering Japan.

RESULTS AND DISCUSSION

Status of food waste in the food supply chain

The flow of food waste in FSC in Japan in FY 2011 is summarized in Figure 1. The characteristics may be summarized as follows.

(1) It was estimated that a total of 37.86 million tons of food waste was generated. There are 3.81 million tons in the agricultural production stage, 3.95 million tons in the storage and transportation stage, 19.96 million tons in the food businesses stage, and 10.14 million tons in the household consumption stage, which comprises 10%, 10%, 53% and 27% of food waste respectively.

(2) Although the generation of food waste in the food businesses stage have a large contribution on the total food waste, the reduction and recycling rate is high, about 80%. Out of those 19.96 million tons of food waste in the food businesses stage, 12% is reduced through dehydration treatment, 52% is recycled as feed,

13% is recycled as compost, 3% is recycled as energy, and only 19% is treated by incineration or landfill as waste.

(3) Of all the food waste generated in the food businesses stage, the ratio occupied by the food manufacturing, wholesale, retail and catering service is 83%, 11%, 6% and 9%, with recycling rate of 78%, 50%, 34% and 16% respectively.

(4) The amount of food waste in the household consumption stage is estimated at 10.14 million tons, among which 94% is treated by incineration or landfill as waste while only 4% is recycled.

(5) Most of the food waste generated in the agricultural production stage, and in the storage and transportation stage is left over at farmland or treated by landfill or incineration.

(6) Among total food waste in FSC, 43% (16.34 million tons) is recycled or reduced. Another 21.52 million tons (3.81 in the agricultural production stage, 3.95 in the storage and transportation stage, 4.24 in the food businesses stage, and 9.52 in the household consumption stage) is disposed as waste, in other words, could be potentially recycled or reduced by further efforts.

Incidentally, according to MAFF, out of those 19.96 million tons of food waste from the food businesses, 10.46 million tons were by-products such as soybean meal and bran, which have been sold commercially as animal feed or fertilizer. They are not normally considered as "waste" in Japan, although they are defined as "food waste" in the Food Recycling Act. When excluding these by-products, there is a total of 9.5 million tons of food waste from the food businesses, 25% is recycled as feed and compost, 25% is reduced through dehydration treatment, 5% is recycled by energy, and 40% is treated by incineration and landfill as waste.

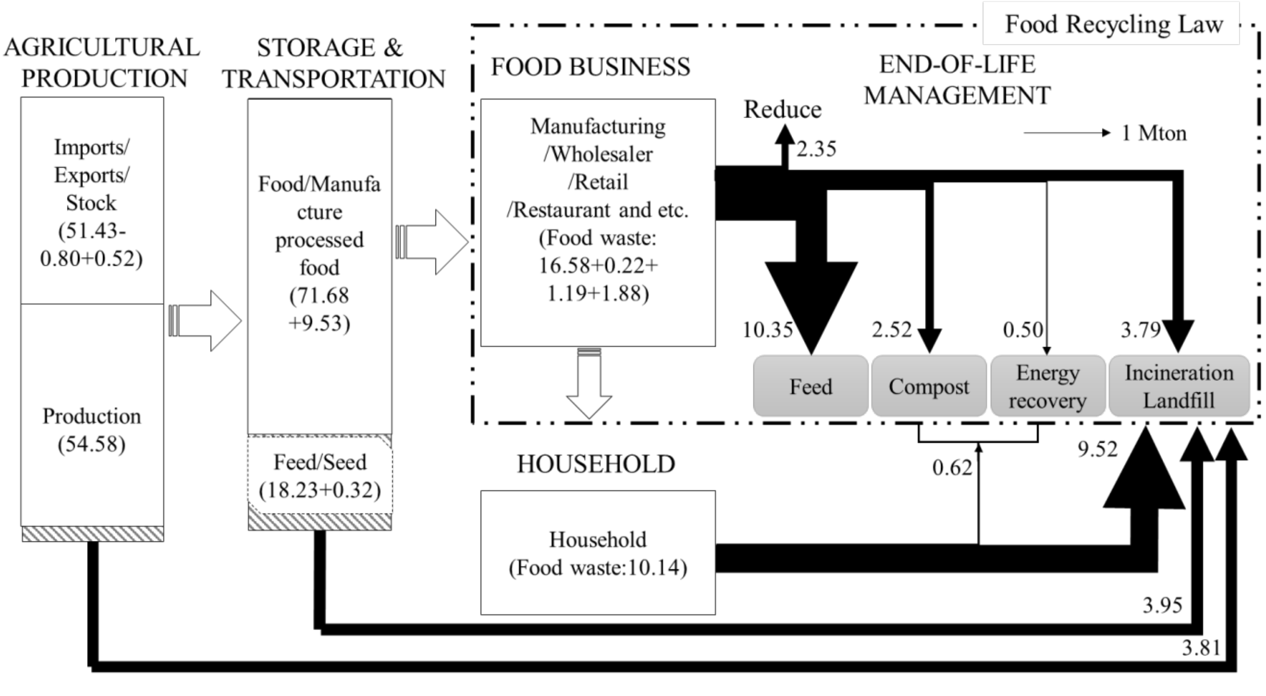

Figure 1. The flow of food waste in food supply chain in Japan in 2011

Further policy recommendations

Although the Food Recycling Act and related initiatives since 2001 have made progress supporting recycling food waste among food business industries, further efforts to systematically reduce and recycle food waste remain a challenge, not only for food businesses, but also at other stages in the food supply chain, especially the consumption in downstream of food supply chain. For this purpose, to further strengthen regulations on food waste reduction, developing integrated municipal solid waste management strategies (not only incineration, but also biogas generation, composting etc.), encouraging further food waste separation practices among residents and related stakeholders, as well as supporting evidence-based integrated food waste education in "Food Education" programs at school, and practical cross-sectoral alliances and concrete commitments could be considered as potentially viable approaches to prevent and mitigate food waste.

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Onsite Rapid Analysis of Asbestos Utilizing Vehicle Equipped with Analytical Instruments in Disaster-Stricken Area

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ABSTRACT

Since the Great East Japan Earthquake in 2011, a prompt response to requests for analyses of disaster waste in stricken areas has been required.

An on-site analysis was therefore carried out in “A” city, one of the areas that was hardest hit by the quake, by utilizing a “Moving Lab” that carried a polarized light microscope and pre-treatment equipment to check for the presence of asbestos in stricken buildings.

A satisfactory analytical result was obtained through the on-site rapid asbestos analysis. There was no difference between the results of an official analytical method and those of the rapid analytical method. The effectiveness of the on-site rapid analysis was confirmed.

Keywords
on-site analysis, asbestos, disaster waste, moving lab

INTRODUCTION

In Japan, regulations stipulate that hazardous substances contained in waste and environmental samples must be analyzed using prescribed official methods.

For these official methods, collected samples are brought to laboratories and instrumental analysis is performed there. These analytical methods are highly precise, but it takes a long time to achieve results. Therefore, it is difficult to respond promptly in case of a disaster or in an emergency.

Many buildings were damaged and large amounts of disaster waste, such as debris including building materials, were generated by the 2011 Great East Japan Earthquake.

Many of the damaged buildings had been built using asbestos-containing materials, and waste that included such asbestos-containing materials was found among the debris.

Consequently, asbestos surveys of building materials were urgently required before demolition of damaged buildings could be carried out.

In this report, we will introduce our survey of the damaged buildings in “A” city, one of the stricken areas. On-site rapid analyses of asbestos utilizing a “Moving Lab” were conducted during this survey.

MATERIALS AND METHODS

Procedure of Asbestos Survey of Damaged Buildings

Damaged buildings were selected from a building list. The location and status of these buildings were inspected at the actual site and the information was inserted onto a map to determine the targets for the survey.

Initial inspections were carried out both inside and outside of these buildings.

Materials that were suspected of containing asbestos were identified by visual inspection, and samples of these were collected. The collected samples were then pretreated and examined using a stereomicroscope and polarized light microscope in the “Moving Lab”.

The flow chart of the asbestos survey in the field is provided in Figure 1.

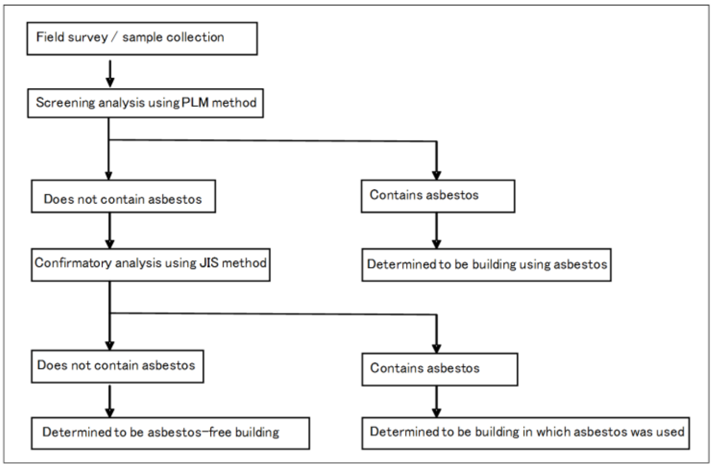

Figure 1 Flow chart of asbestos survey of damaged buildings

Asbestos Analysis for Collected Samples

Asbestos analyses on collected samples were carried out based on EPA 600/R-93-116. A summary of an asbestos analysis is shown in Figure 2, and the condition under which the on-site analyses were conducted is shown in Figure 3.

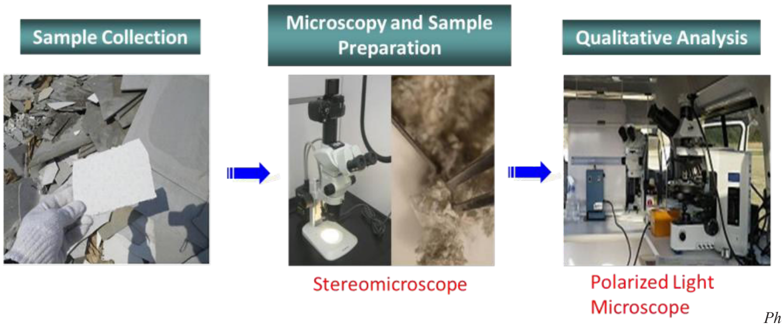

Photo credit: Tokai Techno Co., Ltd.

Figure 2 Summary of Asbestos Analysis

Figure 3 Asbestos analysis on site

RESULTS AND DISCUSSION

A total of 132 steel structure buildings that had been completely or partially destroyed were inspected. However, some of these buildings had already been pulled down or were judged to be too dangerous for sample collection. As a result, samples from 95 buildings were collected for this survey.

Table 1 shows an example of the list of buildings surveyed, and Table 2 shows an example of the record of on-site inspections and sample collection for the damaged buildings. The results of the asbestos analyses of samples collected from the buildings are shown in Table 3.

Table 1 Example of the list of buildings surveyed

Building No.	Property ID	Address 1	Address 2	Address 3	Owner's name	Year built
6	21	1 B-machi	261	35	************	1983
10	101	1 B-machi	289	3	************	1981
13	106	1 B-machi	289	9	************	1979
18	111	1 B-machi	298	3	************	1983
20	134	1 B-machi	299	4	************	1971
21	31208	1 B-machi	299	4	************	1985
28	167	1 B-machi	299	5	************	1976
57	242	C-machi	4	1	************	1996

Table 2 Record of on-site inspections and sample collections for damaged buildings

Building No.	Survey date	Necessity of further survey	L1*	L2*	L3*	Total	Sprayed	Result of visual inspection
6	14-Oct	○	0	0	0	0	no	No spray coating or slate on the 1F, 2F
10	18-Oct	×	0	0	0	0	–	No building
13	14-Oct	○	0	1	1	2	no	Samples were collected from 1F wall insulation material (urethane) and exterior wall board. No spraying or panels on the 1F – 3F. Urethane should be used for the garret insulation material.
18	14-Oct	○	0	0	1	1	yes (survey already done)	A sample was collected from 1F edge of the eaves ceiling slate. A homogeneous material was used for the ceiling. The plumbing was covered with styrofoam. Gypsum board was used in the 1F wall (a sample was not collected).
20	14-Oct	○	0	0	1	1	no	Slate board was used in the 1F rear gas ring (a sample was collected for analysis).
21	14-Oct	×	0	0	0	0	no	No building
28	14-Oct	×	0	0	0	0	no	No ceiling on 1F Siding board was used in the inner wall. (A sample was not collected, only photographed.)
57	14-Oct	○	0	1	1	2	no	No ceiling on the 1F, 2F A sample was collected from the 2F garret insulation material (felton) for analysis.

*L～L3 indicate the level of the scatter of asbestos dust during asbestos removal work.

L1: Working level with extremely high-scattering asbestos, e.g. removing spraying material that contains asbestos

L2: Working level with high-scattering asbestos, e.g. removing material containing asbestos that scatters easily, such as heat insulation, insulation material, fireproof covering material

L3: Working level with relatively low-scattering asbestos, e.g. removing materials containing asbestos, with the exception of those in L1and L2, such as slate board

Table 3 Result of the survey on samples collected from buildings

Building No.	Sampling date	Sample Name	Type	Result of screening	Remarks	Level	Result of JIS analysis	Result of the analysis
13,14	14-Oct	③ 1F heat insulating wall material	insulator	ND		Ⅱ	Detected	ND
	14-Oct	① exterior wall	board	Detected		Ⅲ		Detected
18	14-Oct	1F ceiling eaves slate	board	Detected		Ⅲ		Detected
20	14-Oct	1F wall slate	board	Detected		Ⅲ		Detected
57	14-Oct	2F roof insulator (felton)	insulator	ND		Ⅱ	ND	ND
	14-Oct	1F exterior wall siding	board	ND		Ⅲ		ND
66	14-Oct	4F balcony eaves	board	ND		Ⅲ		ND
71	14-Oct	2F ceiling spray, exterior stairs	sprayed	ND		Ⅰ	ND	ND
71	14-Oct	2F ceiling board, exterior stairs	board	Detected		Ⅲ		Detected
93	15-Oct	1F sprayed ceiling	sprayed	Detected	chrysotile	Ⅰ	Detected	Detected
95	15-Oct	1F PS	board	ND		Ⅲ		ND
96	15-Oct	1F ceiling, eaves	board	ND		Ⅲ		ND
	15-Oct	1F roofing material, eaves	board	ND		Ⅲ		ND
97	15-Oct	2F plumbing elbow, ceiling	insulator	ND		Ⅱ	ND	ND
	15-Oct	exterior siding	board	ND		Ⅲ		ND
98	15-Oct	3F beam under the roof	sprayed	Detected	amosite	Ⅰ		Detected
	15-Oct	3F floor	board	ND		Ⅲ		ND
	15-Oct	2F ceiling	board	ND		Ⅲ		ND
104	13-Oct	2F ceiling, stairs	vermiculite	Detected	chrysotile	Ⅰ		Detected
	13-Oct	3F wall	vermiculite	Detected	chrysotile	Ⅰ		Detected

Sprayed asbestos building material was used in 36 buildings out of all survey objectives, and asbestos was found in 4 samples. Asbestos was also found in molded plates used in 52 of these buildings. Therefore the importance of countermeasures for building materials derived from demolition and debris was reconfirmed.

On the other hand, securing power and management of the effluent produced by the analyses is an issue to be tackled in order to conduct further surveillance in the future.

CONCLUSION

When collected samples are brought to a lab and surveyed according to official methods, it took about a month. On the other hand, asbestos surveys on damaged buildings were completed within 10 days using this rapid on-site analytical method. When the situation is urgent or in case of similar disasters, analyses such as those used in this survey were confirmed to be very useful since they can be conducted rapidly on site.

We are currently performing on-site analyses for radioactivity and PM2.5, in addition to asbestos using the “Moving Lab”. We are planning to conduct various measurements on site as necessary.

ACKNOWLEDGEMENT

This survey was supported by Mr. Fujiwara, of Tokai Techno Co., Ltd., and with the cooperation of many other people. We would like to express great gratitude for that.

Indicators of acidification in mesophilic and thermophilic anaerobic digestion processes of food waste

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ABSTRACT

Thermophilic anaerobic digestion offers several advantages over conventional mesophilic anaerobic digestion, but poor operational stability still prevents it from being widely commercialized. In this study, lab-scale anaerobic digestion of food wastes collected from G-district in Seoul was performed under mesophilic and thermophilic conditions. Results revealed that constant accumulation of volatile fatty acids and consumption of alkalinity led to subsequent increase in FOS/TAC ratio, and process failure due to system acidification was observed for both reactors.

Keywords: Anaerobic digestion, Mesophilic, Thermophilic, Food waste

INTRODUCTION

Due to its value as a potential renewable energy source and high biodegradability, food waste is considered as an ideal subject of anaerobic digestion (Chen Y, Cheng JJ et al., 2008). In the anaerobic digestion process, complex organic materials are first hydrolyzed and fermented by anaerobic microorganisms into fatty acids. The fatty acids are then oxidized by β-oxidation to produce hydrogen and acetate, which are finally converted into methane and carbon dioxide by methanogenic archaea (McCarty and Smith, 1986). Conventionally used anaerobic digestion process is under mesophilic condition, in which a steady-state of degradation and stabilization of organic materials is maintained. Yet, it is known that thermophilic anaerobic digestion offers several advantages over conventional mesophilic anaerobic digestion including a high degree of waste stabilization, decreased detention time, improved solids-liquid separation, and increased destruction of viral and bacterial pathogens (Buhr HO and Andrews JF, 1976). In spite of these benefits, however, poor operational stability still prevents anaerobic digestion from being widely commercialized.

This study was performed to determine the operational stability and real-life applicability of anaerobic digestion of food waste. Both reactors were monitored daily to check the biological stability of the process. The monitoring parameters included pH, biogas yield and composition, alkalinity, and organic volatile acid concentrations.

MATERIALS AND METHODS

Substrate and Inoculum

Food waste was collected from a food waste transit center in G-district of Seoul. Four visits, each on a different day of the week, were made to the transit center in order to make the substrate more representative. Impurities from the collected food waste were removed and weighed before they were ground with a mixer. With grinding as the sole method of pretreatment of the substrate, ground food waste was mixed in order to apply homogeneity and was kept frozen for its future use as the substrate for anaerobic digestion process. Sewage sludge was collected from D-food waste treatment plant in Seoul. No additional alkalinity, or buffer, was introduced into the inoculum.

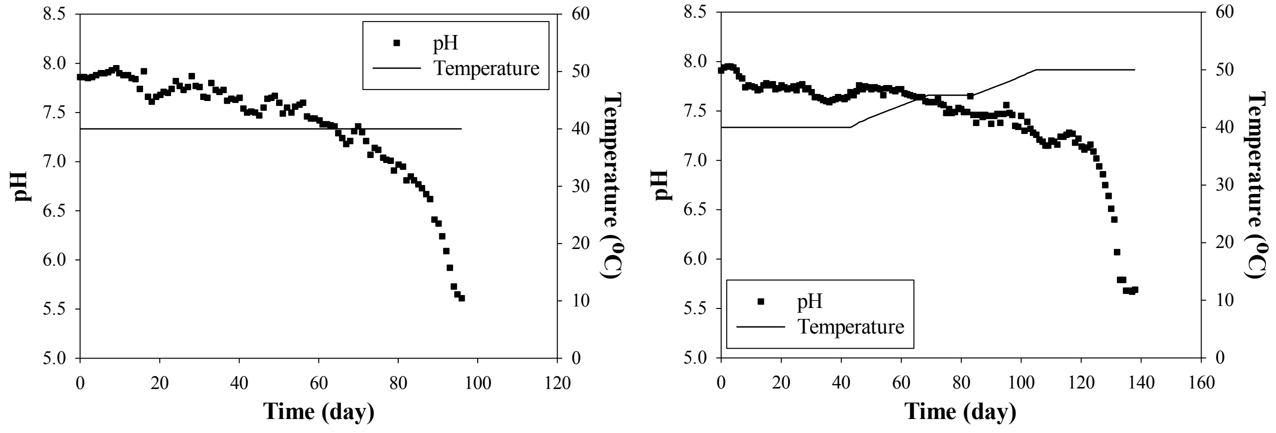
Reactor Operation

Two continuous stirred-tank reactors (CSTR) with an effective volume of 8 L were used in this study. Temperature control of each reactor was achieved by applying an outer layer that serves as a water jacket and a water bath that could circulate heated water within the water jacket. One reactor was set under mesophilic condition at 40°C, and another was set under thermophilic condition at 50°C. The organic loading rate (OLR) of both reactors was to start off as 0.5 g organic dry matter(ODM)/ L·d with a 5 % increment in OLR each day until it reaches 4.0 g-ODM/L·d. Once both reactors were set and daily feeding had started, produced biogas composition was measured daily using gas chromatography (GC) equipped with a thermal conductivity detector (TCD), and helium gas was used as the carrier gas. Occasional organic volatile acid concentration was also measured using a GC equipped with a flame ionization detector (FID). Helium, hydrogen, and air was used as the carrier gas with the main volatile fatty acids (VFA) of interest being acetic acid, propionic acid, butyric acid, isobutyric acid, valeric acid, isovaleric acid, and hexanoic acid.

RESULTS AND DISCUSSION

Temperature and pH

Figure 1 illustrates the temperature and pH of each reactor. Temperature for mesophilic condition remained constant at 40°C. pH started off as 7.86 and maintained its stable neutral pH range despite constant gradual decrease. Drastic reduction in pH was observed after 80 days of reactor operation, dragging the pH level below 6.0 (Figure 1a).



(a) **(b)**

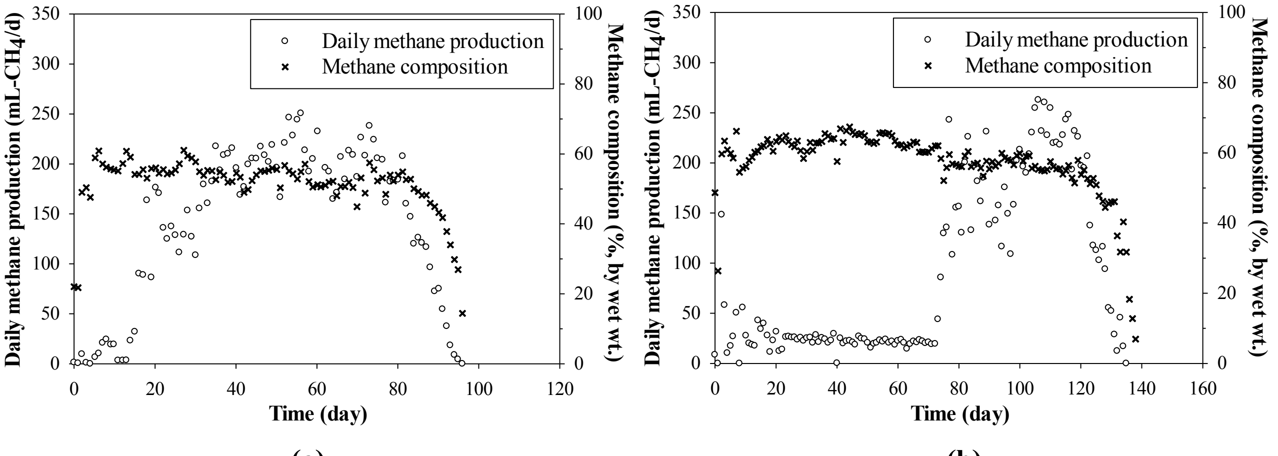
Figure 1 Temperature and pH changes under: (a) mesophilic, (b) thermophilic condition

Gradual and careful control of temperature was applied for thermophilic condition. Daily increment of

0.2~0.3°C was employed until the final temperature of 50°C was achieved. Cessation of temperature increment between Day 70~85 was due to sudden increase in FOS/TAC ratio. pH started off as 7.91 but reduced sharply after Day 120, leading to acidification of the system (Figure 1b). Drastic decrease in pH may have caused microbial inactivity of methanogenic archaea and subsequent inhibition of methanogenesis. Reduction in pH suggests an accumulation of VFAs and a successive imbalance between acid producers and consumers (Franke-Whittle IH, Walter A et al., 2014).

Biogas volume and composition

Among many final products of anaerobic digestion, methane production is one of the most important parameters to monitor in the process. Daily methane production under mesophilic condition was in accordance with the increasing OLR. As the final OLR of 4.07 g-ODM/L/d was achieved at Day 44, relatively stable amount of biogas was produced each day. Methane composition also remained around 50% (by wet wt.) until drastic reduction in daily methane production was observed after Day 80 (Figure 2a). Long acclimation period was necessary for reactor under thermophilic condition. Nonetheless, biogas production was approximately 10% (by wet wt.) greater than under mesophilic condition. Methane composition remained around 60% (by wet wt.) until drastic reduction in daily methane production was observed after Day 120 (Figure 2b). Successive drastic decrease in methane production despite the increased OLR may suggest process instability.

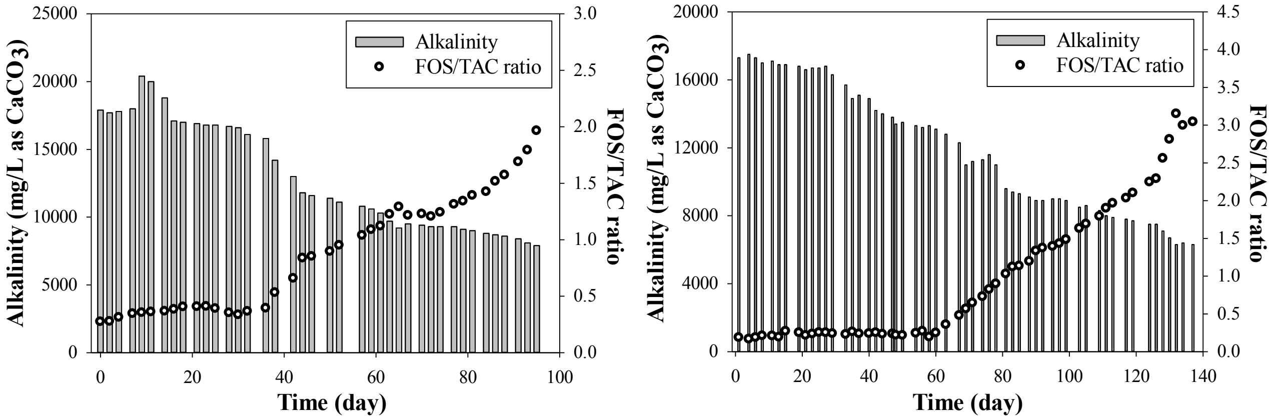


(a) (b)

Figure 2 Daily methane production and composition under: (a) mesophilic, (b) thermophilic condition

Alkalinity and VFA concentrations

Both reactors under different operating temperature showed similar trends in alkalinity and FOS/TAC ratio. Accumulation of VFAs and consumption of alkalinity led to constant and gradual increase in FOS/TAC ratio (Figure 3). The total VFA concentration ultimately exceeded 7,000 mg/L for both reactors, but the ratio between propionic acid and acetic acid (P/A ratio) remained relatively constant under 1.0 throughout the operation. FOS/TAC ratio exceeding a value of 0.5 and P/A ratio greater than 1.4 usually indicates impending reactor failure (Hill DT, Cobb SA et al., 1987).



(a) **(b)**

Figure 3 Alkalinity and FOS/TAC ratio under: (a) mesophilic, (b) thermophilic condition

CONCLUSION

This study may conclude that anaerobic digestion for actual food waste generated in G-district of Seoul cannot operate with stability under the illustrated operating conditions. Since acidification is the main cause of reactor failure, insertion of buffer (alkalinity) and/or modifications in the OLR may be necessary. In addition, anaerobic digestion under thermophilic condition may require longer acclimation period for more stable operation because the inoculum was collected from a food waste treatment plant that operates under mesophilic condition. Constant accumulation of VFAs and consumption of alkalinity led to subsequent increase in FOS/TAC ratio. Yet, the P/A ratio in both reactors remained relatively constant throughout the operation. The results suggest that FOS/TAC ratio may be a better index of anticipating system acidification and reactor failure. Further investigation on the optimal ranges of FOS/TAC ratio and P/A ratio will be necessary for more stable food waste anaerobic digestion operation.

ACKNOWLEDGEMENT

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Evidence of Low Temperature Destruction of 1,2,3,4-Tetrachlorobenzene Enhanced by Alkali and Zeolite

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ABSTRACT

This study is on the thermochemical destruction of an organic Cl compound, 1,2,3,4-tetrachlorobenzene, in an incineration system. The sample on boat was combusted at 600℃ followed by gas combustion at 800℃. An off-gas was adsorptively collected and introduced to a Cl-selective detector by thermal desorption. Destruction efficiency was evaluated by organic halogen residual ratio (OX-RR (µgCl/gCl)). If TeCB was incinerated alone, OX-RR was 1342 µgCl/gCl. Adding NaOH or X-type zeolite to the sample, the OX-RR was decreased to 395 µgCl/gCl and 393 µgCl/gCl, respectively; furthermore, combined application of both additives achieved 15 µgCl/gCl. Addition of an alkali and a zeolite to a sample enhanced decomposition reaction of organic Cl compound. By added NaOH, chemical treatment action occurred in thermal condition as well. By added zeolite, organic Cl compound was absorbed to surface of solid phase. Such the result suggests some physicochemical mechanism enhances destruction of organic Cl compound in thermal treatment.

Keywords: PCBs, thermochemical destruction, organic Cl, incineration

Introduction

After "Yusho disease" revealed the toxicity of PCBs, Japanese government banned the use and production of PCB since 1972. Stockholm treaty (POPs treaty) demands complete destruction of stored PCBs. Since it was not easy to incinerate PCBs-waste in Japan because of dioxin problem during 1990s, chemical destruction process was employed to PCBs destruction instead of thermal process. At that time, the legislative demand for thermal destruction of PCBs was "at least 1100 ℃ for 2 seconds"; however, in 21th century, some trial incineration of "low-concentration PCBs" have been attempted; In course of time, from 2011 on, the condition of "at least 850 ℃ for 2 seconds" was admired. If compared with the former guideline of US EPA (USEPA, 1981) e.g. "1200 ℃, 2 sec O2 concentration 3%", the recent Japanese condition should be considered to have any new innovation, regardless of that they are aware of it or not. Possible factors which enhance destruction are providing of reaction site, i.e. surface of solid phase and alkaline attack to C-Cl bond, namely chemical destruction process in thermal condition. So far we have found such effects with alumina and alkali (Takata et al. 2015) on destruction of organic Cl and Br compounds. The present study with other solid additive, zeolite, gave a notable destruction enhancing effect.

EXPERIMENTAL

Instrumentation

Figure 1 depicts the experimental setup used in this study. Combustion gas was air. A horizontal quartz tube (i.d.: 20 mm, length: 1,200 mm) was supplied with air via a flow meter whose rate was 0.3 L/min. The quartz tube was heated by two serial furnaces. The roles of these furnaces were boat combustion (at 600℃), and gas combustion (at 800℃). The off-gas was washed by purified water in a gas bubbler where HCl was removed, followed by dehumidification using a corrugated glass tube immersed in iced water. Volatile organic chlorine (VOCl) was collected in the Tenax TA tube immersed in dryice-ethanol (ca -60℃). VOCl was determinated by atmospheric pressure helium-radiofrequency barrier discharge-atomic emission spectroscopy (He-rfBD-AES).

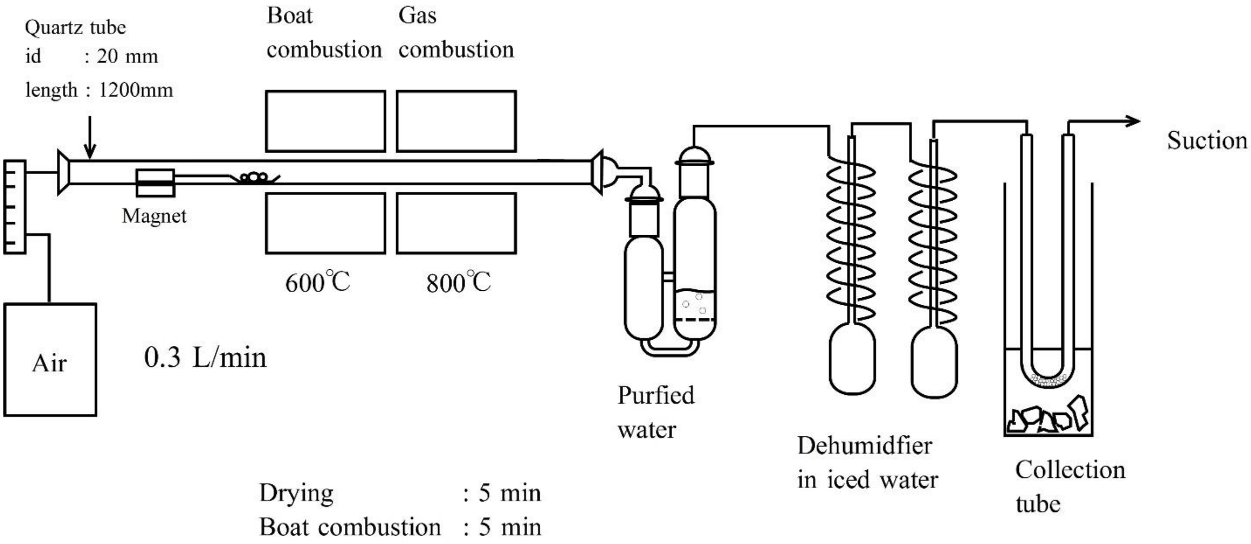

Fig 1. Experimental setup used for incineration and off-gas collection.

Sample

Three μL of toluene solution of 1, 2,3,4 – tetrachlorobenzene (0.066 mgCl/μL) was placed on a ceramic boat with 10 mg of cellulose filter paper (5C, Advantec Toyo, Japan) as a co-combusted material. Three "additives experiments" using NaOH (50 μL of 8 M aqueous solution), Zeolite F-9 (500 mg, Wako Pure Chemical, Japan), NaOH and Zeolite and "non additives" conditions were conducted.

Operation

The sample boat was quickly inserted to combustion zone in the furnace and kept for 5 min. After the combustion, the collection tubes were removed and analyzed by He-rfBD-AES. Limit of quantitation of He-rfBD-AES was 1.81 ngCl. All experiments were conducted thrice.

RESULT AND DESCCUTION

Figure 2 depicts the result of destruction, whose efficiency was evaluated organic halogen-residual ratio (OX-RR):

OX-RR [μgCl/gCl] = (Total residual organic chlorine) / (Total organic chlorine in the original sample).

Note the term "halogen" can be replaced by "chlorine" in this study.

The average of μgCl/gCl for "non additives" was 1342 μgCl/gCl; namely, ca 0.1% of Cl remained as organic form. Addition of NaOH reduced OX-RR to 395 μgCl/gCl; in a similar fashion, addition of zeolite (F-9) resulted in 394 μgCl/gCl. Both alkali and zeolite could enhance the destruction efficiency. Moreover, the combination of zeolite and NaOH minimized OX-RR as low as 15 μgCl/gCl, which is equivalent with destruction and removal efficiency (DRE) higher than 99.995%.

Actually the combustion of boat at 600℃ and gaseous phase at 800℃ was so unstable that a quick boat insertion resulted in very high OX-RR compared with the previous study (Takata et al 2015), in which the insertion of the boat was carefully performed at a slow speed. The rate of volatilization and entry to the heated zone may govern the OX-RR. However, the combined application of alkali and zeolite (F-9) could drastically decreased OX-RR in spite of quick insertion. This result gives an advantage of effective chemical process near solid surface.

However, it must be noted that the solid surface should be selected appropriately, because some other glass-based additives resulted in poor destruction. Because of the coverage by solid materials, some incomplete combustion may occur, so that re-synthesis of any organic chlorinated compounds could not be denied.

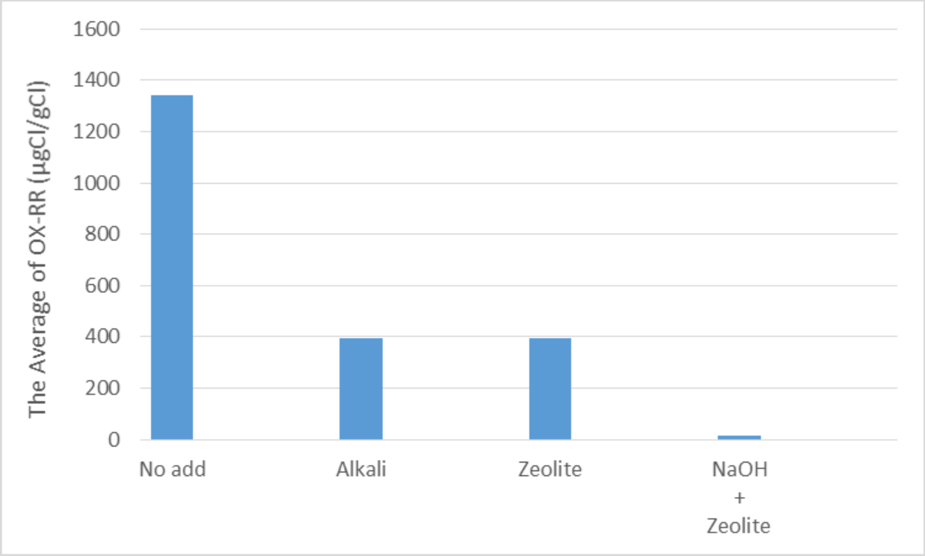

Fig 2. Destruction of 1,2,3,4-tetrachlorobenzene. All experiments were conducted in thrice

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A Study on the Heating Effect of Anaerobic Digestion System using Fermentation Heat from Aerobic Decomposition for Heating Energy and the Characteristics of the Conversion of Organic Wastes into Biogas

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ABSTRACT

South Korea has four distinct seasons and due to seasonal effects, it is difficult to stably maintain anaerobic digestors and heating energy is a required condition for the operation of anaerobic digestion. During the experiment period, the temperature of the anaerobic digestor was 38 ºC on average which confirmed the possibility of medium temperature digestion. In the winter, the temperature tended to decrease, but did not get lower than 25 ºC owing to the heating effect of the aerobic fermentor. Considering that the changing range of temperature decrease was not large, it appears to be a result of the buffering effect of heating. During the experiment period, the temperatures of the aerobic fermentor, anaerobic digestor, outdoor, and in the housing were 37.02 ºC, 60.46 ºC, 14.57 ºC, and 21.82 ºC, respectively. These results confirmed the possibility of medium temperature digestion (30 ºC or higher). In the case of biogas production and methane concentration, the higher the content of organic wastes was, in other words, the higher the VS content was, the greater the biogas production volume tended to become. The maximum production volume was 552 L/m3·day when the VS concentration was 9.48%. During the experiment period, the methane concentration was 65% on average, verifying stable energy conversion.

Keywords: fermentation heat from aerobic decomposition, organic wastes, anaerobic digestion

INTRODUCTION

In South Korea, due to seasonal effects, heating is required for the operation of anaerobic digestion in order to the temperature of anaerobic digestors which is an essential factor for the operation of anaerobic digestors. Generally in South Korea, anaerobic digestion using medium temperature digestion is performed, and about 30% of the operating cost of energy conversion facilities is spent for heating energy, which is a large burden.

The development of anaerobic digestion facilities is difficult in South Korea due to such problems as the large size of energy conversion facilities and the use of heating energy for medium and high digestion temperatures. An operation method for anaerobic digestors that is appropriate for the environmental conditions of South Korea needs to be developed by resolving the problems of operating anaerobic digestors as mentioned above so as to enable the efficient processing and energy conversion of organic wastes. Therefore, in this study, the fermentation heat generated from the aerobic decomposition of organic wastes was used as heating energy to heat anaerobic digestors and the characteristics of the processing and conversion of organic wastes into biogas were examined.

STUDY CONTENT AND METHOD

Anaerobic digestion system using fermentation heat from aerobic decomposition for heating energy in a pilot plant

In this study, a pilot plant that combines a 3 m^3 aerobic fermentor and a 1 m^3 anaerobic digestor installed in 'S' University in Seoul was used. After stabilization was reached through a pilot operation for about four months, the temperature efficiency of heating the anaerobic digestor with the oxidation heat of the aerobic fermentor including winter was examined. For the raw materials inputted to the aerobic fermentor and anaerobic digestor, food wastes and swine manure were used.

Aerobic fermentor experiment and analysis method

To carry out this experiment, the amount of food wastes supplied to the aerobic fermentor was set to 30kg/m3·day. After solid-liquid separation through preprocessing before being supplied to the anaerobic digestor, 31.5kg of food in total was supplied together with 1-2 kg of solid-state organic materials (1.5 kg on average) and one agitation per day was performed. To increase the efficiency of oxidative fermentation heat generation of the aerobic fermentor, the air supply rate was maintained at 10.45L/m3·min.

Anaerobic digestor experiment and analysis method

After mixing swine manure and food wastes through sufficient pulverization, solid-state and liquid-state organic materials were seperated through a solid-liquid separator. Then the solid-state organic materials were supplied to the aerobic fermentor again, and only liquid organic materials of high concentration were supplied to the anaerobic digestor.

RESULTS AND DISCUSSION

Temperament characteristics

The anaerobic processing of organic wastes was performed from January 21, 2015. For the adaptation of microorganisms to organic matter decomposition during the initial stage of experiment, a mixture of 10 L swine manure and 10 L water was prepared for 50 days, which was used for samples. The TS concentration of the organic materials supplied to the anaerobic digestor was 0.81～5.79% (2.58% on average), VS concentration was 0.08～4.56% (1.49% on average), COD concentration was 10,706～51,624mg/L (37,322mg/L), and pH was 7.07～9.21 (8.20 on averages).

Heating effect of anaerobic digestor by the aerobic oxidative fermentation heat and greenhouse

The temperature by the fermentation heat of the aerobic fermentor and the temperature change at each point during the operation period are shown in Fig. 3. The temperature range of the aerobic fermentor a certain trend between 40 and 66 ° C (52 ° C on average). This indicates that the anaerobic digestor can be heated steadily above 50 ° C because the temperature of the aerobic fermentor is constant regardless of outside temperature even in cold winter.

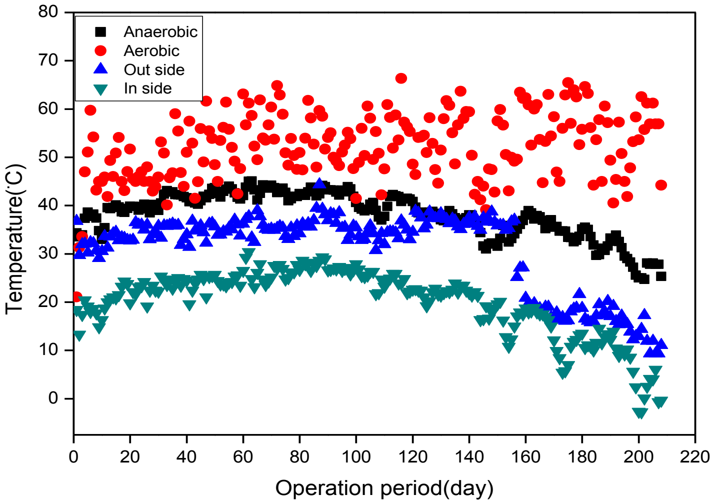

Figure 1. Operation period for system temperature pattern.

DIGESTION EFFICIENCY ACCORDING TO THE VARIATION OF FOOD CONTENT

The anaerobic digestion process was operated by maintaining the hydraulic retention time (HRT) at 50 days. The experiment was performed with 20 L of swine manure and varying contents of food wastes at 4kg (CASE 1), 8kg (CASE 2), 10kg (CASE 3), and 0kg (CASE 4), and with 20 L of water and 8 kg of food wastes (CASE 5). The changing biogas production and methane content according to the changing properties of the organic materials supplied to the anaerobic digestor are shown in Fig. 3.

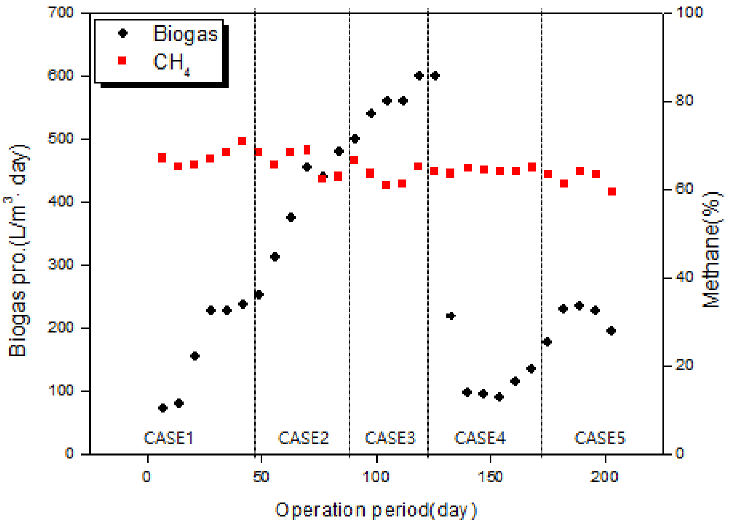

Figure 2. Biogas production and methane content by case

CONCLUSION

1. The oxidative fermentation heat of the aerobic fermentor showed a trend of constant temperature pattern at 40 – 66 ° C even in winter. This indicates that sufficient fermentation heat is generated for heating the anaerobic digestor, which was maintained at 38 ° C on average.

2. The anaerobic digestor was maintained at 30 ° C or higher owing to the heating effect of the fermentation heat of the aerobic fermentor. As a result of the experiment in CASE 1 to 5 with different food waste content in the materials supplied to the anaerobic digestor, the biogas production and methane content were 166L/m3·day and 67% in CASE 1 with a food waste content of 4 kg; 385L/m3·day and 66% in CASE 2 with a food waste content of 8 kg; 552L/m3·day and 64% in CASE 3 with a food waste content of 10 kg; 124L/m3·day and 64% in CASE 4 with 20 L of swine manure only; and 212L/m3·day and 62% in CASE 5 with 20 L water and a food waste content of 8 kg. The average biogas production and methane content during the entire experiment period were 292L/m3·day and 65%. The methane content did not show large variations by case, indicating stable anaerobic digestion during the experiment period.

3. During the winter, the experimentation heat of the aerobic fermentor must be maintained continuously because the anaerobic digestor temperature decreases along with the ambient temperature.

ACKNOWLEDGEMENT

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A Study on the Improvement of National Waste Statistical Research Method based on the Evaluation of Previous National Statistical Researches on Municipal Solid Wastes (1^{st} – 4^{th})

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ABSTRACT

The 5th research will be carried out next. In this study, the results and methods of the 1st to 4th national statistical researches on municipal solid wastes that have been carried out were examined. To evaluate the previous researches, basic unit by the type of municipal solid waste, composition, sampling regions selection method, sample count, research and analysis methods were compared and analyzed.

The evaluation results of previous researches indicate that the sampled regions were difficult to reflect regional characteristics, and with regard to the research method, the gathering of personal information has become difficult due to the changed social atmosphere. Therefore, the selection of sample regions and research method needs to be improved by introducing new concepts.

Keywords: national statistical research on wastes, municipal solid wastes, previous studies

INTRODUCTION

The 1st to 4th researches were carried out amidst continuous changes, and with the 5th research to be carried out in 2016, the need for an examination of the methods of previous researches was raised. For this purpose, the working design reports and statistical research reports of the years when the 'national statistical research on wastes' were carried out were analyzed. Any important information that was not included in the reports was estimated from the contextual relations of facts. Improvement measures for the future statistical research which were derived through an analysis of the problems of the 1st to 4th statistical researches are presented in this paper.

MATERIALS AND METHODS

Analytical method of the results of national statistical researches on wastes (1st – 4th)

Municipal solid wastes were divided into household and non-household sectors. The household sector was classified by house type into detached house, apartment, row house, and multiplex. The non-household sector was divided into production and manufacturing, market and shopping center, business facilities, service business, educational institution, restaurant, and accommodation. The result of the basic unit and the composition are comprised and analyzed by types stated above.

Analytical method of the research methods of national statistical researches on wastes (1st to 4th)

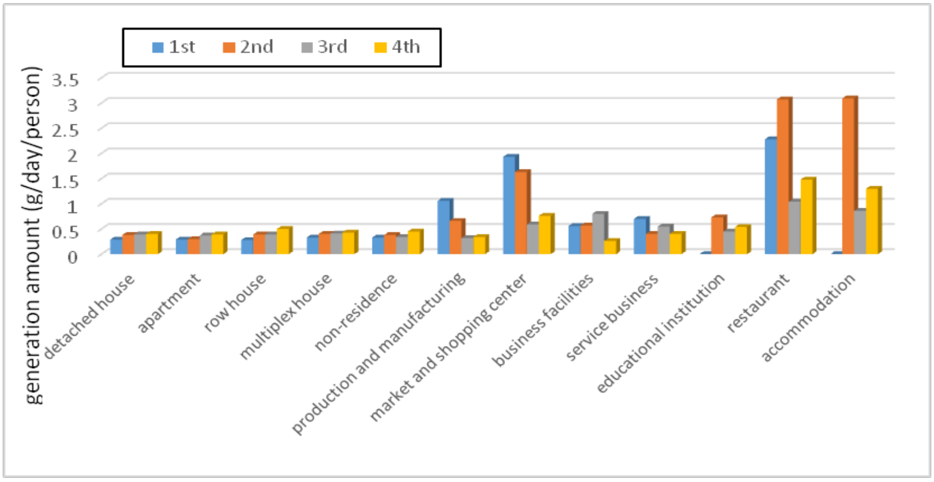
For the examination of the basic unit and properties of municipal solid wastes, the selection of sample regions and the sample count of each sample region are important. As a result, a comparison of the sampling regions, and the sample count between the previous 1st to 4th researches is carried out. The research of municipal solid wastes can be largely divided into a research of economic and social contents which are used as the parameters of basic unit and a research of the generation volume and properties of wastes that are generated from households and non-households. Therefore, a research on the previous 1st to 4th research methods of the economic and social contents are comprised and analyzed for this study.

RESULTS AND DISCUSSION

Analysis of the results of national statistical researches on wastes (1st – 4th)

a. Comparison of basic unit of municipal solid wastes

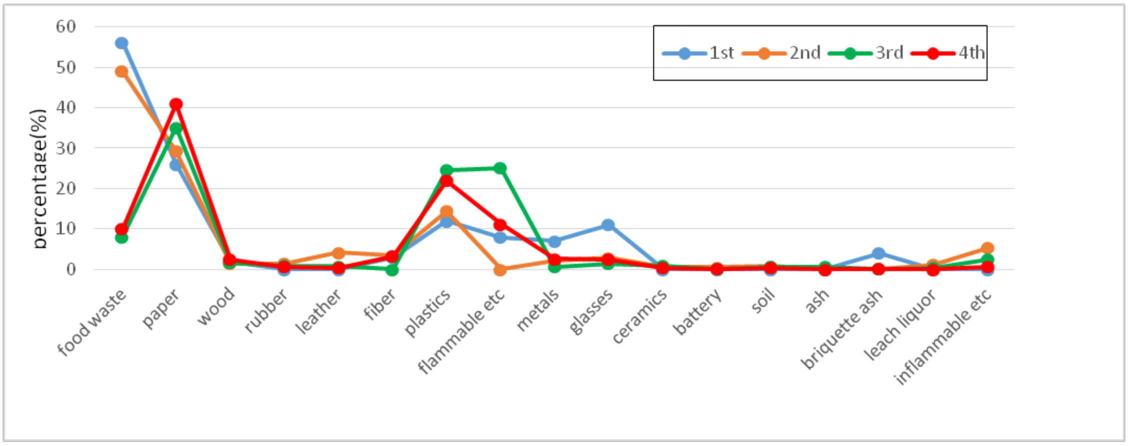
As a result of the comparison of 1st to 4th researches, the basic unit of household sector including detached house, apartment, row house, and multiplex of the 1st and 2nd researches showed very little differences, ranging between 0.24 and 0.34 kg/person/day (standard deviation: 0.021 kg/person/day for 1st research, 0.006 kg/person/day for 2nd research). The basic unit of the 3rd research ranged between 0.0.348 and 0.416 kg/person/day, which showed some differences with those of the 1st and 2nd researches. The basic unit of waste generation by source from the household sector including detached house, apartment, row house, and multiplex tended to increase slightly in each research compared to the previous one.



[Figure 1] Comparison of basic unit of waste generation by detailed source of municipal solid wastes

b. Comparison of the composition of municipal solid wastes

The physical compositions of municipal solid wastes averaged by house type of the household sector in the 1st to 4th researches were compared and analyzed [Figure 2]. In this graph, the patterns of the 1st and 2nd researches are similar as are the patterns of the 3rd and 4th researches, and the percentage of food shows a large difference between the 1st and 2nd researches and the 3rd and 4th researches. The reason for this difference is that during the 1st and 2nd researches, food wastes were included in the standard plastic garbage bags, but from the 3rd research (2006), food wastes were separately disposed. Furthermore, when the 3rd and 4th researches are compared, the percentage of other combustibles decreased whereas the percentage of paper increased from 31% to 36%. The largest components of the 3rd research were paper, combustible other, and plastics, in this order, but those of the 4th research were paper, plastics, food, and other combustibles, in this order.



[Figure 2] Comparison of the compositions of municipal solid wastes from household sector in 1st to 4th researches

Analysis of the research methods of national statistical researches on wastes (1st to 4th)

a. Comparison of the selection of sample regions and sample count

The 1st and 2nd researches divided the entire nation into 45 regions and determined the samples accordingly. The sample count of the 1st research was 10,000 (10,162 samples in actual research) and the sample count of the 2nd research was 13,727 (14,727 samples in actual research). The 3rd and 4th researches selected one focused research region for each city size (special city, metropolitan city, small and medium city, farming and fishing), and four provinces and two cities were selected as other regions. Furthermore, cities, counties, and wards were set in each research region and research was carried out in each city, county, and ward under the judgment of the researcher.

[Table 1] Sample counts of 1st to 4th researches

Division	1st	2nd	3rd	4th
Population	8,903,818	13,726,935	15,782,520	16,570,462
Sample count (unit)	10,162	14,727	7,891	8,285
Sampling rate (%)	0.112	0.100	0.02	0.02

b. Research and analysis method

The economic and social environments in the 1st, 2nd, and 3rd researches were researched by visiting every house, as were the generation amount and properties of wastes. Therefore, it took much time to wait for residents throwing away wastes and survey them, and there was a concern for violation of privacy f or the people throwing away wastes because the samples were collected in a one-on-one manner. In the 4th research, the method of collection and survey at the door was changed to small group units to improve efficiency. Thus, houses or businesses that throw away wastes to waste collection bins were surveyed based on each waste collection bin, and samples were collected from the waste collection bins.

CONCLUSION

To achieve this goal, first of all, new methods of selecting sample regions and sample count using a specialized statistical method, which are different from those of 1st to 4th researches, must be introduced. Considering that the national waste statistics are designated statistics approved by the national government, the sampling and stratification methods for the sample regions need to be specialized. Second, a detailed operation manual about the classification and research methods is required. The research of the household sector had difficulties because the definitions and divisions of house types were unclear and vague. Furthermore, in the research of properties, each researcher used a different method due to the vague sampling and analysis methods, resulting in errors in statistical data. Therefore, the accurate classification method for each source of wastes and the research methods of composition and properties for each type of waste must be specified in the operation manual.

Third, the future national statistical research on wastes must undergo a mutual verification step during the main research in order to attain differentiation from and connectivity with the national waste generation and treatment status. Fourth, smooth cooperation with the public officials in charge of the research regions and with the researched businesses (non-household sector) must be obtained in the preliminary research step before the field survey step. We anticipate that more accurate and objective research of the basic unit will be carried out in the 5th national statistical research on wastes by developing a specialized operation manual that specifies the preliminary research step, main research step (specification of methods for the research of compassion and the research of properties), and the roles of each person in charge of statistics.

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Recovery of Ga and In from MOCVD dust based LED industry by acidic leaching

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ABSTRACT

Recovery of metal values from GaN, a metal-organic chemical vapor deposition (MOCVD) waste of GaNbased power device and LED industry is investigated by acidic leaching. Leaching kinetics of gallium rich MOCVD waste is studied and the process is optimized. The gallium rich waste MOCVD dust is characterized by XRD and ICP-AES analysis followed by aqua regia digestion. Different mineral acids are used to find out the best lixiviant for selective leaching of the gallium and indium. Concentrated HCl is relatively better lixiviant having reasonably faster kinetic and better leaching efficiency. Various leaching process parameters like effect of acidity, pulp density, temperature and concentration of catalyst on the leaching efficiency of gallium and indium are investigated. Reasonably, 4 M HCl, a pulp density of 50 g/L, 100 ℃ and stirring rate of 400 rpm are the effective optimum condition for quantitative leaching of gallium and indium.

Keywords: Recycling, MOCVD dust, Indium, Gallium, Leaching

INTRODUCTION

Indium and gallium are essential metals in the electronic manufacturing industry to manufacture various devices, like; semiconductor and LED chips, cell phones, photovoltaic generation panels, optical communication devices and computers. These metals are vital for the electronics industry because of their unique physical and chemical properties. These metals are produced as byproducts from residue, fume, dust, slag and dross generated during extractive metallurgy of zinc, copper, iron, tin, nickel and lead. Thus, the development of technology for recovery of indium and gallium from secondary resources is essential to meet the demand from the industry.

Considering the gallium content in the coal fly ash, recovery of gallium from this sources should be an attractive option considering resources scarcity in the Korea. Pure metals are recovered from leaching solution through electrowinning, precipitation, wet reduction method, has been reported in the literature. Since above process is associated with the issue like high impurities, in the metal production as an alternative liquid-liquid extraction is a versatile option. Especially, leaching and solvent extraction is essential and promising technology and a key to hydrometallurgy.

Metal-organic chemical vapor deposition (MOCVD) technique has been used for the epitaxial growth of GaN and InGaN for active layers in the fabrication of LED chips. During producing process, gallium rich

MOCVD fine dust particles are generated, is the cause of concern for occupational safety and environmental hazard. Recovery of gallium and indium the MOCVD dust never been reported in literature, an important problem need addressed and the hydrometallurgy process can be a panacea to the issue. In our current study effect of various mineral acid, acid concentration, solid to liquid ratio (pulp density, S/L), and temperature on leaching of the gallium rich waste MOCVD dust has been investigated.

MATERIALS AND METHODS

Materials

The gallium rich (GaN) MOCVD dust was supplied by Enco co.Ltd, Republic of Korea. Other chemicals like H_2SO_4, HNO_3, HCl, H_2O_2, $NaNO_3$, and Na_2CO_3 were of analytical grade supplied by Daejung chemical and metal Co, Ltd, Republic of Korea. The GaN containing MOCVD waste of GaN based power device and LED industry now onward called gallium rich waste MOCVD dust.

Leaching

The leaching reactor used for leaching of the gallium rich waste MOCVD dust. The main reactor vessels, i.e. 500 ml three necked round bottom flask was equipped with an overhead agitator driven by a variable-speed motor. Heating mantle with asbestos covered over coil was used for heating and a thermostat attached to control the reactor temperature. A thermocouple equipped with digital measurement of temperature during continuous operation of the reactor was used to monitor temperature during leaching. An agitation speed of 400 rpm was used throughout the studies as agitation speed has no effect beyond 400 rpm was confirmed through a primary study.

Analysis

The gallium rich waste MOCVD dust was characterized by XRD (X-ray diffraction, Shimadzu XRD-6100). Concentrations of various metals after leaching were measured using ICP-AES (OPTIMA 4300DV, PerkineElmer, USA) after suitable dilution using 5 vol.% of HCl. The maximum deviations permitted were about ± 3% in ICPAES analysis, but for temperature controlled processes the deviation were ± 2 ℃.

RESULTS AND DISCUSSION

The gallium rich waste MOCVD dust was characterized both by destructive and non-destructive analysis. Fig. 1 depicts the XRD pattern of the gallium rich MOCVD dust as it is received, consists of two different phases i.e. GaN and $Ga_{0.97}N_{0.9}O_{0.09}$. Through the XRD analysis of the gallium rich waste MOCVD dust, hexagonal $Ga_{0.97}N_{0.9}O_{0.09}$ (JCPDS No. 32-0398), hexagonal GaN (H-GAN, JCPDS No. 89-7522) and cubic GaN (C-GaN, JCPDS No. 52-0791) peaks were observed. A set of destructive analysis was carried out, samples were digested using aqua regia and 100 ℃ followed by ICP-AES analysis. ICP-AES reveals that the MOCVD dust sample contains 62.1% gallium, 1.86% indium, 0.84% of aluminum and 0.05% of iron.

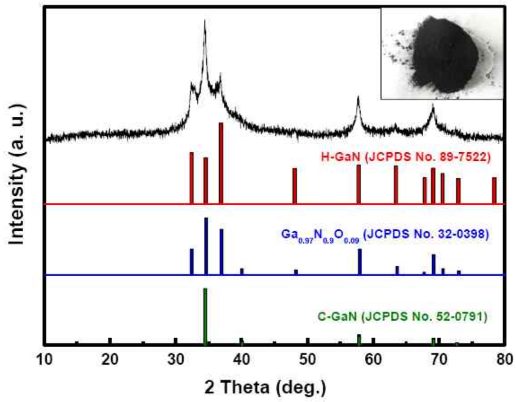

Fig. 1. XRD pattern for the gallium rich waste MOCVD dust as received.

Different lixiviant like 4 M of each mineral acid HCl, H_2SO_4 and HNO_3, were used for leaching of the gallium rich waste MOCVD dust, keeping all other experimental condition constant, i.e. pulp density at 25 g/L, temperature at 25 ℃, agitation speed at 400 rpm for 60 min. As shown in Fig. 2, leaching efficiency of these lixiviant for all important elements like, gallium, indium, aluminum and iron leaching follow the order HCl > HNO_3 > H_2SO_4. Hence, the HCl consider to be the best lixiviant among all. From XRD analysis of leach residue, only GaN peaks were observed. Reasonably concluded that out of two different phases only $Ga_{0.97}NSO_{0.09}$ was leached, leaving back the GaN in residue. These leaching priority behaviors can be explained based on hard-soft-acid-base (HSAB) interaction theory. Because of Ga^{3+} and In3þ are hard acid and all the three anions like Cl^-, NO_3^-, SO_4^{2-} are hard base, hence leaching of Ga^{3+} and In^{3+} facilitated because of hard-acid-hard-base interaction. As hard base properties of three anions follow the order Cl^- > NO_3^- > SO_4^{2-}, hence HCl act as the best lixiviant among all.

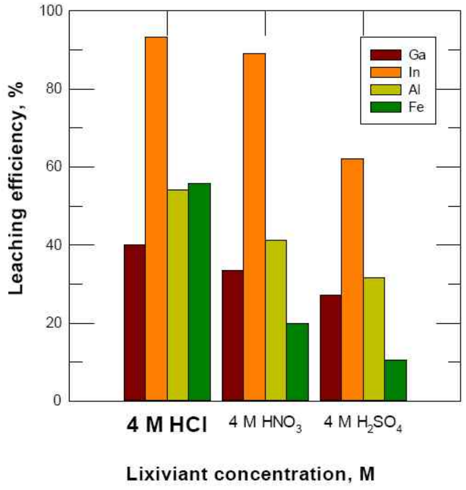

Fig. 2. Effect of various lixiviant on the leaching efficiencies with 4 M of each solution at 25 ℃ for 60 min (Pulp density: 25 g/L, agitation speed: 400 rpm).

Effect of HCl concentration on the leaching efficiencies of the gallium rich waste MOCVD dust was studied. The concentration of HCl varied from 1 to 5 M, keeping all other parameter constant, i.e. pulp density 20 g/L, temperature 25 C, and leaching time 150 min. Fig. 3 shows dependencies of leaching efficiencies on time and HCl concentrations. The results presented in Fig. 3 shows the leaching efficiency of the metals increases with the increase in concentration of HCl acid. Leaching efficiencies for gallium and indium were increased as a function of time and get saturated beyond 60 min. The leaching efficiencies range from 34.08% to 39.04% for gallium, and 81.70% to 86.09% for indium as lixiviant HCl concentration varies from 1 M to 5 M at their saturated point.

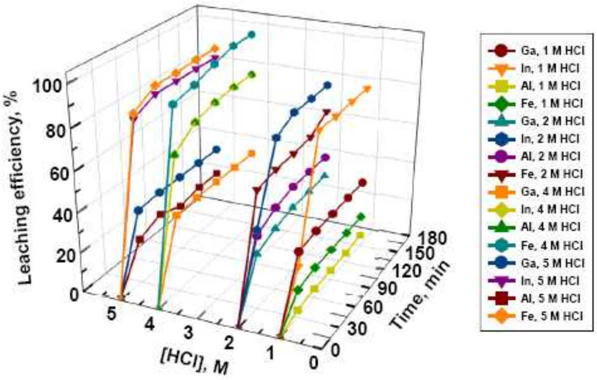

Fig. 3. Leaching efficiencies as function of HCl concentration and time at 25 ℃ for 150 min (pulp density: 20 g/L, agitation speed: 400 rpm).

CONCLUSION

The gallium rich waste MOCVD dust is a biphasic material, contain two different phases like GaN and $Ga_{0.97}N_{0.9}O_{0.09}$. The $Ga_{0.97}N_{0.9}O_{0.09}$ phase of MOCVD dust can be leached easily by a cost effective method using 4 M HCl as lixiviant. Leaching efficiencies of 64.62% and 99.99% for gallium and indium, respectively, were achieved at their optimum condition, i.e. lixiviant of 4 M HCl, pulp density of 50 g/L, temperature of 100 ℃, agitation speed of 400 rpm and time for 60 min. As $Ga_{0.97}N_{0.9}O_{0.09}$ phase of MOCVD dust can be leached quantitatively, a cost effective, environment friendly hydrometallurgy process can be developed for the recycling of the gallium rich waste MOCVD dust. The GaN phase of the gallium rich waste MOCVD dust is hard to leach, a pretreatment process followed by leaching is recommended. The developed process can meet the national urban mining policy and international environmental directives.

ACKNOWLEDGEMENT

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Development of system for explosive gases & DCS (Dichlorosilane) treatment in chemical plant

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ABSTRACT

In this study, It conducted research for elimination of explosive gases and DCS(Dichlorosilane).Using combustion hydrogen for ignition in chemical plant and complete combustion of hydrogen gas was induced to produce air simultaneously. It will be expected to stable disposal of explosive gases(H_2, NH_3, DCS) through low energy consumption by using high temperature heat source(1,100℃) from hydrogen combustion gas.Plasma system was used for gas combustion, H_2, NH_3 gases were into burn simultaneously. It was improved a combustion efficiency, a treatment efficiency of harmful chemicals and low energy efficiency. Basic operation conditions were confirmed to eliminate of explosive gases and DCS in single gas and multi gases. Elimination efficiency of sigle gas was H_2 96%, NH_3 97%, GeH_4 99%, DCS 97%. And, Plasma torch was changed cylindrical shape to trapezium shape to eliminate efficiently for explosive gases and DCS. Efficiency of NH_3 gas was improved 10% after upgrading plasma torch. It was stable to be burn explosive gases(>96%) through shape improvement of plasma system. It will be expected to be applicable for a gas treatment system and reduce energy cost.

Keywords: Arc plasma, H_2, NH_3, Dichlorosilane (DCS), Plasma torch

INTRODUCTION

H_2 gas(explosive gas) was frequently employ to be generated high temperature(1,100 ℃) by combustion in chemical process. But, It has been required stable and efficient treatment by a potential risk. The explosive gases(H_2,NH_3, GeH_4) and DCS(H_2SiCl_2). were eliminated by complete combustion in air but ammonia dissolved in water to treat in elimination process has a disadvantage to be generated a lot of waste water. Thus, A fundamental technique development was required for treatment of stable gas in a chemical process which was used mixed gases(H_2, NH_3, GeH_4, DCS). In this study, To solve a disadvantage occure in chemical process and improve elimination efficiency of explosive gases, and an energy consumption will be take considerable resolve it. An dry-burning process for energy recovery was applied an arc plasma to develop of system for explosive gases(H_2, NH_3, GeH_4) and DCS(H_2SiCl_2).

MATERIALS AND METHODS

System of plasma

The Arc plasma system was applied to eliminate explosive gases and DCS efficiently. Material of electrode was copper for cathode and tungsten for anode were used arc plasma system. Plasma voltage and current were 177 V, 68 A respectively.

Test of elimination efficiency

It was conducted an experiment for a single and mixed gas to understand a burning efficiency in high temperature plasma about explosive gases(H_2, NH_3, GeH_4) and DCS. The initial explosive gases(H_2, NH_3, GeH_4) and DCS gas concentration were 25,000 ppm. N_2 (30 LPM), Air (70 LPM), NH_3 (50 LPM), H_2 (50 LPM), GeH_4 (2.5 LPM), DCS (2.5 LPM) gas flow rate were maintained. Gas detector was FT-IR(MIDAC. I2000) and purity of gases(H_2, NH_3, GeH_4) were 99.9%. Two type of gases mixed into reactor and mixed gases was same in single gas experimental condition. It confirmed an elimination efficiency of explosive gases and DCS to compare concentrations by before and after reaction.

Elimination of gas efficiency by upgrading torch shape

Plasma torch shape was closely related with a combustion efficiency of contact gases. It was observed explosive and DCS gases elimination possibility by developing plasma torch for a stable gas ignition. Plasma torch was changed a trapezium to a cylindrical shape to be effective flame diffusion for developing plasma torch.

RESULTS AND DISCUSSION

Test of elimination efficiency

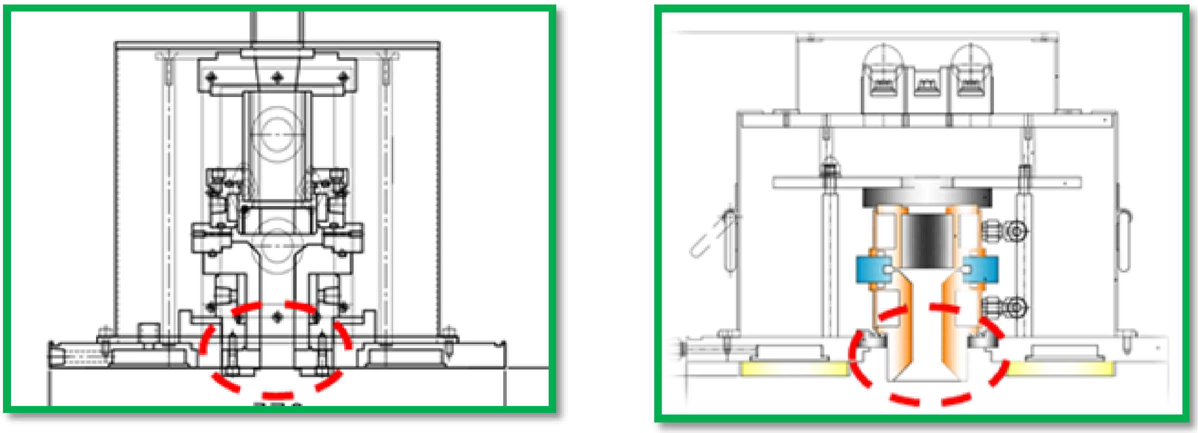
The single gas elimination of efficiency confirmed H_2 96%, initial concentration was about 22,725ppm and outlet 874ppm, NH_3 97%, initial concentration was about 22,967ppm and 659ppm, DCS gas 99%, initial concentration was about 24,280ppm and 72ppm, GeH_4 97%, initial 24,397ppm and outlet 597ppm. The single gas elimination of efficiency was high. In the test, DCS and GeH_4 mixed gases elimination efficiency were DCS 98% and GeH4 99% respectively. Based on the results, Efficiency of gas elimination had a gap between single gas and mixed gases experiment within 1%.

Table.1 Efficiency of gas elimination

	Single gas				**Mixed gas**			
	H_2	**NH_3**	**DCS**	**GeH_4**	**H_2 + NH_3**		**GeH_4 + DCS**	
Efficiency of elimination, %	**96**	**97**	**99**	**97**	**96**	**97**	**98**	**99**

Elimination of gas efficiency by upgrading torch shape

The initial flame spraying long cylindrical shape and subject of disposal gases are disposed at lower section of Plasma arc flame. In this respect, to make high efficiency by using Plasma arc flame required a high power consumptions due to low contact rating between Plasma arc flame and disposal gases. Thus, Upgrading of plasma torch shape was necessary for an extension flame length and a high efficiency of heat source recovery. Direct contact rating between disposal gases(H_2, NH_3, GeH_4, DCS) and Plasma arc flame was improved by changing torch shape from long cylindrical shape to trapezium shape. In this results, Elimination efficiency of NH_3 gas was improved 89% to 98% by a cylindrical and trapezium torch shape.



Initial plasma torch shape

Upgrading plasma torch shape

Figure1. Plasma torch shape

CONCLUSION

Test of elimination efficiency

Elimination gases of efficiency was H_2 96%, NH_3 97%, DCS 99%, GeH_4 97% in a single gas experiment and DCS and GeH_4 mixed gases elimination efficiency were DCS 98% and GeH_4 99% respectively. In the results, It confirmed efficiency of gas elimination had a gap between single gas and mixed gases experiment within 1% and It was a stable gas elimination efficiency.

Elimination of gas efficiency by upgrading torch shape

The shape of torch in plasma system was closely related to an efficiency combustion and contacting gas. Plasma torch was changed a cylindrical to a trapezium shape. The trapezium shape of torch was improved efficiency of NH_3 gas elimination was from 89% to 98% compared with cylindrical. It was improved about 10%. Thus, Efficiency of disposal gases elimination was improved because direct contact rating between disposal gases(H_2, NH_3, GeH_4, DCS) and Plasma arc flame was improved by changing torch shape from long cylindrical shape to trapezium shape.

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Stability Test of Mercury in Waste from Industrial Process using a Sequential Extraction Procedure

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ABSTRACT

Since mercury emission from industrial process has been substantially reduced by utilizing effective air pollution control devices as co-beneficial effects, most of mercury could be released with by-products. Therefore major concerns of mercury releases with such waste streams have been raised in many countries. Stability test was conducted for coal combustion residues and industrial by-product. This study has focused on the evaluation of stability of mercury compounds in by-products from domestic industrial facilities. Stability test was conducted using 5 steps sequential extraction procedure. The mercury compounds extracted was categorized as ion-exchangeable(F1), acid soluble(F2), organic matter-bound(F3), strong complex(F4) and residual(F5) mercury compounds. Fly ash, gypsum (coal-fired power plants), fly ash (metal production facilities), and fly ash (hazardous and municipal waste incinerator) were tested to observe the stability of mercury in such by-products for confirming further utilization, recycling, or recovery. The goals of this study are to investigate stability in various by-products in order to suggest appropriate treatment methods depending on the characteristics of Hg compound contained in each by-product. It is needed to apply proper treatment method considering both mercury concentration and stability.

Keywords: mercury, stability, waste, sequential extraction procedure

INTRODUCTION

Many countries have taken active interest in Minamata Convention on Mercury [UNEP, 2013]. They have made an effort to substitute the industrial process using mercury compounds. Numerous studies and researches of mercury were focused primarily on air emissions. However, the controlled mercury through APCDs was still remained in byproduct and wastewater. Recently, thus some researches and studies have been conducted to treat mercury compounds in solid sample, product and waste. It is important to identify the appropriate treatment method depending on the characteristic of mercury compounds contained. In other words, it is appropriate to apply different treatment methods such as stability/solidification, thermal recovery depending on the stability of bound mercury species. The U.S. Environmental Protection Agency (US EPA) enacted the Land Disposal Restriction (LDR) criteria for hazardous waste management including mercury waste [US EPA, 2012]. LDR categorize mercury wastes as low mercury wastes, high mercury wastes, or elemental mercury wastes. The high mercury wastes are those hazardous wastes containing more than 260 mg-Hg/kg of total mercury contents. Current regulations require that these wastes be treated to less than 0.2

mg-Hg/L using the Toxicity Characteristic Leaching Procedure (TCLP) for mercury residues from retorting, or to 0.025 mg-Hg/L TCLP for all other low mercury wastes. The roasting or retorting treatment is required to meet TCLP standard for the high mercury waste. Besides, the solidification or stabilization used to meet standard level for the low mercury waste. This study provides a result of stability test of mercury in coal combustion residues and industrial by-product from domestic coal power plant and industrial facilities using a sequential extraction procedure. The goals of this study are to investigate the Hg species in various wastes in order to suggest appropriate treatment methods depending on the characteristics of Hg compound contained in each waste, and to classify them into recoverable mercury waste or not for further steps of treatment.

MATERIALS AND METHODS

Sample preparation

Total of 6 samples were collected from domestic industrial process facilities; a coal power plant, a metal production facility, hazardous waste incinerator, and municipal waste incinerator. Types of samples collected were fly ash and gypsum. The collected samples were zipped into plastic bags and transported to the laboratory. Each sample was put in a box, and then mixed and stored to uniform mixing representatively. After air-drying at room temperature for several days on a clean bench, the collected samples were manually crushed using a mortar for further analysis. Hg contents and the sequential extraction test values reported in this study were calculated base on a wet weight of sample

Mercury analysis

The Hg contents of samples were determined according to US EPA method 7471A and 7470A using a cold vapor atomic absorption (CVAA) type mercury analyzer (RA-915+, Lumex, Russia) [9]. The digested sample was transferred to the reduction vessel of the Hg analyzer. The mercury concentration of pretreated sample was analyzed with 3 mL of 10% stannous chloride solution.

Sequential extraction procedure

Sequential extraction procedure (SEP) for mercury compounds was conducted by five steps as shown in Table 1. Bloom et al. (2003) introduced sequential extraction method for Hg in geological solids [Nicolas S. Bollm, 2003]. This method was modified by Sladek et al. (2003), Hall et al. (2005), and Liu et al. (2006). A five-step of sequence extractions was investigated to separate the mercury compounds. It is difficult to identify the specific chemical information, but it is possible to check the stability of mercury compounds in solid samples through this SEP. Extractions were carried out by weighing 0.4 g of sample in 50 mL vials. A aliquot of 40 mL of extraction reagent was added to the sample (sample to extraction reagent ratio = 1 : 100). Each sample with extraction reagent was shaken in and end-to-end shaker at 40 rpm for 18±4 hr. And then, centrifuged at 1600g as Relative Centrifugal Force (RCF) using (1580R, Labogene) for 20 min, and the supernatant liquid was decanted for vacuum filtration through a 0.4-㎛ cellulose nitrate filter. The residue from each step was used in the next extraction step after washing two times with DI water. Each extraction step was conducted using extraction reagent indicated. Hg concentration of the each leachate was measured according to US EPA method 7470A using CVAAs type Hg analyzer (RA-915+, Lumex).

Table 1. Summary of the sequential extraction procedure

Step	Extraction reagent	Description	Typical Hg Compounds
F1	0.5 M NH_4Cl	Ion-exchangeable Hg	$HgCl_2$, $HgSO_4$
F2	0.1 M CH_3COOH + 0.1 M HCl	Acid soluble Hg	HgO, $HgSO_4$
F3	1 M KOH	Organic matter-bound Hg	Hg-humics, Hg_2Cl_2
F4	12 M HNO_3	Elemental Hg	Hg^0, (Hg_2Cl_2)
F5	Aqua region	Sulfide Hg	HgS, m-HgS, HgSe

RESULTS AND DISCUSSION

Mercury fraction and stability

In this study, the sequential extraction procedure was used to provide information regarding the stability of Hg in measured samples. Mercury extracted using each extraction step was named as F1, F2, F3, F4, and F5. Each step indicated the different phase of mercury compounds in sample. The contents and percentages of Hg in each fraction are shown in Figure 1.

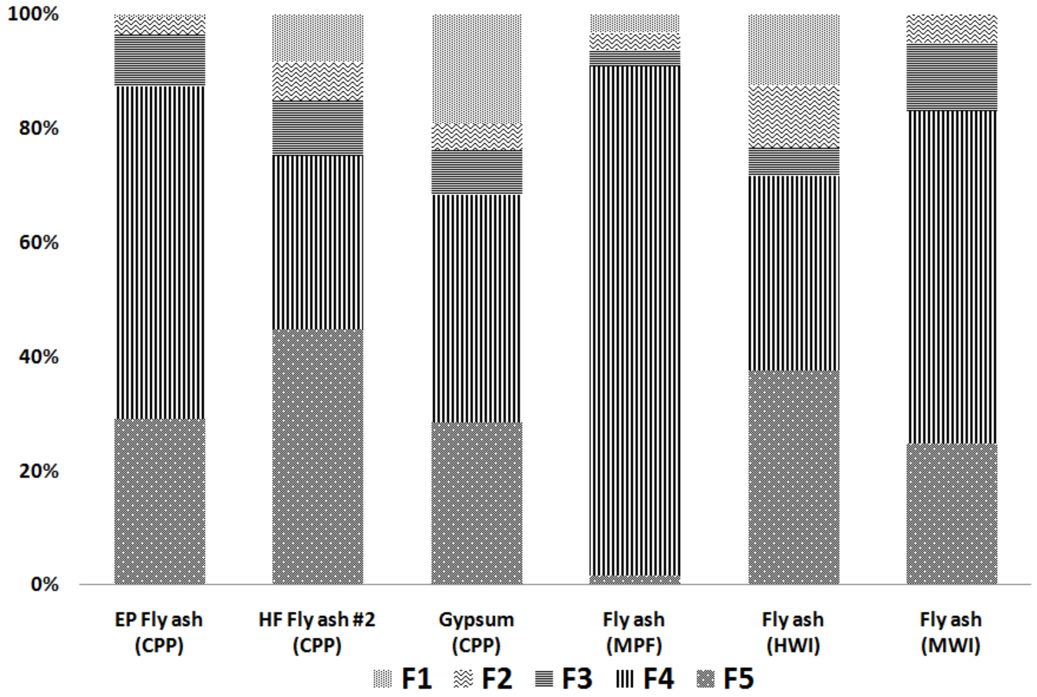

Fig. 1. Percentages of Hg in each fraction by sequential extraction procedure

Gypsum is also known as a stable material. 31.6% of mercury fractions was analyzed between F1 and F3 steps. So, Gypsum is needed to decrease the potential releases during recycle and disposal. Hg content in F5 step from hybrid filter fly ash sample increased compared with electric precipitation fly ash. Hg is usually transformed to more stable form than EP fly ash case. Fly ash from metal production facility has relatively high mercury fraction in F4 as elemental forms. 81% of mercury was contained in F4 fraction. Metal scrap was used as input material in secondary metal production process, and it is known that most of mercury is present in elemental form in metal scrap materials. So, relatively high fraction of elemental mercury was analyzed in fly ash sample. Fly ash samples in waste incinerators had high contents of elemental and residual mercury compounds form F4 and F5 steps. Mercury compounds analyzed in F4 step is known as low mobility form and F5 step is stable form. Waste incinerator fly ash samples were relatively stable form for mercury compounds.

CONCLUSION

The goals of this study are to investigate the Hg species in various wastes in order to suggest appropriate treatment methods depending on the characteristics of Hg compounds. 6 samples were collected from domestic industrial process and analysis of total mercury contents and sequential extraction procedure were conducted. Hg extracted between F1 and F3 was likely to be released into environment. It is necessary to apply appropriate method to handle by-product which contained these portions of mercury. On the other hand, mercury in F4 and F5 fraction is relatively more stable. F4 fraction means strong complex and elemental mercury. Fly ash from metal production facility has relatively high elemental mercury fraction. For this waste, thermal treatment and mercury recovery technology was needed to be applied for proper treatment. Fly ash samples from the waste incinerator have relatively stable mercury compounds. It is necessary to apply proper treatment method considering both mercury concentration and stability.

ACKNOWLEDGEMENT

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The Effect of Particle Size Ranges on Water Holding Capacity of Natural Soils with/without Coal Fly Ash Amendment

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ABSRTACT

This study aims to use FA as an ameliorant to increase water holding capacity (WHC) of the soil. The effect of raw-FA amending on WHC of natural soils with different size ranges was focus on. FA-mixed soil samples were dried at room temperature and 40 ºC. Their moisture losses were measured in one hour interval. The area of water retention curve, which was normalized weight of remained water in the sample as a function of drying time, was defined as WHC in this study. The results showed that particle size of soil has an effect on WHC. The variation of WHC of samples as a function of soil particle size shows highest/lowest WHC appeared in certain size ranges. In addition, they also depend on soil type and temperature. One-sided Welch's t-test suggested that the size dependency of WHC was regarded as significant in some size ranges even when experimental errors were taken into account. In contrast to size effect on WHC, FA amendment gave no impact on WHC. Although FA-mixed soils has a little higher WHC than pure soils in some size ranges, t-test suggested that the difference should be within error ranges. More experiments are necessary to conclude the effect of FA amendment on WHC. However, it can be suggested that size effect on WHC is stronger than FA amendment effect.

Keywords: fly ash, desertification, soil amendment, water holding capacity, size dependency

INTRODUCTION

Combustion processes of coal-fired power plants generate high quantities of fly ash. FA management is a social and environmental problem. On the other hand, land deterioration and following desertification is also a severe problem in arid areas. Therefore, if FA can be recycled as a soil amending material to improve water holding capacity of soils in acid areas, it will solve both FA management problem and desertification problem at the same time. There have been a few studies on the utilization of fly ash to ameliorate soil physical problems [1-2], and it was reported that mixing the coal fly ash can improve physical and hydrological characteristics of the soil [3]. According to a previous research, however, raw fly ash amendment decreased soil WHC but apatite-synthesized FA increased soil WHC at 40 °C [4]. In this context, the effect of raw fly ash amendment on water holding capacity (WHC) of soil would be discussed focusing on soil size dependency. It might give some hints on effective pretreatment of soil and FA.

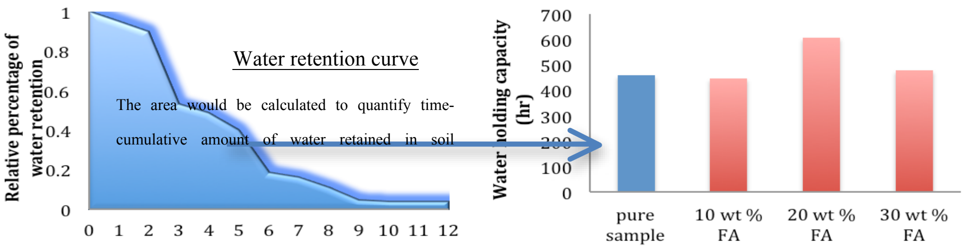

Figure 1. The concept of water holding capacity evaluated in this study

MATERIALS AND METHODS

Fly ash and soils

FA utilized in this study was taken from one coal-fired power plant in Japan. The particle size of tested FA is less than 150 μm. Two kinds of gardening soils named akatama soil (AS) and decomposed granite soil (DGS) were used. In order to study the effect of raw-fly ash amendment on WHC and particle size dependency of soil WHC, the soils were sieved into different size ranges from lager than 2 mm, 1-2 mm, 710 μm-1 mm, 250-500 μm, 150-250 μm, 75-150 μm, and smaller than 75 μm, respectively.

The Calculation of Water holding capacity (WHC)

Drying experiments were conducted under natural condition and at 40 ºC, respectively. Raw-FA was mixed with dried soils at certain mixing ratios as below: 10, 20 and 30 wt%. In order to adjust initial moisture as 30 wt%, 7.5 g of distilled water was added to 17.5 g of pure samples (DGS and AS) or the same weight of FA-mixed samples. The weights of the samples were measured every hour continuously to monitor water retention in the samples. The drying experiments were repeated three times to check experimental errors. WHC was calculated as the area of relative percentage of water retention curve within 12 hours, which could be drawn by drying experimental data. The concept of WHC measured in this study is illustrated in Figure 1. WHC measured in this study means water evaporation resistivity rather than available volumetric capacity for water in soil structure. One-sided Welch's t-test was used to identify if there were significant differences of WHC among FA-amended and pure samples with different size ranges. Significance level of Welch's t-test was 5%.

RESULTS AND DISCUSSION

The WHC characteristics of soil in different size ranges

WHC of soil sample with each size range was standardized based on the average WHC of whole size range for easy comparison. They are shown in Figure 2 for natural temperature and in Figure 3 for 40 °C. The results showed that WHC of soil samples (DGS and AS) have soil size dependency. However, WHC variation as a function of soil size is almost the same with WHC of pure DGS regardless of FA mixing ratio. For example, in the cases of DGS at natural temperature, WHC variation as a function of soil size can be found obviously and DGS with size range of 75-150 μm reaches the maximum. WHC at size range of both 150-250 μm and 250-500 μm also are approximately equal to the maximum WHC. On the other hand, highest WHC appears at size range of 1-2 mm at 40 °C. DGS with size range of both 250-500 μm and more than 2 mm also has almost the same WHC with the maximum at 40 °C. In addition, the size dependency also depends on the temperature. When size range is more than 1 mm, WHC of DGS shows clear temperature dependency. WHC is lower than the average at natural temperature but the highest at 40 °C. WHC of AS also shows the similar results of soil size dependency. The variation of WHC of AS as a function of soil size shows two peaks at 150-250 μm and more than 2 mm under natural condition. In addition, the soil at size range of 150-250 μm has lower WHC than the average at 40 °C. Welch's t-test with 5 % significance level suggests that the size dependency of WHC was regarded as significant in some cases even when experimental errors were taken into account. For example, AS has the second lowest WHC at size range of 250-500 μm and the highest WHC at size range of more than 2 mm at natural temperature, respectively. This difference is regarded as significant. In the case of DGS at 40 °C, statistically significant differences are found between the lowest WHC at size range of 250-500 μm and highest WHC at size range of 250-500 μm, 1-2 mm, and more than 2 mm. These results can be summarized that WHC of soils (AS and DGS) have soil size dependency. When drying temperature is different, optimum size range for highest WHC will be changed.

Effect of Raw FA Amendment on WHC of One Single-size-ranged Soil Samples

Pair t-test was used to check the statistical significance of WHC at the same size range among pure soil and FA-amended soil. The results by t-test are shown in Table 1 and Table 2. The yellow-colored P values in the tables are all less than 0.05, which mean the significant differences of WHC among the FA-amended soil and pure soil. Unfortunately, in all these cases, the WHCs of FA-mixed samples are lower than the pure soil's. The statistical significance checked out by t-test suggested that raw fly ash amendment decreased WHC of the soil that in those single size ranges. On the other hand, the t-test result of WHC is corresponding with previous research results, which shows that only adding raw-FA into the soil would decrease the WHC.

Table 1. P value of the WHC of FA-mixed soils in single size range under natural condition.

Natural Condition	Size Range							
	>2mm	1-2mm	0.71-1mm	0.5-0.71mm	0.25-0.5mm	0.15-0.25mm	0.075-0.15mm	<0.075mm
DGS+10 wt% FA	0.081	0.171	0.113	0.303	0.083	0.255	0.240	0.344
DGS+20 wt% FA	0.354	0.232	0.229	0.376	0.305	0.235	0.397	0.117
DGS+30 wt% FA	0.019	0.052	0.364	0.072	0.159	0.005	0.385	0.262
AS+10 wt% FA	0.129	0.195	0.381	0.477	0.199	0.241	0.243	0.362
AS+20 wt% FA	0.106	0.233	0.491	0.180	0.176	0.056	0.075	0.172
AS+30 wt% FA	0.228	0.298	0.102	0.391	0.067	0.211	0.123	0.497

Table 2. P value of the WHC of FA-mixed soils in single size range at 40 ℃.

40℃	Size Range							
	>2mm	1-2mm	0.71-1mm	0.5-0.71mm	0.25-0.5mm	0.15-0.25mm	0.075-0.15mm	<0.075mm
DGS+10 wt% FA	0.212	0.051	0.477	0.325	0.221	0.006	0.180	0.068
DGS+20 wt% FA	0.405	0.255	0.104	0.149	0.132	0.088	0.176	0.174
DGS+30 wt% FA	0.042	0.261	0.023	0.162	0.393	0.336	0.251	0.192
AS+10 wt% FA	0.030	0.149	0.297	0.106	0.265	0.180	0.242	0.135
AS+20 wt% FA	0.348	0.409	0.190	0.101	0.225	0.176	0.131	0.154
AS+30 wt% FA	0.161	0.267	0.192	0.163	0.311	0.251	0.464	0.051

CONCLUSION

The effects of raw FA amendment on WHC of soils with different size ranges were investigated. WHC of both pure soil and FA-amended soil have size dependency. Certain size range fractions have higher or lower WHC than the average WHC of whole size range. In some cases, WHC differences among different size ranges are regarded as statistically significant by Welch's t-test with 5 % significance level. Because optimum size range for the highest WHC are different between natural temperature and 40 °C, size dependency of WHC depends on the temperature. In contrast, FA amendment gave no significant impact on size dependency. When pure samples have higher/lower WHC at certain size range than the average WHC, FA-amended sample also have higher/lower WHC at the same size range. In addition, t-test also suggests in several cases that WHC is decreased by raw-FA amendment of soil samples in certain size ranges. More experiments will be necessarily focusing on the modification of raw-FA in order to increase the WHC of the soil.

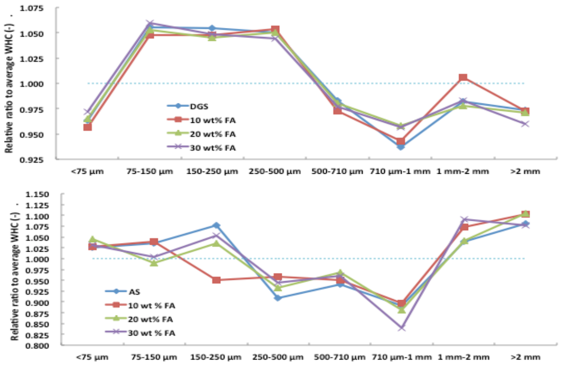

Figure 2. Relativized soil WHC based on the average under natural condition with different size ranges

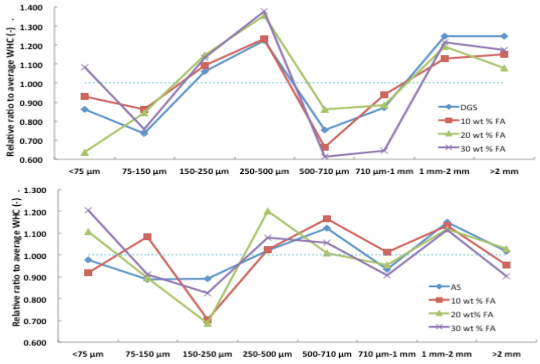

Figure 3. Relativized soil WHC based on the average at 40 ℃ with different size ranges

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Dissolution of waste concrete in HCl solution for indirect carbonation

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ABSTRACT

Research projects on mineral carbonation using industrial wasted are being conducted to reduce CO_2 emission. An indirect carbonation method has been studied because of the advantage of a reuse of products and reaction rate of mineral carbonation. In this study, the dissolution rate of Ca ion from waste concrete into HCl solution was investigated. The kinetic equation was obtained by Avrami model and the activation energy was 37kJ/mol.

Keywords: waste concrete, indirect carbonation, calcium carbonate, CO_2 fixation

INTRODUCTION

Carbon dioxide (CO_2) is the most important factor that cause global warming. Therefore, many researchers have been finding method to reduce CO_2. Mineral carbonation using solid industrial waste is a potential option for reducing of CO_2. Mineral carbonation is based on the carbonation of alkaline-earth metals (i.e. Ca, Mg) to produce mineral carbonate. The carbonate naturally remain in the solid phase, it is possible to storage for long time after CO_2 fixation. In addition, the product of mineral carbonation can be used as industrial raw materials such as construction materials or product filler if the product has suitable purity. The natural ores are typically used as a primary source for mineral carbonation and large amount of ores would be only mined. However, the waste concrete could be an alternative feedstock for mineral carbonates. The chemical composition of waste concrete is calcium, magnesium, aluminum, iron and silicon. Mineral carbonation using waste concrete can be carried out thought direct carbonation and indirect carbonation. Direct carbonation is performed through reaction of solid with CO_2 in the gaseous or aqueous phase. Indirect carbonation includes extraction of alkaline metal ions from waste concrete and carbonation with CO_2 in the gaseous or aqueous. Indirect carbonation has many advantages of a reuse of final product (solid carbonate) and reaction rate.

This study was focused on dissolution(or extraction) step in indirect carbonation using waste concrete. HCl solution was used as dissolution agent. The effect of parameter including of solid-liquid ratio, concentration, and reaction temperature on the dissolution rate of Ca ion in waste concrete was investigated and kinetic parameters are reported.

Characterization of waste concrete

The waste concrete was supplied from the site of demolishing a building in the Yonsei university. The samples were primarily ground and performed magnetic separation, then secondary crushing by boll-mill.

Ground waste concrete was sieved to particle size fraction of less than 75μm. The composition of selected sample was analyzed by X-Ray Fluorescence (XRF) spectrometer (RIX2100, Rigaku corp.) and the structural phase of selected waste concrete were determined by X-Ray diffraction(XRD) with a continuous scan mode over the 2-theta range of 20-80° under 40kV/30mA using CuK- α radiation.

Dissolution rate of Ca in waste concrete

All experiments for the dissolution rate of waste concrete in HCl solution were investigated at atmospheric pressure in round-bottom flask reactor (250ml). The reactor was placed in a circulating water bath to keep the reaction temperature and equipped with condenser which was operated with 4℃ water for reducing the vapor loss of solutions. The prepared HCl solution was fed to the reactor and heated or cooled until reaction temperature. When the temperature was kept constant, the selected waste concrete was added to reactor and mixed with HCl solution using a magnetic stirrer under stirrer speed of 400rpm. The three variables including the concentration of HCl, reaction temperature, and solid-liquid ratio were chosen as the parameter to affect the dissolution rate of Ca into the solution. To determine the effect of the parameters on dissolution rate, the experiment was performed at different condition of one of the parameters when other two parameters were constant. The range of three parameters was presented in table 2. The slurry (HCl solution and waste concrete) was sampled with a 1ml of syringe at 5s, 15s, 30s, 1min, 2min, 3min, 4min, 5min, 10min, and 20min after feeding the waste concrete to reactor and the 1ml of sampled slurry was rapidly filtered with 0.2μm syringe filter (PTFE , whatman). The filtered solution was analyzed by Ion-Exchange Chromatography (IC, IC25A, Dionex) equipped IonPac® CS12A cation-exchange column for measuring the concentration of Ca ion in the solutions. The dissolution efficiency of Ca ion was calculated using following equation:

$$X_{Ca} = m_{amount\ of\ dissolved\ Ca\ in\ solution}/m_{amount\ of\ Ca\ in\ waste\ concrete}$$

RESULTS AND DISCUSSION

Characterization of waste concrete

The composition of waste concrete was presented in table 1. According the result, CaO and SiO_2 were main component of waste concrete. For extraction step, the SiO_2 could be separated by physical filtration. The X-ray diffractogram was shown in Fig. 1. Waste concrete contained tobermorite($Ca_5Si_6(OH)_2 \bullet 4(H_2O)$), quartz($SiO_2$), and muscovite($((KAl_2(Si_3Al)O_{10}(OH,F)_2)$).

Table 1. The composition of waste concrete by XRF

CaO	SiO_2	Al_2O_3	MgO	SO_3	MnO	K_2O	Fe_2O_3	TiO_2	Others
50.10	**38.92**	**5.73**	**1.91**	**1.67**	**0.58**	**0.46**	**0.33**	**0.18**	**0.16**

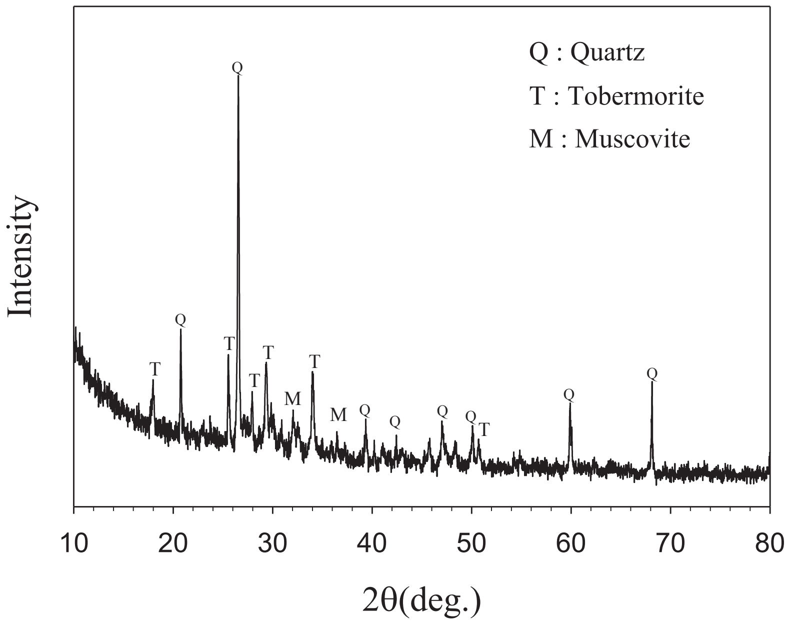
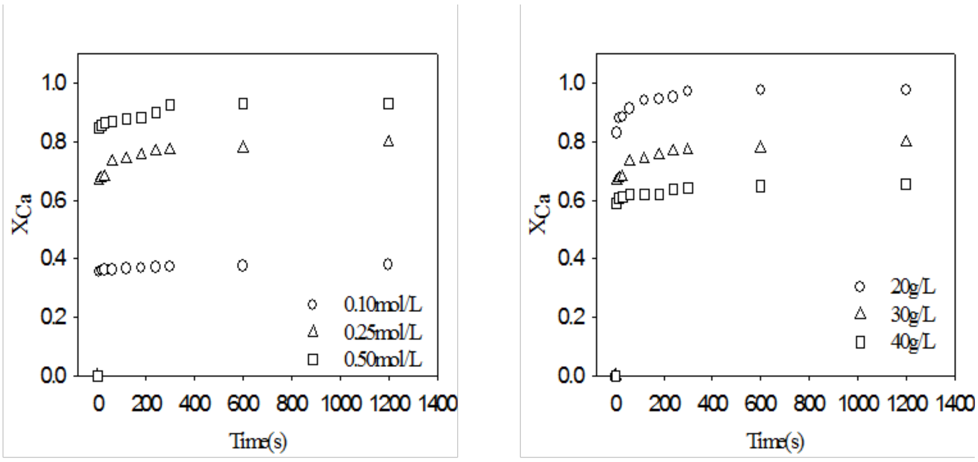


Figure 1. X-ray diffractogram of waste concrete

Dissolution rate of Ca in waste concrete

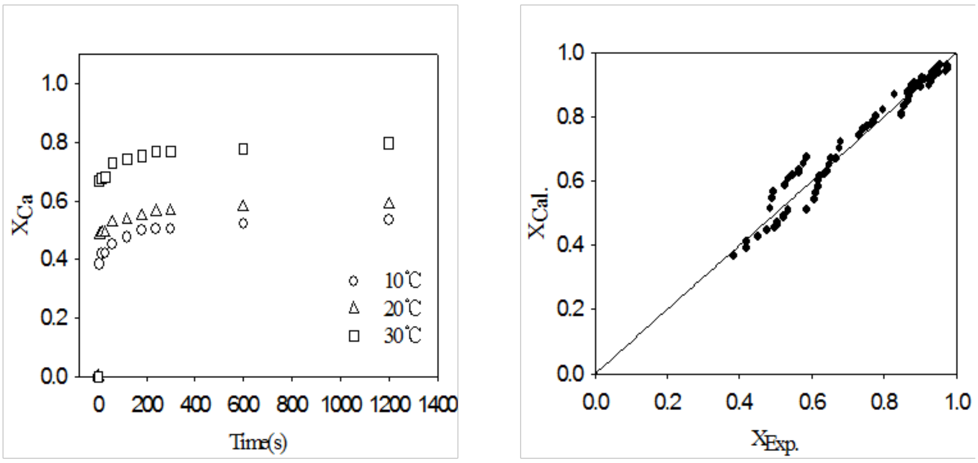
The dissolution rates of calcium ions from waste concrete were shown in Fig. 2. The concentration of Ca ion in the solution was approached to the saturated concentration within 600s in all experiment. The dissolution efficiency of Ca ions increased with increasing in the extraction temperature and the concentration of HCl solution. The result data from dissolution of Ca in HCl solution were fitted into the Avrami model and dissolution rate equation was determined by graphical and statistical method. When the reaction rate is depended on three parameter including the concentration of solution, solid-liquid ratio, and reaction temperature, the term of reaction rate constant could be expressed by function of parameter. The kinetic expression was given by:

$$-\ln(1-X_{Ca}) = 2848.96(C)^{0.58}(S/L)^{-1.52}\exp\left(-\frac{3791.25}{T}\right)t^{0.08}$$



a)The effect of concentration of HCl solution

b)The effect of soild-liquid ratio.



c)The effect of extraction temperature

d)Agreement between Xexp. and Xcal.

Figure 2. The dissolution rate of calcium ions from waste concrete

CONCLUSION

In this study, the dissolution rate of waste concrete in HCl solution was investigated. The dissolution efficiency was depended on concentration of HCl solution, solid-liquid ratio, and dissolution temperature. The kinetic equation was obtained and the activation energy was 37kL/mol.

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Enrichment and Separation of Rare Earth Metals from Dilute Solution by Solvent Extraction: Possible Application for Value Recovery from Effluent of Rare-Earth Extraction Industry

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ABSTRACT

Solvent extraction of Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy from dilute chloride solution has been investigated. In this study, PC-88A and Exxol D-80 is used as extractant and diluents, respectively, for the separation and enrichment of rare-earth metal (Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy) from chloride solution. The condition for optimum extraction efficiency is chosen through the equilibrium pH, extractant concentration, and O/A ratio variation from a simulated solution. Optimum condition was identified varying one parameter at a time. In our current report only effect of equilibrium pH (0.5 to 3) on extraction behavior has been reported. At higher equilibrium pH, the heavy REMs like; Er, Yb, Tm, and Dy are completely extracted without any discrimination, and at lower equilibrium pH (0.5) the light REMs like; Y, La, Pr and Nd get extracted quantitatively leaving heavy REMs in the solution. The equilibrium pH dependence adds potential to the enrichment of these REM followed by separation from very dilute effluents.

Keywords: Rare earth metals, PC 88A, Solvent Extraction, Industrial Effluent

INTRODUCTION

The entire elements in lanthanides, yttrium and scandium, commonly referred as rare earth element (REE) or rare earth metal (REM), are vital commodity for Korean electronics and electrical equipment industry, heavy/light vehicle manufacturing industry, green energy production, battery industry, industrial catalyst, semi-conductor industry, alloy and abrasives industry (Swain, Kang, Mishra, Ahn, & Hong, 2015). Because of unique physical and chemical properties of REM, and rare earth oxides (REO) have a wide range of high-tech functional applications such as in fluorescent materials, permanent magnets, superconductors, lasers, ceramics, semiconductors, catalysts, thermal neutron absorbents, abrasives, additives, semiconductor doping (Swain & Otu, 2011). The unique performance, strategic importance, limited resources, irreplaceable by other materials/metals, ever growing consumers' demands and potential to substantially increase in the future demands for REM, trigger global competition for these metals. As China monopolizes more than 95% of REM supply, is further aggravating economic issues (Binnemans et al., 2013). The Republic of Korea is totally depending on import for compounds or composites of rare earth metals (REMs), hence, recovery of REMs from secondary resources are feasible option and challenge too.

The solvent extraction technique is one of the most versatile method used for the removal, separation and concentration of metallic species from mixed metal aqueous media and has also been used in the extraction of REM. Commercial extraction of REMs has been carried out using different extractants viz. D2EHPA, Cyanex 272, PC 88A, Versatic 10, TBP, and Aliquat 336(Jha et al.; Xie, Zhang, Dreisinger, & Doyle, 2014). The present study examines the possibility for enrichment and separation of rare earth metals from very dilute solution by solvent extraction using PC 88A.

MATERIALS AND METHODS

Chemicals and Reagents

Simulated solutions of REMs (Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy) 50 ppm and 1 ppm each chloride were prepared by dissolving analytical grade reagents YCl_3, $LaCl_3$, $PrCl_3$, $NdCl_3$, $DyCl_3$, $ErCl_3$, $YbCl_3$ and $TmCl_3$ (Alfa-Aesar, 99.9%, Korea) in distilled water. A small amount of HCl was added to the solution to prevent hydrolysis of the metal ions. The commercial extractant 2-ethyl hexyl phosphonic acid mono-2-ethyl hexyl ester (IS Chem Co., Korea) was used as extractant and Exxol D80 (IS Chem Co., Korea) was used as diluent.

Solvent Extraction

The synthetic aqueous phase (100 mL) containing Y, La, Pr, Nd, Dy, Er, Yb, and Tm each was equilibrated with an equal volume of PC 88A in Exxol D80 by shaking in a separating funnel for 5 min. This time was found to be sufficient to attain the equilibrium which was verified in preliminary tests, which showed that about 5 min shaking is sufficient to attain the equilibrium. The initial pH of the aqueous phase was controlled by adding dilute HCl or NH_4OH before equilibration. The equilibrium pH and metal concentrations in the aqueous phase were measured after phase separation of the aqueous and organic phase.

Analytical method

The concentration of metals in the effluent, and raffinate solution was determined using ICP-AES (OPTIMA 4300DV, Perkin-Elmer, USA) after suitable dilution using distilled water. The maximum deviations permitted were about ± 5 % in ICP-AES analysis,.

RESULTS AND DISCUSSION

Effluent of rare-earth extraction industry was analyzed by ICP-AES. The concentration of REM presented below in Table 1. The Table 1 shows in the effluent about 1186 ppm of Nd and 24.98 ppm of the Dy along with other REM.

Table 1: REM content in the effluent of effluent of rare-earth extraction Industry

	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	H0	Er	Tm	Yb	Lu	Th
ppm	1.742	239	0.998	2.20	1186	0.798	1.474	0.558	1.20	24.98	0.072	1.778	0.013	0.114	0.064	0.018

The extraction behavior of Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy was investigated using 0.1 M of PC 88A at two different cases. In one case 50 ppm and another case 1 ppm each REMs (Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy) in the aqueous solution was used for extraction. Figure 1 shows the extraction behavior of REMs as a function equilibrium pH. The equilibrium pH varied from 0.5 to 3.0 and PC 88A concentration kept constant 0.1 M. The Figure 1 shows at equilibrium pH 0.5, only light REMs are selectively extracted leaving the heavy REMs in the solution. The same figure also depicted that the heavy REMs are extracted quantitatively along with light REMs. The extraction behavior of light and heavy REMs was almost same for both the case, i.e., 1 ppm and 50 ppm solution. The Figure 1(a and b) indicates that the light and heavy REMs can be selectively separated at two groups as a function of Equilibrium pH irrespective of their concentration in the aqueous phase. From Figure 1 it can be reasonably concluded that from very dilute solution and moderate concentrated Y, La, Pr, Nd, Dy, Er, Yb, and Tm solution the heavy and light REMs can be separated and concentrated as two different groups. Similarly, if required the heavy and light lanthanides can be separated as well as enriched.

CONCLUSION

(i) The REMs like; Y, La, Pr, Nd, Dy, Er, Yb, and Tm can be extracted and enriched as heavy and light REM group using PC 88A as an extractant from chloride media controlling the equilibrium pH.

(ii) After Nd and Dy recovery from effluents, the minor contents of REMs can be targeted for enrichment followed by recovery by hydrometallurgy process using PC 88A as an extractant.

(iii) Using several times, the same extractant, the heavy and light REMs can be enriched many folds.

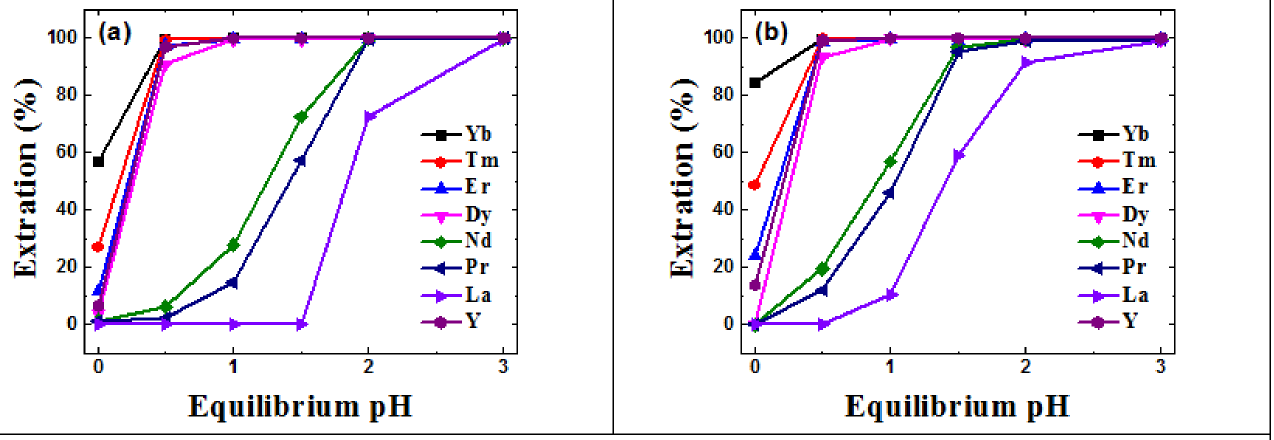

Figure 1: Extraction behavior of REMs as a function of Equilibrium pH (a) from 1000 ppb and (b) from 1000 ppm simulated solution. Experimental Condition: 50 ppm and 1000 ppb each of Y, La, Pr, Nd, Dy, Er, Yb, Tm, and Dy in chloride media, PC 88A concentration of 0.1 M and Equilibrium time 10 min, and room temperature.

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The study on pyrolytic characteristics of biomass by slow pyrolysis for pyrolysis oil; an analysis of GC-MS and FTIR

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ABSTRACT

The slow pyrolysis of pine sawdust was performed to improve the quality of Pyrolysis oil by controlling different temperatures. The slow pyrolysis has low heating rates and a long residence time. The range of the temperature was from 400 °C to 500 °C in anaerobic condition. Pyrolysis oil, char and gas were produced and measured by the mass balance, GC-MS and FTIR. The highest yields of pyrolysis oil was 36 wt % at 400 °C. Above 400 °C, the other products such as char and gas were increased. The chemicals of the biomass increased such as Phenols, Alcohols, providing the high heating value in pyrolysis oil at higher temperature. The stretching vibration peak of C-O (1268-1090 cm $^{-1}$) and C=O (1720-1660 cm $^{-1}$) in char disappeared gradually at different temperatures, indicating the removal of oxygen via carbonylation reaction measured by FT-IR.

Keywords: Slow pyrolysis, Pyrolysis oil, Char, GC-MS, FTIR

INTRODUCTION

The industry of renewable energy grows up because of the unstability of the coal supply and greenhouse gas (Kim K H., Kim T S. et al. 2013). Biomass has the abundant amount of a carbon-based organic compound. The promising technologies for alternative energies were thermal and biological decomposition. Carbon in biomass can be fixed through the photosynthesis, resulting in no change of the carbon concentration at the atmosphere called carbon neutral. The unedible biomass such as forest waste is composed of cellulose-based fabric. It is one of the recycled energy sources instead of being buried or incinerated. The slow pyrolysis can decompose structures of the cellulose, hemicellulose and lignin with low heating rates and a long reaction time. The pyrolysis oil produced could replace fossil fuels with transportation fuel and bio-chemicals. The high level of purification and calorific value should be run at the same time to apply for it though. The char as solid products has high carbonaceous and nutritional factors for agriculture. This gas has contained the syngas component such as methane, hydrogen and carbon dioxide.

In this study, the slow pyrolysis in the semi-batch reactor was used to produce the char, pyrolysis oil and gas. Chemicals in pyrolysis oil and functional groups in solid were measured by using GC-MS and FTIR. Pine sawdust is composed of hemicellulose, cellulose and lignin. The chemical compositions of pyrolysis oil show the products derived from the decomposition of biomass at different temperatures. The spectra of the chars obtained at the different temperatures proved the chemicals of pyrolysis oil in terms of the cleaved C-O (1268-1090 cm $^{-1}$), CHn (3044-2915 cm $^{-1}$) and OH (3504-3335 cm $^{-1}$) at different temperatures. One purpose of this study was to reveal the tendency on relationship between chemicals of liquids and of chars at the different temperatures.

MATERIALS AND METHODS

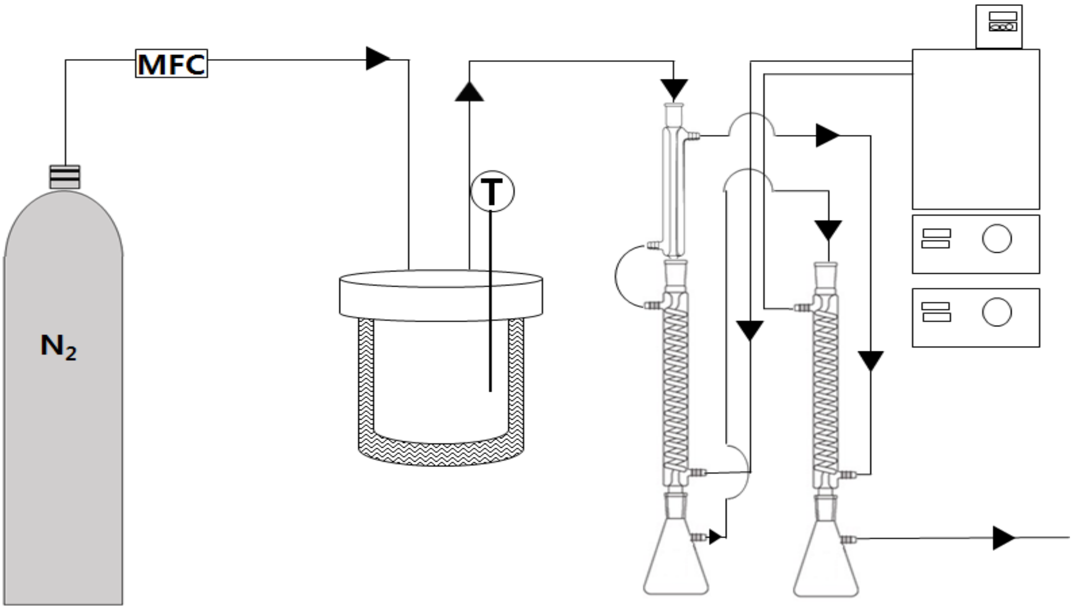

Figure 1. Schematic diagram of slow pyrolysis on pine sawdust

Slow pyrolysis

The experimental was performed with the pine sawdust by using slow pyrolysis in Fig. 1. The sample was from the National Forestry Cooperative Federation in Republic of Korea. This sawdust was dried at 65 °C for 5 days in the oven. The particle size of sawdust sieved was 0.425 mm. The slow pyrolysis has low heating rates and a long residence rate in semi-batch reactor, 1L (Wang Z., Jianqin C. et al., 2009). Nitrogen as a carrier gas made the inside reactor under the absence of oxygen at supplied 150 mL/min. The temperature was monitored through a K type thermocouple inside the reactor. The heating rate was 10 °C/min. The long reaction time was 40 min at the programmed temperature. The slow pyrolysis was performed at 400 °C, 450 °C and 500 °C. The pyrolysis vapor at temperatures was condensed in chiller at - 11 °C. It was condensable liquid called pyrolysis oil including moisture and organic fraction. Non-condensable vapor was vented into the hood. After pyrolysis finished, the char remained in the reactor with the dark carbonaceous one.

RESULTS AND DISCUSSION

Yield produced at different temperatures

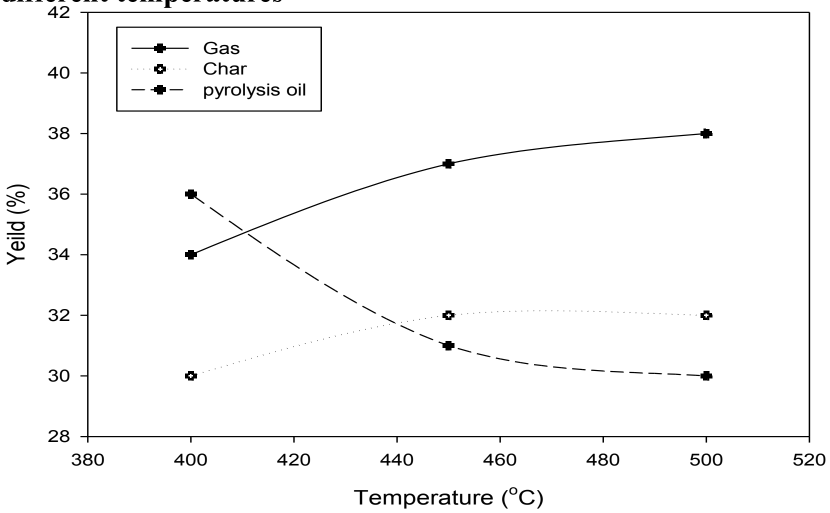

Figure 2. Yields derived from the slow pyrolysis: Gas, Char, and pyrolysis oil

As shown in the Fig. 2, the yield of products was changed depending on effect of temperatures. The char and gas were increased from 30 wt %, 34 wt % to 32 wt %, 38 wt % at the higher temperatures. On the other hands, the pyrolysis oil was decreased gradually from 36 wt % 30 to wt. % at the higher temperature. The maximum yield of the pyrolysis oil was observed at 400 °C. The higher temperature of the slow pyrolysis led to escalate the large amount of gases with the reaction of hydrocarbon and aromatic compounds in slow pyrolysis (Chaiwong K., Kiatsiriroat T. et al., 2013). With the increased yield of gas, the pyrolysis oil was decreased with the rejected H_2O, CO, CO_2, and CH_4 via deoxygenation reactions such as dehydration, decarbonylation and demethylation (Stefanidis, S. D., Kalogiannis K. G. et al., 2009).

Char characteristics

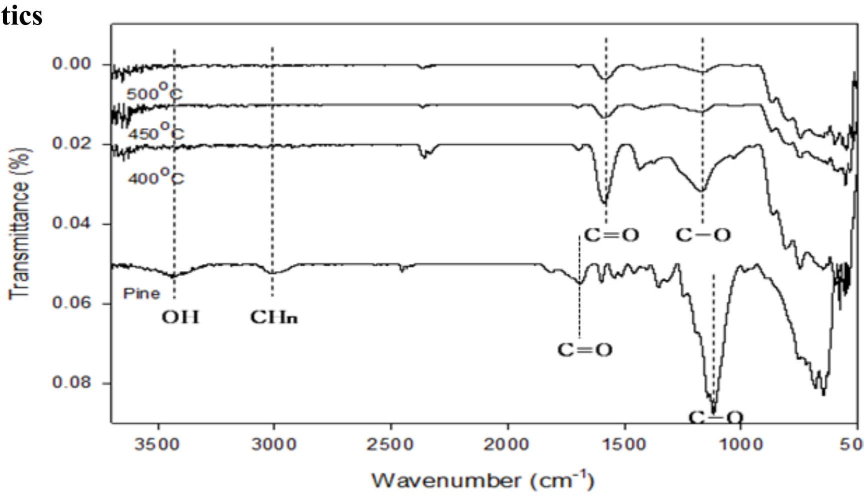

Figure 3. Effect of temperature on FTIR spectra of Pine and its chars

Fig. 3 shows the FTIR spectra of chars produced at different temperatures compared with one of the raw material. The IR bands of the chars indicated the stretching vibration peak of C=O (1720-1660 cm^{-1}), C-O (1268-1090 cm^{-1}), CHn (3044-2915 cm^{-1}) and OH (3504-3335 cm^{-1}) (Sharma K. S., Wooten J. B. et al., 2004). The intensity of the band at C-O (1268-1090 cm^{-1}) and C=O (1720-1660 cm^{-1}) was decreased gradually from raw materials to 500 °C in agreement with the results that the yield of gas could be higher above 400 °C. CHn (3044-2915 cm^{-1}) and OH (3504-3335 cm^{-1}) disappeared after slow pyrolysis, implying completely dehydration of holocellulose at 400 °C (Zhenya W., Jianqin C. et al., 2009).

Pyrolysis oil characteristics

Table 1. Effect of temperatures on the compositions of liquids

Functional Group	Temperature (℃)		
	400	450	500
Phenols	51.75	54.50	57.97
Furans	23.27	21.84	18.92
Ketones	8.77	8.23	7.97
Alcohols	8.13	8.91	10.72
Sugars	4.51	3.94	2.53
Aldehydes	3.03	2.50	1.51
Acids	0.52	0.07	0.38

Functional groups in the pyrolysis oil were described about the conversion of each compositions on the Table 1. It reported that the chemicals of pyrolysis oil were derived from each components of lignocellulose; Cellulose, Hemicellulose, Lignin. At the higher temperatures, the Phenols, Alcohols were increased, indicating the decomposition behavior of lignin (Robert J., Evans and Thomas A. et al., 1987). The decreased Ketones, Aldehydes, and Acids groups produce higher quality of pyrolysis oil with stable and low viscosity in pyrolysis oil at higher temperature. The high heating value in pyrolysis oil was produced by converting Furans into aromatic compounds for alternative fuel (Zhenya W., Jianqin C. et al., 2009).

CONCLUSION

This study of the purpose is to investigate pyrolysis characteristics of products derived from decomposition of lignocellulose at different temperatures. Products were studied by the analysis of GC-MS and FTIR. The slow pyrolysis can produce the pyrolysis oil, char and gas at the different temperatures. The temperature at 400 °C would be the point for maximum yield of 36 wt % for pyrolysis oil with the minimum yield of char, gas. The stretching vibration peak of CHn (3044-2915 cm^{-1}) and OH (3504-3335 cm^{-1}) disappeared, indicating release another phase such as H_2O, CO, CO_2, CH_4. The dehydration of holocellulose was measured, implying the increase of Ketones, Sugars. The decomposition of lignin and cellulose could have influenced in increasing the yields of Phenols, Alcohols at 450 °C, 500 °C. This study resulted in the effect of temperature on the decomposition of lignocellulose for the high quality pyrolysis oil.

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Mercury immobilization by chelate-complexation for MSWI fly ash: its dependency on chelate/mercury ratio, chelate/mercury storage time & temperature and effect of co-existing ions

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ABSTRACT

Japan currently utilizes incineration as the main method of municipal solid waste disposal. One of the biggest advantages of incineration is the reduction of the mass and volume of waste by up to 90%. Incineration residues, in particular, fly ash contains heavy metals such as mercury (Hg), cadmium (Cd) and lead (Pb) found in the waste stream that vaporize during combustion and condense on the fine fly ash particles in the air pollution control system. In Japan, the Waste Disposal and Public Cleansing Law prohibits the disposal of fly ash unless it is treated via melting, cementation, chemical agents or leaching with acids and other solvents. This study focuses on the use of a chemical agent, namely sodium diethyldithiocarbamate (SDDC), which is widely used at incineration sites across Japan for the immobilization by chelation of heavy metals in the fly ash. For the purpose of this study, mercury (Hg) was selected as the targeted heavy metal. The main objective of this study was to understand the different factors that affect how SDDC forms complexes with Hg. Several factors were studied, namely, effect of SDDC-Hg ratio, SDDC storage time, SDDC-Hg mixture storage temperature and impact of co-existing ions. The main method of testing SDDC-Hg complexation is as follows: Mercury chloride (Hg^{2+}) and SDDC solution were mixed at an initial concentration of 100 µg-Hg/L with SDDC-Hg molar ratios ranging from 0.01 to 10. The Hg-SDDC mixture solutions were shaken at 200 rpm for 10 minutes and then left at room temperature for 24 hours to complete Hg-SDDC complexation. Free Hg^{2+} in the mixture solution was then measured using Cold Vapor Atomic Absorption Spectrometry with tin(II) chloride as a reducer. Results show that variation in SDDC-Hg ratio and the presence of co-existing ions affect complexation, specifically the ability of SDDC to immobilize Hg^{2+} ions.

Keywords: mercury, MSWI fly ash, chelate, complexation

INTRODUCTION

Due to limited landfill space, Japan has become one of the success stories when it comes to enforcing sorted collection and recycling for the promotion of a sound material-cycle society as a goal to reduce the amount of municipal solid waste (MSW) generated. However, Japan still has to rely heavily on incineration as the main method of MSW disposal, with up to 80% of all MSW disposed of in this way. Incineration, however, still generates up to 10% by volume, residues in the form of bottom ash (BA) that remain after waste combustion and fly ash (FA) that are removed from flue gases. Due to the presence of heavy metals such as cadmium, lead and mercury, particularly in the FA, it cannot be disposed of unless treated according to the Waste Disposal and Public Cleansing Law. One common treatment method used is a group of chemicals called chelating agents which can immobilize the heavy metals in the FA and prevent them from leaching out once the FA is landfilled or reused. This study focuses on one particular type of chelating agent, sodium diethyldithiocarbamate (SDDC), which is widely used at incineration sites across Japan for treating MSW incineration (MSWI) FA. However, in 2011 at a MSWI facility located in Nagano, post-SDDC treated FA was found to have leached mercury exceeding the standard allowable limit of 0.005mg/L. The circumstances and factors surrounding this incident were unknown. However, this incident was recorded to have occurred intermittently but no particular cause or pattern for its occurrence could be identified. With the low-usage of mercury in consumer products, proper recycling systems and strict mercury emission controls across Japan, it is puzzling that the MSW could contain high amounts of mercury that would end up in the FA. Also, another question arose as to why the SDDC was able to form complexes with other heavy metals and thereby prevent leaching but was unable to do so for mercury. As a first step towards finding the root cause of this problem, it was important to identify and study the factors that could affect the SDDC-mercury complexation, hence the motivation for this research.

MATERIALS AND METHODS

SDDC-Mercury ratio study

Mercury chloride (Hg^{2+}) and SDDC solution were mixed at an initial concentration of 100 µg-Hg/L with SDDC-Hg molar ratios ranging from 0.01 to 10. The SDDC-Hg mixture solutions were shaken at 200 rpm for 10 minutes and then left at room temperature for 24 hours to complete SDDC-Hg complexation. Free Hg^{2+} in the mixture solution was measured using Cold Vapor Atomic Absorption Spectrometry with tin(II) chloride ($SnCl_2$) as a reducer and 9M sulfuric acid to create an acidic medium for the Hg^{2+} reduction.

SDDC storage study

This study was carried out by preparing the SDDC solution and storing it at a room temperature of 25! ± 3!ºC. The SDDC solution was used for SDDC-Hg ratio study at storage intervals of 0, 5, 10, 20 and 50 days.

SDDC-Hg mixture storage temperature study

SDDC-Hg mixtures at pre-selected ratios of 0.1 to 10 were stored at 5ºC, 25ºC and 35ºC respectively. These mixtures were then used for the SDDC-Hg ratio study in order to understand the effects of storage temperature.

Effect of co-existing ions study

Ca^{2+}, Na^{+}, Mg^{2+} and Cl^{-} containing solutions were prepared using calcium nitrate tetrahydrate, sodium nitrate, magnesium nitrate hexahydrate and sodium chloride solids respectively. Ionic-Hg mixtures at pre-selected molar ratios (Co-existing ions: Hg) of 0.1, 1, 10 and 20. SDDC was then added to each mixture based on SDDC:Hg molar ratio of 1. Next, the shaking, storing, diluting steps are carried out similarly to that of the SDDC-Hg ratio study. The mixtures are then analyzed using the mercury analyzer.

RESULTS AND DISCUSSION

Effect of SDDC-mercury ratio

Referring to Fig. 1, the result of the study on the effect of SDDC-Hg ratio shows an interesting trend. Detected free mercury decreases steadily from SDDC-Hg ratio at 0.1 until it reaches a ratio of around 5. Beyond this point, the detected free Hg begins to gradually increase up to ratio of 10. One particular concern is the

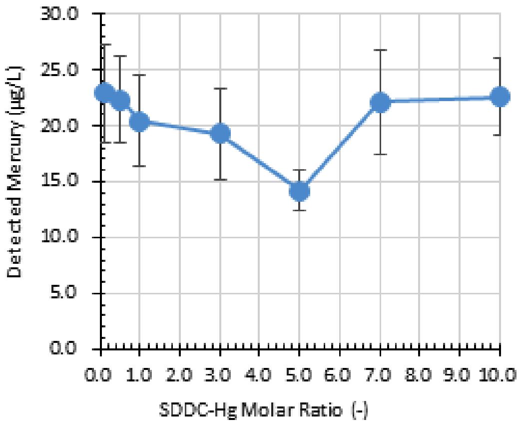

Fig.1 Effect of SDDC-Hg ratio

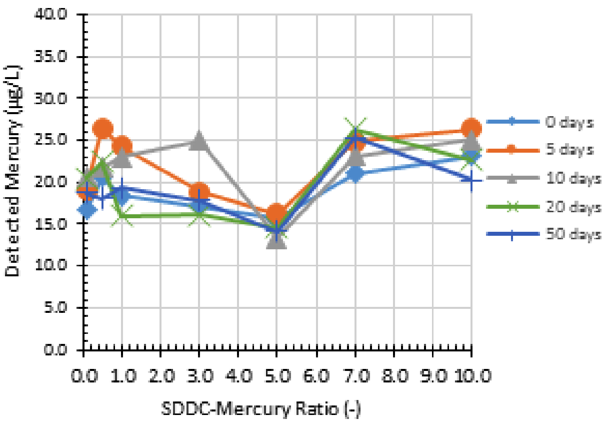

Fig.2 Effect of SDDC storage time

functional group/groups of complexes formed and whether these change as the concentration of SDDC varies. The major hindrance to the understanding of this mechanism is that currently, there is no spectrometry equipment available in the market that is able to detect chemical concentrations below 100ppb. Specifically, identification of chemical bonds and distinct species is currently not possible due to lack of specialized equipment. For example, current FTIR analysis requires a minimum concentration of at least 100,000 ppb for water-base samples.

Effect of SDDC storage time

SDDC is water soluble. However, it decomposes slowly in aqueous solution to form carbon disulfide and methylamine or other amines. This decomposition is accelerated by acids. Taking this factor into consideration, should decomposition of the SDDC solution occur during long storage at incineration facilities, it may be possible to suggest this as one of the causes of mercury leaching since the complexation-forming efficiency of SDDC would have changed. However, based on Fig. 2, detected free Hg shows a relatively consistent trend, indicating little change in chelating efficiency. Therefore, for storage of up to 50 days at least at room temperature, SDDC retains its ability to form complexes with Hg.

Effect of SDDC-mercury mixture storage temperature

As shown in Fig. 3, for all three temperatures, the curves show a trend similar to the one obtained for SDDC-Hg ratio study. Gradual decrease of detected mercury occurs beyond ratio 0.1 down to a lowest point and then rising again beyond that to 10. The noticeable difference is that for SDDC-Hg mixture stored at 5°C, the lowest point of detectable mercury has somehow shifted from ratio 5 to 3. Currently, the mechanism of how this happens is not understood but it may be that the average kinetic energy of the complexation reaction at 5°C has changed owing to different complexation forms, resulting in the shift. Further investigation is necessary to confirm this.

Effect of co-existing ions

As mentioned early, MSWI fly ash contains huge quantities of ions that exist alongside Hg. In fact, there are thousands of times more ions such as Ca and Cl than Hg. As shown in Fig. 4, with the dosage of ions such as Ca^{2+}, Mg^{2+}, Na^{+} and Cl^{-}, the detected free Hg increases greatly, in effect double the amount that of the solution without any ionic addition. This clearly shows that these various ions that exist in large quantities in

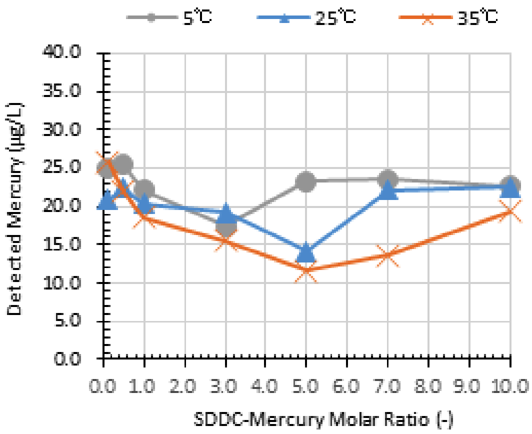

Fig. 3 Effect of SDDC-mercury mixture storage temperature

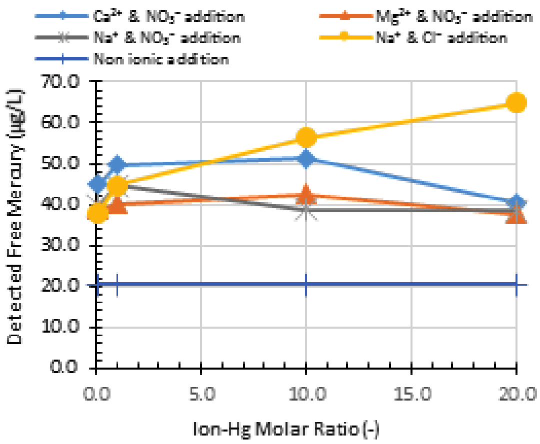

Fig. 4 Effect of co-existing ions

FA inhibit SDDC-Hg complexation. From the curves, as far as cations are concerned, it can be seen that Ca^{2+} ions are creating greater inhibitions on SDDC-Hg complexes compared to Mg^{2+} and Na^+. This inhibition, however is surpassed in greater magnitude by Cl^- ions, particularly at higher concentrations.

CONCLUSION & RECOMMENDATION

Based on the findings obtained from this research thus far, the factors that affect SDDC-Hg can be identified. Excessive SDDC is not able to form complexes with all available Hg but instead leads to higher release of free Hg. SDDC storage time does not affect chelating efficiency for up to 50 days of storage (at room temperature). SDDC-mercury mixture storage temperatures at 5°C, 25°C and 35°C show a similar complexation trend. At 5°C, the SDDC-Hg ratio at which the lowest value of Hg is detected shifts to the left (lower ratio). Co-existing ions interfere with SDDC-Hg complexation, leading to higher levels of detectable Hg. The current understanding on SDDC-Hg complexation is definitely still at a preliminary stage and further research is necessary to clarify the the mechanism and interdependence of each factor.

ACKNOWLEDGEMENT

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Color preference of trash containers for combustible waste, incombustible waste, PET bottles and cans scaled by binary pairwise comparison method

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ABSTRACT

Trash bins (trash containers) can be regarded as an important social infrastructure to keep public places sanitary and beautiful. The authors assume that the trash bin design will influence the waste segregation efficiency (functionality) of trash bin. The objective of this research is to find preferred color of trash bins for combustible waste, incombustible waste, PET bottles and cans. The authors conducted web questionnaire survey to scale the preference degree of trash bin color by binary pairwise comparison method. Color preferences were evaluated quantitatively as Z values based on Thurston's law of comparative judgment. In this research, the authors found that the most preferred colors of trash bins were red for combustible waste, black for incombustible waste, blue for can and white for PET bottle, respectively. Gray color was always preferred for all types of wastes. In contrast, purple was not preferred for any wastes.

Keywords: trash bin, color design, web-questionnaires

INTRODUCTION

In Japan, waste separation has been implemented over 40 years. There are 5 main types of wastes: combustible waste, incombustible waste, PET bottles, cans (metals) and glasses. Even through almost all of Japanese people already know the importance of waste recycles, segregation efficiency of recyclable wastes is still low in their daily life, especially in public places. For example, we can always find foreign substances such as PET bottles in collected "combustible wastes". In any places including private and public spaces, we always use trash bins (trash containers) to collect our wastes. Therefore, we can consider trash bins as an important social infrastructure to keep public/private spaces sanitary and beautiful. There are many different design of the trash bin in Japan. Two examples are shown in Figure 1. In this study, the authors focus on the trash bin design, especially color, because we assume the trash bin color will influence the waste segregation efficiency


Figure 1. Two types of trash bin design in Japan

(functionality) of trash bin. For example, blue color is used for all trash bins shown in the upper of Figure 1. On the other hand, the blue is only used for "cans" trash bin in the lower. It is uncertain which design is better or preferable to make people notice appropriate trash bin when they dispose of some wastes. In this research, the objective is to find the preference degree of different colors of four types trash bins (combustible, incombustible, can and pet bottle) design for people.

PREFERENCE DEGREE EVALUATE METHODS

Concept of method

In this research, we used web questionnaires data to scale the preference by binary pairwise comparison method. At first we decide 10 common different colors for the trash bins design, and marked these color by blue—A, red—B, yellow—C, brown—D, pink—AB, green—AC, orange—BC, white—W1, gray—W2, black—W3, receptively (see Figure 2). In the web questionnaires, two trash bins with different colors were shown to the questionees. They were requested to only answer which color they feel better depending on their image. Selection ratio dataset were analyzed to quantify the preference degree (Z value) using Thurston's law of comparative judgment.

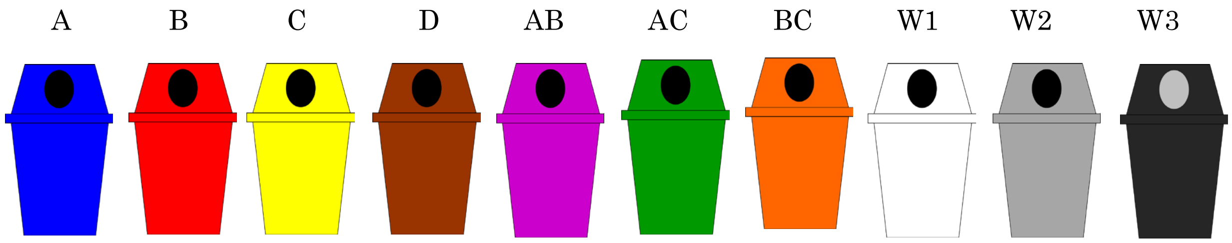

Figure 2. Trash bins with different colors

Preference degree scaled by Thurston law of comparative judgment

For pairwise comparison method, each object is matched with each of the other objects. In this research, the objects are the trash bin with different colors. Thurston's law of comparative judgment assumes cumulative Gaussian normal distribution with the mean of 0 and the variation of 1 to describe the relation between selection ratio and the difference of preference (see Figure 3). Selection ratio data were converted by inverse transform of cumulative Gaussian normal distribution curve (see equation 1) and the average of converted data represents the degree of preference (Z value) (see Figure 4).

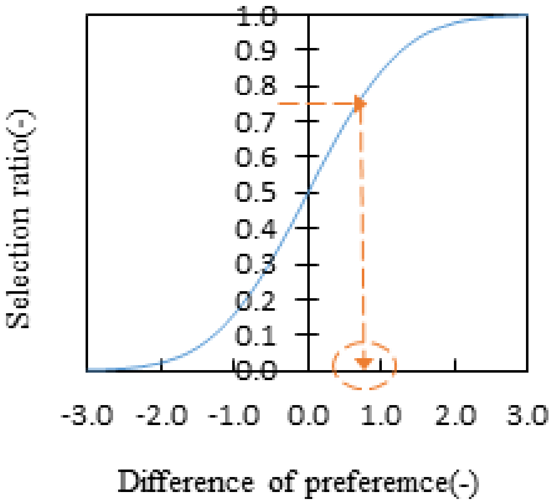

Figure 3. Relation between selection ratio and preference difference described by cumulative Gaussian distribution curve (mean=0, variation=1)

	A	B	…	W3	Average (Z value)
A	0	Z_A-Z_B	…	Z_A-Z_{W3}	Z_A-1/10(Z_A+Z_B+…+Z_{W3})
B	Z_B-Z_A	0	…	Z_B-Z_{W3}	Z_B-1/10(Z_A+Z_B+…+Z_{W3})
…					
W3	Z_{W3}-Z_A	Z_{W3}-Z_B	…	0	Z_{W3}-1/10(Z_A+Z_B+…+Z_{W3})

Figure 4. Calculation concept of color preference Z valve

$$F(A)=\frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{Z_{AB}}\exp\left(-\frac{(Z_A-Z_B)^2}{2\sigma^2}\right)dZ_A \qquad \text{(Eq.1)}$$

where F(A) is selection ratio of object A, σ is standard deviation (=1.0), Z_{AB} (Z_A-Z_B) is the difference of color preference between object A and object B, Z_A and Z_B are preference of object A and object B, respectively. In this study, we got 210 questionnaires. Questionees were adjusted to set equal male/female balance and equal age distribution from 20’s to 60’s at 10-year age interval.

RESULTS AND DISCUSSION

Figure 4 shows the calculated Z values (color preference) of trash bin colors for combustible waste, incombustible waste, can and PET bottles, respectively. Higher Z value means higher preference. The color with higher preference makes people feel as “appropriate color” for target type of waste. Obviously, the most preferred colors of trash bins are red for combustible waste, black for incombustible waste, blue for can and white for PET bottles, respectively. Although red color is preferred for combustible wastes trash bin, it does not give good preference to people as other waste trash bin. Orange color is also preferred as combustible waste trash bin. There are large gap of the preference between red/orange and others. Because such preferred colors remind fire color, they seem to be preferred. Black and gray are preferred for incombustible waste. As the same with preferred colors for combustible waste, there are large gap between black/gray and other colors for incombustible waste. Such preferred colors might remind “anti-fire” and thus seem to be preferred. On the other hand, preferred colors for cans are strange. They are blue, gray, yellow and orange. They have no color similarity although preferred colors for combustible waste, incombustible waste and PET bottles have color similarity. White and gray are specifically preferred for PET bottles. Green is also preferred compared with other colors excluding white and gray. This might be derived from the color of green tea bottles. In this survey, gray is relatively preferred for all types of wastes. In contrast, purple is not preferred regardless of waste type. Two types of further studies are necessary. The first aims to explain reasons of color preference. The other aims to evaluate the effect of trash bin color on waste segregation efficiency.

CONCLUSIONS

This study aimed to find appropriate design of trash bins to promote trash bins’ functionality and help people activate waste segregation behaviors. According to web-based questionnaires, the authors found preferred trash bin colors for 4 types of wastes (combustible waste, incombustible waste, can, and PET bottles). They are red for combustible waste, black for incombustible waste, blue for can and white for PET bottles, respectively.

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Table 1. Calculated Z values of trash bin colors for combustible waste, incombustible waste, can and PET bottles

Combustible		Incombustible		Can		PET bottle	
Color	Z valve	Color	Z valve	Color	Z valve	Color	Z valve
B	0.3264	W3	0.3740	A	0.1334	W1	0.3822
BC	0.2921	W2	0.3396	W2	0.1237	W2	0.3420
W2	0.0664	A	0.1060	C	0.0929	AC	0.1608
D	0.0474	D	0.0715	BC	0.0833	C	0.0534
W1	0.0179	BC	-0.0459	AC	0.0060	A	0.0338
C	-0.0505	AC	-0.0701	W3	-0.0299	BC	0.0315
W3	-0.1145	C	-0.0854	B	-0.0336	B	-0.0473
AC	-0.1230	AB	-0.1147	D	-0.0784	W3	-0.1631
A	-0.2190	W1	-0.1783	W1	-0.1201	D	-0.3018
AB	-0.2431	B	-0.3967	AB	-0.1774	AB	-0.4915

*Higher Z value means higher color preference, which make people feel appropriate color for target type of waste

Survey on readability of biomass energy online information in Indonesian language (*Bahasa Indonesia*)

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ABSTRACT

Although Indonesia is one of the wealthiest biomass countries, the utilization of its biomass potential is still low. Low public understanding on biomass energy is suspected as one of the main causes as also revealed by previous studies. This study presents a survey on readability of biomass energy information which is available in internet and written in Indonesian language. In this survey, nineteen textual information were read by university students as the subject of survey. Subjects were then asked to fill out seven check-lists and one open-ended question regarding the readability of the texts. The check-lists were weighted by some scores ranges. This study indicates a need of improvement in preparation of written information on biomass energy. In the preparation of biomass energy information, the focus should not only from the content point of view, but also from the readability of the information.

Keywords: internet, Indonesia, biomass information, readability of information, survey

INTRODUCTION

Indonesia is one of the richest biomass countries, however the utilization of its biomass potential is still fairly low (Hasan et al. 2012) (Abu Bakar & Ameer 2011). As Indonesia is the world's third largest rice producer and a rice consumer as well as the world's largest palm oil producer country, the biomass potential in Indonesia mainly comes from rice residues (rice husks) and palm oil residues (Anon n.d.) (Hasan et al. 2012).

Some recent studies on adoption of renewable energy technology show that information on renewable energy still remains as one of the barriers. In a neighboring country to Indonesia, Malaysia, there is an understanding gap on renewable marine energy information particularly between policy makers, investors, and the general public. This gap has also become a barrier to push the technology forward (Lim & Lam 2014). The implementation of renewable energy in India still also faces some barriers which are related to its information, such as the lack of a formal information channel on renewable energy for small and medium-scale enterprises, poor access to renewable energy information compared with the access to conventional energy technologies, lack of easy access to information about the latest renewable energy technologies, and also the preference of general public to take their friend's advice rather than to obtain information from experts (Luthra et al. 2015).

Biomass information in the Indonesian language (*Bahasa Indonesia*) may also be difficult to understand, which, in turn, is influencing the Indonesian people's knowledge on renewable energy. Regarding the information source in Indonesia, internet becomes the most accessed media surpassing television, newspaper, radio, tabloid, and magazine (Insight 2012). Indonesian people are also among the largest users of internet and the number of internet users in Indonesia has grown dramatically this decade (Anon n.d.).

Therefore in this paper, we present a survey on readability of biomass energy information available in internet written in Indonesian language.

MATERIALS AND METHODS

We selected 19 educational materials on biomass energy available in internet. We used Google® Indonesia as the search engine and employed the following terms/keywords in the Indonesian language; *energi biomassa, biomassa, energi terbarukan biomassa,* and *tenaga biomassa*. The translation of those terms is biomass energy, biomass, renewable energy of biomass, and biomass power respectively. The textual materials were read by university students as the subject of survey. University students were selected as the subject because most of the internet user in Indonesia is in the age of undergraduate level of university student (see Figure 1).

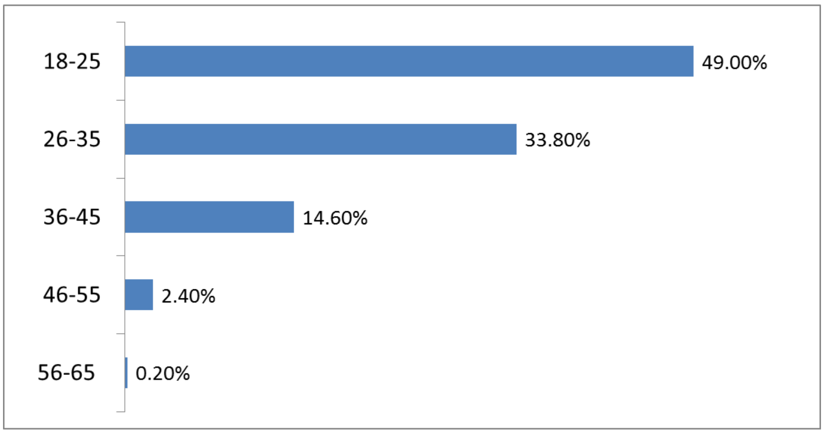
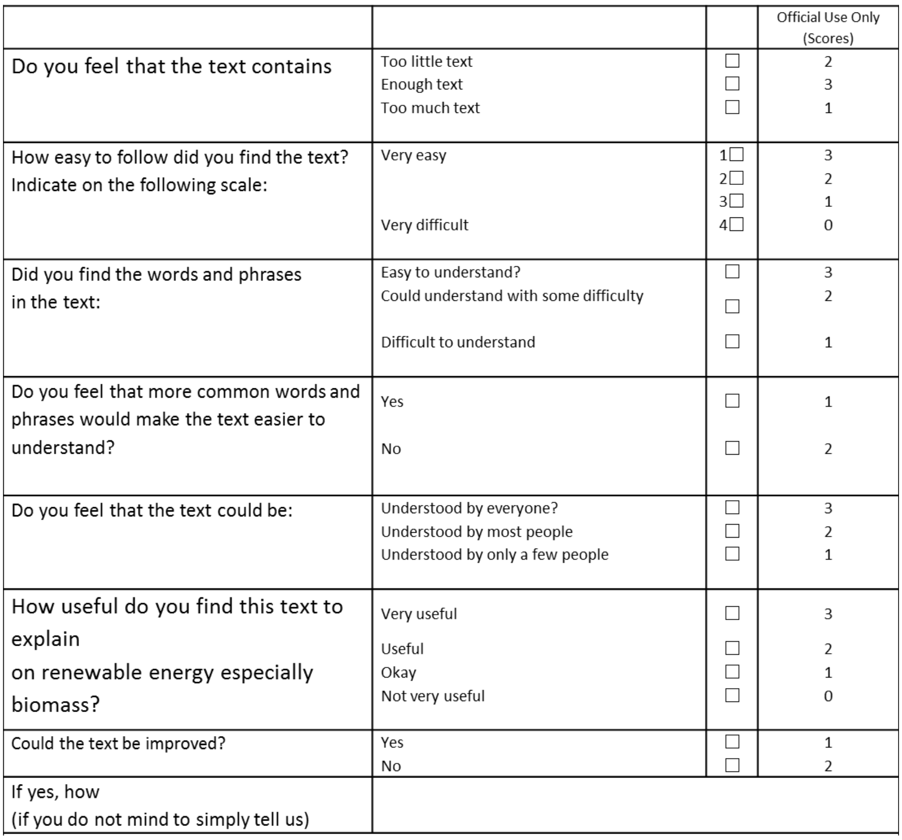


Figure 1. Internet user in Indonesia by age

Subjects were then requested to fill out seven check-lists and one open-ended question regarding the readability of the texts. The check-lists were weighted by some score ranges as shown in Figure 2. The score of the text, ranging from 6 to 19, indicates level of difficulty in reading and understanding a particular text. This check-lists and question is modified from the work of Harvey and Fleming on their assessment on printed health promotion materials used by Environmental Health Department of United Kingdom (Harvey, Harold D and Fleming 2003).



			Official Use Only (Scores)
Do you feel that the text contains	Too little text	☐	2
	Enough text	☐	3
	Too much text	☐	1
How easy to follow did you find the text? Indicate on the following scale:	Very easy	1☐	3
		2☐	2
		3☐	1
	Very difficult	4☐	0
Did you find the words and phrases in the text:	Easy to understand?	☐	3
	Could understand with some difficulty	☐	2
	Difficult to understand	☐	1
Do you feel that more common words and phrases would make the text easier to understand?	Yes	☐	1
	No	☐	2
Do you feel that the text could be:	Understood by everyone?	☐	3
	Understood by most people	☐	2
	Understood by only a few people	☐	1
How useful do you find this text to explain on renewable energy especially biomass?	Very useful	☐	3
	Useful	☐	2
	Okay	☐	1
	Not very useful	☐	0
Could the text be improved?	Yes	☐	1
	No	☐	2
If yes, how (if you do not mind to simply tell us)			

Figure 2. Readability indicators including its scoring

Since the length of the texts vary ranging from 200s words to 1200s words, reading all nineteen texts could overburden a subject. However, one-subject-reading-one-text could overburden recruitment of subject because each text should be read by nearly a hundred subjects for the statistical point-of-view. Therefore, each subject only read either three or four texts consisting of short, medium, and long texts.

RESULTS AND DISCUSSION

Table 1 shows the readability score based on the reading survey of each biomass energy texts. As the score ranging from 6 for the least readable text to 19 for the most readable text, biomass energy information in Indonesian language available in internet are indicated easy to read which consequently easier to understand.

Table 1 Readability score of biomass energy texts based on the reading survey

Text number	1	2	3	4	5	6	7	8	9	10
Readability score	12.48	14.51	12.16	14.73	13.81	14.34	14.51	12.72	13.88	12.82
Text number	11	12	13	14	15	16	17	18	19	
Readability score	15.32	13.58	12.92	12.75	13.20	15.09	12.62	13.70	14.44	

However, these scores were obtained from university student in undergraduate level as the subject of this survey. It could be an appropriate explanation why the scores of each text do not vary. As the various public education levels, the score of the readability may also vary.

However, we met some difficulty during this survey especially in requesting subjects to voluntarily read the text and to fill out the check-list afterward. We found some of check-lists left unfilled especially from long texts. Only medium and short texts were filled out. This finding indicates long written information is less preferable than the shorter one.

CONCLUSION AND RECOMMENDATION

This study aimed to indicate the need of improvement in preparation of written information on biomass energy. Besides focusing on content as the common practice of preparation, we also need to consider whether the information is friendly to public's reading ability. As a common practice so far, scientist and engineer are mostly spend most of the preparation effort to the content of information only. This study suggests them to pay more attention on the readability factor in preparation of written information on biomass energy.

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Acid fermentation of wasted primary sludge producing volatile fatty acids as an external carbon source for a post denitrification process

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ABSTRACT

In this study, the acidogenic reaction was promoted in a lab-scale anaerobic baffled reactor (ABR) with short hydraulic retention time (HRT) to produce sufficient volatile fatty acids (VFA) during treatment of the primary sludge wasted from a municipal wastewater treatment plant. The produced VFA was utilized as an external carbon source for a post denitrification process. The performance of ABR on the VFA production and total solids reduction was observed with different operating conditions with 2, 4, 6, and 8 days of HRT corresponding organic loading rates were 6.7, 3.4, 2.2, and 1.6 kgCOD/m^3·day, respectively. As HRT increased the removal rate of TCOD was also increased (82.5, 84.2, 96.9, and 95.9% in average for HRT of 2, 4, 6, and 8 days, respectively) because the settlement of solids was enhanced in the baffle by the decrease of upflow velocity. At HRT of 2 days the average concentration of VFAs in the effluent was measured at 1,306±552 mgCOD/L corresponding to 107% increment as compared to the VFA concentration in the influent. However, as HRT increased VFA concentration was decreased to 143±552 mgCOD/L at HRT of 8 days. On behalf of VFAs introduction as a carbon source, the post denitrification process showed very good performance on the removal of nitrate. The average removal rate of nitrate was 80 to 90% where the influent nitrate concentration was around 100 mg/L with various HRT from 2 to 6 hours. We observed the specific VFAs production rate of 0.074 gVFAs/gVSS/day and the average specific denitrification rate of 0.166 gNO_3^--N/gVSS/day. Consequently, we found ABR could be applied as an efficient acid fermentation process to produce a high amount of VFAs from wasted primary sludge and checked out the great feasibility of utilizing it as a carbon source for a post denitrification process.

Keywords: anaerobic Baffled Reactor (ABR), primary sludge, volatile fatty acids, acid fermentation, post denitrification

INTRODUCTION

In anaerobic baffled reactor (ABR) process, acidogenesis and methanogenesis are spatially separated by the baffles installed inside the reactor, and thus, the anaerobic digestion stages can be individually controlled. It also maintains relatively short hydraulic retention time (HRT; 1.3–20 hours) for economical operation, long solid retention time (SRT; 20–100 days) through sludge return, and has a high solid-liquid separation effect through the baffles (Langenhoff et al., 2000; Tawfik et al., 2011). It is known that acidogenic bacteria are easier to deal with in terms of operation. VFAs which are the products of acidogenesis can also be more easily controlled than methane (i.e., a gas phase), are low-molecular-weight organic matter that can be easily decomposed by microorganisms, and can be used as useful resources for a microbial fuel cell (MFC) and a denitrification process, which require organic carbon sources. This research aimed to apply ABR process to treat the primary sludge wasted from a municipal wastewater treatment plant and to produce volatile fatty acids which was introduced as an external carbon source for a post denitrification process. For this purpose, an ABR device that consists of a complete mixing zone at the front end and a baffle zone at the rear end was organized, and the organic acid production and solid reduction rate were observed at various hydraulic retention time (HRT).

MATERIALS AND METHODS

Feed characteristics

The primary sludge used as feed was collected from the J domestic treatment plant in Paju, Republic of Korea. The digestion sludge was collected directly from a conventional single anaerobic digestion reactor operated in the same treatment plant and seeded into the laboratory scale ABR type-acid fermentation reactor. The wastewater including high concentration of nitrate without any organic carbon was artificially synthesized by dissolving sodium nitrate ($NaNO_3$) reagent powder in tap water having concentration of 100 mg NO_3^--N/L. This synthetic wastewater was introduced into the post denitrification process along with the effluent from the ABR type-acid fermentation reactor.

Laboratory scale experiments

Figure 1 illustrates the schematic diagram of the ABR type-acid fermentation with post denitrification process. The total effective volume of the reactor used for the 2 and 4 day HRT experiments was 30 L, and the volume ratio of the mixing zone to the baffle zone was set to 2:1. On the other hand, the total effective volume of the reactor used for the 6 and 8 day HRT experiments was increased to 60 L. The supernatant in the baffle zone was continuously supplied to the post denitrification reactor along with the synthetic wastewater including high strength nitrate. The post denitrification had the complete mixing zone of 52 L for the denitrification and the baffle zone of 52 L for the sludge settling. It should be noted that the process was operated without any artificial temperature control. The average temperatures of the reactors were 22-23 ℃.

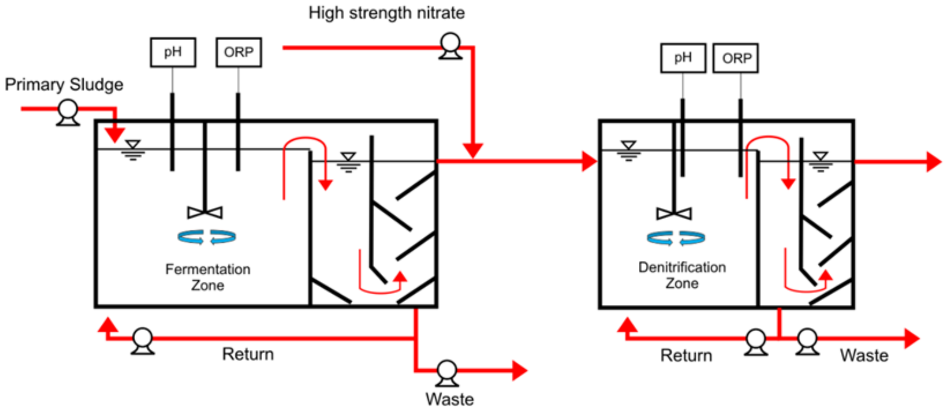

Figure 1. Schematic of ABR type-acid fermentation with post denitrification reactor

RESULTS AND DISCUSSION

Organic matters variation

The average influent and effluent TCOD concentrations in the ABR type-acid fermentation reactor were 18,431 mg/L and 14,546 mg/L, respectively. After post denitrification process, the average effluent TCOD concentration was observed at 455 mg/L (Table 1). The effluent TCOD concentrations of the ABR type-acid fermentation and post denitrification reactor decreased by about 21% and 97%, respectively, compared with the influent TCOD of each reactor. The TCOD in the effluent from acid fermentation reactor includes large amount of VFAs produced in acid fermentation process. Figure 2 shows the variation of VFAs as compared with the SCOD concentrations in the effluent of ABR type-acid fermentation reactor with the HRT of 4 days. In average, the ratio of VFAs to SCOD concentration was found to be 0.8, which indicated the VFAs consisted of 80% of the SCOD in the effluent from the acid fermentation reactor. The average specific VFAs production rate was 0.074 mgVFAs/mgVSS/day. This value was similar between industrial and municipal mixtures at approximately 0.070 mgVFAs/mgVSS/day (Elefsiniotis et al., 2005).

Table 1. Wastewater quality in ABR type-acid fermentation combined post denitrification process

Parameters	Unit	Influent	Effluent from acid fermentation/Influent into post denitrification	Effluent of post denitrification
TCOD	mg COD/L	10,220 – 37,560 (18,431)	3,140 – 29,360 (14,564)	115 – 1,230 (455)
SCOD	mg COD/L	972 – 3,528 (1,499)	1,614 – 4,728 (2,422)	21 – 247 (64)
VFAs	mg COD/L	241 – 4,058 (1,351)	326 – 4,775 (1,930)	–
TSS	mg SS/L	6,750 – 26,225 (14,351)	688 – 18,630 (9,431)	50 – 1,860 (729)
VSS	mg VSS/L	6,700 – 14,750 (10,694)	663 – 12, 325 (6,987)	57 – 2,075 (560)
NO3-	mg N/L	35 – 97 (68.74)	Not measured	1 – 74 (16.50)
NO2-	mg N/L	Not measured	Not measured	0 – 15.88 (3.38)
TN	mg N/L	41 – 124 (74.48)	61 – 225 (141.76)	10 – 223 (37.72)

Nitrogen removal

The average influent and effluent TN concentrations in the ABR type-acid fermentation reactor were 74.48 mg/L and 141.76 mg/L, respectively (Table 1), indicating the concentration of TN increased by 47.5% after the ABR type-acid fermentation because dissolved nitrogen was additionally produced during the hydrolysis and autoxidation of the solid part of influent and the sludge inside the reactor. After post denitrification process, the average effluent TN concentration was 37.72 mg/L, which presented the TN removal rate of 73.4% as compared with the average influent TN (141.76 mg/L) into the post denitrification reactor. The average NO_3^--N concentrations in the influent of ABR type-acid fermentation reactor and the effluent of post denitrification reactor were 68.74 mg/L and 16.5 mg/L, respectively. The effluent NO_3^--N concentrations of the post denitrification decreased by about 80.8% as compared with the influent NO_3^--N. The specific denitrification rate was 0.166 gNO_3^--N /gVSS/day. Previous research reported that the specific denitrification rate generally ranged from 0.011 to 0.754 gNO_3^--N/gVSS/day when VFAs were utilized as an external carbon source for denitrification (Elefsiniotis et al., 2005).

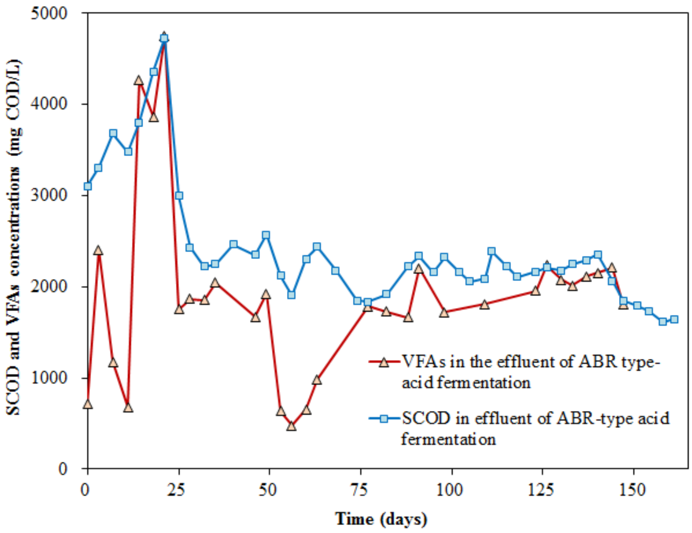

Figure 2. VFAs and SCOD in the effluent of ABR type-acid fermentation reactor (HRT of 4 days)

CONCLUSION

Laboratory scale experiments showed that the removal rate of TCOD, TSS, and TN were found to be 97%, 95%, and 73%, respectively. The specific VFAs production rate was 0.074 mgVFAs/mgVSS/day and the average specific denitrification rates were 0.166 gNO_3^--N/gVSS/day for the ABR type-acid fermentation-post denitrification reactor. This value was in the range of general denitrification efficiency of previous studies. Consequently, a primary sludge was successfully treated by the application of acid fermentation process with short HRT even by preventing methanogenesis and the produced VFAs were then utilized successfully as an external carbon sources for the post denitrification process to achieve a high removal of nitrate.

ACKNOWLEDGEMENT

This work is supported by a grant from the Waste to Energy and Recycling Human Resource Development Project (YL-WE-15-001) funded by the Korea Ministry of Environment and also from the National Research Foundation (No. 2014R1A2A2A09049496) of Korea funded by the Korea Ministry of Science, ICT and Future Planning.

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Experimental Studies on Long-term Behavior of Mercury Containing-Waste under Monofill Condition

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ABSTRACT

An attempt was made to evaluate the effect of emission control of mercury by the monofill of solidified black mercury sulfide. Four types of solidified test pieces were examined for a long term containment under the monofill condition. The precipitation upto approximately 800 mm was equivalent to the precipitation in the impermeable surface for 40 years. The results indicated that the mercury emission from solidified test pieces was very low even though certain distribution to liquid and gas phases was observed. Not only the low mercury transfer from the test pieces, but also the delay or inhibition of mobilization of mercury would be occurred in this study. These results suggested that the emission control of mercury must be achieved by the monofill of the solidified black mercury sulfide.

Keywords: Mercury, Solidification, Sulfur polymer, Low-alkali cement

INTRODUCTION

Spent metal mercury that is currently utilized as resource will be categorized as waste if it is not utilized for the uses allowed under the Minamata Convention on Mercury. In Japan, the recycled metal mercury was accounted to 52 ton in 2010, but the generation of spent metal mercury should increase by the limitation of mercury utilization. It must be required that the metal mercury is managed in an environmentally sound manner. Previous studies proposed the stabilization of mercury by sulfurization followed by solidification with sulfur polymer. This methodology was partially proven for the control of mercury emissions in a short period, but long-term behavior of mercury was not elucidated. This study aims to identify the effect of containment of the solidified mercury sulfide under the landfill condition in order to develop the long-term safety control of mercury waste in waste landfills. Series of lab scale column experiment were carried out for evaluating the behavior of mercury emissions from solidified test pieces.

MATERIALS AND METHODS

Four types of solidified test pieces of black mercury sulfide (metacinnabar) were prepared as shown in Table 1. All samples were molded as a cube about 7.8 cm on each side. Sample SP was prepared by solidifying mercury sulfide by sulfur polymer and others were prepared by low-alkali cement under different conditions. Sample CB+ was prepared by solidifying mercury sulfide by the cement B with dehydrating agent. Although these samples were prepared in the same dimension, their mercury contents were not the same.

Figure 1 shows the outline of the column experiment in this study. To create the monofill condition, the solidified mercury sulfide was filled with granite sand. Precipitation was simulated as 4.5 mm per day, using the nitrogen-bubbled ionized water with oxygen scavengers. Leached liquid was sampled from the drainage at the end. Gas in the top space of the column was circulated thorough the amalgam adsorption tube which captured the gaseous mercury.

Total mercury in the leachate was measured by a direct thermal decomposition mercury analyzer MA-3000 (Nippon Instruments Corp., Tokyo, Japan). Other cation and anion compositions were determined by an Inductively Coupled Plasma Atomic Emission Spectroscopy iCAP6000 and an ion chromatograph Dionex ICS-1600 (Thermo Fisher Scientific Inc., Tokyo, Japan), respectively. Gaseous vapor mercury was measured by an atmospheric mercury analyzer with gold amalgamation system WA-4 (Nippon Instruments Corp., Tokyo, Japan).

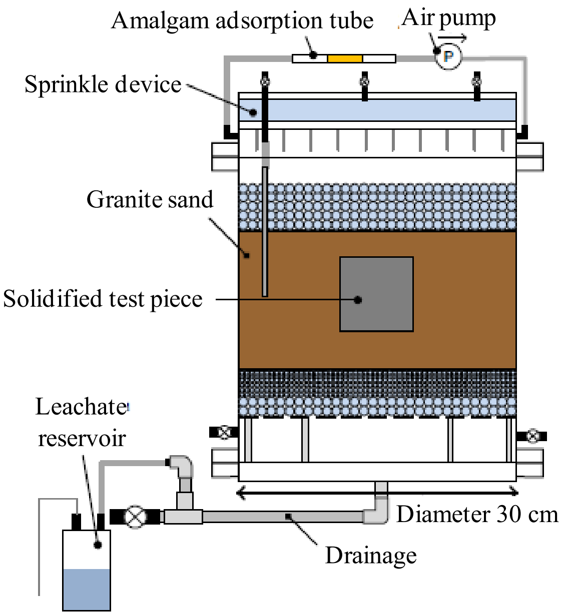

Figure 1 Outline of experimental columns used in this study

RESULTS AND DISCUSSION

Figure 2 shows the cumulated amount of precipitation in the experimental column. The precipitation rate was not significantly different across all columns. The precipitation upto approximately 800 mm was equivalent to the precipitation in the condition of normal cover soil for 2 years and in the condition of impermeable surface for 40 years. After 40 days of experiment, leachate was stably generated about 95-98% of precipitation. Redox potential (Eh) of leachate was kept around 300-500 mV, indicating the oxidative condition of the column. Lack of electron donor in the column filled with granite sand might be ascribed for this condition. The concentration of Ca^{2+} and SO_4^{2-} in the columns CA, CB and CB+ showed the peak at the initial phase, then decreased gradually. These ions must be discharged from the cement component utilized solidified pieces, suggesting the initial flush leaching in the cement-solidified series.

Table 1 Condition of solidified test pieces of black mercury sulfide

	Solidification	Weight	Density	Hg content
SP	Sulfur polymer	1.51 kg	3,200 kg/m^3	430 g-Hg/kg
CA	Low-alkali cement (Company A)	1.20 kg	2,500 kg/m^3	340 g-Hg/kg
CB	Low-alkali cement (Company B)	1.14 kg	2,400 kg/m^3	340 g-Hg/kg
CB+	CB with dehydrating agent	1.15 kg	2,400 kg/m^3	350 g-Hg/kg

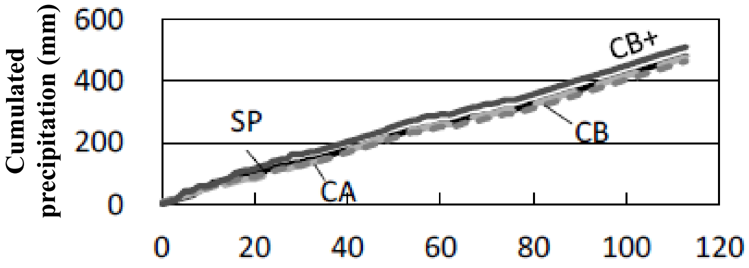

Figure 2 Cumulated precipitation in the experimental column

Figure 3 shows the time course change of total mercury concentration detected in the leachate sample. Total mercury was detected less than 1.0 ug/l from the all columns through the experimental period. There would be several possible reasons for this low mercury concentration in the leachate, such as (1) leachability from the solidified piece was low enough, (2) granite sand filled in the column adsorbed the solubilized mercury, (3) the solidified piece did not have enough chance to contact with moisture or solubilised mercury that was diluted by mercury-free moisture under the precipitation condition in this study.

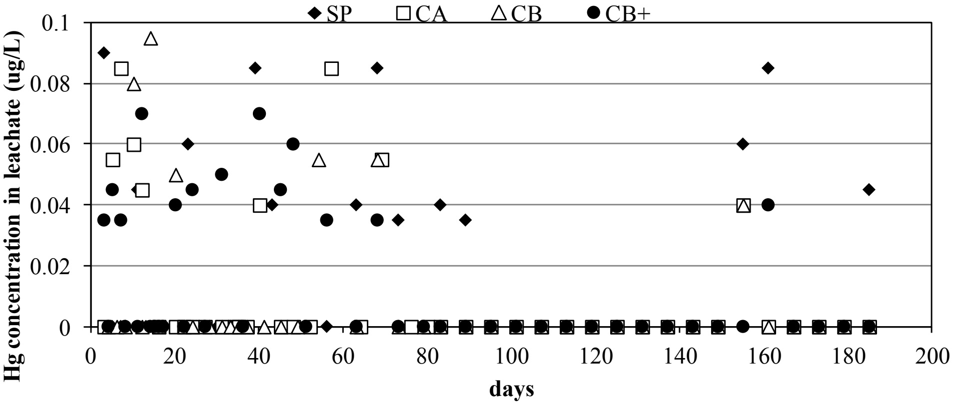

Figure 3 Concentration of total mercury in the leachate

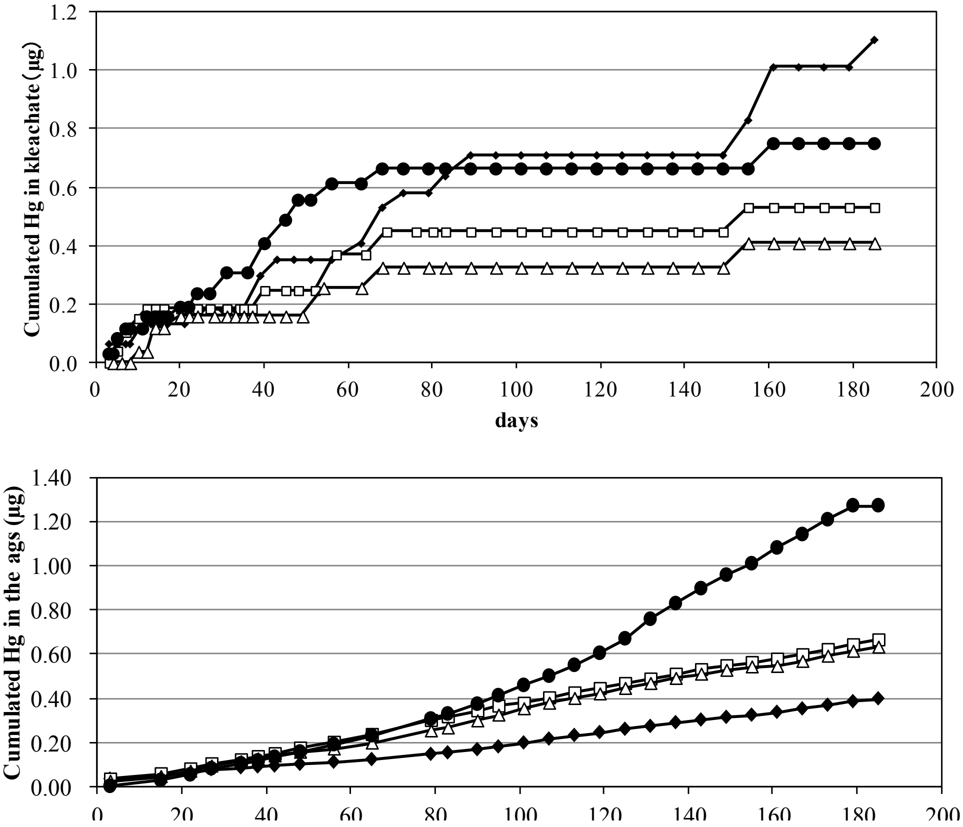

Figure 4 Cumulated amount of mercury in the leachate (upper) and gas (lower)

Cumulated amount of mercury detected in the leachate and gas were shown in Figure 4. The cumulated amount of mercury in the column SP was the highest in all the columns though it was not significantly different from that of CB+ during the first 50 days of the experiment. Compared to these 2 columns, the cumulated amount of mercury in the columns CA and CB was relatively low. In contrast, the mercury collected from the gas in the column SP was lowest amongst all the columns.

Ratio of mercury transferred from the solidified piece to mercury contained in the solidified piece was shown in Table 2. The ratios of transfer into liquid phase and gas phase ranged as low as 0.011-0.019ppm and 0.0060-0.032ppm, respectively. Even though the total mercury transferred from the solidified piece in CB+ was relatively higher than those in other three conditions, the solidification of black mercury sulfide have exhibited the certain extent of containment of mercury compound.

Table 2 Ratio of mercury transferred from the solidified piece to mercury contained in the solidified piece

	SP	CA	CB	CB+
Leachate	0.017 ppm	0.013 ppm	0.011 ppm	0.019 ppm
Gas	0.0060 ppm	0.016 ppm	0.016 ppm	0.032 ppm
Total	0.023 ppm	0.029 ppm	0.027 ppm	0.050 ppm

CONCLUSION

Four types of solidified pieces of black mercury sulfide were examined for a long term containment under the monofill condition. The precipitation upto approximately 800 mm was equivalent to the precipitation in the impermeable surface for 40 years. The results indicated that the mercury emission from solidified test pieces was very low even though certain distribution to liquid and gas phase was observed. Not only the low transfer of mercury from the test piece, but also the delay or inhibition of mobilization of mercury was observed. This study suggested effectiveness of emission control of mercury by the monofill of the solidified black mercury sulfide.

ACKNOWLEDGEMENT

This research was partially supported by Environment Research and Technology Development Fund (3K153004) by Ministry of the Environment, Japan.

A Study on the Heating Effect of Anaerobic Digestion System using Fermentation Heat from Aerobic Decomposition for Heating Energy and the Characteristics of the Conversion of Organic Wastes into Biogas

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ABSTRACT

South Korea has four distinct seasons and due to seasonal effects, it is difficult to stably maintain anaerobic digestors and heating energy is a required condition for the operation of anaerobic digestion. During the experiment period, the temperature of the anaerobic digestor was 38 ºC on average which confirmed the possibility of medium temperature digestion. In the winter, the temperature tended to decrease, but did not get lower than 25 ºC owing to the heating effect of the aerobic fermentor. Considering that the changing range of temperature decrease was not large, it appears to be a result of the buffering effect of heating. During the experiment period, the temperatures of the aerobic fermentor, anaerobic digestor, outdoor, and in the housing were 37.02 ºC, 60.46 ºC, 14.57 ºC, and 21.82 ºC, respectively. These results confirmed the possibility of medium temperature digestion (30 ºC or higher). In the case of biogas production and methane concentration, the higher the content of organic wastes was, in other words, the higher the VS content was, the greater the biogas production volume tended to become. The maximum production volume was 552 L/m3·day when the VS concentration was 9.48%. During the experiment period, the methane concentration was 65% on average, verifying stable energy conversion.

Keywords: fermentation heat from aerobic decomposition, organic wastes, anaerobic digestion

INTRODUCTION

In South Korea, due to seasonal effects, heating is required for the operation of anaerobic digestion in order to the temperature of anaerobic digestors which is an essential factor for the operation of anaerobic digestors. Generally in South Korea, anaerobic digestion using medium temperature digestion is performed, and about 30% of the operating cost of energy conversion facilities is spent for heating energy, which is a large burden.

The development of anaerobic digestion facilities is difficult in South Korea due to such problems as the large size of energy conversion facilities and the use of heating energy for medium and high digestion temperatures. An operation method for anaerobic digestors that is appropriate for the environmental conditions of South Korea needs to be developed by resolving the problems of operating anaerobic digestors as mentioned above so as to enable the efficient processing and energy conversion of organic wastes. Therefore, in this study, the fermentation heat generated from the aerobic decomposition of organic wastes was used as heating energy to heat anaerobic digestors and the characteristics of the processing and conversion of organic wastes into biogas were examined.

STUDY CONTENT AND METHOD

Anaerobic digestion system using fermentation heat from aerobic decomposition for heating energy in a pilot plant

In this study, a pilot plant that combines a 3 m³ aerobic fermentor and a 1 m³ anaerobic digestor installed in 'S' University in Seoul was used. After stabilization was reached through a pilot operation for about four months, the temperature efficiency of heating the anaerobic digestor with the oxidation heat of the aerobic fermentor including winter was examined. For the raw materials inputted to the aerobic fermentor and anaerobic digestor, food wastes and swine manure were used.

Aerobic fermentor experiment and analysis method

To carry out this experiment, the amount of food wastes supplied to the aerobic fermentor was set to 30kg/m3·day. After solid-liquid separation through preprocessing before being supplied to the anaerobic digestor, 31.5kg of food in total was supplied together with 1-2 kg of solid-state organic materials (1.5 kg on average) and one agitation per day was performed. To increase the efficiency of oxidative fermentation heat generation of the aerobic fermentor, the air supply rate was maintained at 10.45L/m3·min.

Anaerobic digestor experiment and analysis method

After mixing swine manure and food wastes through sufficient pulverization, solid-state and liquid-state organic materials were seperated through a solid-liquid separator. Then the solid-state organic materials were supplied to the aerobic fermentor again, and only liquid organic materials of high concentration were supplied to the anaerobic digestor.

RESULTS AND DISCUSSION

Temperament characteristics

The anaerobic processing of organic wastes was performed from January 21, 2015. For the adaptation of microorganisms to organic matter decomposition during the initial stage of experiment, a mixture of 10 L swine manure and 10 L water was prepared for 50 days, which was used for samples. The TS concentration of the organic materials supplied to the anaerobic digestor was 0.81～5.79% (2.58% on average), VS concentration was 0.08～4.56% (1.49% on average), COD concentration was 10,706～51,624mg/L (37,322mg/L), and pH was 7.07～9.21 (8.20 on averages).

Heating effect of anaerobic digestor by the aerobic oxidative fermentation heat and greenhouse

The temperature by the fermentation heat of the aerobic fermentor and the temperature change at each point during the operation period are shown in Fig. 3. The temperature range of the aerobic fermentor a certain trend between 40 and 66 ° C (52 ° C on average). This indicates that the anaerobic digestor can be heated steadily above 50 ° C because the temperature of the aerobic fermentor is constant regardless of outside temperature even in cold winter.

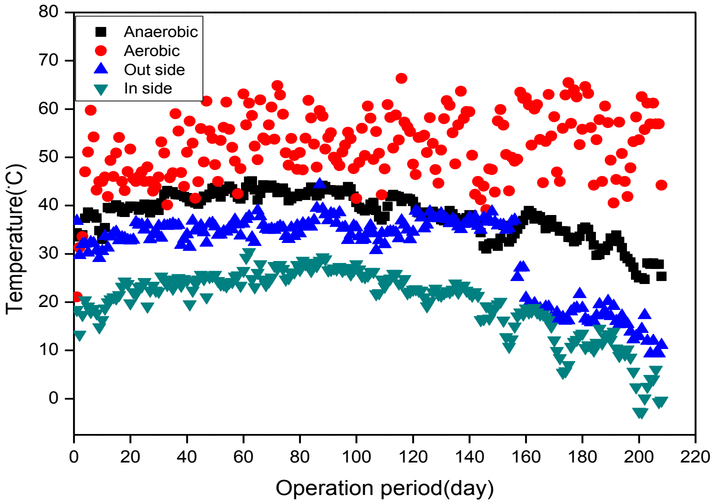

Figure 1. Operation period for system temperature pattern.

DIGESTION EFFICIENCY ACCORDING TO THE VARIATION OF FOOD CONTENT

The anaerobic digestion process was operated by maintaining the hydraulic retention time (HRT) at 50 days. The experiment was performed with 20 L of swine manure and varying contents of food wastes at 4kg (CASE 1), 8kg (CASE 2), 10kg (CASE 3), and 0kg (CASE 4), and with 20 L of water and 8 kg of food wastes (CASE 5). The changing biogas production and methane content according to the changing properties of the organic materials supplied to the anaerobic digestor are shown in Fig. 3.

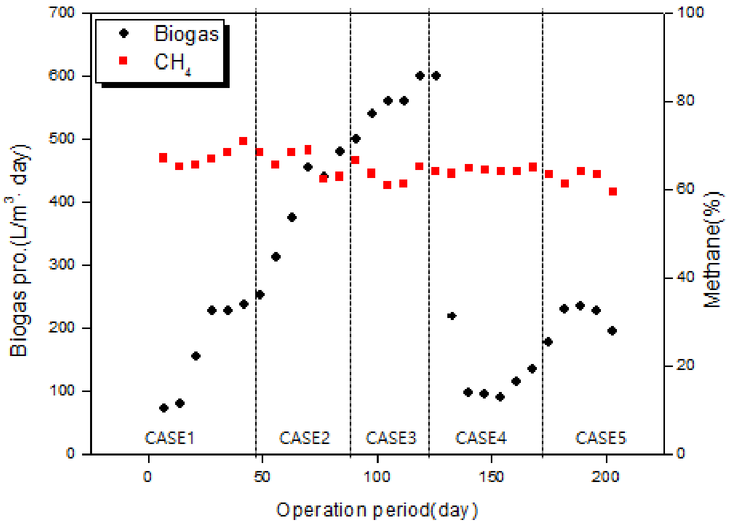

Figure 2. Biogas production and methane content by case

CONCLUSION

1. The oxidative fermentation heat of the aerobic fermentor showed a trend of constant temperature pattern at 40 – 66 ° C even in winter. This indicates that sufficient fermentation heat is generated for heating the anaerobic digestor, which was maintained at 38 ° C on average.

2. The anaerobic digestor was maintained at 30 ° C or higher owing to the heating effect of the fermentation heat of the aerobic fermentor. As a result of the experiment in CASE 1 to 5 with different food waste content in the materials supplied to the anaerobic digestor, the biogas production and methane content were 166L/m3·day and 67% in CASE 1 with a food waste content of 4 kg; 385L/m3·day and 66% in CASE 2 with a food waste content of 8 kg; 552L/m3·day and 64% in CASE 3 with a food waste content of 10 kg; 124L/m3·day and 64% in CASE 4 with 20 L of swine manure only; and 212L/m3·day and 62% in CASE 5 with 20 L water and a food waste content of 8 kg. The average biogas production and methane content during the entire experiment period were 292L/m3·day and 65%. The methane content did not show large variations by case, indicating stable anaerobic digestion during the experiment period.

3. During the winter, the experimentation heat of the aerobic fermentor must be maintained continuously because the anaerobic digestor temperature decreases along with the ambient temperature.

ACKNOWLEDGEMENT

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Study on the combustion process of waste in the Vertical combustor

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ABSTRACT

Fed the waste from the feeder of combustor, and primary air were supplied, adjusting the ratio from 0.4 to 0.5. Chemical composition of flue gas and solid material were analysed at 4 sampling points in waste layers and one point in the gas layer of combustion room, during Vertical combustor operation.

Following phenomena are confirmed.

・Waste instantly become dehydrated at the upper drying zone of waste layers.

・Materials are partially combusted and decomposed at pyrolysis zone below drying zone.

・Flue gas is being generated in the burning zone and up-drafting from the top surface of the waste.

・Flue gas consists of 30% of hydrogen, carbon monoxide and hydrocarbon compounds in total, and 70% of uncombustible gas.

・Unburned carbon compounds contained in residue are completely combusted, being exposed in ash zone at more than 600 degree C for over 6 hours.

・Secondary air contacts to combustible flue gas at areas above solid combustion layers and results in complete incineration.

Study on NOx generation process is in progress by investigating intensity measurement of NOx and HCN in solid waste layers. As a result NOx could not detect but HCN was detected at high density

Keywords: vertical combustor, waste, low air-ratio, combustion process, pyrolysis

INTRODUCTION

There is a wide variety of general waste, from low-calorie waste with high water content such as paper diapers to high-calorie waste such as waste plastics. Because of its processing characteristics, a vertical combustor can stably achieve complete combustion across this wide gamut of waste types without the need for combustion improvers.

Starting with our first in 1994, we have delivered combustor to 25 facilities to date, all of which are operating stably and incinerating their predetermined target amounts of waste.

DESCRIPTION OF VERTICAL COMBUSTOR

Fig. 1 shows the design of the vertical combustor. The waste injected into the furnace is combusted and pyrolysed continuously by the primary combustion air, which has an air ratio of approximately 0.2–0.5 and is supplied from the furnace bottom. The pyrolysis gas is combusted completely by the secondary combustion air supplied to above the waste layer and the unburned carbon in the pyrolysis residue is combusted completely over adequate time by the air supplied from the furnace bottom.

Although the composition of the waste injected into the furnace fluctuates, a certain amount of the primary combustion air is supplied from the furnace bottom, so that the combustible materials in almost a certain amount of the waste, whose amount corresponds to the amount of the supplied air (oxygen), are combusted.

The heat from this combustion generates pyrolysis gas, which contains high concentrations of hydrogen (H_2), carbon monoxide (CO), and hydrocarbon (C_mH_n). The shape of the furnace is a vertical cylinder. The air in the furnace is agitated and mixed by a sufficient amount of the secondary combustion air blown on the waste layer to achieve complete combustion.

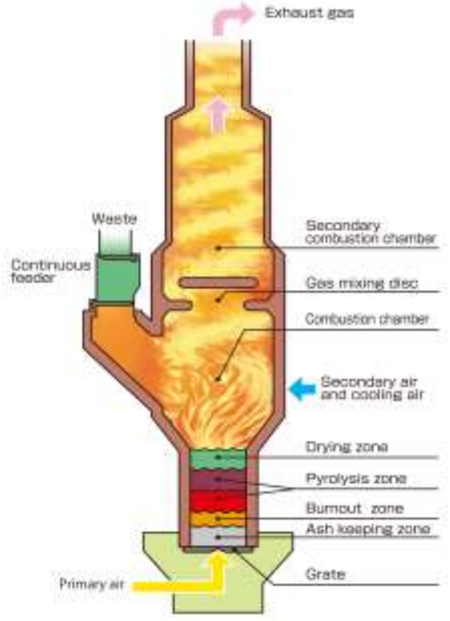

Fig.1 Outline of Vertical Combustor

METHODS

Analysis of the State of Combustion in the Vertical Combustor

Gas and ash generated during the combustion process of a vertical combustor that disposes of 27 t / 24 h of general waste during its operation were sampled from the waste layer and analyzed.

Fig. 2 shows the sampling positions. A total of five nozzles were used, four of which were located in the waste layer with a vertical pitch of 250 mm per nozzle and the fifth in the gas layer 1,300 mm above the highest of the four nozzles sampling the waste layer, but below the secondary combustion air nozzle. Sampling probes A–D were inserted about 200 mm from the inner wall of the furnace and probe E was inserted to the approximate center of the furnace.

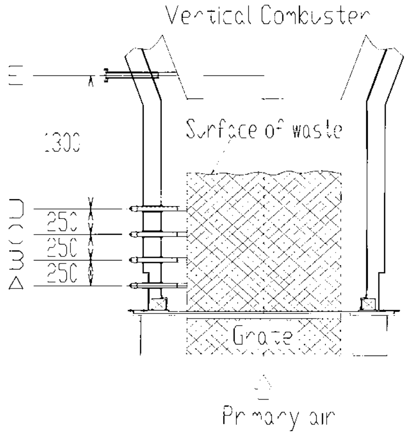

Fig.2 Location of gas sampling nozzles

The combustion gas was aspirated for approximately 30 minutes from the five sampling locations simultaneously, under two conditions of primary combustion air ratios of approximately 0.4 (RUN1) and 0.5 (RUN2). Fig. 3 shows the steps of the sample processing method. Once the gas was collected, the solid material (ash) in the furnace was also sampled from the four locations, A to D. Figs. 4–9 show the analysis results.

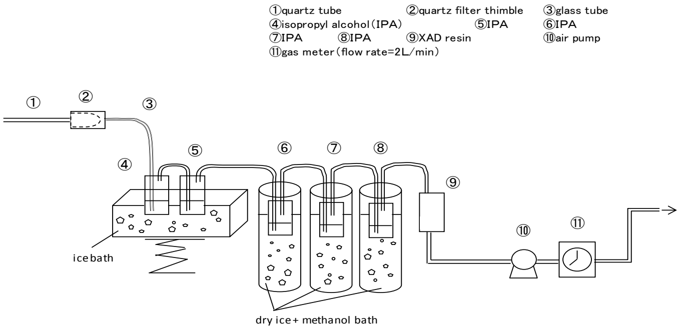

Fig.3 Outline of gas sampling method

RESULTS AND DISCUSSION

As shown in Fig. 4, the water content in the combustion gas decreased from point D (upper area) to point A (lower area), indicating that drying was progressing. Figs. 5 and 6 show the change in the combustion gas components for RUN1 and RUN2, respectively. At the furnace bottom, the O_2 concentration was 21%, whereas the concentration of all the other components was close to 0%. The O_2 concentration decreased as the height increased. The concentrations of carbon dioxide (CO_2) and the combustible gases (CO, H_2, and C_mH_n) generally increased as the height increased, with some deviations from this trend, usually between points C and D, indicating that combustion and pyrolysis were progressing in the waste layer.

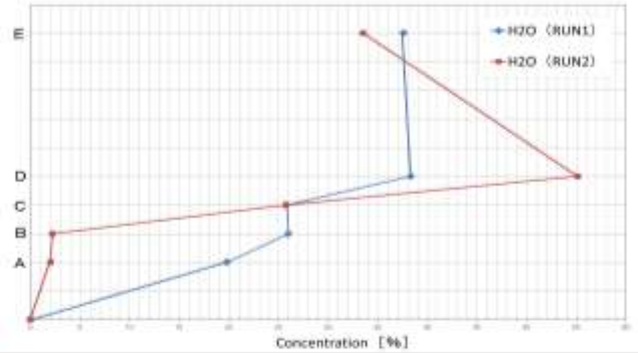

Fig.4 H2O content in the sampling gas

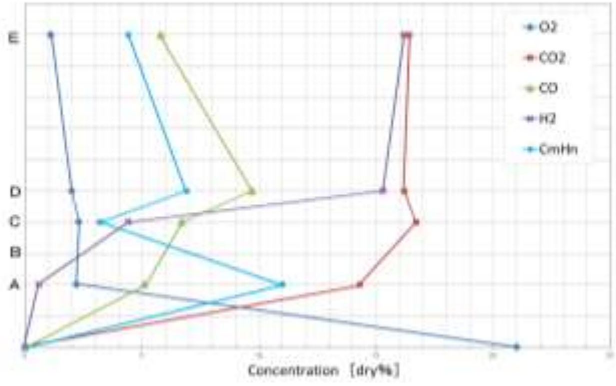

Fig.5 Result of sampled gas analysis (RUN1)

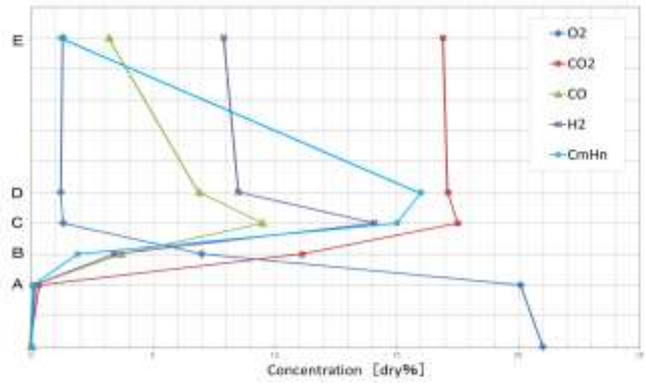

Fig.6 Result of sampled gas analysis (RUN2)

Fig.7 shows the change in the carbon content of the ash. Under both RUN1and RUN2 conditions, the content generally decreased from point D to point A, with the content dropping to below 2% at point A. In addition, the unburned carbon remaining at point A decreased even further in the incinerated ash discharged from the furnace bottom. This shows that the waste layer below point A also contributed to the complete combustion of the unburned carbon.

The concentration of tar was also measured and found to be 3–6 g/m^3_N, the same range as an updraft type gasification furnace for biomass.

In the vertical combustor, the tar generated in the waste layer is decomposed completely because the pyrolysis gas is combusted in the upper section of the furnace. Therefore, there is not a problem due to tar.

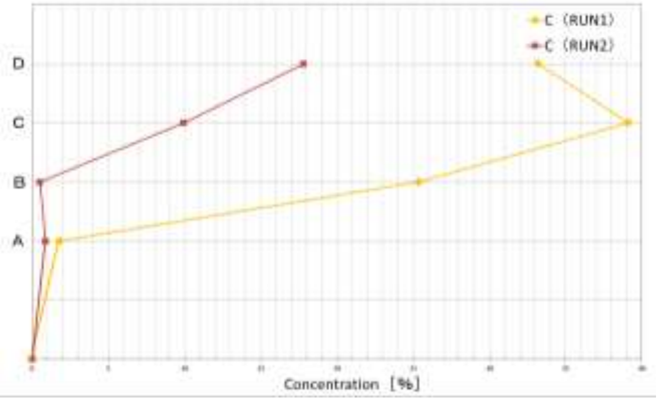

Fig.7 Carbon content in the sampled ash

To observe the generation behavior of nitrogen oxides (NO_x) in the waste layer, the concentrations of NO_x and hydrogen cyanide (HCN) were measured at the four positions, A–D. Figs. 8 and 9 show these results. Although the concentration of the intermediate product, HCN, is high, the amount of NO_x in the waste layer is low, indicating its generation is suppressed by the two-staged combustion.

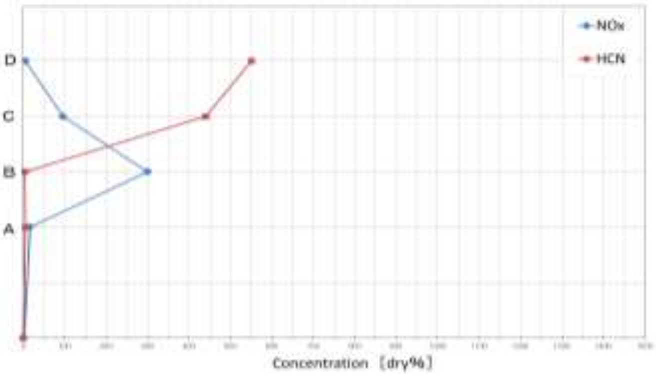

Fig.8 Concentration of NOx and HCN
In the sampled gas (RUN1)

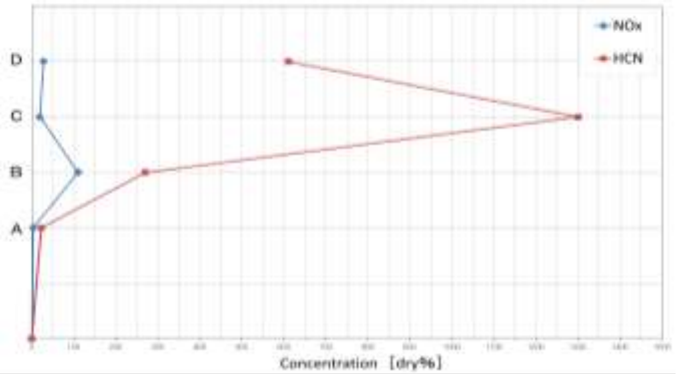

Fig.9 Concentration of NOx and HCN
In the sampled gas (RUN2)

When comparing the primary combustion air ratios of approximately 0.4 and 0.5, drying and pyrolysis occurred within a narrow range for the 0.5 air ratio and the concentration in the final discharge of the combustion exhaust gas decreased. Although the calorific value of the combustion gas (pyrolysis gas) discharged from the waste layer was approximately 3,060 kJ/m^3_N when the primary combustion air ratio was approximately 0.4, the value decreased to approximately 960 kJ/m^3_N when the air ratio was approximately 0.5. Fig. 10 shows the carbon balances under the two conditions. The calorific values of the waste before and after the test were approximately 7,120 kJ/kg on average.

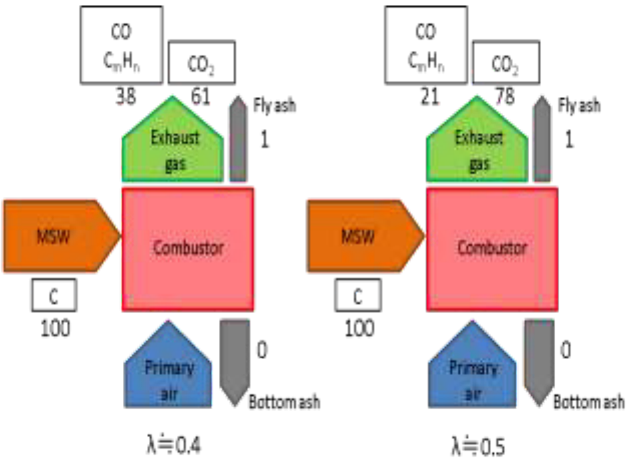

Fig.10 Carbon balance around the combustor

CONCLUSION

- The vertical combustor (vertical stoker type incinerator) realizes complete combustion through gradual evaporation of the moisture in the upper area of the waste layer; decomposition into the pyrolysis gas and the pyrolysis residue, which contains the unburned carbon due to the partial combustion / pyrolysis reaction in the waste layer by the primary combustion air supplied from the furnace bottom; and retention of the pyrolysis residue in the waste layer for a long period of time, allowing it to maintain a temperature of 600 °C or higher.
- For general waste, the primary combustion air ratio of approximately 0.4 allowed effective use of the waste layer for drying, pyrolysis, and combustion.
- The gas discharged from the waste layer of the vertical combustor contained a high concentration of combustible gas and the combustor can be used as a gasification furnace.

In future, we would like to deploy the vertical combustor in energy utilization facilities for various fuels in addition to facilities for incineration of the waste and contribute to solving global environmental and energy problems.

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A Study on the Improvement of National Waste Statistical Research Method based on the Evaluation of Previous National Statistical Researches on Municipal Solid Wastes (1st – 4th)

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ABSTRACT

The 5th research will be carried out next. In this study, the results and methods of the 1st to 4th national statistical researches on municipal solid wastes that have been carried out were examined. To evaluate the previous researches, basic unit by the type of municipal solid waste, composition, sampling regions selection method, sample count, research and analysis methods were compared and analyzed.

The evaluation results of previous researches indicate that the sampled regions were difficult to reflect regional characteristics, and with regard to the research method, the gathering of personal information has become difficult due to the changed social atmosphere. Therefore, the selection of sample regions and research method needs to be improved by introducing new concepts.

Keywords: national statistical research on wastes, municipal solid wastes, previous studies

INTRODUCTION

The 1st to 4th researches were carried out amidst continuous changes, and with the 5th research to be carried out in 2016, the need for an examination of the methods of previous researches was raised. For this purpose, the working design reports and statistical research reports of the years when the 'national statistical research on wastes' were carried out were analyzed. Any important information that was not included in the reports was estimated from the contextual relations of facts. Improvement measures for the future statistical research which were derived through an analysis of the problems of the 1st to 4th statistical researches are presented in this paper.

MATERIALS AND METHODS

Analytical method of the results of national statistical researches on wastes (1st – 4th)

Municipal solid wastes were divided into household and non-household sectors. The household sector was classified by house type into detached house, apartment, row house, and multiplex. The non-household sector was divided into production and manufacturing, market and shopping center, business facilities, service business, educational institution, restaurant, and accommodation. The result of the basic unit and the composition are comprised and analyzed by types stated above.

Analytical method of the research methods of national statistical researches on wastes (1st to 4th)

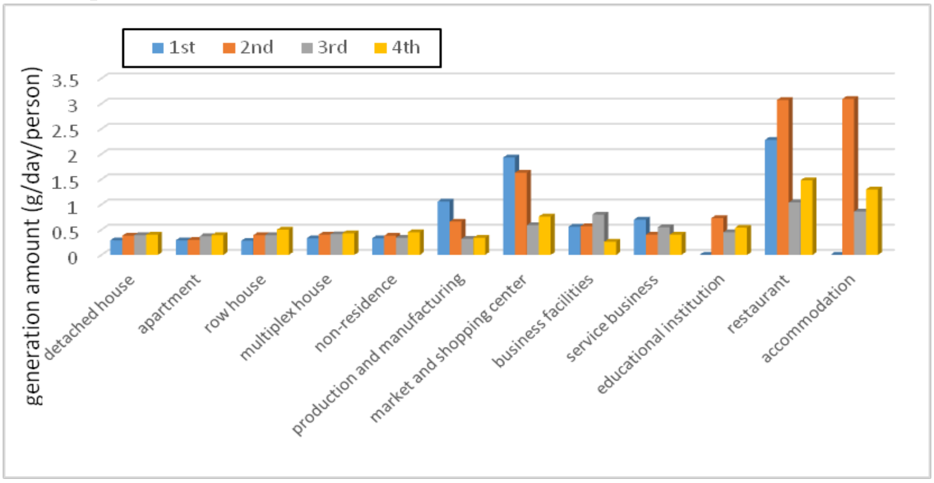
For the examination of the basic unit and properties of municipal solid wastes, the selection of sample regions and the sample count of each sample region are important. As a result, a comparison of the sampling regions, and the sample count between the previous 1st to 4th researches is carried out. The research of municipal solid wastes can be largely divided into a research of economic and social contents which are used as the parameters of basic unit and a research of the generation volume and properties of wastes that are generated from households and non-households. Therefore, a research on the previous 1st to 4th research methods of the economic and social contents are comprised and analyzed for this study.

RESULTS AND DISCUSSION

Analysis of the results of national statistical researches on wastes (1st – 4th)

a. Comparison of basic unit of municipal solid wastes

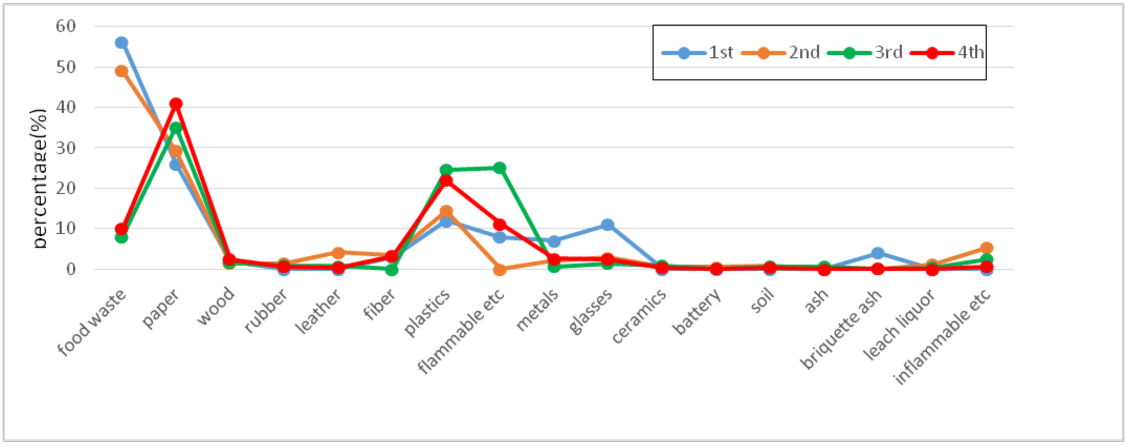
As a result of the comparison of 1st to 4th researches, the basic unit of household sector including detached house, apartment, row house, and multiplex of the 1st and 2nd researches showed very little differences, ranging between 0.24 and 0.34 kg/person/day (standard deviation: 0.021 kg/person/day for 1st research, 0.006 kg/person/day for 2nd research). The basic unit of the 3rd research ranged between 0.0.348 and 0.416 kg/person/day, which showed some differences with those of the 1st and 2nd researches. The basic unit of waste generation by source from the household sector including detached house, apartment, row house, and multiplex tended to increase slightly in each research compared to the previous one.



[Figure 1] Comparison of basic unit of waste generation by detailed source of municipal solid wastes

b. Comparison of the composition of municipal solid wastes

The physical compositions of municipal solid wastes averaged by house type of the household sector in the 1st to 4th researches were compared and analyzed [Figure 2]. In this graph, the patterns of the 1st and 2nd researches are similar as are the patterns of the 3rd and 4th researches, and the percentage of food shows a large difference between the 1st and 2nd researches and the 3rd and 4th researches. The reason for this difference is that during the 1st and 2nd researches, food wastes were included in the standard plastic garbage bags, but from the 3rd research (2006), food wastes were separately disposed. Furthermore, when the 3rd and 4th researches are compared, the percentage of other combustibles decreased whereas the percentage of paper increased from 31% to 36%. The largest components of the 3rd research were paper, combustible other, and plastics, in this order, but those of the 4th research were paper, plastics, food, and other combustibles, in this order.



[Figure 2] Comparison of the compositions of municipal solid wastes from household sector in 1st to 4th researches

Analysis of the research methods of national statistical researches on wastes (1st to 4th)

a. Comparison of the selection of sample regions and sample count

The 1st and 2nd researches divided the entire nation into 45 regions and determined the samples accordingly. The sample count of the 1st research was 10,000 (10,162 samples in actual research) and the sample count of the 2nd research was 13,727 (14,727 samples in actual research). The 3rd and 4th researches selected one focused research region for each city size (special city, metropolitan city, small and medium city, farming and fishing), and four provinces and two cities were selected as other regions. Furthermore, cities, counties, and wards were set in each research region and research was carried out in each city, county, and ward under the judgment of the researcher.

[Table 1] Sample counts of 1st to 4th researches

Division	1st	2nd	3rd	4th
Population	8,903,818	13,726,935	15,782,520	16,570,462
Sample count (unit)	10,162	14,727	7,891	8,285
Sampling rate (%)	0.112	0.100	0.02	0.02

b. Research and analysis method

The economic and social environments in the 1st, 2nd, and 3rd researches were researched by visiting every house, as were the generation amount and properties of wastes. Therefore, it took much time to wait for residents throwing away wastes and survey them, and there was a concern for violation of privacy f or the people throwing away wastes because the samples were collected in a one-on-one manner. In the 4th research, the method of collection and survey at the door was changed to small group units to improve efficiency. Thus, houses or businesses that throw away wastes to waste collection bins were surveyed based on each waste collection bin, and samples were collected from the waste collection bins.

CONCLUSION

To achieve this goal, first of all, new methods of selecting sample regions and sample count using a specialized statistical method, which are different from those of 1st to 4th researches, must be introduced. Considering that the national waste statistics are designated statistics approved by the national government, the sampling and stratification methods for the sample regions need to be specialized. Second, a detailed operation manual about the classification and research methods is required. The research of the household sector had difficulties because the definitions and divisions of house types were unclear and vague. Furthermore, in the research of properties, each researcher used a different method due to the vague sampling and analysis methods, resulting in errors in statistical data. Therefore, the accurate classification method for each source of wastes and the research methods of composition and properties for each type of waste must be specified in the operation manual.

Third, the future national statistical research on wastes must undergo a mutual verification step during the main research in order to attain differentiation from and connectivity with the national waste generation and treatment status. Fourth, smooth cooperation with the public officials in charge of the research regions and with the researched businesses (non-household sector) must be obtained in the preliminary research step before the field survey step. We anticipate that more accurate and objective research of the basic unit will be carried out in the 5th national statistical research on wastes by developing a specialized operation manual that specifies the preliminary research step, main research step (specification of methods for the research of compassion and the research of properties), and the roles of each person in charge of statistics.

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Removal of chromium (VI) ion from water by coir pith

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ABSTRACT

Chromium (VI) contaminated through using water especial ground water that is polluted by waste water from industrial discharged directly to the environment. Chromium (VI), a slow poison, causes negative health effects on human beings, thus becoming a national concern. It is widely distributed and observed in the anthropogenic environments, especially in leather tanning operations, metal processing, stainless steel welding, chromate production, and chrome pigment production. High chromium concentrations more than QCVN 40:2011/BTNMT, column A limit of 0.05 mg/L, have been observed in electro plating wastewater of Nam Son company is 200mg/l (Science and Technology magazine, Da Nang University). The removal of Chromium is a persistent challenge in this area where long-term cumulative Chromium exposure is a matter of concern. In this study, we have created a material from Coconut coir pith-an agricultural solid waste was used as biosorbent for the removal of Chromium (VI) after modification with $ZnCl_2$ and temperature. The maximum adsorptive capacity Qmax = 695mg/g, and optimum pH for Cr (VI) adsorption was found to be 2.0. Besides, the material can work effectively on a wide range of temperature, estimate from 25^0C to 60^0C, having the adsorptive capacity larger than approximately 94%. In addition, with 1 gram activated coir pith per litter; the contact time of 30 minutes; pH = 2 and the initial hexavalent Chromium concentration smaller than 416 mg/l, the resident concentration gets QCVN 40:2011, column A.

Keywords: removal, chromium, coir pith

INTRODUCTION

Nowadays, heavy metal pollution especially Chromium (VI) is assessed as an international concern because of implicit risk accumulated that affected badly on human health. Mostly, Chromium (VI) contaminated through using water especial ground water that is polluted by waste water from industrial discharged directly to the environment. The removal of Chromium is a persistent challenge in this area where long-term cumulative Chromium exposure is a matter of concern. Nowadays, there are many Chromium treatment methods in the world, as well as Vietnam, such as: adsorption, ionic exchange, precipitation, Biosorption… However, adsorption has been widely used due to economical and efficient characteristics. Coir pith is an adsorptive material and widely used in pollutants treatment. However, in order to apply this material to reality, we have to prepare from inexpensive and available sources such as activated coir pith carbon. Hence, in this research we created $ZnCl_2$ – Coir pith modified having ability to readily adsorb Chromium (VI) ions.

MATERIALS AND METHODS

Material

Coir pith was collected from local coir industries. It was dried in sunlight for 5 h and sieved to 250–500µm particle size and then zinc chloride activated coir pith carbon was prepared. Coir pith was stirred in a boiling solution containing zinc chloride in the weight ratio of 2:1.The filtered material after drying was carbonized at 700◦Cunder controlled conditions. After cooling, the excess zinc chloride present in the carbonized material was leached out using dilute HCl. Then the carbon was repeatedly washed to get rid of excess ZnCl2 and dried

Zinc chloride and Chromium (VI) solution was prepared at Laboratory of Environmental Analysis, Faculty of Environmental Sciences, VNU University of Sciences, Hanoi

Chromium (VI) remaining concentration after treatment was analysis by atomic absorption spectroscopy (AAS) SHIMADZU AA 6800 (Japan) machine.

Method

Relationship between activated coir pith mass and chromium (VI) concentration

Preparation chromium (VI) solution at differences Cr (VI) concentration: 5, 10, 20, 40 and 80 mg/l; adjust pH = 6 with the material mass/ solution volume = 0.05g/50ml. Shaking well this flask at room temperature (25^0C) by using agitation machine at 200 rpm for 30 mins. After that filtrate the solution and analyze concentration of Cr (VI).

Effect of pH

Effect of pH on adsorption of chromium was studied using 50ml solution with the concentration of Cr(VI) is 40 mg/L and 0.133g of the adsorbent at difference pH: 1, 2, 4, 6 and 8 adjusted by using NaOH 0.1M or HCl 0.1M.Shaking well this flask at room temperature (25^0C) by using agitation machine at 200 rpm for 30 mins. After that filtrate the solution and analyze concentration of Cr (VI).

Effect of temperature

Effect of temperature on adsorption of chromium was studied using 50ml with the concentration of Cr(VI) is 40 mg/L and 50mg of the adsorbent at -4^0C, 14^0C, 25^0C, 51^0C, 58.5^0C. Shaking well this flask at room temperature (25^0C) by using agitation machine at 200 rpm for 30 mins. After that filtrate the solution and analyze concentration of Cr (VI).

Effect of contact time

Effect of contact time on adsorption of chromium was studied using 50ml solution with the concentration of Cr(VI) is 40 mg/L and 0.133g of the adsorbent at difference time contact: 5, 15, 30, 45, 60 mins. Shaking well this flask at room temperature (25^0C) by using agitation machine at 200 rpm for 30 mins. After that filtrate the solution and analyze concentration of Cr (VI)

RESULTS AND DISCUSSION

Material properties

After modification, The Coir pith is not only change in physical and chemical properties but also changes in the surface electro magnetic. Hence, it can adsorp more Chromium(VI) than the unmodified coir oith

SEM images

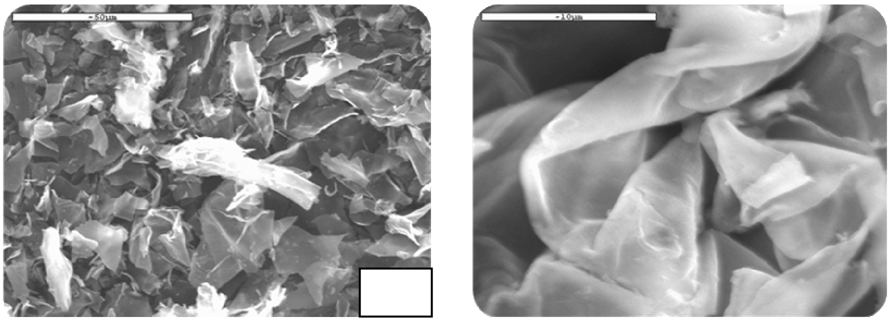
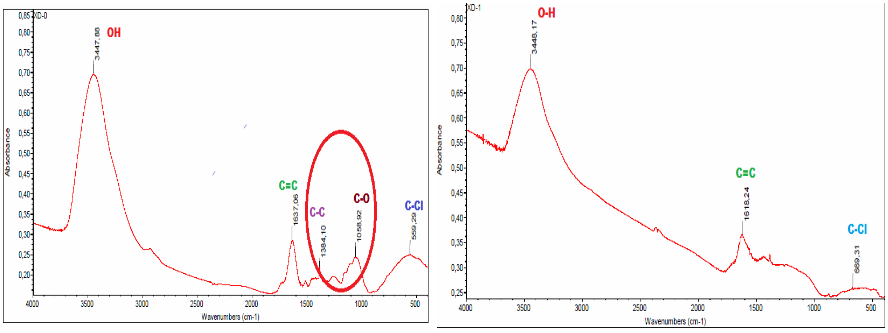

a) b)

Figure 1: SEM image of coir pith: a) unmodified coir pith; b) modified coir pith

Comparison between figure 1 a and 1 b, we clearly seen that the coir pith before and after modified had changed in physiccal property. After modified, the coir pith have much more holes to adsorption more Cr (VI) than the unmodified coir pith

FTIR images

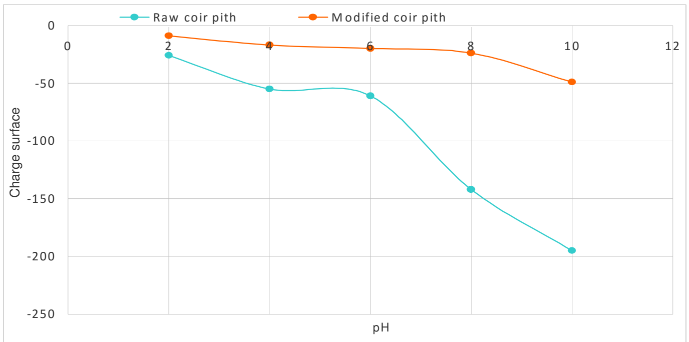


a) b)

Fifure 2: FTIR image of coir pith: a) unmodified coir pith; b) modified coir pith

Two figure above show that the activated coir pith cacbon are lost some function group (C-C and C-O) that is contained in xenlulozo group because of cacbonzied by thermal at 700^{0}C with the key purpose is eliminate the unnecessary organic compounds for more eficiently adsorption capacity

Electro surface characteristic



Fifure 3: The relationship charge surface between before and after modification

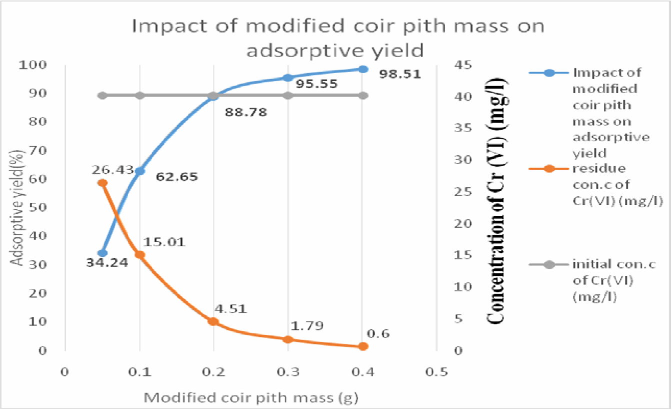
The figure tell us about the charge surface of modified and unmodified coir pith, we can see that the less pH, the more charge surface that mean the more adsorption capacity for the material attract anion and the optimal pH for adsorption is 2. We also see the modified coir pith has higher charge surface than the unmodified. That why the modified material has much higher adsorption capacity. Despite the surface charge of modified coir pith is negative, it can still adsorption a lot of anion $Cr_2O_7^{2-}$ because the OH^- containing in the structure of modified coir pith can associate with two ion H^+ instead of one ion H^+ like normal. There fore, the charge surface of the sample after modified actually is + 1 that can attract anion strongly

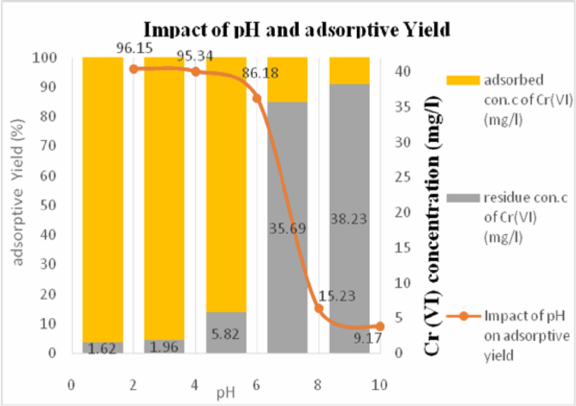
Adsorption capacity

Relationship between activated coir pith mass and chromium (VI) concentration

The experiment result indicates that with the increase in mass of baked modified coir pith, the adsorptive also grows considerably and climbs to 98.51 % at the material weight of 0.4g.

Effect of pH



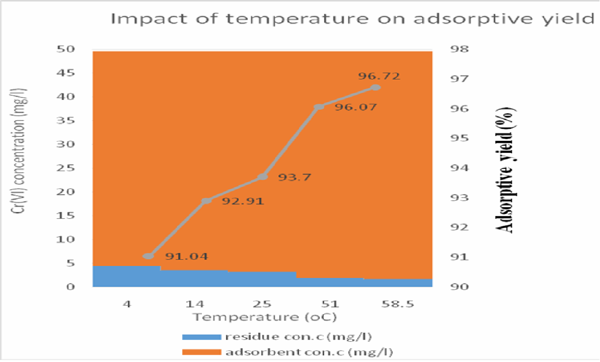


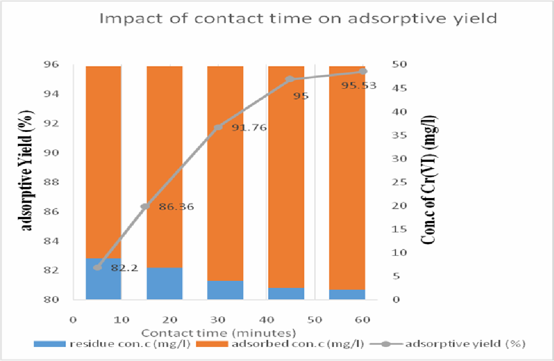
ZnCl$_2$-modified Coconut coir pith can work on a wide range of pH. From 6 to 10, the adsorptive yield is low and decreases dramatically to 11.2% (at pH=10) which evidence that it works weakly on the basic environment. On the other hand, the adsorption becomes efficiently around acidic range pH<6 (> 86.18%) and the optimal pH is 2 (98.54%).

Effect of temperature

Temperature does not play a very vital role in Cr (VI) treatment. In spite of low or high temperature, the adsorptive yield is always good, higher 90%. Hence, the material can be apply efficiently in normal condition

Effect of contact time





The more time contact, the more chromium (VI) be adsorbed. Just only from half to an hour, the efficiency is more than 90%

CONCLUSION

These studies show that the ZnCl$_2$ activated coir pith carbon developed from agricultural solid waste, coir pith, is an effective adsorbent for the removal of chromium ions from aqueous solution. Chromium removal was substantially greater for modified coir pith than for raw coir pith. In addition, with 1 gram activated coir pith per litter; contact time is 30 minutes; pH = 2 and the initial Cr (VI) concentration is smaller than 416 mg/l, so the resident concentration gets QCVN 40:2011, column A. With short time contact and suitable with Vietnam weather as well as the sources of coir pith are rich & easy – finding, modified coir pith is an effective adsorbent in not only scientific field but also in financial field.

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The role of energy efficiency service providers in low carbon transition in Vietnam

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ABSTRACT

The Governments of Vietnam has initiated a long term dialogue on low carbon transition within the energy sector in Vietnam, specifically targeting energy efficiency initiatives. Many factors influence whether small and medium enterprises invest in energy efficiency measures, such as: awareness of energy efficiency and its benefits, technical potential for energy efficiency in their production, availability of suppliers and information of specific solutions, financial opportunities for the small and medium enterprises, legal framework that promotes energy efficiency (or at least is not a barrier), etc. The objective of this study is to identify and assess energy efficiency service providers (EESPs) and/or energy service companies (ESCOs) in Vietnam in order to ensure that quality solutions are available and trusted by the brick, ceramic and/or food processing industries and the lending banks financing energy efficiency investment projects. Focusing on those three sectors, this paper analyses the information and data received from the survey. The survey has targeted 185 EESPs/ESCOs and draws on information from feedbacks of 102. And as the results, the main characteristics of the EESPs/ESCOs and its issues, problems, barriers and perspective in relationship with other market players are indicated and the factors for supporting the development of the EESPs/ESCOs partner are recommended.

Keywords: energy efficiency, energy efficiency service provider, energy service company

INTRODUCTION

Focusing on quality solutions are available and trusted by the brick, ceramic and/or food processing industries, this paper analyses the information and data received from the survey of energy efficiency service providers (EESPs) and/or energy service companies (ESCOs) . The detailed steps are illustrated in Figure 1.

Figure 1. Steps of analysis process

Building list of EESPs/ESCOs

General information on EESPs/ESCOs have been collected from the previous and on-going assessment and survey implemented by Ministry of Industry and Trade (ENTERTEAM 2014, IIEC, 2009, ECONOLER, 2011), enterprises reports and websites. As a result, the list of 185 EESPs/ESCOs has been identified which covers 12 types of entities, including:

- ECC: State-owned centre for energy efficiency/technological application under local administrations;
- UR: Consulting or research centres within universities and research institutions, associations;
- EESC: Private energy efficiency service companies. EESCs provide energy efficiency services such as energy audit reports, energy efficiency opportunities;
- ESC: Private energy equipment and service providing companies;
- BP: Boiler Providers;
- BCP: Brick/Ceramic kiln Providers;
- NFBP: Non - fired brick production line providers;
- TP: Tunnel kiln providers;
- CP: Chiller Providers;
- VSDP: VSD Providers;
- LP: Lighting Providers;
- BGP: Biomass gasification technology Providers

The list covers all from energy audits, energy advisory services, sale and instalment of energy efficiency technology, leasing energy efficiency equipment paid via the enterprise's reduced energy expenses, etc…

SURVEY METHODS

Design survey form

In addition to the information obtained during the desk review, the questionnaire has been designed to collect additional information of the listed EESPs/ESCOs to be surveyed. The questionnaire covers the following areas: Legal status; Business model; Human resource; Infrastructure; Organization; Services, products provided and customers and market; Business management and development; Approximate turnover of the energy service business; Assessment of the prospects of the market; EESPs/ESCOs trade promotion; Fund arrangement for business.

Data collection

The questionnaire has been communicated by several ways to ensure that they reach all targeted EESPs/ESCOs: by courier, by email, by fax. The questionnaire will also be uploaded on the website and a link to download this file will be inserted in the questionnaire. The EESPs/ESCOs have been encouraged to download and work on the electronic version.

The survey verification team has reviewed the responded questionnaires to see if any of them contains too much missing or unacceptable data. Questionnaires, which were wrongly filled, have been followed up by telephone for correction and completion. The survey coordinator has kept track of returning questionnaires and updated it daily so that the surveyors know exactly where to put effort for their follows-up. The list of organizations is used for summarizing activities and contacts undertaken with each organization and also for serving as a dashboard for data collection progress update. Periodical follow-ups via emails and phone calls have been arranged with the statistic expert and surveyors at the EESPs/ESCOs to discuss the questionnaire collection progress and any encountered problems.

Collect initial information on EESPs/ESCOs

Figure 2 illutrates 12 types of EESPs/ESCOs identified in the survey list in their number and percentage. As a result, there have been 102 feedback sheets among 175 targeted EESPs/ESCOs accounted for 60% which could show good representative from EESP market in Vietnam (Figure 3).

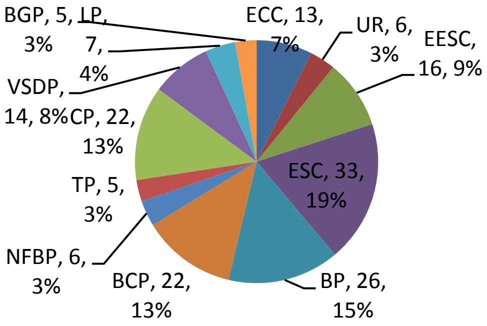

Figure 2. Types of the EESPs/ESCOs identified in the survey list

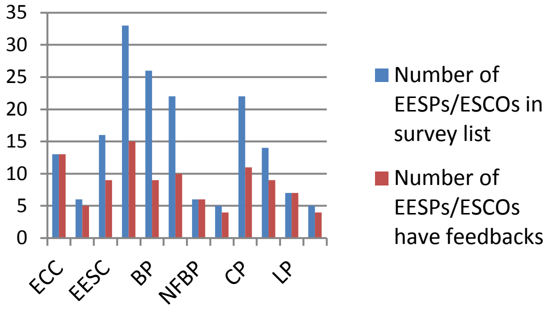

Figure 3. Number of the EESPs/ESCOs in survey and feedback lists

COMPREHENSIVE ANALYSIS AND FINDINGS

- Overview of the EESPs/ESCOs in organization's characteristics, number of staff, size of energy efficiency services... It is found that 26.5% of the EESPs (including ECCs, URs and EESCs) just provide energy efficiency services such as energy audit reports, energy efficiency opportunities... and 74.5% of the ESCOs (including ESCs, BPs, BCPs, NFBPs, TPs, CPs, VSDPs, LPs, BGPs) provide not only energy efficiency services but design, engineering, construction, implementation, commission and maintenance of energy efficiency measures. Most of them are located in Ha Noi and Ho Chi Minh City. Most of them have done their business with customers in 3 target sectors. In the last 5 years, food processing sector has been covered by almost providers but brick and ceramics have been mainly focused on by ESCOs such as BPs, BCPs, NFBPs, TPs, and VSDPs.

- Assessment of EESPs/ESCOs experiences through type of contracts, financing sources, knowledge level about ESCO business aspects, methodology and process required for EPC project development, design, implementation, risk assessment and savings follow up... It is found that 45% of the providers (including ECCs, EESCs, ESCs, BCPs, NFBPs, VSDPs, LPs, BGPs) drive their business on energy efficiency services. The biggest numbers of “walk though audits”, “investment grade audits” and EPC projects implemented in last 5 years are belonged to ECCs, ESCs and EESCs. Some URs, BPs, and TPs have little consideration for energy efficiency services. In term of capacity buiding, training courses are still limited in most of the ESCOs.
- Assessment of technical skills and knowledge for identifying energy conservation measures and baseline development. There is a gap found that air conditioning, lighting in-door, automatic and control systems, waste heat recover, brick extruder system, and ceramics kiln technological transfer are most proposed energy conservation measures while boiler systems, heating/hot water system, renewable energy sources/systems, compressed air, industrial cooling, and equipments for non-fired brick production line are least proposed energy conservation measures. Looking at typical services offered there are possible major gaps in solutions as compared to the needs of the 3 target sectors. The weakest point seems to be a limited involvement of the suppliers of high potential energy efficiency equipments.
- Understanding level for the EPC requirements related to measurement and verification during investment grade audits development. Most of the EESPs/ESCOs have recognized the importance of measurement and verification for all EPC activities. In term of equipment’s investment, many EESPs have sufficient kinds of measurement equipments for investment grade audits development. But the ESCOs usually rent or borrow when identifying energy efficiency solutions in need. The staffs of providers located in Ha Noi and Ho Chi Minh City seem have better knowledge and experience in metering and monitoring of energy use for both electrical and thermal energy.
- Knowledge of contract types, business plan, requirement and negotiations. Most of the EESPs/ESCOs agree that energy efficiency and EPC market trends are growing. The knowledge about the types of markets and customers targeted and the products and services offered is pretty good. However, the knowledge about the contract types and the requirement and negotiations is poor. Teams of project financial analysis and project risk analysis are not normally organized in the EESPs/ESCOs. The existence of a business plan and capacities for the development and completion of such document of the EESPs/ESCOs is also very poor.
- Assessment of capacities for project financial and client credit worthiness during the different project development phases. It is found that the most common financing approaches of the EESPs/ESCOs are using “own equity”, “customer’s internal budget” and “commercial banks’ lending to their customer”. The least financing approach is “state fund”. In view of financial arrangement, many EESPs have conducted financial assessments of energy efficiency projects but neither have actually financed or arranged financing. An important element of the ESCO’s business is its ability to provide quality engineering and installation services for energy efficiency projects. Among 23 ESCOs who have financial arrangement, it’s recognized that “lack of energy efficiency awareness of the bank”, “no guarantee for the loan”, “can't access to other sources of capital from the government and other energy efficiency support funds”, “interest rate is higher than the profitability level of the energy efficiency projects”, “the bank/fund have no budget/plan for energy efficiency projects”, and “acceptable loan amount is too small compared with the total investment” are mostly encounted as a financial difficulty for energy efficiency projects.
- Observation of key barriers to scale up the energy efficiency service market in the three target sectors. Most of the providers agreed that “lack of a legislative framework for the EPC”, “lack of appropriate financing support/incentives for projects development and implementation” and “perceived risk for energy efficiency and EPC projects” are barriers that have limited the development of EPC market. Besides these most common barriers, the EESPs/ESCOs have ranked other seven barriers including: “state owned energy service providers are not autonomy, and do not have enough incentive to perform EPC”; “mistrust from the customers”; ”customers are not interested in investment on energy efficiency and saving”; “no compulsory regulations on energy efficiency and saving investment”; “small size of projects and high transaction costs”; “customers focus on increasing the turnover rather than reducing costs by saving energy”; and “unfavorable tax incentives for energy efficiency equipment importation and installation”.

ENABLING FACTORS AND POLICIES

Following is the identification of the factor and policy that can support the development and implementation of the energy conservation measures in brick, ceramics and food processing sectors.

Awareness and technical factors

- Awareness level of energy efficiency and EPC concept specificities from both clients and service providers - overall benefits are needed to fully understand. Incomprehensive awareness caused a mistrust from the (potential) customers. It’s linked to the fact that “customers are not interested in investment on energy efficiency and saving” or “customers focus on increasing the turnover rather than reducing costs by saving energy”.

- Awareness level of energy efficiency financing mechanisms and energy saving benefits also specificities from other stakeholders such as policy makers and bankers. It’s been voiced from the surveyed EESPs/ESCOs that low awareness has caused ”lack of a legislative framework for the EPC”, ”lack of appropriate financing support/incentives for projects development and implementation” and “perceived risk for energy efficiency and EPC projects”.
- Measurement and verification works in both clients and service providers are needed to be focus on. In the previous stage, this project has created a comprehensive overview of energy efficiency in small and medium enterprises and thus overcome the barriers to the collection of high quality data that has been identified for the bricks, ceramics and food proccessing sectors as the provision of external funding and support has overcome the motivational and resource problem that has lead to poor reporting.

Financial factors

- Low priority of energy efficiency investments on the corporate agendas and dedicated financing mechanisms for EPC projects. A financial product should be designed to be attractive to the target industrial or commercial customers, easy to use with reasonable security terms. As seen in the table, the client consider that the ESCO contracts lack of flexibility and afraid of long commitment – it may cause perceived risk for energy efficiency and EPC projects. In the case of the ECCs, the specific financing approaches include ”financing with ECC as borrower”, ”financing with customer as borrower” and/or ”vendor financing with ECC implementation”. But all of these will need financing available from commercial financial institutions, therefore finacial factors are limiting the involvement of the ECCs in demonstrating EPC projects.
- Low energy price decreases a motivation for energy efficiency investment in SMEs.
- Unfavorable tax incentives for energy efficiency equipment importation and installation. Like any industry operating in commercial markets with non-subsidized pricing on inputs and outputs, the SMEs have a strong commercial incentive to monitor their energy-use as energy costs are a key driver for commercial success. This basic observation was confirmed during interviews with members of the respective industry organizations.

Policy factors

- There are not compulsory regulations/laws on energy efficiency and saving investment.
- Procedures for some financial assistance projects are difficult to access.
- Supporting policy for the EESPs/ESCOs in their energy efficiency project implementation is very weak.

CONCLUSION

This analysis shows the gaps in technical and commercial capacity of EESPs/ESCOs. There are many EESPs/ESCOs working around in Vietnam. They are usually small and medium enterprises and have large network with other and medium enterprises in brick, ceramic and food processing sectors. They are also the key player in promoting energy efficiency solutions to the market.

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Developing Indicators on Evaluation and Proposing a Model towards Green Manufacturing for Vietnam Brewery Enterprises

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Abstract

Brewing industry in Vietam has made a significant contribution to the national economy. The industry, however, is also known as one of sectors which consume a considerable amount of energy and water in its production process as well as generate large volumes of waste and pollutants. Currently, many organizations and researchers are seeking for effective tools to hamonize business actvities with optimal consumption of natural resources and environmental protection responsibilities. Based on review and analysis of environmental problems associated with the brewing enterprises and international experiences, green manufacturing is proven as an effective solution which can assist the industry to survive and to develop sustainably in the competitive maket. The scope of this study is to develop indicators on evaluation towards green manufacturing for Vietnam's brewing enterprises. A preliminary evaluation was also conducted at an enterprise in Hanoi.

Keywords

Green manufacturing; indicators; natural resources consumption and environmental pollution; brewing industry.

1. Introduction

Brewing is a long-standing sector, accounting for a big proportion of the alcohol, beer and beverage sector in particular and the food processing industry in general in Vietnam. The average growth rate of this sector is reported at 9-10 % per year. There are about 119 plants in Vietnam (with the exclusion of very small beer plants) and atotal design capacity in 2013 is reproted at 4.84 billions of liter per year in 2013. Along with a rapid growth in the number of the brewing plants and production scale, natural resources consumption and environmental pollution associated with the industry have become increasingly prominent and required more attention. A number of studies have indicated that the brewing industry have been consuming a relative large volumn of water and energy in the manufacturing process, generating numerous waste, resulting in environmental contamination and ecological imbalance (MOIT, 2014).

Given that the production resources is becoming increasingly limited and that the economic sector is facing many competitive factors, it is critical that the industry is developed in conjuction with greening production. According to UNEP 2013, green manufacturing aims to reduce the amount of natural resources required to produce finished goods through manufacturing processes with high energy and materials efficiencies and a minimal generation of waste and pollution. A effective tool to help businesses towards green growth is the development of indicators on evaluation, monitoring the implementation of green manufacturing, thereby helping business leaders make appropriate and effective policies (OECD, 2011). In Vietnam, there have been a few studies on the manufacture towards green , however those studies provided only initial support related to environmental protection and energy saving in brewing enterprises. In addition, no specific study or any significant deployment involved to the development of indicators and model towards green manufacturing based on a key principle of optimal utilizaion of raw materials and reductions of waste discharge into the environment. Given that, the objective of the study are to establish indicators of evaluation, monitoring towards green manufacturing for brewing enterprises and to propose a suitable model in the conditions of Vietnam.

2. Materials and Methods

The study was conducted for brewing enterprises in Vietnam with the focus of developing indicators of evaluation and monitoring the implementation of green manufacturing. The study is carried out with the use of the following methods:

- Desk study review: compile and review available documents in support of (1) clarifying the concept of green manufacturing, international experience in the development of indicators on evaluation, monitoring the implementation of green manufacturing with the consodreation of different enterprise scale, production processes, and (2) analyzing environmental issues associated with brewing production in Vietnam.
- Investigation and field survey: This step is used to collect information and empirical data of brewery enterprises under green manufacturing approach, including gathering information and data on the management system, operating process related touse of natural resources and energy, waste discharges into the environment.

- Mass and energy balance: This method is used to specify the input and output of the production process to evaluate the use of natural resources, the total amount of waste generated. The results of this evaluation will faciliate the selection of appropriate solutions and the development towards green manufacturing through minimising the input pressure of the production process and reducing waste generation.
- Cost- benefit analysis: This method is used to calculate and compare the benefits and costs of different green manufacturing appoaches to facilitate the selction of the most suitable approach for specific enterprise(s).

The indicators is established on above research methods and will be implemeted for an enterprise in Hanoi as a pilot test. The premilinary results will be analyzed and used to support the proposed development of a model towards green manufacturing in brewing industry in Vietnam.

3. Results and discussion

Developing indicators on evaluation towards green manufacturing for brewing enterprises

Based on review and analysis of production process and waste streams (Figure 1), different key environmental issues are identified for the brewing industry in Vietnam, including the following:

- High water and energy consumption for the production process. For example, 0.6-2m^3 of water and 10-30 kWh required to produce a hl beer, are reported for most brewing enterprises in Vietnam which are gernally 1.5 times to 5 times higher than those required for best available processes.
- Large amount of waste water with significant pollutant load. According to a survey conducted by MOIT 2014, five out of 22 plants did not have sewage system (23%).
- Solid wastes including wort residues (biomass residue, yeast residual...), filter aids residue, broken bottles, etc.

The above noted findings indicate a great need of resource saving and waste reduction as challenges for the brewing industry in Vietnam when moving towards green production.

As part of this study, international experiences are reviewed in support of development of indicators on evaluation, monitoring of green manufacturing implementation, especially the study of sustainable manufacturing indicators of OECD, 2011; Eco-efficiency indicators of WBCSD, 2009; Resource efficiency and pollution indicators at enterprise scale of UNIDO & UNEP, 2011...The review indicates that each method has its pros and cons in application. However, all indicators have the common goal is to help enterprises to monitor, set objectives and evaluate the green manufacturing process over time, therefore it will help the business leaders can give approciate decisions accordingly.

It is critical to improve the environment to help emterprises moving forward to the green manufacturing sucessfully, as environmental improvement always go together with profitability and increased competition. Giving that, the first step is to evaluate the environmental performance through the development of environmental indicators. It is noted that an enterprise can not achieve all enviromental indicators immediately as this is a continuous improvement process that requires a roadmap with specific action plans to achieve proposed objectives and address priority issues. With the consideration of analysis of advantages and disadvantages associated with different methods as well as the existing environmental conditions of the domestic brewery industry, the study proposed indicators on evaluation, monitoring of green manufacturing for Vietnam's brewing enterpries with the forcus of environmental indicators.

Based on the proposed indicators, each brewery enterprise will choose indicators that are most suitable to its conditions. Specifically, the indicators are proposed, based on two (2) main components with five (5) criterios and seventeen (17) indicators to evaluate and monitor the implementation of green manufacturing for brewery enterprises in Vietnam. These indicators have been reviewed and selected based on the relationship between manufacturing (the management and operation) and the environment. Detailed indicators are shown in Table 1.

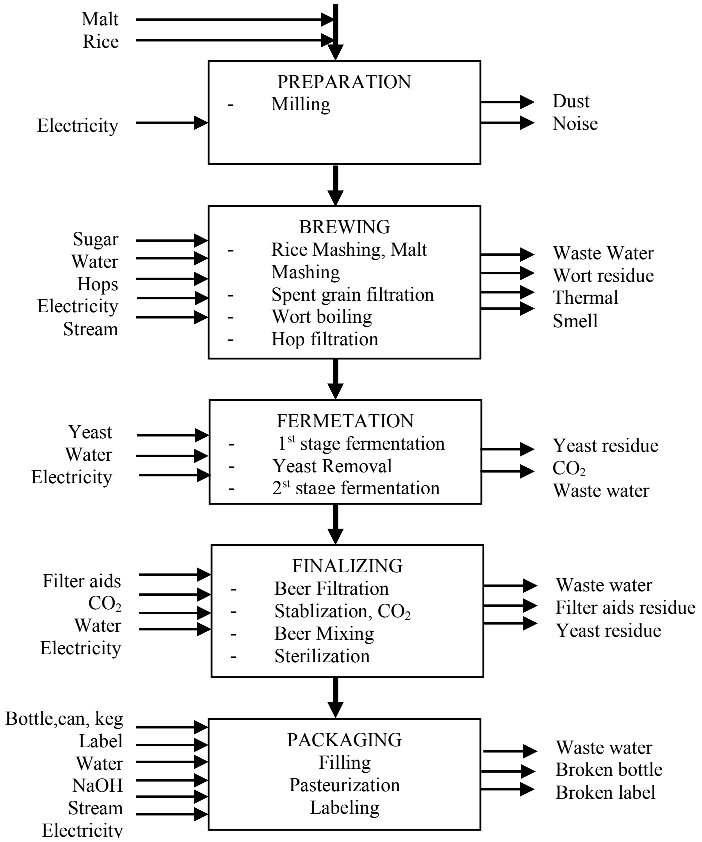

Figure 1. Brewing production and waste flow Diagram

Table 1. Indicators on evaluation towards green manufacturing for the brewing enterprises

Items	Criterios	Indicators	Unit/ National Technical Regulation
A. Evaluation of management's efforts			
	Effective application of policies (4)	+ P1: Number of goals and objectives on efficient use of natural resources and minimization of waste achieved	%
		+ P2: Number of green initiatives is applied	Number of green initiatives
		+ P3: Ratio of green suppliers (adopted ISO 14000, ISO 50000 , HACCP ...)	%
		+ P4 : Number of employees are trained on green solutions	Number of employees
	Regulatory Compliance (3)	+ R1: Level of compliance with environmental protection legislation (waste water , air emission) • Wastewater : Pollutant concentration in waste water (pH , BOD5 , COD , SS , total N , total P) • Air Emission: Pollutant concentration in air emission: (dust , SO2 , NOx , CO)	Comapre to National Technical Regulation
		+ R2: Number of violations/ penalty cost by not compliance with the environmental regulations	Number of violations/millions VN dong
		+ R3: Number of environmental are handled/ resolved	Number of complaints
	Effective of Finance (1)	+ F1: The annually budget for green projects (VND /year)	Millions VN dong
B. Evaluation of operating efficiency			
Inputs (I)	Effective use of natural resources	- I1: Raw material consumption Intensity (Malt/ substitute materials, filter aid powder...)	Ton (kg)/hl
		- I2: The percentage of material recycled / reused	%

	(material, water, energy) (5)	- I3: Renewable proportion of energy	%
Operating process (O)		- O1: Water consumption Intensity	m^3/hl
		- O2: Energy consumption Intensity (elictricity, thermal)	MJ /hl
Outputs (E) *- Products* *- Waste*	Minimization of pollution impacts (4)	- E2: Percentage of restricted substances used in products	%
		-E1: Solid Waste intensity (normal/hazardous) (wort residue, yeast residue, broken bottles, activated sludge , broken labels ...)	t/hl
		-E3: The percentage of solid waste recycled / reused	%
		-E4: Water releases Intensity	m^3/hl

Evaluating indicators and proposing a model towards green manufacturing for a pilot company

Based on the evaluation and assessment conducted at a pilot company in Hanoi, the study identifies strengths, difficulties and priority issues to help the Company moving towards green manufacturing. The study then also indentifies key short-term and long-term goals that need to be achieved as well as the selection of appropriate indicators of evaluation and monitoring towards green manufacturing for the Company.

The results also shows that although the Company always complies to environmental regulations and give high commitment to save natural resources and minimize environmental impact. However, the curent consumption level of some raw materials (electricity, water, thermal...) of the Company is very high and above averaged level, ascompared to other domestic beer companies (Table 2)

Table 2. Intensity of some material consumption and waste generation of A pilot company vs. the common norms

Material consumption/ Waste generation	Traditional technology*	Medium technology *	Best available technology (BAT)*	A pilot Company
Water (m3/hl)	2 – 3.5	0.7 – 1.5	0.4	**0.88**
Thermal (MJ/hl)	390	250	150	**230**
Electricity (kWh/hl)	20	16	8 – 12	**15**
Waste water (m3/hl)	1.8 – 2.8	0.55 – 1.2	0.25	**0.68**

* Source: According to the handbook of cleaner production for the brewing industry, the Ministry of Industry and Trade, 2008

From the outcome of analysis and assessment of indicators, management system and operation process, material and energy flows, the study initially identify a number of measures to be applied and additional equipment to be invested to help the Company moving towards green manufacturing. Specifically, 13 proposed measures/solutions with 2 groups of low and high priority application, as shown in Table 3.

Table 3. Proposed measures/solutions with 2 groups of low and high priority application

Solutions with high priority application	Solutions with low priority application
Management Aspects	
Applying 5S management system (sort, set in order, shine, standardise, sustain) for the processing areas	Developing a comprehensive strategy for green manufacturing
Early developing and applying of environmental management system ISO 14000 , energy management system ISO 50000	Integrating management systems (ISO 14000, ISO 50000, 5S with the existing management system ISO 9000, HACCP)
Improving monitoring systems , monitoring and reporting on resource consumption and environment	
Enhancing staff awareness/ training and encouraging on green manufacturing	
Technology Aspects	
Investing automatic valves; high-pressure nozzles, recyling wastewater from bottle washing for keg washing at bottling area	Recovery of cooling water from the fast cooling process
Recovering wort residue	Cyclon/filter to recover material dust at milling areas

Upgrading effectiveness of the condensate recovery system to add water to boilers	
Upgrading insulation system for hot and cold surfaces in the area have not been implemented	
Investmenting for using biogas for boilers	
4 management solutions; **5 techonology solutions**	**2 management sollutions;** **2 technology sollutions**

4. Conclusions

Towards sustainable development applied for brewing enterprises in Vietnam, development of indicators on evaluation of green manufacturing implementation is one of effective solutions. The study has also evaluate the application of these indicators for a pilot company in Hanoi. In particular, the study identifies priority issues to be addressed along with a number of key solutions that need to be implemented in different priority ways.

In addition to the initial results, further research should be implemented to address the following:

- Conducting a further analysis to define a comprehensive model for the Company, moving towards green manufacturing, in order to establish a detailed action plan, and conduct an analysis of economic benefits and the ability to maintain a continuous improvement.
- Conducting a long-term assessment for the Company to assess the feasibility of the indicators over time, as well as to define appropriate solutions to help the Company moving towards to green manufacturing efficiently accordingly.
- Expanding the application of the indicators for other enterprises with different technological levels in order to refine the lists of apropriate indicators for brewery enterprises in Vietnam

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A study on the characteristics of the bench-scale torrefaction process with mixed biomass: Waste wood and Sewage sludge

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ABSTRACT

Torrefaction technique is thermochemical process to obtain the high heating value of solid fuel at mild temperature, 200 ~ 300 ℃. Torrefaction process was performed to determine yield and characteristics of torrefied solid fuel on the operation temperature and reaction time at 0.1 TPD bench scale. The mixed biomass waste wood with sewage sludge was used. In torrefaction, the temperature and reaction time in rotary kiln are impact factors on the quality of the torrefied materials because the moisture contents of mixed biomass has 55 wt.%. The results are that reaction time is longer, the temperature variation in kiln was in the stable state. As the higher temperature in the torrefaction process, the heating value of torrefied materials is also higher. Therefore if the reaction time is longer, the torrefaction process will be more stable and the quality of torrefied solid fuel is higher. Because the reaction will happen at the rear rotary kiln in longer torrefaction process. From this study, it can be obtained the technique of solid fuel converted by high moisture contents waste biomass as high energy resources.

Keywords: Torrefaction, Sewage sludge, Waste wood, Solid fuel, Thermal decomposition

INTRODUCTION

The environmental problems from fossil fuel and the greenhouse gas will cause the global warming. Therefore the interest in the renewable energy is increased all over the world. However the biomass fuel has higher moisture contents, hydrophilic and lower heating value than fossil fuel. If these biomass is used as energy, the fuel efficiency is too low. But if carbon dioxide and moisture are removed, the biomass can be converted into solid fuel as a similar level to fossil fuel by torrefaction process. (Park, D. K, 2007)

From the torrefaction process in oxygen-free condition, the molecular of biomass lose oxygen and hydrogen, but increase the amount of carbon. In this thermal decomposition, the low fraction of oxygen attaches to carbon molecular and then it affects the heating value. Thus the torrefied materials will be higher energy dense of the products. (Park, Y. S., 2012)

In this study, it was determined about characteristics of torrefied materials by operation temperature and reaction. In fact operation temperature will be used as heat resource in drying process. In economic perspective, it can be determined that the mixed biomass has potential for recovery a stable solid fuel (Haryadi, 2009).

MATERIALS AND METHODS

In this study, the characteristics of raw biomass are shown in Table 1. The waste wood 40 wt.% and sewage sludge 60 wt.% were mixed evenly.

Table 1. Biomass ultimate and proximate analysis

Comment	proximate analysis1)		ultimate analysis2)							LHV2)
			C							
	Moisture	Ash	Fixed carbon	Volatile	H	N	S	Cl	O3)	
waste wood	11.0	1.8	7.9	32.8	5.7	3.2	0.1	0.2	37.3	3,630
sewage sludge	84.6	3.2	0.3	6.0	1.1	0.9	0.0	0.0	3.8	150

1) as received basis, 2) wet basis, 3) by difference

To torrefy the mixed biomass, the rotary kiln type reactor was used. The kiln size on bench scale was 1,400 * 250 mm and capacity is 6 kg/hr. The table 2 shows the operation conditions for being on steady state. From these variables, the optimum conditions can be determined to obtain the torrefied materials yield. For this study, the torrefaction reactor was applied to rotary kiln. And the residence time of feeding materials was determined by the rotary kiln speed of rotation. Thus the residence time for torrefaction was set during forty minutes and one hour in this study. The produced gas, torrefied gas, was analyzed by gas chromatography and the produced solid, torrefied materials, were performed for heating value and proximate analysis. The lower heating value was calculated from higher heating value. In addition, the used HHV analyzer was bomb calorimeter (Parr, Parr 6400).

Table 2. Operation conditions for torrefaction process

No.	Reaction Temperature (℃)	Resident time (min)	amount of mixed biomass (kg)
1	250	40	6.04
2		60	4.01
3	270	40	8.14
4		60	6.04

RESULTS AND DISCUSSION

When the mixed biomass was input, after 10 ~ 20 minutes, the stable condition in the torrefaction kiln was maintained and the reaction temperature was at both 240 and 260 ℃. Regardless of the operating conditions, the torrefaction has evaporation process because the feeding materials were contained high moisture content approximately 55wt.%. Therefore it takes about 60 minutes to approach the steady state.

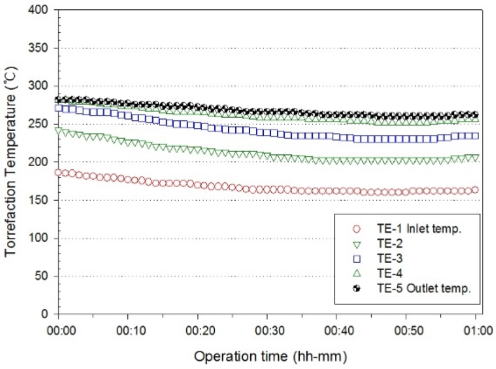

Figure 2. Temperature variation in torrefaction reactor at 250 ℃, 60 min.

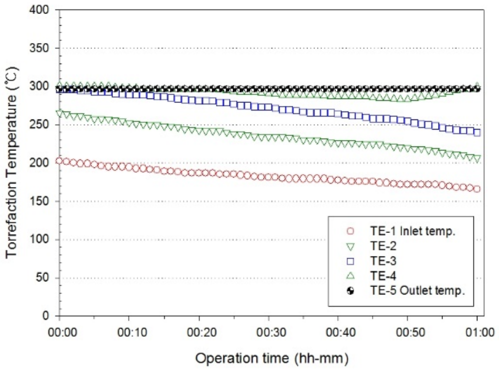

Figure 3. Temperature variation in torrefaction reactor at 270 ℃, 60 min.

In spite of the high content of moisture, after sufficiently dried the mixed biomass in dry process the torrefaction reaction occurred and then the produced torrefied material which had high energy capacity.

From the figure 4, It can be determined that when the torrefaction process was performed during 60minutes, the torrefied materials had lower moisture content than mixed biomass at both 250 and 270 ℃. And also the amount of fixed carbon was increased from the volatile materials in thermal decomposition process. From the proximate analysis of dry basis, when compared to the ash content of torrefied materials, the content of ash was similar to mixed biomass and 250℃ and 270 ℃ because of the ash content of sewage sludge, which had approximately 16 wt.%.

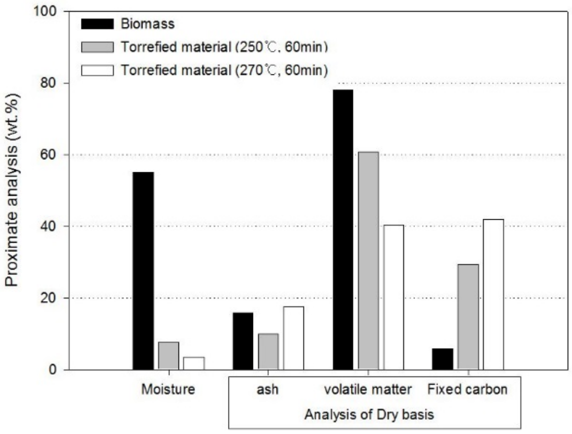

Figure 4. Comparison the proximate analysis of torrefied materials and mixed biomass in 60 min

The figure 5 and 6 shows that as the reaction temperature was increased, the low heating value with wet basis of torrefied material also increased. At 40 minutes reaction time, the heating value of torrefied material was increased from 3,890 kcal/kg to 4,060 kcal/kg and at 60 minutes, it was from 4,300 kcal/kg to 5,300 kcal/kg. At the same reaction time 60min, the amount of ash was increase so the heating value was also lower than at the low temperature. From these results, it can be determined that the reaction temperature is impact factor on the torrefied material's quality. However the yield of the torrefaction materials were decreasing with the higher temperature and longer reaction time.

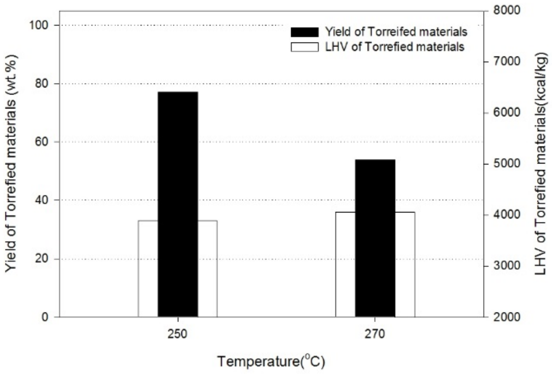

Figure 5. Comparison LHV and yield of torrefied materials between 250 and 270℃ in 40 min.

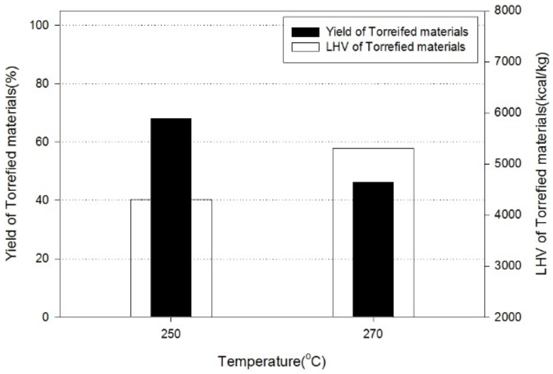

Figure 6. Comparison LHV and yield of torrefied materials between 250 and 270℃ in 60 min.

CONCLUSION

The main purpose of this paper was to determine the impact factors in torrefaction process by using the mixed biomass which was mixed with waste wood 40wt.% and sewage sludge 60wt.%. The results were that for maintaining the stable condition, the torrefied material was influenced on temperature rather than reaction time. Because the feeding materials contained high moisture, torrefaction needs the sufficiently drying step. During the long torrefaction process, the drying process occurred at the front of rotary kiln and then the stable torrefaction reaction occurred at the rear part of the reactor. At the constant reaction time, the results from the characteristics of the torrefied materials according to operation temperature were that the yield of the torrefied materials decreased but the heating value increased. Because in torrefaction process at 250 ~ 300℃ the volatile matter had been thermal decomposed and then content of fixed carbon increased. In hence, from performed study, the operation temperature is influence on the torrefied mater's quality.

ACKNOWLEDGEMENT

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A study on torrefaction of the mixed biomass depending on the ratio of sewage sludge

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ABSTRACT

Torrefaction is the thermal decomposition process at low temperature range from 200 to 350 ℃. And can obtain higher the heating value than biomass. If the sewage sludge was mixed with waste wood in the proper ratio, the torrefied material can be used as a fuel resources. Because the sewage sludge has the high moisture and low quality biomass and the waste wood has the low moisture and high quality.

Therefore the effective factors on quality of torrefied materials can be determined for this study such as reaction temperature and proper mixing ratio. The biomass was mixed at various ratio. The ratio of waste wood and sewage sludge was 6:4, 4:6, and 2:8 in this study. From this torrefaction results, it can be known that as the sewage sludge fraction had been higher, the heating value was lower, due to the ash content in torrefied materials based on sewage sludge. Moreover at 4:6 and 6:4, the volatile matter in mixed biomass occurs actively the thermal decomposition. Therefore when the high moisture and low quality biomass was mixed the low moisture and high quality biomass at the ratio of 4 to 6, the quality of torrefied materials is higher from an economic point of view.

Keywords: Torrefaction, Mixed biomass, Waste wood, Sewage sludge, Torrefied material

INTRODUCTION

Torrefaction occurs at mild temperature from 200 ℃ to 300 ℃ under free-oxygen condition. It has lots of advantages. In general, the torrefaction makes uniform torrefied materials and advanced solid fuel. It also has higher energy dense and possibility to long distance transportation than raw biomass. But if the moisture contents of raw biomass is high, the torrefaction time will be longer for drying step. Therefore the sewage sludge cannot be a fuel. Because the sewage sludge has lots of content of moisture and the heating value is very low compared to lignocellulosic biomass. If this sewage sludge is torrefied with low moisture and high quality materials such as waste wood, then the torrefied materials can be much higher quality as a fuel than raw biomass (Park, Y. S., 2012).

In this research, the characteristics of torrefied materials were studied by using the mixed biomass with waste wood and sewage sludge. In particular the ratio of waste wood and sewage sludge was set 6:4, 4:6, and 2:8 to know about the effect of moisture contents. To compare the quality of torrefied materials, the heating value, mass yield and also energy dense was analyzed. Determining the characteristics of produced torrefied materials will be applied as a basis data for bench and pilot scale in torrefaction process.

MATERIALS AND METHODS

The ultimate and proximate analysis of mixed biomass for this study is shown in table 1. To investigate with characteristics of torrefaction in accordance with different ratio, these two biomass were mixed for each ratio. As the figure 1, the torrefaction process was designed and it was lab scale.

Table 1. Biomass ultimate and proximate analysis

Comment		Waste wood	Sewage sludge
Proximate Analysis (wt.%, as received basis)	Moisture	29.6	77.8
	Volatile matter	14.0	51.8
	Fixed Carbon	2.2	17.9
	Ash	0.7	6.0
Ultimate analysis (wt.%, dry basis)	C	48.18	35.98
	H	5.89	5.57
	N	2.87	3.94
	O	38.87	22.15
Heating Value (MJ/kg, dry basis)		20.70	16.14

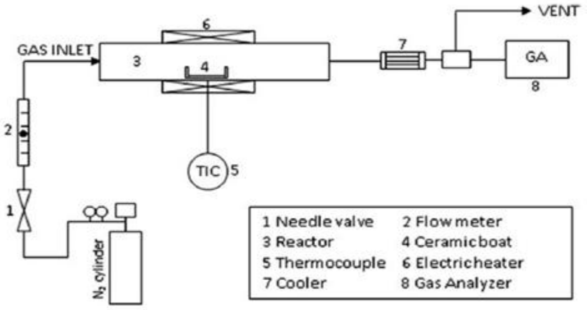

Figure 1. Schematic of the torrefaction for mixed biomass

The table 2 shows the reaction conditions to compare the characteristics of torrefaction process. The ratio of waste wood and sewage sludge was 6:4, 4:6, and 2:8. By using the mixing reactor, biomass was mixed evenly. These mixing ratio for biomass means the moisture content of input materials. The moisture contents influence on the torrefaction and the quality of torrefied materials. To compare the quality of torrefied materials depending on the ratio of mixed biomass, the ultimate analysis, heating value and the mass yield were investigated. This mixed biomass was react at 200, 250 and 300 ℃ during 40min under free-oxygen. The mass yield of torrefied materials was calculated by following equation.

$$\text{Mass yield of torrefied material} = \frac{Output\ amount\ of\ materials}{Input\ amount\ of\ biomass}$$

Table 2. Reaction conditions for torrefaction process with mixed biomass

No.	Ratio of waste wood and sewage sludge	Reaction Temperature (℃)	Resident time (min)	amount of mixed biomass (g)
1	6:4	200, 250, 300	40	20
2	4:6			
3	2:8			

RESULTS AND DISCUSSION

The torrefied materials from variable temperature and mixing ratio were investigated by using proximate analysis of dry basis as shown from figure 2 to figure 4. From these results we obtained that the volatile matter in mixed biomass is decreased during the thermal decomposition with increase of reaction temperature. In particulate, when the reaction temperature was from 250 ℃ to 300 ℃, the thermal decomposition had occurred actively and then the fixed carbon content was increased. And it can be known that during the torrefaction with 6:4 and 4:6, the thermal decomposition was more active than 2:8. The produced gas which means torrefied gas in thermal decomposition was applied as supplied fuel depending on the gas composition.

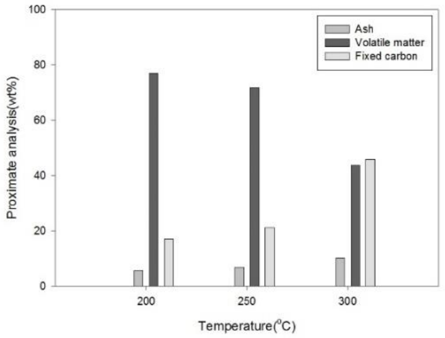

Figure 2. Proximate analysis of W:S=6:4 (dry basis)

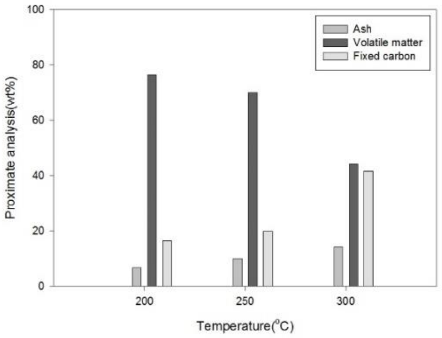

Figure 3. Proximate analysis of W:S=4:6 (dry basis)

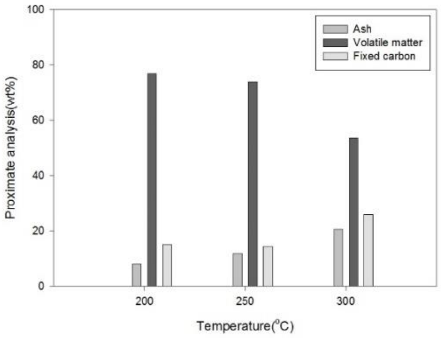

Figure 4. Proximate analysis of W:S=2:8 (dry basis)

The mass yield and high heating value on dry basis of torrefied materials were shown from the figure 5 to figure 7. Regardless of the sewage sludge fraction, the heating value was increased at higher temperature. The main reason was that the rate for the loss of moisture was higher during a constant reaction time. However as the sewage sludge fraction was higher, the heating value was lower. There were two reasons. One was the lower mass yield and the other was ash content in torrefied materials based on sewage sludge. (Poudel, J., 2015)

When the ratio of waste wood and sewage sludge was 4:6, the mass yield was decreased from 95.61 wt.% to 46.97 wt.% by increasing temperature from 200 ℃ to 300 ℃. But the high heating value was increasing about 22 % from 18.81 MJ/kg to 24.11 MJ/kg.

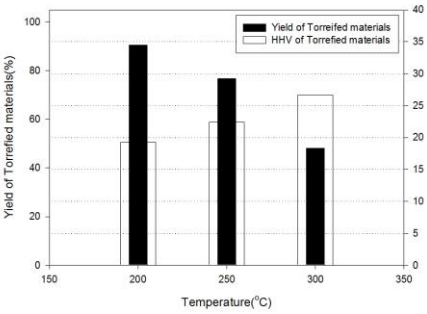

Figure 5. Characteristics of torrefied materials at W:S=6:4

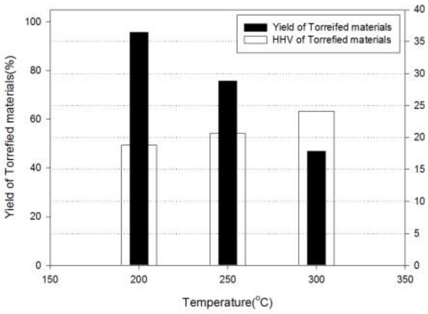

Figure 6. Characteristics of torrefied materials at W:S=4:6

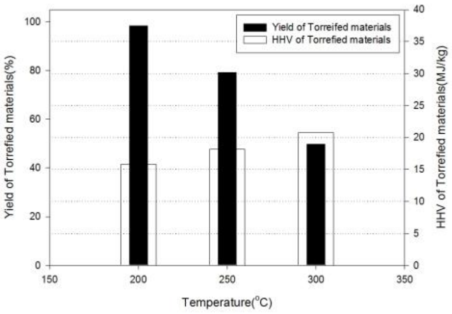

Figure 7. Characteristics of torrefied materials at W:S=2:8

CONCLUSION

The main purpose of this research was to compare the characteristics of torrefied materials depending on the mixing ratio of waste wood and sewage sludge. The mixing ratio means content of moisture in mixed biomass to apply sewage sludge. It is one of the important factors to determine the quality of torrefied materials.

From these study, it can be investigated that at 4:6 and 6:4, the volatile matter in mixed biomass occurs actively the thermal decomposition. From this reaction, the content of fixed carbon is higher, and this torrefied material can be used as a solid fuel. Because during 40 minutes on torrefaction, the high heating value was 20.51 MJ/kg at 250℃. Therefore when the high moisture and low quality biomass was mixed the low moisture and high quality biomass at the ratio of 40 to 60, the quality of torrefied materials is higher. In the perspective on economic, the torrefaction of mixed biomass will be profits in sewage sludge treatment.

ACKNOWLEDGEMENT

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A study on the mixing characteristics and the transition of moisture content of the waste biomass for application to the solid fuel production

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ABSTRACT

Torrefaction is a promising heat-treatment method being developed for biomass to increase the use of biomass in its thermochemical conversion processes. However, Commercial scale Torrefaction system has insufficient research. And single waste biomass was limited to satisfy the regulations of the domestic solid fuel quality standards by producing solid fuel. In order to design a commercial scale torrefaction system, there is a need to study the mixing characteristics of the mixed waste biomass.

In this paper, the sewage sludge in order to know the mixing characteristics of the waste biomass was mixed with waste woods and rice husks. And bulk density and moisture contents was measured to determine the mixing characteristics. Mixed waste biomass of waste wood and sewage sludge, hand mixing, was to increase the bulk density in order to shovel mixers and paddle mixer. Further, Bulk density of biomass proud 10 minutes was higher than the arrogant 5 minutes.Conversely, In the case of rice husk, Bulk density was similar same.

Keywords: Waste Biomass, Torrefaction, Mixing Characteristics, Solid Refuse Fuel

INTRODUCTION

Waste biomass utilization, either as a precursor for electricity generation or biofuel production, has received a lot of attention in the last decade in the wake of increasing calls for renewable energy utilization. Torrefaction is a promising heat-pretreatment which can address some of the limitations of raw waste biomass for combustion and gasification. In general, Moisture and volatile matter was removed in waste biomass through low temperature heat treatment in anoxic or hypoxic. Therefore, a lot of researcher investigated torrefaction technology in order to create high quality solid refuse fuel. However, research on the commercial scale torrefaction system was lacking. And single waste biomass was limited to satisfy the regulations of the domestic solid fuel quality standards by producing solid fuel. For design a commercial scale torrefaction system, it is necessary to understand for mixing characteristics about various waste biomass. Because, successful feeding and reaction time was determined bulk density and moisture contents of mixing waste biomass.

MATERIALS AND METHODS

The sample used in this work were three waste biomass, Waste wood, Rise husk and Sewage sludge. The results of proximate analysis, ultimate analysis and calorific value was shown in following table.

Table 1. Result of waste biomass analysis

	Proximate analysis (wt.%)				Ultimate analysis (wet basis)(wt.%)					
	Moisture	**Fixed carbon**	**Volatile**	**Ash**	**C**	**H**	**N**	**S**	**Cl**	**O**
Waste Wood	11	17	70.2	1.8	40.7	5.7	3.2	0.1	0.2	37.3
Rice Husk	10.5	16.4	60.4	12.7	35.7	4.9	0.5	0.1	0.1	35.5
Sewage Sludge	84.6	0.6	11.6	3.2	6.3	1.1	0.9	0	0	3.8

Sewage sludge was difficult to apply solid fuel produced by single material, because moisture content was more than 80%, and heavy metal contents was higher than the domestic solid fuel quality standards. So, it may be a mixture of waste wood and rice husk to satisfy the regulations of the domestic solid fuel quality standards by producing solid fuel.

Table 2. Heavy metal contents of waste biomass (Unit: mg/kg)

	Mg	Cd	Pb	Ar	Cr
Waste Wood	0	1.9	4.9	N.D.	2.2
Rice Husk	0	N.D.	0.5	0.4	17.8
Sewage sludge	1.8	1.2	16.6	3.4	23.6
Domestic solid fuel quality standards	below 0.6	below 5	below 100	below 5	below 70

In this paper, Sewage sludge was mixed to waste wood and rice husk for determined mixing characteristics of waste biomass. And bulk density and moisture contents was measured to determine the mixing characteristics. Moisture was measured using an infrared moisture meter (FD-660, KETT), it was measured according to ASTM, sample weight was 5g and set temperature was 105℃. Bulk density was measured using by 100mL measuring cylinder.

RESULTS AND DISCUSSION

To determine the mixing characteristics of the waste biomass, sewage sludge and waste wood mixed with a respective weight ratio using by hand mixing, Shovel mixer and Paddle mixer. The results of the measured bulk density is shown below.

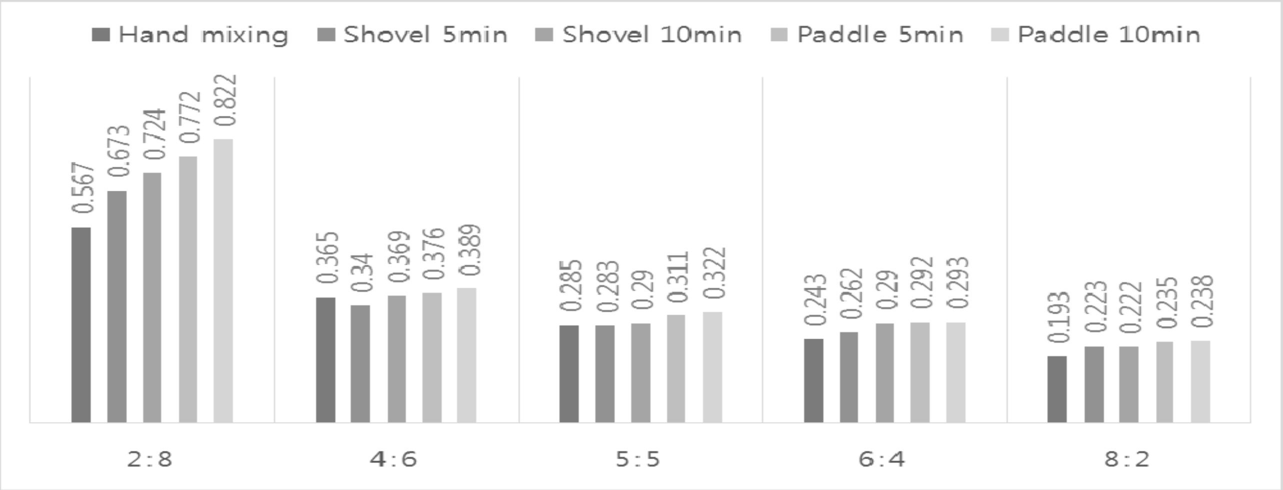

Figure 1. Bulk density of mixed waste biomass (Waste wood + Sewage sludge)(Unit: mg/ml)

To determine the mixing characteristics of the waste biomass, sewage sludge and rice husk mixed with a respective weight ratio using by hand mixing and Paddle mixer. The results of the measured bulk density is shown below.

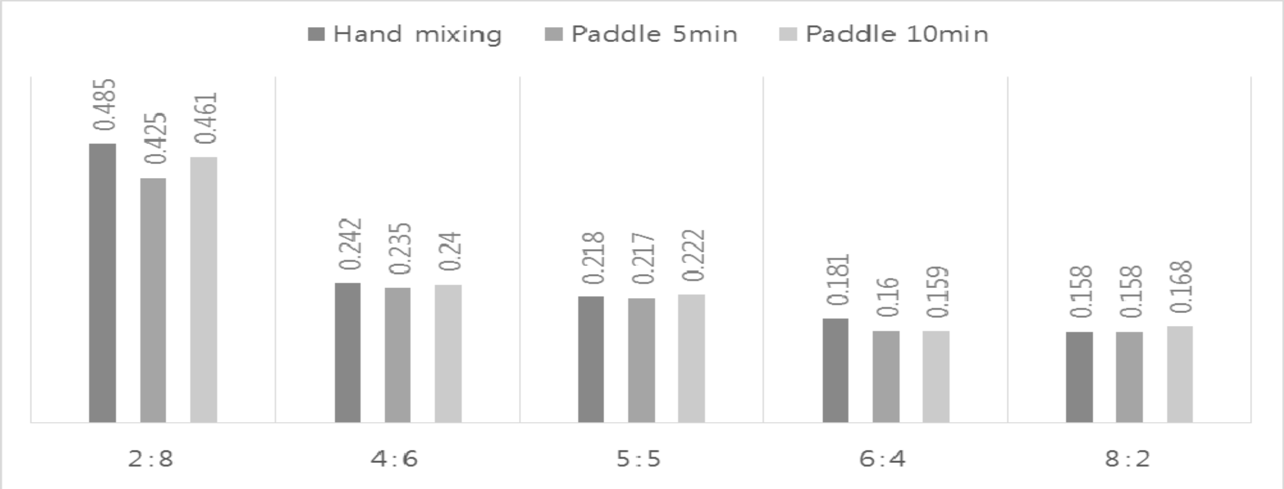

Figure 2. Bulk density of mixed waste biomass (Rice husk + Sewage sludge) (Unit: mg/ml)

The moisture measurements of the mixed waste biomass waste wood, rice husk and sewage sludge is shown as follows.

Table 3. Moisture contents of mixed waste biomass

Moisture contents (%)	2:8	4:6	5:5	6:4	8:2
Waste wood + Sewage sludge	72.7	57	51.4	42.9	29.3
Rice husk + Sewage sludge	67.7	54	43.5	40.1	24.6

As a result, mixed waste biomass of waste wood and sewage sludge was increased bulk density in order to the Hand mixing, Shovel mixer and Paddle mixer. Further, bulk density of stirred for 10 minutes was higher than 5 minute stirring mixed waste biomass. Conversely, In the case of rice husk, Bulk density was similar.

CONCLUSION

The purpose of this study was to determine the mixing characteristics of the mixed waste biomass for solid fuel production according to torrefaction technology. According to result, bulk density of mixing waste biomass using by paddle mixer was higher than others. And the longer the mixing time was increased bulk density. In the case of result for mixed waste biomass using by waste wood, bulk density was increased through sewage sludge of high density was penetrated between vacancies of waste wood. So, bulk density was increased means that mixing was better. Bulk density of the rice husk is similar won't have the vacancies, such as waste wood. Therefore, paddle mixer was suitable to mixing waste biomass for produced solid waste fuel using by torrefaction technology.

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Post-Earthquake Disaster Waste Management - A Case Study

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ABSTRACT

Disasters can create huge volume of waste depending on the severity and nature. Earthquake being one of the most high impact disasters, the waste generated must be properly management and disposed in interest of sustainable rehabilitation and public health. This paper presents an overview of post-earthquake disaster waste management based on existing literature and case studies. The literature available discusses the situation and management methodologies of their respective timeline where as the case studies of recent Nepal Earthquake is the storyteller of the present and near future. It is envisaged that the literature gaps identified and the 4R (Reduce, Reuse, Recycle and Rehabilitation) principles presented in the paper will be a new insight for future research on disaster waste management and will also lead to preparedness and response towards such future problems.

Keywords: Disaster Waste Management, Construction Demolition Waste (CDW), Earthquake, 4R.

INTRODUCTION

Disasters are dance of the devil destroying the earth in terms of fire, flood, earthquake tsunami etc, which have enormous effect on environmental, economic and social aspects of day to day life at different magnitude and forms (Brown et al. 2011). Huge volume of debris and waste can be generated by strong earthquake. It has been found, sometimes the waste generated due to disasters are equivalent to 5-15 times of the annual waste generation of that particular community (Reinhert and McCreanor 1999). In this study, the cases of Japan, Pakistan and Turkey have been considered due to their geographical locations and Nepal which was a recent disaster. Literatures were found on general disaster management of Tornados, Typhoons, Tsunami, floods etc. Studies focusing on post-earthquake disaster management are scant. In this paper, an attempt has been made to bridge the gap based on standalone literature and case studies. Detailed literature has been discussed with focus on 3R and disaster management strategies. The findings of the paper will lay a path towards decision making of the stakeholders of post-earthquake waste management team as well as show new ways towards sustainable research.

The rest of the paper has been divided into four sections. Section two describes literature in detail. Section three presents the case study of Nepal. In the next section the discussion and 4R principles are being proposed followed by discussions and conclusions.

PREVIOUS SEVERE EARTHQUAKES

The Great Hanshin earthquake struck Japan with an intensity of over 7 on the Richter scale on January 17, 1995. The estimated quantity of waste generated was 15 million cubic meters, generated from damage to nearly 200,000 thousand buildings and other infrastructure included .The only positive aspect of the earthquake was the manner in which the Japanese disaster prevention authorities responded to the crisis. In response to the disaster, rubberized shock absorbers were installed below bridges and to minimize damage from domino effect, the Japanese authorities added more space between buildings. The national government responded by introducing disaster management policies which proved effective in upcoming years (Kobayashi 1995).

The 1999 İzmit earthquake in northwestern Turkey peaked 7.6 on the moment magnitude scale, and took the lives of an officially estimated 17,127 people and left half a million people without a shelter. Reports from September 1999 show that 120,000 poorly engineered houses were damaged beyond repair, 35,000 houses were either heavily damaged or had collapsed. Once the rescue phase was completed, the demolition wastes were disposed of at 17 official dumpsites, which excluded the disposal of demolition waste to sea, river, river bad, lake and agricultural areas. Despite their best efforts, the emergency response forced small quantities of rubble to be illegally dumped along the coastline and in some valleys. Crushing plants were installed for recycling of the demolition wastes. Feed material into the crushers were not segregated and thus could not be processed properly due to frequent blockages in the system (Buycan 2004).

The Northern part of Pakistan experienced an earthquake of massive proportions, tipping 7.6 on the Richter scale in October 2005, resulting from the collision of the Eurasian and Indian tectonic plates. The aftermath of damage to life and property approximated a horrific 73,000 deaths, 128,000 injured and 600,000 houses destroyed, and expected loss equivalent of US$5.8 billion to the Government. Disposal and recycling were observed as the most effective means of treating debris. Sites for landfill were limited to only the materials considered inert for the quality of the soil. Assigning greater importance to recycling became a pertinent and viable solution for the debris considered hazardous to the soil. Land filling sites were assigned for rubble obtained from destruction as well as secondary demolition of damaged structures. Materials commonly found in buildings such as bitumen, metal, wood could not be separated due to the lack of existing infrastructure and the cost associated with the process (Latif et al. 2014).

CASE STUDY

Kathmandu Valley was rattled by a catastrophic earthquake on April 25. The earthquake caused large amount of CDW generation and has impacted the housing and human settlements sector the most. The total damage and loss in this sector is estimated to be NPRs 303,631 million and NPRs 46,748 million respectively. The damage accounts for physical housing damage and damage to household goods, the loss for demolition and debris clearance, transitional shelters and rental loss including the real estate sector. Several heritage cites more than a century years old were reduced to rubble. Huge loss was incurred by Nepal Govt. due to decrease in the number of tourist. Many old building around the streets of Thamel near Basantapur Darbar Square either got collapsed or in a deformed state supported by wooden columns inclined at an angle of 60 degree with the wall. The buildings were made of locally made mud bricks. The main material of the buildings were bricks, timber, sanitary pipes, GI Sheets, glass, asbestos etc.

Fig 1: Earthquake affected photos of Nepal

The Government and the Army of Nepal did exceptional job with the management of these huge amount of debris. Still significant amount of waste is lying around the valley. According to the government officials no information is available about the disposal of these CDW. CDW was found lying beside the bank of the river

Bishnumati. Due to petrol and diesel crisis, people are compelled to live in the temporary shelter, the wastes couldn't be transported and dumped in proper disposing sites. They are filling up lowland areas of the valley.

In Lalitpur, huge damage to lives and the infrastructure was done including Patan, its district headquarters (385 km²). Patan Durbar Square complex, which are good specimen of ancient Newari architecture, is the residence of the former Patan royal family. Several multi-sized and multi-styled temples such as Krishna Temple, Bhimsen Temple and the Golden Temple are situated here, among which two temples- Char Narayan (the oldest temple of the Square) and Hari Shankar were destroyed. Together with local and government help, Patan Museum and Department of Archaeology collected the encrypted window, doors and broken pieces of the temples for preservation. Banks and bed of river Bagmati were dumped with demolition waste with other solid wastes. Several NGOs use the banks to segregate city wastes as their operation sites. Buildings were left in a state which is beyond any repair or renovation. The old wooden sculptures and other artifacts of the temples were kept in a safe place inside the museum complex. The heavy metal leachate from CDW is polluting River Bagmati. Littering is in action in the sites and many reusable materials such as timber (used as fuel) and steel bars are said to be getting stolen from the affected sites due to lack of security.

Bhaktapur, a historic town, was also damaged including 116 (67 complete and 49 partial) heritage sites. The quake has badly damaged the Bhaktapur Durbar square, a significant heritage site included in the UNESCO world heritage list. The main premises of Taleju Temple here also witnessed damages in the disaster. The building of the municipality office, temples of Rameshwor, Batsala, Narayan, Biswaroopa, Siddiganesh, Sweetbhairav, Siva Mahadev, were damaged by the quake. Many age old artifacts are kept inside the palace guarded by armed forces at Darbar Square. The damaged buildings and temples were given extra support by wooden pillars to prevent it from collapsing. Some buildings were in a process of planned demolition. The main components of the building were bricks and timber. These buildings were load bearing buildings typically comprised of 3 stories. The roof was made with wood planks supported by rafters. According to the locals, the bricks and timber from the building will be reused to a significant amount for future reconstruction of the buildings. The catastrophic impact of the earthquake on the built environment of Nepal is the result of the significant seismic vulnerability of unreinforced masonry buildings which are predominant. There is a general lack of awareness of seismic risk in communities, coupled with lack of dissemination of improved construction practices (particularly rural areas), and a slow mechanism for enforcement of relevant building codes.

4R PRINCIPLES IN DISASTER WASTE MANAGEMENT

In this study, the principles of 3R i.e. Reduce, Reuse, Recycle has been extended to another dimension which is very important in case of disaster waste management; which is Rehabilitation. Modern construction technologies can help people to build their houses in a better way to make them earthquake resistant. Most of the aged buildings preventive maintenance. Since there are no building regulations implemented while construction, the necessary and efficient precautions are rarely taken into consideration. Most buildings in Nepal are self-made with very little support from certified engineers. It's not the earthquakes that kill people; but the collapsing of buildings which are not seismic resistant does. It would allow to reuse a significant percentage of the debris and to give it a useful destination, for instance for the construction of sub bases of roads and road shoulders, or to complete foundations of buildings. To process the debris in that way would have as an additional advantage as there would be less need for the exploitation of new raw materials this is also sometimes considered as a cause for the occurring of a number of landslides caused by the earthquake.

The labor costs in Nepal are low and there are a lot of unskilled laborers available in the market. Manual techniques can be opted for a lot of operations, for instance preventing pollution with plastic, asbestos, textile, etc. through handpicking. Another example is removing metal, reinforcement bars and timber. Considering the low labor costs and the present steel price, it pays to remove these bars and metal, even with a sledge hammer, before they are transported. Pilot scale recycling plant should be setup in different part of the country for proper management of CDW. Segregation at site should be the first priority for proper CDW management. This will help to identify the recyclable and non-recyclable materials. The main constituents of debris from Nepal earthquake are Bricks, Stone, Mud, Concrete, Steel bars, wooden frames, CGI sheets, etc. Clean concrete without any foreign elements is however next to impossible. The process should incorporate manual or mechanical removal of foreign matters. Best solution is to provide incentives to demolition contractors for selective demolition at source to recover and recycle much of the materials in relatively clean and uncontaminated form.

Rubble should be immediately disposed in the selected lands to prevent ecological hazards. This will initiate fast process in the work of rehabilitation. Buildings should be made considering future seismic blow. In Nepal engineers did a good job giving temporary wooden support to old and misaligned buildings. Many people are still living in the tents and temporary made houses with CGI sheets as its rooftop. Due to petrol and diesel crisis the situation exacerbated. Unavailability of transport is curbing the process of rehabilitation.

CONCLUSION

Emergency CDW management should be an integral part of disaster response system. A discrete department must control and management of wastes. Dumping along river banks, coastlines and in mountainous valleys makes handling of the wastes difficult due to inaccessibility of heavy machinery and should be prevented at all costs . The metalloids in CDW cause many health hazards. Sorting at source should be implemented for proper recycling potential of materials. Waste processing/crushing machines and screeneres should be properly selected with trained personnel at hand to operate the machinery. Unauthorized handling of waste has to be prevented. All scope of recycling and re-use of waste must be carefully considered in order to save energy, resources, time and money by treating C&D waste resources. It is important to effectively monitor and control unofficial tipping for transportation of waste, which may lead to increased costs and resources as well as minimized recycling potential.

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STUDY TO REFINED SIO_2 FROM RICE HUSK ASH IN THERMAL POWER FACTORY TO PRODUCE HIGH QUALITY BUILDING MATERIAL

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ABSTRACT

Thermal power plant using rice husk is a effective solution - while rice husk is a promised agricultural waste sources. However, there are not more method to utilize rice husk ash generating. In previous studies, we have confirmed the potential of creating building material from rice husk ash. However, the reuse of rice husk ash not effective. If conducting refined, artisanal pure SiO_2 husk ash will create construction materials quality. Experiments carried out with NaOH to remove the carbon content in rice husk ash, neutralized with acid to create a gel, calcined to remove organic matter. Obtained pure SiO_2 and high-value, can be replaced by 30% in the sample of cement building materials.

Keywords. Rice husk, refine SiO_2, waste recycle, thermal power factory, high quality building material .

1. INTRODUCTION

In recent times, facing the problem of energy crisis, many solutions were created to solve this problem. One potential solution that is the thermal power plants burning agricultural waste. Husk is a source of waste products provide high heat. Additionally, ash from the incineration of waste rice husk SiO_2 rich promise as a potential material for the production of construction materials. From previous studies, this research is done with the goal of creating rice husk ash materials best serve for the production of construction materials. Husk ash is undergoing refinement to get the best quality, to produce building materials of high quality. The subject is not merely for the purpose of recycling agricultural waste, but also with the aim of creating sustainable materials and building a green economy, improve the urban ecological cycle.

2. MATERIALS AND METHODS

2.1. Experiment 1: Create templates, sample handling and processing

Rice husk ash from thermal power plants is black, a few white ash, dry, porous, soil and mild. Sample impurities are removed, crushed and sifted through a sieve with pore size of 250µm. Samples were stored in sealed containers.

Figure 1. (from left to right) Original sample, Sample after grinding and sifting, Preservation of samples

2.2. Experiment 2: Extract SiO_2 from rice husks

- Weigh 20 g sample into a 1000 ml beaker. Then for the 250 ml 5m NaOH. Boil a glass beaker of ash sample with 5m naoh for 4 hours. After boiling, the solution to conduct filter removes dust and rice husk ash residues.
- For 2m HCl solution with appropriate amounts to a neutral environment. Mixed in a gel, washed with water several times to remove chloride ion .sau dried gel that provides 100 ° c temperature for 24 hours, then calcined at 550oc for 2 hours to remove organic matter. Then proceed to sample grinding and sifting through 250µm sieve.

 a.	 b.	 c

 d	 e	 f

Figure 2. Handling of ash samples

2.3 Experiment 3: Check the activity of the material

For the ability to replace the two samples with high or low efficiency, we need to check the nature of the material. Samples were analyzed specific weight, moisture, water absorption, the absorption of lime, carbon content.

2.4. Experiment 4: Casting sample

Figure 3. 40 × 40 × 160mm sample

- Conduct a rate of casting mortar cement 450g ± 2g, ± 5g sand 1350g and 225g ± 1g countries, including rice husks and rice husks refined crude is used to replace cement.
- Casting the following form:
- Common sample: Cement + Sand + Water
- Samples of raw rice husk ash: coarse rice husk ash + cement + sand + water
- Samples of rice husk ash has refined**:** refined husk ash + cement + sand + water

Use a mixer to mix each batch of grout. Then the labeling or marking of the mold to pattern recognition.

Table 1 Additive: Cement Ratio

Component	Raw sample		Extracted sample		
	10%	20%	10%	20%	30%
Cement and Ash	405g+45g ash±2g	360g+90g ash ±2g	405g+45g ash ±2g	360g+90g ash ±2g	315g+135g ash ±2g
Sand	1350g±1g	1350g±1g	1350g±1g	1350g±1g	1350g±1g
Water	225g±1g	225g±1g	225g±1g	225g±1g	225g±1g

Samples were measured water absorption and mechanical properties such as compressive strength and bending strength.

3. RESULTS AND DISCUSSION

3.1. The shape of the sample

Ash samples taken from the plant also shaped husk, with black-gray, mixed with sand, which is processed to remove sand and by crushing and screening through 250µm sieve. After processing the samples husk ash is black and smooth. This proves that the sample contains a lot of burn out the carbon. If you use direct ash samples will reduce the compressive strength of mortar samples. Results from previous studies by the authors showed that samples made from rice husk ash mortar reduces compressive strength of the sample about 20%. Therefore, rice husk ash must be treated to remove carbon.

So with the morphological characteristics of the ash samples prepared with silica samples weobserved by eye, the silica samples have porosity and permeability of high water, so when associated with cement mortar to make a much stronger form.

Figure 4. Sample after grinding

Figure 5. SiO_2 extracted from rice husk ash

3.2. Sample processing performance

Average of 20 g ash from factory 15.6g we are refining the mixture containing mainly SiO_2 (in addition to small amounts of OH^- and Cl^-) with 78.17% efficiency.

3.3. Results of experiments testing the activity of the material

The activity of rice husk ash raw materials and refined husk ash has been expressed through the parameters: a volume, humidity, carbon content, water absorption, calcium absorption. The results are presented in the table below.

Table 2. Laboratory results of the test activity materials

Parameter	Unit	Sample	
		Sample 1	Sample 2
Density	kg/m^3	425.67	375.44
Carbon content	%	24.45	0
Moisture	%	4.45	3.22
Water absorption	%	64.25	83.78
Calcium absorption	mgCaO/g	251.2	358.33

Sample 1: raw sample
Sample 2: refined sample

Table 3. The water absorption of mortar samples

	Sample 1		Sample 2		
Ratio	10%	20%	10%	20%	30%
Water absorption (%)	4.13	4.51	3.37	3.45	3.57

3.4. Laboratory test results of physical properties

Compression experiments on six half-acre (three samples from the long, after bending fracture). Each value must not exceed the average value ± 10% and dividing each value is 160mm (units are MPa = 1N/mm2). On average 6 results, standard deviation values if more than 10% of the average value, leave it and average the remaining five samples. If 1 out of 5 valid samples remaining differences over an average of 10%, leave whole.

Figure 6. Raw Sample and Refined sample after soaking with water 28 days

Table 4. Compression

	Sample 1		**Sample 2**		
Unit	10%	20%	10%	20%	30%
mm^2	16000				
N	32600	14000	55840	57440	18300
Mpa	20.4	8.8	34.9	35.9	11.4

4. CONCLUSION

4.1 Conclusion

Nowadays, with a rice agriculture, the oldest rice production capacity of Vietnam's exports ranked second in the world thus utilizing rice husk as a model farm - a closed industry. Do not just take advantage of resources such agricultural waste rice hulls bring help reduce environmental pollution but also help reduce the import of fuel, raw materials for construction materials, reducing production costs, the price is very cheap husk only from about 1000 – 2000 VNĐ/ bag.

Through the process husk ash samples obtained sio_2 product purity is relatively large, not carbon. compressive strength test results in samples used to replace 10% SiO_2, 20% cement and high results compared to the remaining three samples. with the silica content of 10%, 20% of the total weight of cement required for casting according to Vietnamese standard 6016-1995, the compressive strength of samples were obtained from 34 - 35.9N/mm^2 which can be used to make mortar to build walls and ceilings plastered. also can be applied to form ash concrete with average grades from 200-300 N/mm^2 concrete form by the average grade of cement used is usually from 35-40N/mm^2 marks. the concrete samples with average grades are often used to build residential. with the results of this research material silica extracted from rice husk ash of thermal power plants capable of replacing 20% cement.

With silica additive nature absorbs water when mixing mortar or concrete to have to add water to the mixture reaches the viscosity. to plaster products are achieved the best performance it is necessary to apply this plaster model results in areas where stable weather and cool, dry place and avoid the hot sun will cause the wall surface cracks or floor due to sample drying and shrinkage mortar again. but the remaining three samples should not be used as building materials as a result of compressive strength of less than 30N/mm^2 compared with standard grade cement.

4.2 Recommendations

In the future, additional studies follows:

- To study the effects of water, additives for construction materials made from rice husks were refined.

- Manufacturing of mechanical devices aimed at automatically refined husk ash.

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STUDY TO UTILIZE MAKING COMPOST FROM PEPPER SHELLS

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ABSTRACT

Over the past 10 years , Vietnam has been the world leader in the export of pepper . Comes with pepper export products always generate large amount pepper shell waste . This amount pepper shell is discharged , untreated , contributing to serious environmental pollution . The theme is carried out with the aim to take advantage of pepper shell to produce compost through aerobic biodegradation . This study was carried out including two main experiments : Experiment compost on microbiological criteria casing material supplemented with probiotics and experiments to assess the effects of microbial organic fertilizer on annual crops . Experiments microbial composting targets are made from shells with 3 models , model no additional preparations , used as a control ; additional model BIO - SEMRS preparations , Enchoice, and *Aspergillus sp* isolated in the laboratory . After 50 days incubation , product launch quality is very good . Tested on chickpea crop showed non - toxic products and inhibit the growth of crops . Output product meets standards of the Ministry of Agriculture .

***Keyword**:* Compost, probiotics, microbial compost, microorganisms, pepper shells.

1. INTRODUCTION:

From 2001 to now , Vietnam always keep the leading position in terms of value and export volume of pepper on the world market. In Chau Duc District , Ba Ria Vung Tau province has 25 white pepper processing facility, a manufacturing facility from 500kg to 3,000 kg of white pepper / day . Total processed on 130 ton of white pepper / year and emit about 26 tons of shell, creating the stench from the waste pile to pollute the environment , the amount of this waste accounts for a relatively large area of land , the natural process of decomposition takes place slowly causing costly destruction . Therefore some research applications of micro-organisms , enzymes in the decomposition process shown pepper crust and feasibility of the essential topics in the application of scientific methods to partially reduce and limit the amount of waste into the environment . Currently the application of biological methods to handle environmental pollution is a problem is the experts as well as public opinion is concerned because the biological measures when applied generally very radical and handling costs low point . Therefore, the project entitled " Production of microbial organic fertilizer from pepper shell " were made to solve environmental pollution problem and the consumption of shell to create valuable products for agriculture .

2. RESEARCH METHODS

2.1 Survey methodology and selected probiotics

The serving probiotics for experiments were purchased in the market with two products: BIO-S.EMRS Environmental Microbiology company producing powder, liquid preparations Enchoice by Puritan Co. production , and *Aspergillus sp* isolated from coir.

Figure 1: a) BIO-S.EMRS preparations, b) Enchoice preparations, c) A*spergillus*

2.2 Composting method

2.2.1 Research model

Composting model is designed with foam insulation material, rectangular shape, dimensions L x W x H = 44cm x 32cm x 20cm. Inside the system is filled with four gas distribution pipelines located along the width of the model. 6mm diameter tube, the tube perforated gas distribution have d = 2mm, leaking drainage pipe from the decomposition placed in the bottom, left side of the model. Above the gas distribution system installation support and add 1x1 mm gravel layer mesh material to restrict air distribution duct obstruction. Air is brought into the model by continuous aeration machine.

Figure 2. Compost model

2.2.2 Analysis of the inputs

Pepper shell taken from Chau Duc District were dried, analyzed input parameters such as temperature, moisture content, organic matter content, Total C, N, K, P.

Table 1 Input Analysis

Parameters	**Unit**	**Pepper shell**
Temperature	^{0}C	31
Moisture Content	%	31,7
Organic compound	%	97,56
Total Carbon	%	54,2
Total Nitrogen	%	2,97
Total Phosphorus	%	0,248
Total Potassium	%	0,087

2.2.2 Research processing

Experimental is progress according to the following steps for physical type database distributed merge suitable for made product best quality and shortest time

- **Step 1** : collecting pepper shells.
- **Step 2** : specified block amount of template into each model, adjust C / N ratio in 25 ÷ 30 . Adjust pH = 6,5 ÷ 8,5; Moisture Content about 50 ÷ 60%.
- **Step 3** : building compost model.
- **Step 4** : operating model .

The model is :

- Mixing manual. Identify temperature 3 times / day.
- Addition of water (if necessary) in 650 ml spray bottle to ensure sufficient microbial moisture for their development .

- **Step 5 :** keep track of the daily model and analyze the following criteria :

- Record the ambient temperature and the temperature at noon each model in the model 3 positions (positions 1 and 2 positions center around) ;
- Sampling of each model pH meter ;

- Measure the volume decline in the model ;
- Shuffling all form of models and add water to a moisture content of 50 ÷ 60 % ;
- Collect samples for analysis of organic matter content 3 days / times

- **Step 6** : From the analysis , comment and evaluate the factors that affect the composting process. At the end of composting process , sampling and analysis criteria : pH , moisture , organic matter and comparison with industry standard 10 TCN 526-2002 microbial organic fertilizer Department of Agriculture.

2.3 Appy in short – temp plant

Use plastic cups as the substrate for growing plants placed in cool conditions, 50% relative humidity, light intensity of 2,000 lux, temperature 27 ^{0}C. The model includes four batches, each batch of green beans grown 10 the experiment was repeated 3 times then get average results.

3. RESULT AND DISCUSSION

3.1 Research 1: Producing compost from pepper shell.

3.1.1 Parameters in compost model

- ***Temperature:***

Temperatures in the model were significantly higher in the first 12 days ranged between 31^{0}C and 52^{0}C (thermophilic phase), the Blank model (increasing temperature from 31^{0}C to 49^{0}C), S.EM (from 32^{0}C increased to 58^{0}C), Enchoice (increased from 31^{0}C to 45^{0}C), *Aspergillus* (increased from 31^{0}C to 52^{0}C) demonstrated the activity of aerobic microorganisms in thermophilic conditions, thermal models Enchoice preparations not increased by the decomposition process mainly due to the enzyme does not generate much heat. In this condition, micro-oragnism converts complex organic material into simpler. Then the temperature began to decrease and stabilize to ambient temperature 30^{0}C.

- ***pH:***

pH values in all 4 models are in the range of 5.5 to 8.5 is optimal for microorganisms in the composting process. pH of 4 models of the early days were plunged in the early stages of the composting process, the acid accumulation and pH decrease results, inhibits the growth of fungi, microorganisms and enzymes, organic compound inhibits decomposition. Then the acid is converted into simple components such as amino acids, sugar ... for micro-oragnism use and emissions of CO_2, NH_3 to pH of 4 models are up again and stable end-stage annealing process.

- ***Moisture Content:***

Humidity is classified as operational factors of the compost production process but very important factors affecting the quality of compost products. Humidity is always only 4 models in the range 50-60%, 1 some time in the humidity of the model may be beyond optimal range due to additional moisture by hand are not.

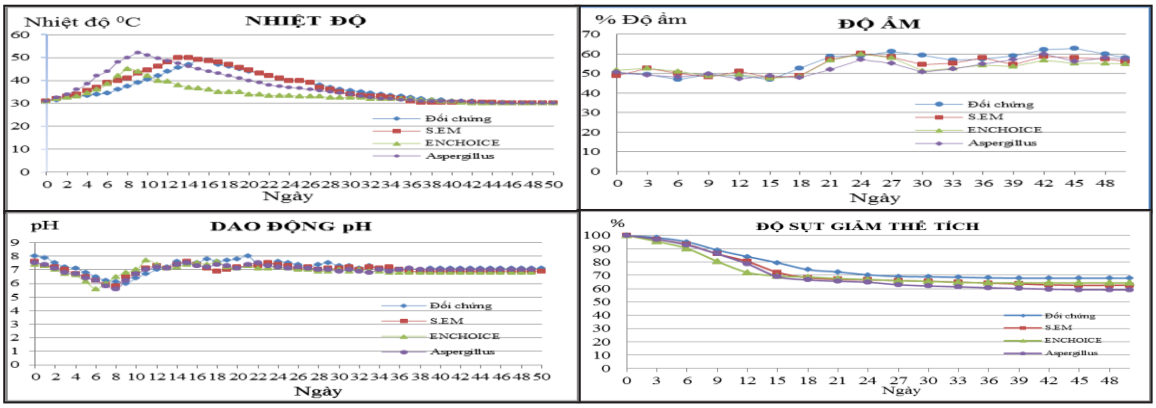


Figure 3: Variability parameters temperature, pH, moisture, volume during composting

- ✓ The decline in volume*:*

The volume in 4 models declined composting proved resolution process takes place substances strongly reduced target size shell material. Looking at the chart we can see the model Aspergillus largest volume decline, the remaining three models less volume decline. In the first 15 days of very strong volume decline: reduced model controls 20.52%, 27.85% reduction S.EM model, model Echoice fell 30.55%, Aspergillus model drop volume 31, 06%, then the volume continues to decline but from the 30th volume slowed. After 50 days incubation volume decline in the model as follows: 40.87% Aspergillus model, model S.EM 37.5%, 35.74% Enchoice models, model controls 32.2%.

- ✓ ***Organic compound***

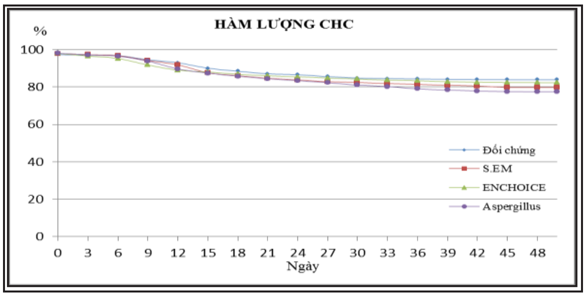


Figure 4: This chart shows the decline in organic matter content in the composting mass

- ✓ Organic matter content in 4 models are markedly decline demonstrates the process of organic matter decomposition occurs rapidly and evenly. Three models Control, S.EM, *Aspergillus* during the first 3 days of composting process of organic matter content decreased very slowly, and additional models Enchoice from the start composting organic matter content decreased rapidly. This suggests that additional enzymes to efficiently handle faster organic matter by microorganisms microorganisms need time to adapt to the environment. But after 50 days incubation model fungus Aspergillus additional speed decomposition strongest model Control content of organic matter decomposition at least. Demonstrated that the addition of Aspergillus for effective treatment of organic best.
- ✓ ***Carbon and Nitrogen Content:***

Based on the carbon content can be found in three additional models of probiotics in the early days faster reduction Control model , and then descending to the stable end annealing process . In the first 15 days : Control model (54.10 % to 50.07 %) , S.EM model (54.40 % to 48.72 %), Enchoice model (54.46 % to 48.95 %), *Aspergillus* (54.49 % to 48.61 %) , which indicates supplemented by microorganisms and enzymes into the incubation model and depending on the capabilities of each type of rapid decomposition of microorganisms and enzymes that function reduce the amount of C respectively .

Nitrogen content in the top model in 6 days by microorganisms decreased slowly during this period has started to adapt to the environment . From day 6 to day 18 when this microorganism has adapted to the environment should gradually decline than initially , Blank model (from 2.87 % to 2.41 %) , S.EM (2.87 % to 2.38 %) , Enchoice model (2.71 % to 2.26 %) , *Aspergillus* (2.87 % to 2.36 %) . Later models were reduced and stabilized in the remaining days : Blank model reduced to 2.06 % and then stabilize , S.EM decreased to 1.92 % , 1.86 % Enchoice , *Aspergillus* 1.84 % . 3 models have proved complementary preparations decreased faster than the Blank model, however *Aspergillus* faster reduction model model model S.EM Enchoice and this proved to be more active *Aspergillus* and speed decompose more quickly than nitrogen content decreases rapidly .

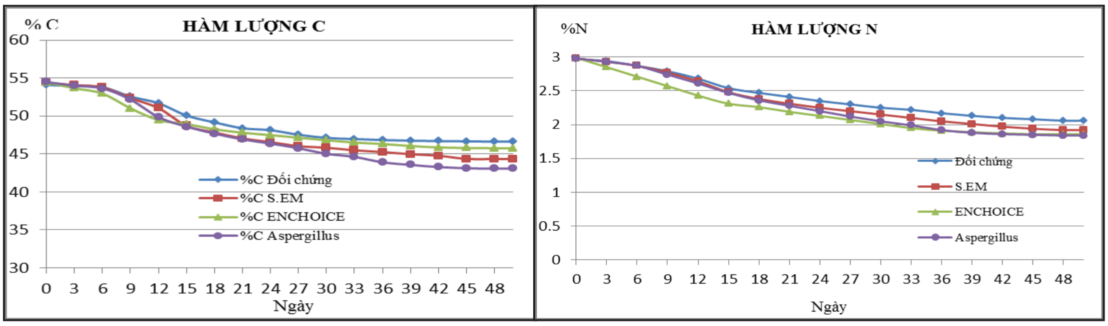


Figure 5: This chart shows the decline in C and N in the tumor Compost

3.1.2 Discussion

After 50 days incubation has finished compost is created with the results expressed in the following table:

Table 2 Research result

Treatment	VT1 Blank model	VT2 S.EM	VT3 Enchoice	VT4 *Aspergillus*
Operation parameter				
Time period (day)	50	50	50	50
Temperature (^{0}C)	30 - 49	30 - 50	30 - 45	30 - 52

pH	6,0 – 8,01	5,6 – 7,5	5,8 – 7,6	5,6 – 7,5
Input weight (kg)	14,8	14,8	14,8	14,8
Product				
Colour	Brown - black	Brown - black	Brown - black	Brown - black
Output weight (kg)	10,0	9,25	9,5	8,75

With the shell material consumption associated with the use of additional 1 strains of microorganisms and enzymes , composting process ended after 50 days .

In the first weeks , when the full complement of favorable conditions for the enzymes , bacteria , fungi , Micro-organism volume increased significantly for increased speed decomposition , the carbon content was converted into CO_2. Demonstrate after 50 days incubation volume was generated good quality compost products dark brown , soft , no odor , has good porosity . Given that the model has additional Aspergillus decomposition of organic matter faster and more stable than the control model .

On the other hand, compared to the industry standard 10 ISO 526-2002 for microbial organic fertilizer made from household waste by the Ministry of Agriculture and Rural Development issued , we obtain :

Parameter	Unit	Criteria	*Aspergillus*
Total Carbon	%	≥ 13	43,07
Total Nitrogen	%	≥ 2.5	1,84
Total Phosphorus	%	≥ 2.5	0,467
Total Potassium	%	≥ 1.5	0,095

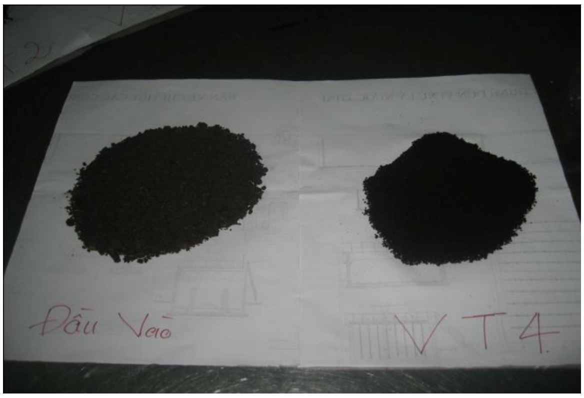


Figure 6: Compare products supplemented with Aspergillus shell initial target

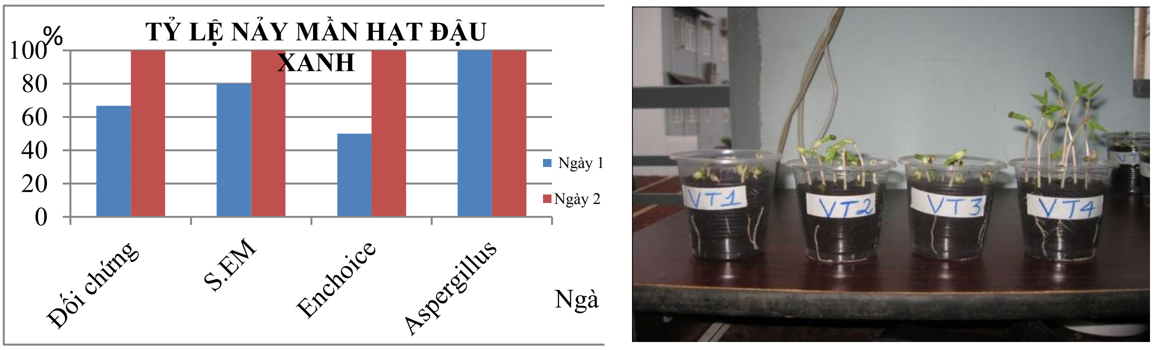
Due to non-standard products 10 TCVN 526-2002 for microbial organic fertilizer made from shells set by the Ministry of Agriculture and Rural Development issued should need additional fertilizer NPK mixture of superphosphate and chemical company Lam Thao quality , type ratio N : P : K = 6:20:10 (N content : 6 ± 0.3 % , effective P_2O_5 content : 20 ± 1 % , K_2O content : 10 ± 0.5 %).

So to be 100kg compost standards for nitrogen , need compost product mix 75kg and 25kg categories NPK ratio of N : P : K = 6:20:10 .

The amount is added to the rate of 25kg NPK (6:20:10) in the form of compost 100kg . What levels of N, P , K reached after additional N : P : K = 2.67 % : 4.37 % : 2.08 % .

So after mixing nutrients , compost products have reached the standard of nutrition standards 10 TCVN526 -2002 for micro- organic fertilizer made from cassava residue by the Ministry of Agriculture and Rural Development issued .

In Experiment 2: Application of compost products on short-term crops, Model *Aspergillus* germination was 100% on day 1, day 1 model S.EM 80% germination rate is 100% on day 2. Enchoice model after day 1 the lowest germination rate of 50% on day 2 is 100% controlled model 1 day germination rate is 66.67% on day 2 was 100%. Products form non-toxic compost for seed germination of mung bean germination grown 100% after 2 days.



a) b)

Figure 6: a) This chart shows the percentage germinating pea green, b) green beans planted after 2 days

4. CONCLUSION

After the 50 day study with input material consumption shell with 4 models to supplement S.EM, Enchoice, *Aspergillus* isolated from coconut fiber and 100 % control model for pepper shell results : pepper shell supplemented with *Aspergillus* best quality compost rate : N : P : K = 2.67 % : 4.37 % : 2.08 %. It is a very good organic fertilizer for plants , not harmful to plants With production of 130 mt of white on white / year and emit about 26 tons of shell environment if exhausted power consumption of waste criteria above may be produced 15.37 tonnes of organic fertilizer microorganism pepper crust served for agricultural production .

Manufacturing process simple, low- cost investment, less labor in the household applied has created products of organic micro- serve agricultural production, reducing fertilizer costs in the agricultural production to bring high economic returns for farmers, solve pollution problems production environments .

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Analysis of Waste-to-Energy Conversion Efficiencies based on Different Estimation Methods in Seoul Area

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ABSTRACT

Waste-to-Energy(WtE) plants may reduce the amount of waste disposed and recover the heat in the form of electricity or steam. It has been considered as one of most important energy sources in specific region. It has, however, limitations in terms of stable energy resources due to uneven waste properties, amount of waste generation and heat requirements by season. The purpose of this study was to analyze the energy production and actual utilization in resource recovery facilities and to secure the preliminary data for its efficient utilization. 4 WtE plants were investigated in Seoul metropolitan area. This study analyzed the heat recovery efficiency of each WtE plant using different estimation formula. As a result, that of facility A was 0.74 by Korea's energy efficiency method, which was the highest among the WtE plants and in facility D, energy loss was the highest due to a mismatch of pollution control facilities. It means energy recovery efficiency could be improved through optimization of treatment process. In summer, energy is being wasted by steam throwaway because heat demand is relatively low compared to other seasons. Thus, the alternative like district cooling needs to be considered to improve energy efficiency as well as other private businesses or district heating using additional steam.

Keywords: Waste-to-Energy, Energy Conversion, Energy Recovery Efficiency, MSW

INTRODUCTION

Various technologies are under development maximizing the usage of new and renewable energies by adopting the strategy making green industry and technology as new growth engines. The development of the renewable energy technology is becoming more urgent to replace the fossil fuel. Furthermore, incineration ratio has increased because of a ban on the dumping of waste at sea and shortage of landfill sites. Therefore the improvement of energy recovery efficiency in waste-to-energy plant may become an effective solution that makes possible the reduction of carbon emission and increase of renewable energy and stable waste treatment. The renewable energy plan in the Republic of Korea shows gradual increase of the renewable energy from 3% in 2010 to 6% in 2020 and finally 11% in 2035[1].

In this respect, Waste-to-Energy plants are becoming important energy sources in each local area because it can supply basic heat in the form of electricity or steam. The purpose of this study was to analyze the efficiency in energy production and actual utilization in resource recovery facilities and to search for possible way of improving energy utilization in W-t-E plants.

MATERIALS AND METHODS

Subjected Waste-to-Energy Plants

4 Waste-to-Energy plants in Seoul metropolitan area were studied to evaluate energy recovery efficiency. It was carried out in terms of MSW process, operation status and utilization of waste heat during 2011 ~ 2013.

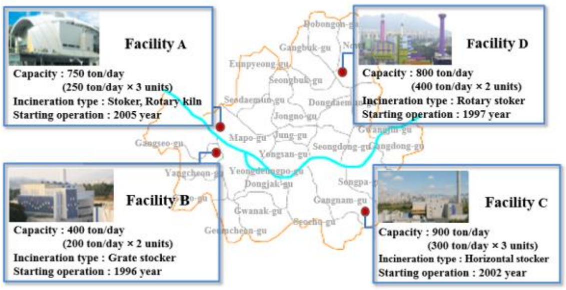

Figure 1. W-t-E plants investigated in Seoul Metropolitan Area

Energy Recovery Status at W-t-E Plants

Table 1 shows the utilization status of waste heat in each facility. In case of facility A and B, waste heat is not only supplied as energy source for heating purpose but also converted to electricity through power generators. Whereas, facility C and D are producing just steam. The highest ratio of outside energy supply appears at facility C with 95.5%. For other facilities except facility C, the energy supply to outside is relatively low about 73 ~ 76%. The facility C is considered to take an important role in district heating in southern area of Seoul.

Table 1. The utilization status of waste heat at each W-t-E plant (Unit:%)

WtE Plant		A	B	C	D
Steam	Inside	21.4	24.2	4.5	24.4
	Outside	13.6	70.8	95.5	75.6
Electricity	Inside	4.5	3.3	-	-
	Outside	2.5	1.7	-	-
Hot water	Inside	-	-	-	-
	Outside	58	-	-	-
Total		100	100	100	100

[Remark] Inside denotes energy utilization inside the plants, etc.

Formula for Energy Recovery Efficiency

Energy recovery efficiency was calculated using Korea's Energy Recovery Method(1)[2], R1(2)[3] and Heat Loss Equation(3)[4] based on related references.

$$\text{Recovery Efficiency} = \frac{Total\ Recovered\ Energy}{Total\ Input\ Energy}\times 100 \qquad (1)$$

$$R1 = \frac{Ep-(Ef+Ei)}{0.97\ \times(Ew+Ef)} \qquad (2)$$

where, **E_P** means annual energy produced as heat or electricity. It is calculated with energy in the form of electricity being multiplied by 2.6 and heat produced for commercial use multiplied by 1.1 (GJ/year)

E_f means annual energy input to the system from fuels contributing to the production of steam (GJ/year)

E_w means annual energy contained in the treated waste calculated using the net calorific value of the waste (GJ/year)

E_i means annual energy imported excluding E_w and E_f (GJ/year)

0.97 is a factor accounting for energy losses due to bottom ash and radiation

$$\text{Heat Loss} = \frac{Total\ \ Heat\ \ Loss}{Total\ \ Heat\ \ Input} \times 100 \qquad (3)$$

RESULTS AND DISCUSSION

The Comparison of Energy Recovery Efficiency

Energy recovery efficiencies were calculated for all WtE plants. According to Recovery Efficiency formula, the average of energy recovery efficiency in 2013 was 0.70 and it was 0.68 when calculated by Heat Loss method but R1 method showed the highest value as 0.81. In Fig. 2, heat loss method and heat recovery method show similar values, and R1 method show the highest value at all WtE plants. Because R1 was prepared by EU, it is considered difficult to reflect individual situation. In Energy Recovery method, all the energy output was considered without considering actual utilization. Thus, it needs to apply exact range of actual input data and realistic output data for realistic and accurate calculation. In facility D, energy loss increased due to a mismatch in pollution control devices. This facility has several add-on control devices without considering temperature drop-off. It means that process needs to be improved to acheive more effective energy recovery efficiency.

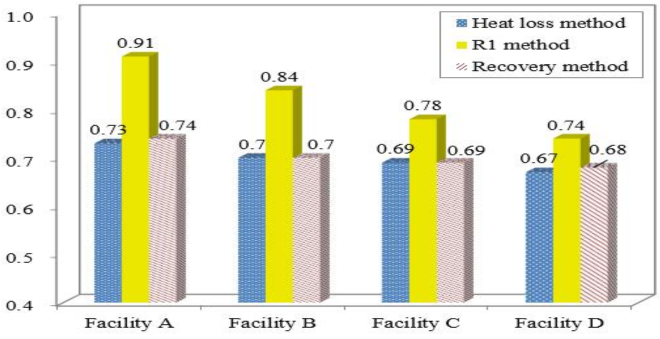

Figure 2. Energy Recovery Efficiency at Each W-t-E Plant (2013)

Seasonal Variation of Energy Utilization

The average energy recovery efficiency except summer ranged 71.2 ~ 76.1% while it was 63.4 ~ 68.9% in summer. The main reason is considered the release of staem to the atmosphere because of relatively low heat demand in summer season.

A and B facilities producing electricity showed relatively higher efficiency than D facility in summer. It means that energy as electricity form has efficient utilization, when seasonal factor is countered. C facility was not influenced by season because the energy produced was totally used at surrounding district facilities.

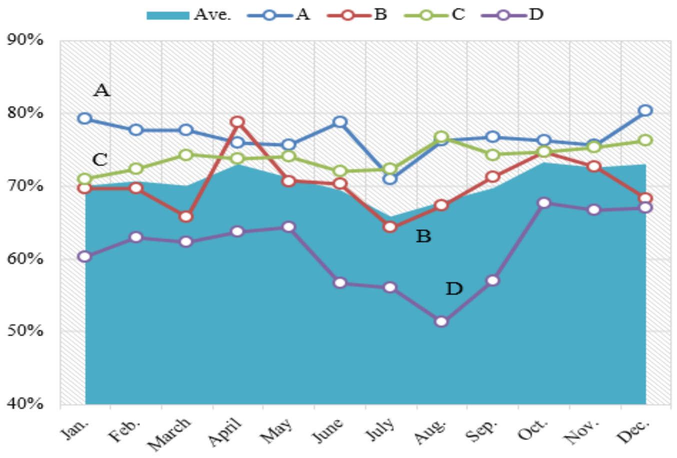

Figure 3. Seasonal Variation of Energy Utilization Efficiency at Each W-t-E Plants

CONCLUSION

Different energy recovery efficiency estimation methods have showed different efficiency results when applied to W-t-E plants in Seoul area. R1 formula is considered some limitation to apply to specific situation like high energy use for district heating.

In summer, energy utilization efficiency has been analyzed relatively low because heat demand is relatively small and steam is wasted. Thus, various approaches like district cooling needs to be considered to improve energy efficiency.

It should be also considered to develop new demands such as private energy utilization processes to increase overall energy utilization efficiency. In addition, it needs to install new infrastructure to show higher efficiency energy conversion from various wastes.

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Keynote lectures

Current Perspectives on 3Rs Related Activities on E-waste Management in Asia Pacific Region

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ABSTRACT

Rapid advances in technology and ready availability of newer designs at cheap prices have motivated customers to discard old electrical and electronic equipment (EEE) even before their useful life is over. This has resulted in mountains of used EEEs, referred to as electronic waste or e-waste, to be managed by the relevant authorities. Finding a sustainable, economically viable, technically feasible and socially acceptable strategy to deal with end-of-life (EOL) management of EEEs has been not easy due to their large quantities and toxic nature. A recent report published by the United Nations University estimated that globally 41.8 million metric tonnes of used EEEs were discarded during 2014 and this volume is expected to rise by 21% to 50 million tonnes by 2018. Recyclable materials in e-waste are a valuable resource which could be explored by efficient systems. The Asia-Pacific region contributes to the largest revenue share in the global e-waste management market. Emerging economies in Asia Pacific such as Korea, India, China, Japan, Vietnam and Taiwan are expected to be fastest growing markets for e-waste recycling. This paper identifies the roles of E-waste inventory, Extended Producer Responsibility (EPR), manufacturers, and Public Private Partnerships (PPPs) as key enabling factors in transforming e-waste sector into an economic industry. Research & Development (R&D) and technology transfer are also identified as key drivers for harnessing economic potential for e-waste sector.

Keywords: e-waste, resource recovery, extended producer responsibility, public private partnerships, research and development

GENERATION OF E-WASTE

The generation of reliable data on the exact amount of e-waste generated in different regions of the world is difficult to achieve as the amount of used EEE reaching its end-of-life cannot be measured directly with some reliability. The Global E-waste Monitor 2014, published by the United Nations University (UNU, 2014) estimates that the global quantity of e-waste generation in 2014 was around 41.8 million tonnes (Mt). This amount is estimated to reach 50 Mt by 2018, with an annual growth rate of 4 to 5 per cent. The study also found that the Asian region produced the highest amount of e-waste (16 Mt or 38% of total), followed by Americas (11.7 Mt) and Europe (11.6 Mt). The top three Asia-Pacific countries with the highest e-waste generation in absolute quantities are China (6 Mt), Japan (2.2Mt) and India (1.7Mt).

ISSUES AND CHALLENGES OF ENVIRONMENTALLY SOUND MANAGEMENT OF E-WASTE

The issue of environmentally sound management (ESM) of e-waste is a global problem arising from transboundary movement among all countries and regions, and thus requires global solutions. Large amounts of e-waste are currently being exported to developing countries for the purpose of reuse, refurbishment, recycling and recovery of precious materials. Many recycling and recovery facilities in these countries operate in an environmentally unsound manner causing significant environmental and health impacts. Significant amounts of e-waste containing hazardous materials can be seen dumped in open-land and waterways. The major environmental and health impacts occur during open burning of e-waste to recover precious metals. In spite of these significant environmental and health impacts, recycling and recovery operations have generated a huge informal employment sector in these countries. In addition to receiving e-waste from developed countries, developing countries are also emerging as significant generators of e-waste themselves. One of the main problems faced by developing countries is the lack of funds and investment to finance formal recycling infrastructures, and the absence of appropriate legislation to deal with the issue. Extended producer responsibility (EPR) is seen globally as one of the most effective ways of dealing with the e-waste issue. However, unlike in the developed world, implementing EPR in developing countries is a major challenge for policy makers. The competition between the formal and informal recycling sectors to gain access to e-waste is also a major problem.

SIGNIFICANCE OF RESOURCE RECOVERY AND RECYCLING OF E-WASTE

Although e-waste is usually regarded as a problem, it is easy to overlook the opportunities associated with e-waste, especially at a time where resource use and depletion is also a global issues. Strictly speaking, it can be argued that the problem with e-waste is not due to the materials that are contained in them but due to the inappropriate ways that they are dealt with at the end-of-life. EEE manufacturing consumes many precious metals and therefore an important resource for the world’s demand for metals. Mining of used EEE to recover the metals contained in them needs only a fraction of energy required to mine them from natural ores. E-waste contains many valuable materials such as iron, copper, aluminium and plastics and also many precious metals such as gold, silver, platinum and palladium. Global Waste Monitor 2014 (UNU, 2014) reports that the gold content of total e-waste generated in 2014 is roughly 300 tonnes, which represents 11% of the global gold production from mines in 2013.

Although the resource value of materials such as metals in EEE are well known and availability of technologies to recover these materials are increasing becoming available, only a fraction of e-waste is currently recycled in even in developed countries. There are number of reasons why this is the case. Firstly, end-of-life EEE does not reach the recycling process as part of the EEE is stored at home. Secondly, of the collected e-waste, a part is sent directly to recycling for environmentally sound recovery of materials while the rest is reused and then recycled or exported for reuse in developing countries where environmentally sound recycling facilities rarely exist. Even in environmentally sound recycling facilities materials can be lost in the process as it is not possible recover 100% of the materials. However, rudimentary recycling processes employed in developing and transition economies achieve far less recovery yields especially with valuable metals. Whereas an advanced integrated smelter could recover over 95% of the gold, recycling practices in developing countries could achieve only around 25%.

ROLE OF PRIVATE SECTOR/MANUFACTURERS AND PUBLIC PRIVATE PARTNERSHIPS

The private sector (EEE manufacturers) and public sector (national and local governments) must work closely in order to meet the overall objectives of e-waste management. Governments require the assistance from the private sector to develop proper infrastructure to turn the growing e-waste problem into an opportunity. Environmental sound and economically efficient resource recovery and recycling of e-waste cannot be achieved by public sector (national of local governments) alone. In this regard it is very useful to explore the strengths that private sector can bring in to assist the public sector. Local governments need to explore opportunities to create shared value, where businesses and the community benefit from a product or service provided by the private sector. Private sector firms can derive economic benefits by reducing risk, enhancing productivity and expanding markets, while making a substantive contribution to improved and equitable service delivery by municipalities. Such arrangements are generally referred to as public private partnerships (PPPs). PPPs have proven to be remarkably successful in both accelerating progress in service delivery and areas such as environmental management, including business and value-chain programming. E-waste resource recovery and recycling industry is not an exception.

ROLE OF EXTENDED PRODUCER RESPONSIBILITY (EPR)

Extended Producer Responsibility (EPR) is regarded an environmental policy approach in which a producer’s responsibility for a product is extended to the post-consumer stage of a product’s life cycle. EPR typically involves a shift in administrative, physical and financial responsibility from governments or local authorities to producers. EPR also encourage producers to take environmental considerations into account during the design and manufacture phases of product development thereby seeking to achieve a reduction in the environmental impact of products, throughout their lifespan, from production through end-of-life. The key objective of EPR is to support improvements in the environmental efficiency of products throughout their life cycle. The following are regarded as possible achievements of EPR:

ROLE OF R&D

The traditional manufacturing process in the electronics industry has been linear in nature and adheres to the standard “profit” focused approach which can be regarded as “take-make and waste”. Currently, many EEE manufacturing companies are attempting to move away from this approach. Products are “the carriers of material’s flow, energy usage, functional performance and environmental impacts”. The challenge is to ensure that an integrated circular “whole systems design” encouraging a borrow-use-return approach to be taken and the linear method abandoned. This process incorporates design for environment (DfE).

THE WAY FORWARD

As a way forward, the policy makers in Asia Pacific countries may find following activities useful in their attempt to achieve sustainable e-waste management, in particular, to create enabling conditions for enhancing the business and economic potential of resource recovery and recycling from e-waste:

- Well defined national e-waste management strategy based upon 3R concepts. Such strategy should not only address the environmental and health impacts of e-waste (end-of-pipe) but also look at the reduction of e-waste through green design (up-the-pipe). It should also create enabling conditions for relevant stakeholders to develop business and economic opportunities to recover the materials from e-waste. The strategy should take into account the financial, institutional, political and social aspects of e-waste management, in particular, incorporating the activities of informal e-waste recycling sector

- Well defined regulatory procedure adequate enough to control illegal exports of e-waste and to ensure their environmentally sound management.
- Improve country's ability to gather data and inventory on e-waste generation including their transboundary movement and to access appropriate and cost effective technologies to manage e-waste within their own borders. Such inventory should clearly identify the key players in the e-waste recycling value chain
- Establishment of proper intuitional infrastructures for collection, storage, transportation, recovery, treatment and disposal of e-waste at regional and national levels.
- Development of scientific resources such as experts and laboratories to conduct environmental and human health impacts of e-waste
- Improving the working conditions and minimisation of work related toxic exposure at e-waste collection, processing, recovery and disposal facilities.
- Awareness raising programmes and activities on issues related to health and safety aspects of e-waste in order to encourage better management practices.
- Develop public-private-community partnerships to encourage the establishment of formal e-waste recycling and disposal enterprises.
- Address the obstacles related to implementing EPR and mandating producers, importers, retailers with cost of collecting, recycling and disposal of e-waste.
- Require the countries that export used EEE to developing countries to formally test the equipment prior to export.
- Prohibit import of e-waste if the receiving country does not possess adequate capacity to manage these wastes in an environmentally sound manner.
- Identification of organisations or institutions with potential to develop innovation hubs and centres for excellence for developing and promoting environmental sound e-waste recycling technologies. These centres of excellence should conduct R&D on innovative technologies and should be able to assess the applications of relevance of technology transfer.
- Develop standards for collection, storage, transport, recovery, treatment and disposal to ensure environmentally sound management of e-waste

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Special sessions

Supplementing energy demand in rural areas in Vietnam by use of rice straw biomass as energy source

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ABSTRACT

The use of rice straw as energy source has been playing an inferior role over the last decades, though the global rice and rice straw production has risen steadily. In 2013 the global harvest of rice accounted more than 738 million tons (FAOstat, 2016). Typical grain to straw ratios vary between 0.7 and 1.5 (Bakker et al, 2013), thus the current annual global rice straw harvest can be assessed in the range of 520 to 1,100 million tons, whereas a major part remains energetically unused and is combusted close to the harvested area.

A joint Vietnamese-German research project will develop and integrate an innovative process technology for biogas production from rice straw in the regional value chains in a village in the province of Tiền Giang under consideration of sustainable development and climate protection. The research project, carried out by four Vietnamese and German partners, will develop and operate a biogas pilot plant in a village in the Mekong Delta using rice straw as main substrate. Over the project run-time of three years the potential rice straw masses and qualities will be investigated as well as the emissions from the paddies during rice growth and after harvest and the effects of the application of the digestate for fertilizing purposes on the emission characteristics. Capacity building and the development of a climate project will support the acceptance and implementation of the up-scaled plants after the project run-time.

Keywords: Biogas, Mekong Delta, Rice straw, Climate change

INTRODUCTION

In Vietnam the traditional use of rice straw as construction material or cattle feeding has largely decreased and thus most of the rice straw is either combusted close to the harvested areas, emitting-high amounts of GHGs particulate matter or remains in the paddies, where it is mainly converted to carbon dioxide and methane. Since 1991, the production of paddy rice has been doubled and depending on the rice species the amount of rice straw amounts to 58 million tons/year, which would equivalent to 15 million tons methane if it would be fully processed to biogas. The electric energy in Vietnam is mainly provided by hydropower and fossil fuels. However, it is intended to extend the market of renewable energies, especially because the energy demand is rising by 10-12% per year (GSO, 2016), and the production of biogas from rice straw as energy source will be inevitable and it shall contribute especially as energy source in the rural areas.

Nevertheless, the engineering of biogas processing from rice straw as well as the implementation of biogas plants in rural structures comprise the need of research concerning material mass flows, energy potentials and technological adaptation (Kadam et al. 2000).

In accordance with the National masterplan for power development the production of biogas will increase over the next two decades by 500 MW until 2020 and another 200 MW until 2030 (Government of Vietnam, Decision 1208/QD-TTg). By today, the energy use of rice straw remains difficult in practice because of the challenges of the decomposition of lignin and the high concentrations of silicates and none of the previous approaches led to the development of a marketable biogas plant. The objective of the joint project BioRist is to develop a method for biogas processing from rice straw and to implement it in a rural community in the Mekong Delta.

METHODS

Subjected site of research

The village of Hậu Mỹ Bắc B is located in the province of Tiền Giang in the Mekong Delta, about 70 km in the Southwest of Ho Chi Minh City. The main gross income of the province relates on the rice production. According to the General statistics office of Vietnam (GSO, 2016), over 90% of the total agricultural area of Tiền Giang is managed as paddies. Several cooperatives in the province take part in the global program of Good Agricultural Practices (GAP). This program includes the training and implementation of modern methods and technologies in order to increase the quality and competiveness of the local rice products.

Development and operation of a biogas pilot plant

The hub of the research project is a biogas pilot plant which will accomplish the production of biogas from rice straw. The process is being developed and tested in Germany and will be implemented in the study area in December 2016. The process consists of a mesophilic continuously stirred tank reactor (CSTR) and of a second reactor, which will increase the degradation by addition of reagents. The input of energy (electrical/thermical) will be insignificant higher than in usual biogas processes. The run time of the pilot plant will last two years, in which the operation conditions (e.g. retention time, co-fermentation, pre-treatment of the substrates) will be adapted and optimized in order to obtain the maximum yield of biogas, which ranges between 210-320 m^3 CH4/t ODM).

Potential and mass flow analysis

The agricultural areas of the commune and their current use will be studied by a detailed survey of the land use patterns. The data will be completed by the amounts and characteristics of the seasonal varying crops, as well as the potential land use changes, which will be possibly induced by the Vietnamese administration or by climate change impacts. Further, the quantities of current material use of rice straw such as the production of mats, hats or the use as substrate for mushroom production will be analyzed. Hence, it will possible to estimate the availability of the rice straw in the area.

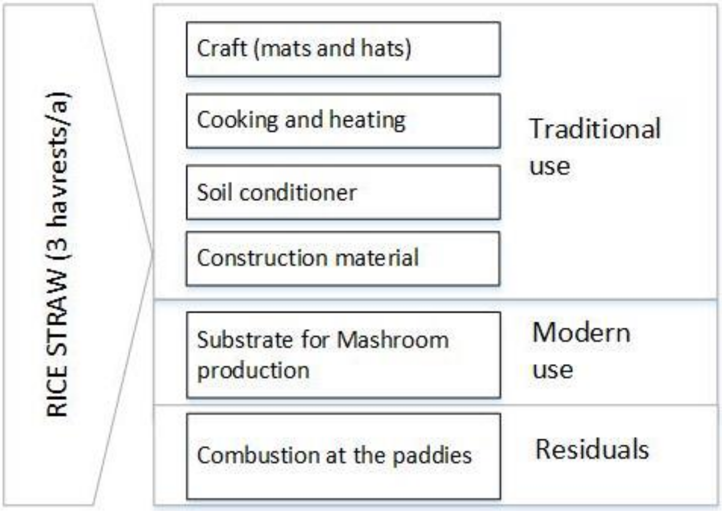

Figure 1 current rice straw uses and purposes

A structured household survey and a waste stream analyze will lead to reliable data on quality and quantity of available bio wastes from kitchen, gardening and animal breeding, which could be co-fermented in the biogas plant. These data will feed a database, which will be the base of a material flow analysis.

Emissions

The quantification of the benefits of the biogas plant towards climate change is part of this project. Therefore, the first step is the quantification of methane emissions from the current rice straw management by the usage of flux chamber or open path measurement methods. The second step is the evaluation of the treatment (composting) of the fermentation residues in terms of their emission potentials. The determination of methane and nitrous oxide fluxes from storage and processing of these residues plays a major role in this connection. The third and last step will focus on the application of the processed fermentation residues on arable soils. Main part will be a GHG balance considering emissions from managed soil and possible emission reductions from the substitution of mineral fertilizer due to compost from fermentation residues.

Capacity building

One of the major challenges for the implementation and operation of innovative technologies in rural Vietnam is to obtain acceptance and support of the villagers. Furthermore the sustainable operation of requires trained technicians and engineers, which is considered as a problematic issue in Vietnam. To cope with this situation, it is planned, to cooperate closely with the villages leaders and to carry out regular information assemblies and training courses in the village and to involve and train the future technicians from the beginning. The close contact to the Vietnamese cooperation partner Lotus Environment Technologies enables the local production of the marketable plant after the project runtime.

Climate protection project

In parallel with the technology development, project implementation and operation, the research on the climate change mitigation and the study of carbon business model and NAMA's (Nationally Appropriate

Mitigation Actions) will be embedded into the entire project cycle. Considering the special and innovative technologies applied in BioRist project, it is suggested to propose a new CDM methodology or to revise the existing CDM methodology in order to estimate the GHG emission reduction by BioRist project in an academic and tailor-made manner. Vietnam is developing three NAMAs in the sector of energy supply, waste management and the energy efficiency of cement industry. An exploration of the NAMAs possibility of BioRist Project and the way scaling-up and replicating BioRist project in Vietnam, even Southeast Asia is proposed.

ACKNOWLEDGEMENT

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Effect of Seasonal Variations of Organic Loading Rate and Acid Phase on Methane Yield of Food Waste Leachate in South Korea

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ABSTRACT

This paper described that methane yield is affected by the seasonal variation of organic loading rate (OLR) and acid phase parameters in the bio-gasification facility treating food waste leachate (FWL) in Korea. The operating bio-gasification facility in G city was selected as a target for this study. Seasonal fluctuation of methane yield was remarkably showed repeatedly in this facility. Especially methane yield in summer showed a significantly lower value comparing with the other seasons. In order to check the operation efficiency, Precision investigation (methane yield, OLR, etc) was conducted from March 2014 to April 2015. The characteristics parameters and operating factors of the two-stage anaerobic digestion were analyzed and derived including volatile fatty acids (VFAs), CODcr, Nutrients, TN, etc. Comparing the analysis data, OLR and VFAs tended to increase rapidly up to 4.96 kgVS/m^3·day and 9,263 mg/L respectively in summer. In contrast, Methane yield in same season was 0.55 m^3CH_4/kgVS which lower than 0.70 m^3CH_4/kgVS, the average value of the other seasons. Also methane content was decreased from 69.0 % to 57.9 %. The results presented that methane yield were influenced by the operating conditions in accordance with the organic loading fluctuations. In other words, It appeared to be the results of a large input amount of food waste leachate and unstable loading state in anaerobic digester.

Keywords: methane yield, organic loading rate, anaerobic digestion, two-stage digestion, food waste leachate

INTRODUCTION

According to prohibition for direct landfill ('05) and ocean dumping ('13) of organic waste (including food waste), the treatment of organic waste is getting urgent and serious (Korea Ministry of Environment, 2012). The government is planned to construct new bio-gasification facility which can transfer food waste to renewable energy (Korea Ministry of Environment, 2007). However, most of the operating bio-gasification facilities don’t meet the current criteria including methane yield, etc. The reason is that deterioration in operation efficiency is seasonal variation of input organic loading and immaturity of field operation (Peter W., 2010). Methane yield, one of the key monitoring parameters in anaerobic digestion, can be mainly affected by the unstable control of anaerobic digestion. The influence of operation factors such as OLR, status of acid phase, etc is reviewed in this paper for looking at the correlation between them.

MATERIALS AND METHODS

Selection of facility and sampling

A bio-gasification facility in G city where food waste leachate has been treated by the two-stage anaerobic digestion selected for the investigation. The details of this facility are shown in Table 1. Sampling was conducted during all of seasons excepting winter. Samples were collected from the inlet and outlet of the anaerobic digester and stored in refrigerated condition before they were analyzed.

Table 1 Outline of target bio-gasification facility in this study

	Treatment material	Digestion method	Volume of digester	Design capacity	HRT
G bio-gasification facility	FWL	Wet type, high temperature, two-stages	4,830 m^3	200 ton/day	24.1 day

Analytical methods

CODcr was analyzed by closed reflux, titration method (5220C) (APHA, 1998). Nutrients (carbohydrate, protein, fat) were determined by Korean Food Standard Codex (Ministry of Food and Drug Safety, 2015). Total nitrogen (TN) and ammonium nitrogen (NH_3-N) were analyzed according to oxidation method and UV/visible spectrometry of Official Testing Method with respect to water pollution process (Korea Ministry of Environment, 2015, ES 04363.1a, ES 04355.1b). Total phosphorus (TP) and phosphorus-P (PO_4-P) were analyzed according to UV/visible spectrometry and ascorbic acid method of Official Testing Method with respect to water pollution process (Korea Ministry of Environment, 2015, ES 04362.1b, ES 04360.2b). n-Hexane extractable material was determined by Official Testing Method with respect to water pollution process (Korea Ministry of Environment, 2015, ES 04302.1). Volatile fatty acids (VFAs) were determined according to Standard method 5560 D. gas chromatographic method 4.a. (APHA, 1998). Pre-treatment solutions extracted with diethyl ether was analyzed by gas chromatography (GC-FID, Aglient 6890, USA). Gas chromatography used FID detector and DB-FFAP (25 m × 0.32 mm × 0.5 µm) column.

Precision investigation in anaerobic digestion

Operating data including gas production (m^3), Volatile solids (VS, %), methane contents (%) in biogas, etc were collected in precision investigation from March 2014 to April 2015. Each parameter was elicited by calculating the monthly average value. Methane yield (m^3CH_4/kgVS) was calculated with daily operation data such as gas production (m^3/day), CH_4 content (%), treatment amount of FWL in facility and VS_{in} concentration (%).

RESULTS AND DISCUSSION

Characteristics of acid phase in bio-gasification facility

Table 2 and Table 3 show the seasonal characteristics of acid phase in target bio-gasification facility. The results of summer in Table 2 showed that Carbohydrate, easily biodegradable nutrient was highest in summer.

n-Hexane which can cause the scum problem in anaerobic digester was 9,680 mg/L in acid phase. Total VFAs in acid phase were 6,244 mg/L (spring), 9,263 mg/L (summer) and 6,120 mg/L.

Table 2 Seasonal characteristics of acid phase

	Nutrients (g/100g)			CODcr	TN	NH_3-N	TP	PO_4-P	n-Hex
	Fats	Proteins	Carbohydrates	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Spring	4.29	2.46	3.62	-	4,493	1,313	-	-	5,080
Summer	2.41	2.35	4.78	159,680	4,260	559	710	88.5	9,680
Autumn	1.03	1.52	4.49	85,170	4,752	280	528	136	8,180
Average	2.58	2.11	4.30	112,425	4,502	717	619	112.3	7,647

Table 3 Seasonal characteristic of VFAs in acid phase

	Volatile fatty acids (mg/L)									
	Acetic acid	Propionic acid	Isobutyric acid	Butyric acid	Isovaleric acid	Valeric acid	Isocaproic acid	Hexanoic acid	Heptanoic acid	Total
Spring	6,146	49	N/D	48	N/D	N/D	N/D	-	N/D	6,244
Summer	2,691	4,041	958	120	1,192	165	40	47	11	9,263
Autumn	1,472	3,231	702	86	453	105	37	33	N/D	6,120
Average	3,436	2,440	553	85	548	90	26	40	4	7,209

Operation status of methane phase in bio-gasification facility

Figure 1 showed the VFAs variation in methane phase during the investigation period. In general, VFAs was affected the inhibitory effect to methanogen about above 3,000 mg/L of total VFAs concentration that is the guideline by the local government of Bayem (Stockl and Oechsner, 1993, Gronauer and Effenberger, 2007). Since the beginning of June 2014 that summer begins in South Korea, VFAs concentration was increased gradually up to maximum 6,427 mg/L. Figure 2 presented biogas production in target facility. All of methane and biogas showed similar tendency with VFAs in acid phase.

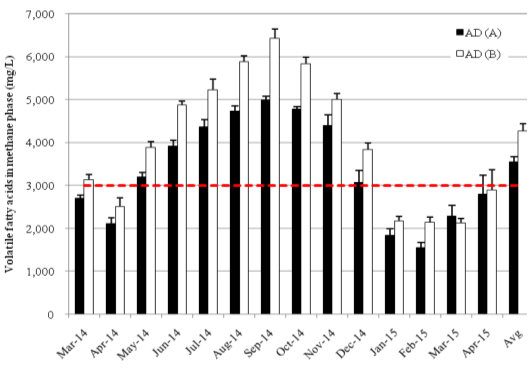

Figure 1. VFAs concentration in methane phase

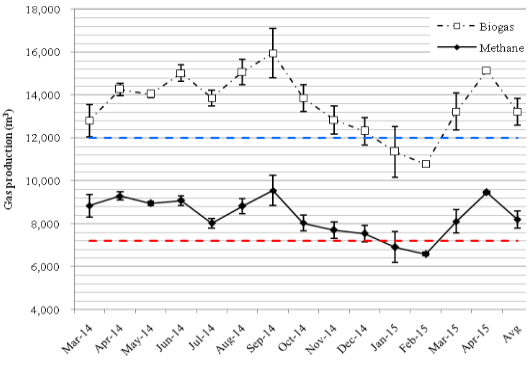

Figure 2. Biogas production in bio-gasification facility

Biogas contents were shown in Figure 3. Methane content was reduced gradually until 57.9 % in July 2014 and recovered in November. Figure 4 showed the correlation between methane yield and organic loading rate. Average methane yield and OLR were 0.67 $m^3CH_4/kgVS$, 2.76 $kgVS/m^3$·day, individually. On the whole, OLR and methane yield showed reverse inclination. Especially from June 2014 to August 2014, both of them seems a distinct collation. The maximum OLR was 4.96 $kgVS/m^3$·day and minimum methane yield 0.49 $m^3CH_4/kgVS$ in July 2014.

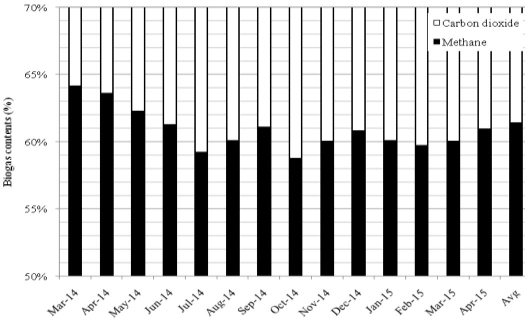

Figure 3. Biogas contents (%)

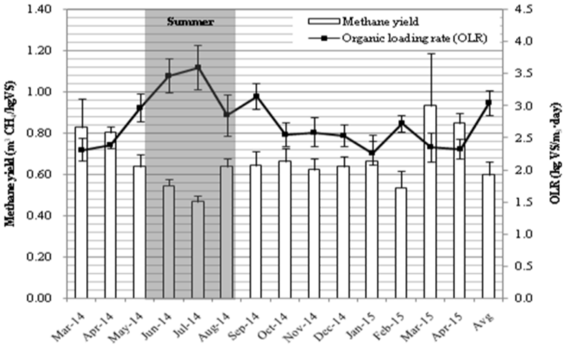

Figure 4. Methane yield and OLR in anaerobic digestion

CONCLUSION

This study aimed to confirm the relevance between methane yield and operation factor of bio-gasification facility. In the comparison of those parameters, methane yield showed the tendency of diverse relation with seasonal variation of organic loading in methane digester. Also VFAs concentration of acid phase had an effect on methane yield in summer season. It seems that those like two-stage anaerobic digester should be needed delicate management and coping skill on abrupt organic load change by season.

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Biomass Utilization and Bioenergy Recovery in India: Supply Chain Perspective

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ABSTRACT

Biomass as a renewable energy source is identified as one of the potential solution as substitute of fossil fuels, taking advantage of modern biomass conversion technologies for production of heat & electricity, liquid & gaseous transportation fuel, biogas etc. In India, 611 million ton/year of agricultural field residues are generated, of which 158 million tons (25%) can be considered surplus based on the current utilization patterns and are thus potentially available for a biomass-based industry. The major barrier preventing the commercialization of biomass to energy sector in India, is the complex conversion process and their respective supply chain. This paper offers a brief idea about the current scenario of biomass availability, its utilization and addresses the problems related to its supply chain and identifies their possible solutions.

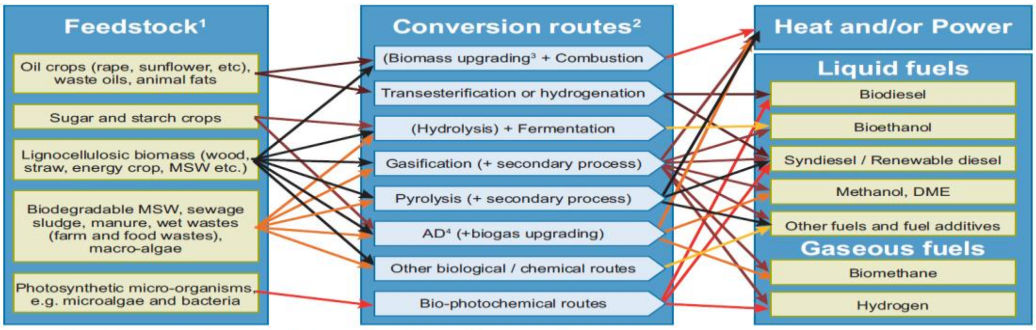
Keywords: Renewable energy, biomass, supply chain, key issues, measures.

INTRODUCTION

Energy crisis, pollution, increasing greenhouse gas emission, global warming and subsequent climatic changes are the major environmental issues. Since fossil fuel consumption is mainly implicated for increasing CO_2 emission and associated global climatic changes, the sustainable exploitation of clean and renewable energy resources comes in forefront and should be considered as an appropriate solution to address these issues globally (Edrisi S. A. & Abhilash P. C., 2016). Nowadays, biomass is considered as one of the main sources of energy for both developed and developing countries. Presently, the total potential for renewable power generation in India is estimated at 147615 MW, this includes 17,538 MW (11.88%) from biomass and 5000 MW (3.39%) from bagasse-based cogeneration in sugar mills (Energy statistics, 2015). The biomass power industries are facing challenges for the stable operation in the entire supply chain that severely impact its growth. One metric ton of lignocellulosic biomass can produce 240-300 liters ethanol. This paper offers a brief idea about the current scenario of biomass availability and its utilization and also addresses the problems related to its supply chain and identifies suitable solutions of the issues.

PRESENT STATUS OF THE BIOMASS UTILIZATION IN INDIA

Biomasses such as fuel wood, animal dung, crop residue are widely used as a source of energy in developing countries. In India, 611 million ton/year of agricultural field residues are generated, of which 158 million tons (25%) can be considered surplus based on the current utilization patterns and are thus potentially available for a biomass-based industry. The most important surplus residues are sugarcane bagasse (41 million ton/year), paddy straw (28 million ton/year), wheat straw (21 million ton/year) and cotton stalks (19 million ton/year). Banana residues may also be important (Cardoen D., Joshi P. et al., 2015). The used pattern of crop residues for fulfilling domestic energy needs is not uniform amongst the regions in India. It has been observed in recent years that the production of electricity, biogas and biofuels (ethanol and biodiesel) are the most attractive components among the energy produced from biomass and bio wastes. Figure 1 shows Brief description of the identified biomass and the conversion routes of biomass to biofuel products.



[1] Parts of each feedstock, e.g. crop residues, could also be used in other routes

[2] Each route also gives co-products

[3] Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)

[4] AD = Anaerobic Digestion

Figure 1. Conversion routes of biomass to bioenergy products (Ghosh., 2015)

Followings are the main bioenergy product in India and their production status.

Heat, electricity and CHP : Combination of heat and power (CHP) facilities are highly resource efficient and provide increased levels of energy services per unit of biomass consumed. A total of 288 biomass power and cogeneration projects (2665 MW capacity) have been installed in the country for feeding power to the grid consisting of 130 biomass power projects (999.0 MW) and 158 bagasse cogeneration projects in sugar mills with surplus capacity aggregating to 1666.0 MW. In addition, around 30 biomass power projects (350 MW) are under various stages of implementation. (Kumar A., Kumar N., 2015).

Bioethanol : Ethanol is mainly produced in India from sugarcane molasses its production in the year presently will be near to 2.2 billion liters. But the production is only sufficient for 1.5% blending with petrol in where the targeted blending is 5% according to the EBP. Ethanol produced from molasses generated in after October 2015 and supplied for ethanol blending would be exempted from excise duty. Many industries and R&D (Praj industry, chemtex, DBT-ICT) are taking initiatives to convert biomass to ethanol.

Biodiesel : The GOI had launched the National Biodiesel Mission (NBM) identifying jatropha as the most suitable inedible oilseed for biodiesel production. The Planning Commission of India had set an ambitious target of planting 11.2 to 13.4 million hectares to jatropha by the end of 11th Five Year Plan (2011/12). The central government and several state governments provide fiscal incentives for supporting planting of jatropha and other inedible oilseeds. Several public institutions, government departments, state biofuel boards, state agricultural universities and cooperative sectors are also supporting the biofuel mission in various capacities (GAIN, 2015).

Biogas : In 2014-15, about 20,700 lakh cubic meters of Biogas is produced in the country which is equivalent to 5% of the total LPG consumption in the country. The Government is also extending substantial subsidy for setting up of new Biogas plants. Within states, Maharashtra tops the production with 3578 lakh cubic meters while Andhra Pradesh comes next with 2165 lakh cubic meters. Under the twelfth five year plan (2012-2017), the government of India had set a target to set up 6.5 lakh biogas plants across the nation with a budget of Rs.650 crore under a program called, the National Biogas and Manure Management Program (NBMMP) (Singh R. and Setiawan AD, 2013).

BIOMASS SUPPLY CHAIN FOR BIOENERGY PRODUCTION

Supply chain is the movement of material between the source and the end-user. Waste biomass supply chains for energy production are comprised of (i) biomass harvesting/collection (from single or several locations) and pre-treatment, (ii) storage (in one or more intermediate locations) , (iii) transport (using a single or multiple echelons), (iv) energy product conversion and (v) supply to the consumer/grid network as depicted in figure 2. The performance of the supply chain depends on the degree of coordination and integration between the actors/entities, along with efficient flow of products and information (Sharma B., Ingalls, R. G. et al., 2013). The increased complexity of this system dictates the need for developing sophisticated customized supply chain planning and coordination methodologies as opposed to the well explored traditional supply chain management.

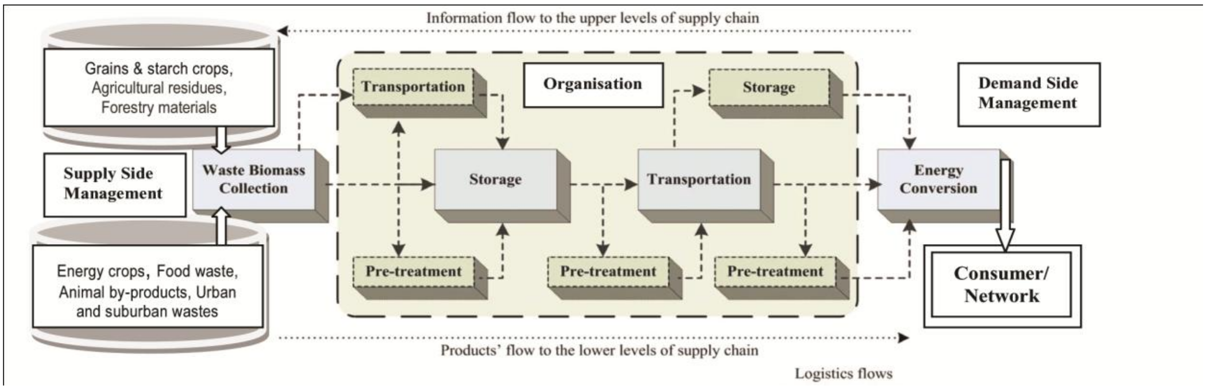


Figure 2. Graphical representation of different stages of waste biomass supply chain (Ghosh., 2015)

DISCUSSIONS AND CONCLUSION

Despite of the advantages the biomass energy generation industry is facing difficulties and undergoing losses due to the lack of coordination between different stages of the supply chain. Table 1 shows the major sustainability issues of the supply chain and the possible solutions of the problems.

Table 1. Key issues in the biomass supply chain and the possible measures

Challenges	Proposed Measures
Feedstock acquisition cost, high investment and capital cost, inefficient resource management and the government non-intervention approach hinders the expansion of biomass to energy sector	Government at all levels should reorganize biomass resources in all regions to promote their supervision and management and thoroughly investigate the current scenario before approving any biomass project.
Regional and seasonal availability of biomass cannot guarantee a continuous supply and results in the seasonal variation of the fuel price. Also the storage of low density biomass poses a major challenge.	Direct purchasing pattern where farmers and plant owners do the feedstock transaction directly can reduce the feedstock cost due to elimination of third party brokers. Multi feedstock utilization facility should be established.
Inefficiency of conversion facility and core technology and equipment shortage to be able to compete in the fuel market.	Proper research and development system should be constructed in order to grasp core technology and avoid import of equipment.
Pressure of transport section with increasing distance (high moisture content and low density)	Decentralized small plants can readily decrease the transportation cost.
Lack of producer participation and investor's	Community participation and public awareness through

initiative, limiting financing channel due to the high market risk related to biomass industry.	promotional campaigns can influence the decision of different agency about participation and investment.
Immature industry chain makes it virtually impossible to get long term contracts for consistent feedstock supply in reasonable price. Investors and the potential users have not been technically and commercially developed.	There should be a clear understanding between the different stakeholders associated with biomass project. Also in order to establish a stable mechanism for selling, the enterprises need more communication with downstream firms.
Land use issues specifically deforestation that leads to the loss of ecosystems.	Marginal land and unproductive agricultural land should be selected for energy crops plantation.
Risks Associated with Price and Market Demand Variability Driven by Government Policies.	Government should exempt the excise duty on different renewable fuel products.

The bioenergy sector comprises a complex set of technologies and a thorough knowledge and expertise on the equipment handling is important to build and maintain bioenergy plant. Government should pay attention in the technology innovation and provision of funds to R&D. Also the gap between research and implementation should be minimized by promoting collaboration between industry and academia. The barriers identified relating to different sectors must be discussed among different stakeholders and it should be ranked according to its priority to develop targeted policies. Providing economically, environmentally and socially sustainable bio-energy requires an optimization of the structure and functioning of the supply chain/network, adjusted to the specific conditions of the respective production system (climate and topology, feedstock, technologies, final application). A sustainable and robust supply chain leading to a business model is the only solution for effective results addressing the constraints of the stakeholder's rationally.

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Material Flow Analysis as a Base for Benchmarking in Waste Management

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ABSTRACT

Modern waste management systems have reached a high state of development. The paper proposes a new approach for making even further progress in view of reaching waste management goals at best cost effectiveness. The objective of the paper is to demonstrate the power of material flow analysis to improve waste management decisions. Based on a comprehensive case study of benchmarking Austrian waste management (AWM), advantages and challenges of a mass balance approach on the level of goods and substances are discussed. Using the software STAN, a quantitative material flow system comprising all relevant inputs, stocks and outputs of AWM is established. Data for waste input was taken from official statistics; substance concentration and transfer coefficients have been collected through a comprehensive literature research and stakeholder interviews. In addition, data uncertainties were assigned. Material balances on the level of goods and selected substances (C, Cd, Cr, Cu, Fe, Hg, N, Ni, P, Pb, and Zn) were developed to characterize AWM, and to serve as a base for benchmarking. The results reveal the benefits of a mass balance approach due to data consistency and transparency as a base for subsequent assessment methods and future decision making. Further, deficiencies of present evaluation systems for waste management are identified.

Keywords: *waste management, material flow analysis, assessment, benchmarking*

INTRODUCTION

The primary goals of waste management (WM) are based on the precautionary principle and on sustainability aiming at protection of human health and environment, conservation of resources, after care free waste treatment and landfilling without jeopardizing future generations. Countries have reached different levels of WM; especially many developed countries have reached high standards. For future development, the question arises, how to improve the current WM system regarding these goals. For an appropriate assessment, the generation of a transparent and profound knowledge base is essential.

In WM, material flow analysis (MFA) is often used to collect and manage information on investigated systems. MFA is based on the mass balance principle and ensures that all inputs are equal to the outputs ± stocks (Brunner and Rechberger, 2004). Inputs, stocks and outputs have to be balanced on both levels of goods (wastes, air, off-gas, products etc.) and substances (elements or chemical compounds). A review on MFA in the field of WM (Allesch and Brunner, 2015) reveals the high potential of MFA to support goal-oriented WM if both levels of goods and substances are taken into account.

The goal of this paper is to show the power of MFA to support WM decisions and to point out deficiencies of present evaluation systems for WM.

MATERIALS AND METHODS

Within the case study (Allesch, Brunner et al., 2016) a benchmarking framework was established based on the following five goals of the Austrian Waste Management (AWM) Act: (i) to protect humans and environment, (ii) to minimize air pollution and gases affecting the climate, (iii) to conserve resources, (iv) to ensure that materials recycled do not present a greater risk than comparable primary raw materials, and (v) to ensure that only such waste remains as can be stored without danger for future generations. During successive evaluation steps, these goals (n = 5) are substantiated, categorized, and subdivided by sub-goals (n = 9) and indicators (n = 77).

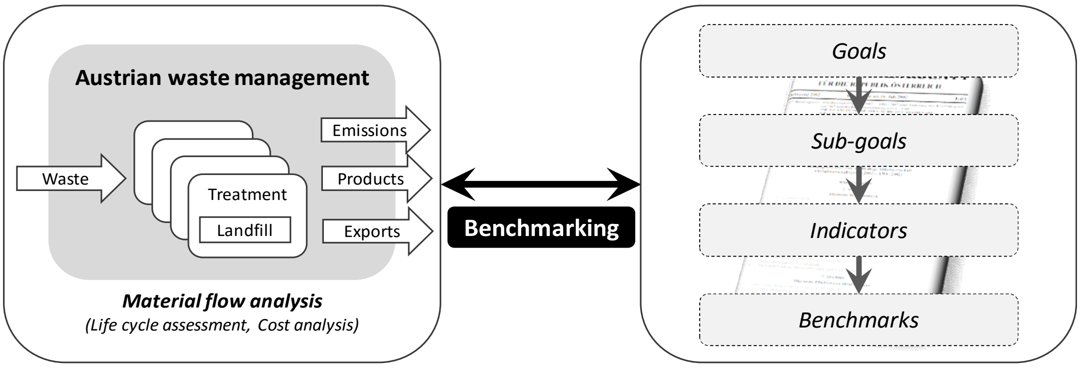

Figure 1 Benchmarking system for waste management

For each indicator, a benchmark was assigned to compare the status quo of AWM with given WM goals. The benchmarks serve as pivot to assess if goals are reached, and they point to directions how WM can be further developed. The benchmarks are individually defined; for example, WM emissions are compared with geogenic background concentrations. The ratio of the indicators over the respective benchmarks results in "level of target achievement" for every indicator and thus sub-goals, goals and the AWM system can be assessed.

The approach is based on a comprehensive MFA of AWM on the level of goods and selected indicator substances (C, Cd, Cr, Cu, Fe, Hg, N, Ni, P, Pb, and Zn). Austrian as well as imported waste, and precipitation on landfills serve as inputs into the MFA system. The outputs, calculated by transfer coefficients, are emissions to air, soil and water, secondary products, and exported waste. The transfer coefficients describe the partitioning of materials in a process (Brunner and Rechberger 2004). Landfills are defined as stocks within the WM system. Inputs, stocks and outputs of this system have to be balanced on both levels of goods and selected substances. The software STAN 2.5 (Cencic and Rechberger, 2008) is used to perform the MFA. Data was collected by a comprehensive and detailed investigation, including official statistics (e.g. BMLFUW 2014), stakeholder interviews, literature reviews, and data collected by various research projects. In total, over 100 processes of collection, recycling, treatment, and disposal, and about 300 mass flows of wastes, residues, secondary products, and emissions have been taken into account. Due to the diverse and diverging information sources, and the varying data quality, data uncertainty had to be taken into account (Laner, Feketitsch et al., 2015).

In addition to and based on MFA, life cycle assessment (LCA) was used for assessment if WM objectives are reached, and economic analysis was applied to analyze cost-effectiveness of the entire WM system. The economic analysis comprises both internal costs (of WM stakeholders, e.g. costs for collection and transportation) and external costs (not covered by WM stakeholders, e.g. CO_2-emissions).

RESULTS AND DISCUSSION

Figure 2 provides a summary of the MFA. In total about 17 million tons of waste were taken into account. After collection and transport, waste is treated, incinerated or landfilled. A significant share leaves the system as secondary resources for recycling or energy recovery. About 2 million tons, mainly ashes, slags, and mineral waste, are landfilled. The corresponding "emissions" to the environment (primarily purified off-gas and leachate from incineration, composting and landfilling) amount to 3 million tons.

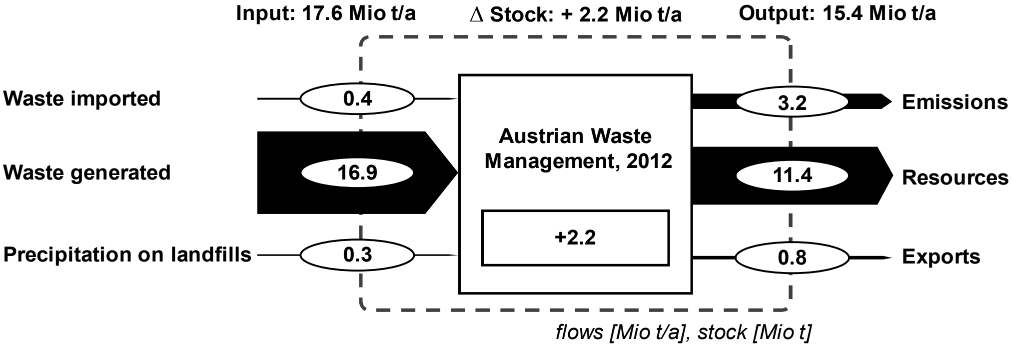

Figure 2 Overview of material flows and stocks within Austrian waste management

The balancing on the level of substances shows that about one third of carbon and half of nitrogen are emitted to the air through biotechnical and thermal treatment. Separately collected metal fractions like iron, copper, lead, nickel and zinc are mainly recycled. Residues from thermal processes which are landfilled contain relevant parts of cadmium, phosphorus, chrome, lead and zinc. About 50% of cadmium is recycled either in form of metals or plastics. Further, about 20% of mercury is recycled.

Based on MFA, WM costs are calculated for Austria (8.4 million inhabitants, 17 million tons of waste per year, GDP EUR 34,000 per capita and year). Internal costs for collection, transportation, treatment and landfilling amount to about EUR 2.7 billion (EUR 320 per capita and year). External costs are estimated at around EUR 0.5 billion (EUR 50 per capita and year). The calculated level of target achievement for each goal shows the high standard of Austrian waste management. The study revealed potential for optimization with regards to air pollution and greenhouse gases, as well as conservation of resources.

CONCLUSION

The combination of benchmarking and macroeconomic cost analysis allows evaluating to which degree and at what costs given WM goals are reached. This MFA based methodology points out deficiencies, identifies potentials for improvement regarding the fulfilment of objectives, and demonstrate possibilities to reduce costs and increase cost effectiveness. MFA allows a complete characterization of WM systems and hence represents a crucial fundament for such assessments. The results reveal the following benefits of a mass balance approach:

1. Since inputs, stocks and outputs are balanced, data consistency is guaranteed.
2. MFA allows a transparent way to inform researchers as well as external stakeholders; it is therefore particularly well-founded for goal oriented decisions.
3. A complete, unambiguous and consistent dataset is an excellent and necessary base for subsequent assessment methods such as LCA.
4. The results are reproducible and have known data uncertainties.
5. MFA is instrumental as an indispensable base for planning and operating WM systems and for developing effective strategies.

The project also disclosed present shortages of assessment methods, such as lack of tools to take into account risks to human health, to evaluate risks of recycling hazardous substances in product cycles and the environment, and to assess long term risks due to landfilling with time horizons > 100 years.

As a conclusion, the assessment shows the high standard of AWM but also points out deficiencies. The combination of MFA, economic analysis and benchmarking supports waste managers in optimizing their processes and systems, and serves as a strategic base for future decision-making by authorities and WM stakeholders.

ACKNOWLEDGEMENT

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Recycling and Current Management Practices and Material Flow Analysis (MFA) of Batteries in Korea

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ABSTRACT

Batteries are generally categorized into primary (non-chargeable) and secondary (chargeable) forms. The primary batteries include alkalis-manganese battery, mercury battery, lithium battery, and others, while the secondary batteries cover nickel cadmium (Ni-Cd) battery, Nickel-metal hydride (Ni-MH) battery, lithium ion battery, lithium polymer battery, lead storage battery, and others. Lithium-based secondary batteries widely used for manufacturing various types of portable devices (e.g. cell phones and laptops) are dismantled to recover valuable parts during recycling processes. On the contrary, primary batteries equipped in watches, toys, remote controllers and automatic locking doors frequently are replaced with shorter life-cycle. Ni-Cd batteries and Ni-MH batteries are commonly used as surrogate of alkalis-manganese batteries. Recycling of batteries is an issue of concern in waste management and pollutant control policy, due to various heavy metals and precious elements (e.g. Au, Ag and Li) in the batteries. In Korea, used batteries such as alkalis-Manganese battery, lithium battery, nickel-cadmium battery, silver oxide cell, nickel metal hydride battery have been managed with the extended producer responsibility (EPR) policy since 2003 (Manganese battery, Alkaline manganese cell, Nickel metal hydride battery have been included in 2008) to increase recycling of the waste from consumers and to simultaneously reduce of their negative effects on the environment. This study presents the recycling and management practices of used batteries, especially focusing on material flow, physical and financial responsibility of used batteries in Korea. The data required for this study was collected from the literature review, statistical data provided by the ministry of environment (MOE), discussion with the experts, survey and field visits to the local government office, MOE, recycling facilities.

Keywords: recycling, batteries, EPR, MFA

INTRODUCTION

In recent decades, remarkable development in field of electronic industry has arisen needs of light-weight, portable design. Occurrence of the electronic devices is strongly associated with development and enhancement of batteries. In recent years, recycling of batteries has become a critical issue in waste management and pollutant control policy. In EU, the collection and recycling of used batteries are ruled by waste electrical and electronic equipment (WEEE) Directive and are managed by adopting the EPR system. Korea also manages its used batteries using the EPR system. However, recycling rate was lower than the recycling target invoked by the MOE. There have been several studies on the management of used batteries and recycling technologies in recovering waste elements (NIER, 2012; Baek et al., 2012; Shin et al., 2013). In this study, the present management system of batteries is discussed with the analysis of the mass flow by life cycle stage of manganese-alkaline batteries in Korea.

MATERIALS AND METHODS

The data required for this study were collected from the literature review, statistics developed by the ministry of environment (MOE), discussion with the experts, survey and field visits to the local government office, MOE and battery recycling facilities.

RESULTS AND DISCUSSION

In Korea, the recycling of used batteries is managed by the EPR system. Figure 1 illustrates the role and responsibility of each stakeholder in the management of batteries by the EPR system. The physical, financial and end-of-life management system of used batteries is presented in Figure 1.

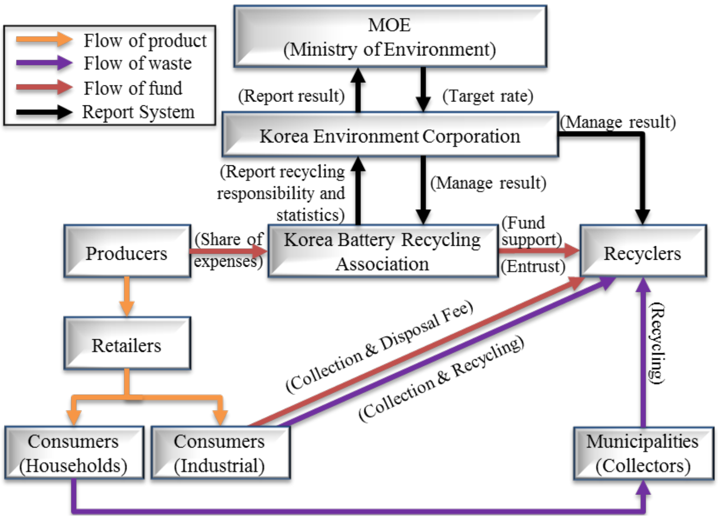

Figure1. Recycling system of used batteries in Korea by EPR (Reference: MOE, 2010)

As shown in Figure 2, the recycling target by the MOE was around 20~65% depending on the type of batteries. The recycling rate achieved for the year 2013 ranged from 4.6 to 58.1%.

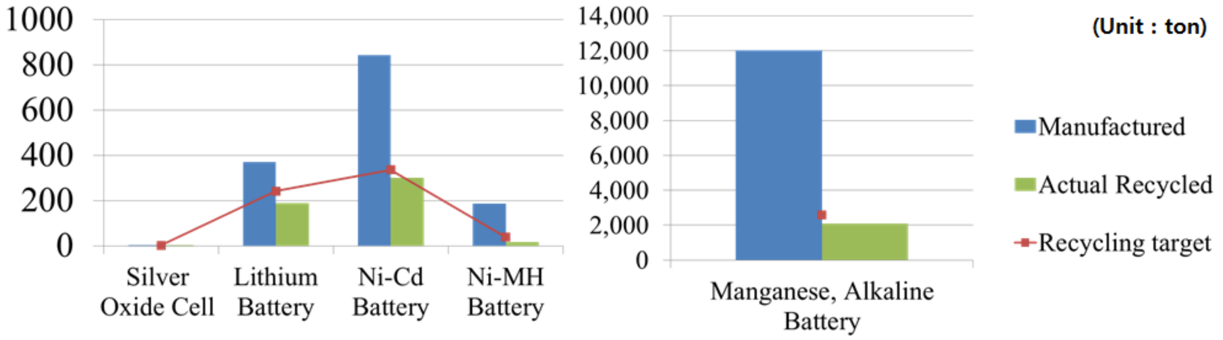

Figure2. Recycling rates of batteries in Korea by EPR (Reference: MOE, 2014)

As a result of material flow analysis of manganese-alkaline batteries in Korea (Figure3.), approximately 12,025 ton were put on the market in 2013. About 28% of domestic demands batteries were distributed to household sectors. Approximately 9,066 ton of the batteries are stored. Some of the batteries are collected by source separation for recycling. The large amount of batteries sold to industrial follows the unknown pathway. The accurate amount of incineration and landfilling is unknown so far.

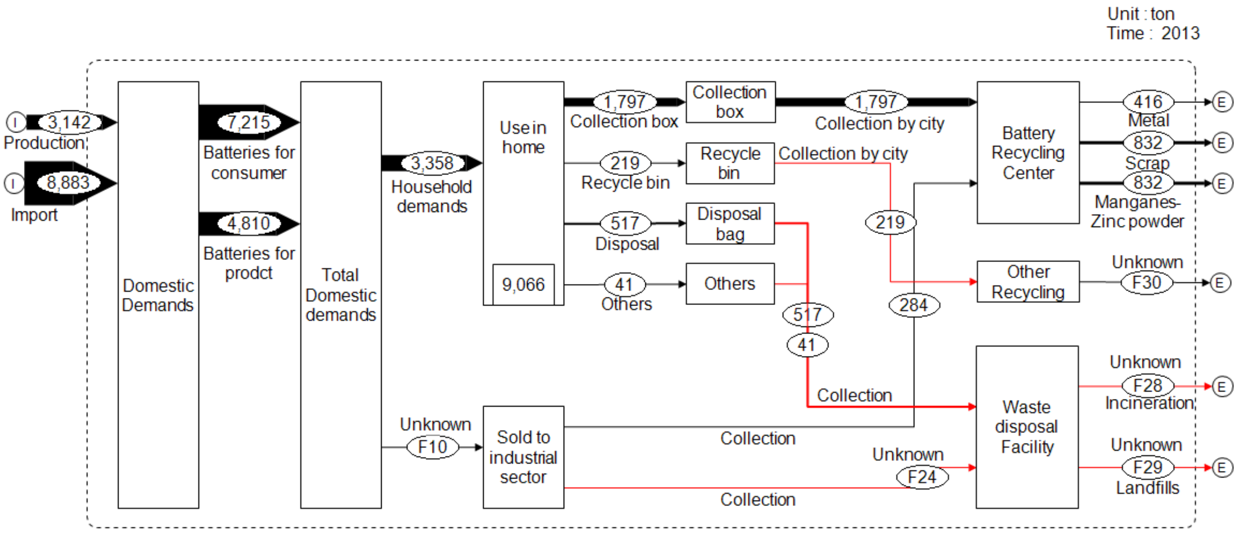

Figure3. Material flow of manganese-alkaline batteries in Korea by EPR (Reference: MOE, 2014)

CONCLUSION

Considering the present management status of batteries in Korea, the study proposes the need of stringent policy and awareness program for a better collection system. As a result of this research, it was analyzed that the recycling rate of used Manganese, alkaline batteries was less than 20%. In addition, it was difficult to identify the pathways of unrecycled batteries. Therefore, it is necessary to extensively determine the material flow of unknown pathways and establish the legislation for distributors such as take-back obligation. The study also suggests the need of a better recycling methodology with highly advanced technologies to recover various heavy metals (e.g. Hg, Cd) and precious elements (e.g. Au, Ag and Li). This study would further help decision makers to come up with an innovative policy for an effective management of used batteries in the future.

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Life Cycle Assessment of On-site Anaerobic Digestion System for Small-scale Food Waste Generation Sources

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ABSTRACT

Smaller businesses, which generate food waste of less than 100 tons/yr, and households are not covered by the Food Waste Recycling Law. To increase food waste recycling, these small-scale generation sources should be considered. Anaerobic digestion (AD) is an effective waste-to-energy technology. The purpose of this study was to evaluate the reduction effects achieved by on-site AD of food waste using life cycle assessment (LCA). Four scenarios were considered: three on-site AD scenarios that used produced biogas in a solid oxide fuel cell, combined heat and power system, and gas-engine-driven heat pump and an incineration scenario as a reference treatment method. The functional unit was "treatment of 1 ton of food waste generated." The results showed that, compared with incineration, on-site AD systems reduced all environmental impacts considered to some extent. For instance, for global warming, greenhouse gas (GHG) emissions were reduced by 140, 710, and 89 kg-CO_2eq/t in on-site AD with solid oxide fuel cell (SOFC), combined heat and power (CHP), and gas-engine-driven heating pump (GHP), respectively, compared with incineration. On-site AD systems can reduce net environmental impacts (fossil fuel consumption, global warming, urban area air pollution, and acidification) by replacing methods that consume fossil fuels. Uncertainty and sensitivity analysis is needed to identify key factors for future research. Estimation of food waste generation from small-scale businesses is also needed to evaluate total reduction effects from on-site AD systems within Japan.

Keywords: life cycle assessment, anaerobic digestion, on-site treatment, food waste, greenhouse gas

INTRODUCTION

Food waste is significant; 17.4 million tons (6.4 million and 11 million tons from businesses and households, respectively) of food waste was generated in Japan as of 2010 (MAFF and MOE 2013). Under the Food Waste Recycling Law that went into effect in 2001, businesses that generate more than 100 tons/yr of food waste are obliged to recycle food waste. However, smaller businesses, which generate less than 100 tons/yr of food waste, and households are not covered by the law. Consequently, 3.3 million and 10 million tons of food waste from these small –scale businesses and households are currently incinerated. To increase recycling, these small-scale generation sources should be considered.

Anaerobic digestion (AD) is an effective waste-to-energy technology. It contributes to fossil fuel energy savings and greenhouse gas (GHG) reduction. Especially for small-scale generation sources, an on-site AD system is more convenient than the conventional, commercial AD system, which needs to collect and treat several tons of food waste. On-site AD benefits small-scale businesses that have not only electricity but also heat demand. Therefore, an on-site AD system would be an attractive approach if adequate reduction effects on environmental impacts is expected. The purpose of this study was to evaluate the reduction effects achieved by on-site AD of food waste using life cycle assessment (LCA).

MATERIALS AND METHODS

Scenarios considered

Two business types were considered as case studies. As listed in Table 1, four scenarios, including incineration (INC) as a reference treatment method, were considered. In the INC, food waste was disposed of as mixed waste without source separation and collection. Although an incineration facility is assumed to have an electricity production facility with an efficiency of 15%, produced electricity is low, considering its lower heating value. In the OAD_{SOFC} scenario, the methane gas in produced biogas was available for a solid oxide fuel cell (SOFC) after a purification process. Considering the power output of SOFC is 0.7 kW, OAD_{SOFC} was considered for fast food restaurant because it can supply enough electricity and heat needed. In the OAD_{CHP} and OAD_{GHP} scenarios, urban gas was added to meet the power output of a combined heat and power (CHP) system and gas-engine-driven heating pump (GHP) equipment, respectively. Inventory data obtained from the on-site AD equipment under demonstration with the treatment capacity of 400 kg/day was used for both treatment capacities.

Table 1 Considered scenarios

Scenario name	Treatment capacity	Considered business type	Biogas utilization method	Substitutions
INC	50 kg/day	Fast food restaurant	–	· Commercial electricity
OAD_{SOFC}	50 kg/day	Fast food restaurant	SOFC	· Commercial electricity · Heat (hot water) provided by boiler using urban gas
OAD_{CHP}	400 kg/day	Lunch bag catering factory	CHP*	· Commercial electricity · Heat (hot water) provided by boiler using urban gas
OAD_{GHP}	400 kg/day	Lunch bag catering factory	GHP*	· Heat (air conditioning) provided by GHP using urban gas

–: collected and incinerated as business waste, SOFC: solid oxide fuel cell, CHP: combined heat and power, GHP: gas-engine-driven heat pump, *: urban gas was added to biogas. Mixing rate on volume basis = 1:9 (biogas):(urban gas).

Functional unit and system boundary

The functional unit is “treatment of 1 ton of food waste generated.” After calculating the environmental impacts caused by the treatment of food waste generated annually, the results are converted into a per 1 ton of food waste unit. Moisture content and lower heating value of food waste was assumed to be 79.1% and 2,000 MJ/ton, respectively, although the characteristics of food waste would differ between business types.

The system boundary includes the collection of food waste, treatment (incineration or AD), and final disposal. The system flow of each scenario is described in Figure 1. The system boundary was from the collection of food waste to the treatment. However, collection was only considered in INC because the other scenarios, which employed on-site AD treatment, did not need a collection process. Regarding fossil fuel consumption, the system boundary considered the stages from raw material extraction to final use (combustion), and associated environmental impacts were allocated to the process consumed the fossil fuel.

Environmental impacts

Global warming, fossil fuel consumption, urban area air pollution, and acidification were considered.

After characterization of each environmental impact category, damage assessment for four objects, needing protection, i.e., human health, social assets, biodiversity, and primary production, was conducted. Finally, integration was conducted, in which the results of the four objects in need of protection were converted into a single index (JPY: Japanese yen) by means of weighting factors. The calculation utilized characterization, damage, and integration factors identified by LIME2 (JLCA 2012). These factors were retrieved from the Life Cycle Assessment Society of Japan's website (JLCA). Concerning global warming, CO_2 emissions derived from biomass are regarded as carbon-neutral, and were therefore excluded from the calculation. Table 2 shows a list of impact categories and corresponding damage factors.

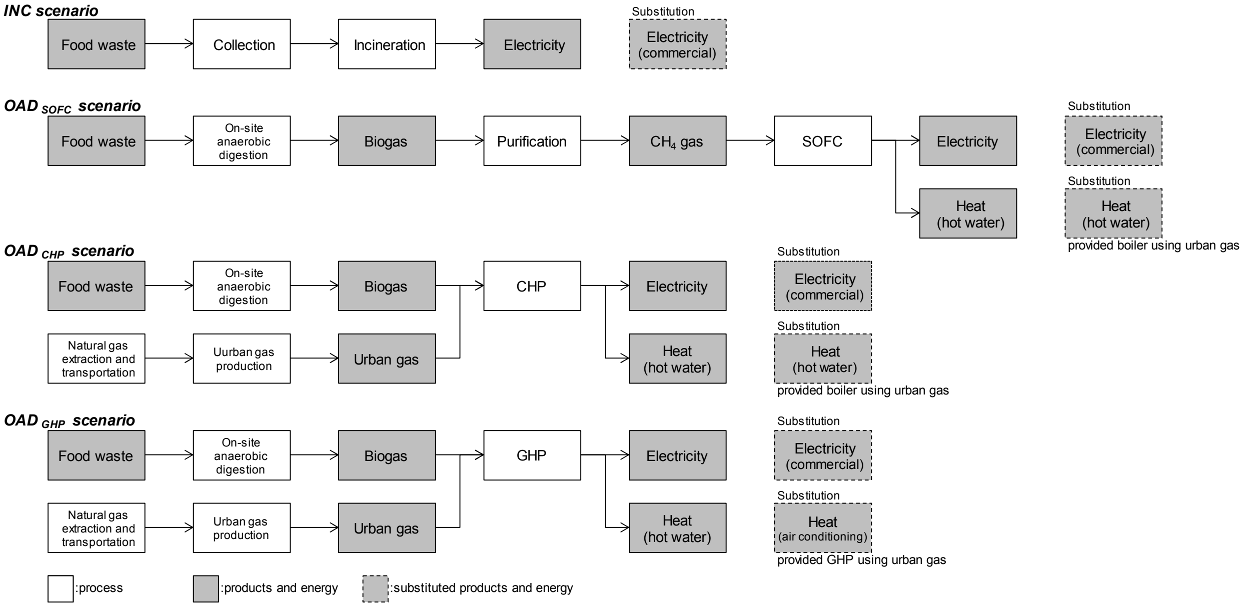

Figure 1 System flow for each scenario

SOFC: solid oxide fuel cell, CHP: combined heat and power, GHP: gas-engine-driven heat pump, *: urban gas was added to biogas. Mixing rate on volume basis = 1:9 (biogas): (urban gas).

Table 2 Impact categories, their objects, and units of characterization factors

Impact category	Object	Unit of characterization factor
Fossil fuel consumption	Crude oil, Coal, Natural gas	Consumption energy [MJ]
Global warming	CO_2, CH_4, N_2O	GWP [kg-CO_2eq]
Urban area air pollution	SO_x, NO_x, $PM_{2.5}$, PM_{10}	UAF [kg-SO_2eq]
Acidification	SO_2, NO_x	DAP [kg-SO_2eq]

GWP: global warming potential, UAF: urban air pollution characterization factor, DAP: deposition-oriented acidification potential. Characterization factors for $PM_{2.5}$ and PM_{10} were not available in LIME2.

RESULTS AND DISCUSSION

As shown in Table 3, global warming and fossil fuel consumption showed similar tendencies as did urban air pollution with acidification. Compared with incineration, on-site AD systems reduced all environmental impacts considered to some extent. For instance, with global warming, GHG emissions were reduced by 140, 710, and 89 kg-CO_2eq/ton in the OAD_{SOFC}, OAD_{CHP}, and OAD_{GHP} scenarios, respectively, compared with the INC scenario. The OAD_{CHP} scenario had the lowest environmental impacts, except for acidification, because this system has the advantage of being able to use urban gas for electricity and heat production. However, it should be noted that if the lunch bag catering factory, which intends to employ this system, has already introduced the CHP equipment, the benefit become much lower. This is because the substitution should be for hot water from the CHP and not the boiler. On the other hand, the $\mathrm{OAD_{CHP}}$ scenario had the highest acidification due to urban gas consumption.

Table 3 Results of each environmental impact (characterization)

				Incineration	On-site anaerobic digestion		
					SOFC	CHP	GHP
Fossil fuel consumption	Electriciy	Consumption	MJ/ton	574	906	605	751
		Substituted	MJ/ton	-579	-2,221	-29,167	0
	Urban gas	Consumption	MJ/ton	0	0	29,881	29,881
		Substituted	MJ/ton	0	-766	-16,070	-31,642
	Diesel fuel	Consumption	MJ/ton	174	0	0	0
	Total		**MJ/ton**	**169**	**-2,081**	**-14,751**	**-1,011**
Global warming	Electriciy	Consumption	kg-CO_2eq/ton	30.1	52.9	35.4	43.9
		Substituted	kg-CO_2eq/ton	-33.9	-129.8	-1,704.4	0.0
	Urban gas	Consumption	kg-CO_2eq/ton	0.0	0.0	2,093.4	2,093.4
		Substituted	kg-CO_2eq/ton	0.0	-53.7	-1,125.9	-2,216.8
	Diesel fuel	Consumption	kg-CO_2eq/ton	13.9	0.0	0.0	0.0
	Direct GHG emission		kg-CO_2eq/ton	2.1	2.9	2.9	2.9
	Total		**kg-CO2eq/ton**	**12.2**	**-127.6**	**-698.6**	**-76.7**
Urban area air pollution	Electriciy	Consumption	kg-SO_2eq/ton	0.01	0.02	0.01	0.02
		Substituted	kg-SO_2eq/ton	-0.01	-0.05	-0.67	0.00
	Urban gas	Consumption	kg-SO_2eq/ton	0.00	0.00	0.61	0.61
		Substituted	kg-SO_2eq/ton	0.00	-0.02	-0.33	-0.65
	Diesel fuel	Consumption	kg-SO_2eq/ton	0.00	0.00	0.00	0.00
	Direct GHG emission	Incineration	kg-SO_2eq/ton	0.18	0.00	0.00	0.00
		On-site AD	kg-SO_2eq/ton	0.00	0.04	0.04	0.04
	Total		**kg-SO_2eq/ton**	**0.18**	**-0.01**	**-0.34**	**0.02**
Acidification	Electriciy	Consumption	kg-SO_2eq/ton	0.02	0.03	0.02	0.03
		Substituted	kg-SO_2eq/ton	-0.02	-0.08	-1.07	0.00
	Urban gas	Consumption	kg-SO_2eq/ton	0.00	0.00	3.55	3.55
		Substituted	kg-SO_2eq/ton	0.00	-0.09	-1.91	-3.76
	Diesel fuel	Consumption	kg-SO_2eq/ton	0.02	0.00	0.00	0.00
	Direct GHG emission	Incineration	kg-SO_2eq/ton	0.47	0.00	0.00	0.00
		On-site AD	kg-SO_2eq/ton	0.00	0.21	0.21	0.21
	Total		**kg-SO_2eq/ton**	**0.50**	**0.07**	**0.80**	**0.03**

Figure 2 shows the results of integration. Considering the four environmental impacts, on-site AD systems showed negative values. This result indicated on-site AD systems contribute to net environmental impact reduction by substituting fossil fuel, with commercial electricity and/or urban gas, consumption. Of the four environmental impacts, global warming was the most significant for on-site AD whereas urban air pollution was the most significant for incineration.

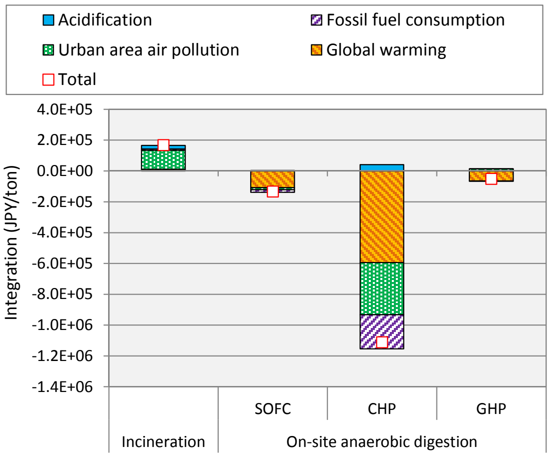

Figure 2 Results of integration

CONCLUSIONS

It was revealed that on-site AD systems could reduce environmental impacts compared with incineration.

ACKNOWLEDGEMENT

We are grateful for the cooperation of Osaka Gas Co., Ltd. providing data related to on-site AD treatment process.

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Life Cycle Assessment of Food Waste to Energy in Korea

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ABSTRACT

Korea Government plans to increase of organic waste plants current 21 to 32 till 2020, total capacity of them will be 8,408 ton/day. This study considered the characterization and weighting models as Life cycle assessment (LCA) results. The aims of this paper are to analyze the flow of materials and energy and to evaluate food waste to energy plants using LCA and compare them with combined compost or feed plants. Feed-biogasification plant was worst performing due to using of liquefied natural gas for drying of food waste. Biogasification-C is demonstrating the best practice because of the adoption of large-scale and biogas consumption on site, followed by Biogasification-B, Compost-Biogasification, Compost, and Biogasification-A, and Feed- Biogasification. In conclusion, the improvement of the energy options could reduce significantly the environmental impacts.

Keywords: Environmental impact, Biogasification, Compost, Feed

INTRODUCTION

As can be seen from Figure 1, there was the “waste to energy potential” of 17.6% from solid waste in Korea. The waste to energy potential can be estimated from combustible waste and organic waste, which was generated for 69,250 ton/day and divided into 39,911 ton/day of combustible waste and 29,339 ton/day of organic waste. The organic waste can be used for biogas production. Korea Government plans to increase of organic waste plants current 21 to 32 till 2020, total capacity of them will be 8,408 ton/day. Life cycle assessment (LCA) for the environmental assessment includes important four phases: goal and scope definition; inventory analysis; impact assessment; and interpretation. The impact assessment steps include classification, characterization, normalization, and weighting. Characterization is a modeling of impact categories using science-based conversion factors. Weighting is a process that assigns relative significance to impact categories taking the form of a single value or weighted impact of a system (Lee and Inaba, 2004). This study considered the both modeling as LCA results. The objectives of this study are to analyze the flow of materials and energy and to evaluate food waste to energy plants using LCA and compare them with combined compost or feed plants.

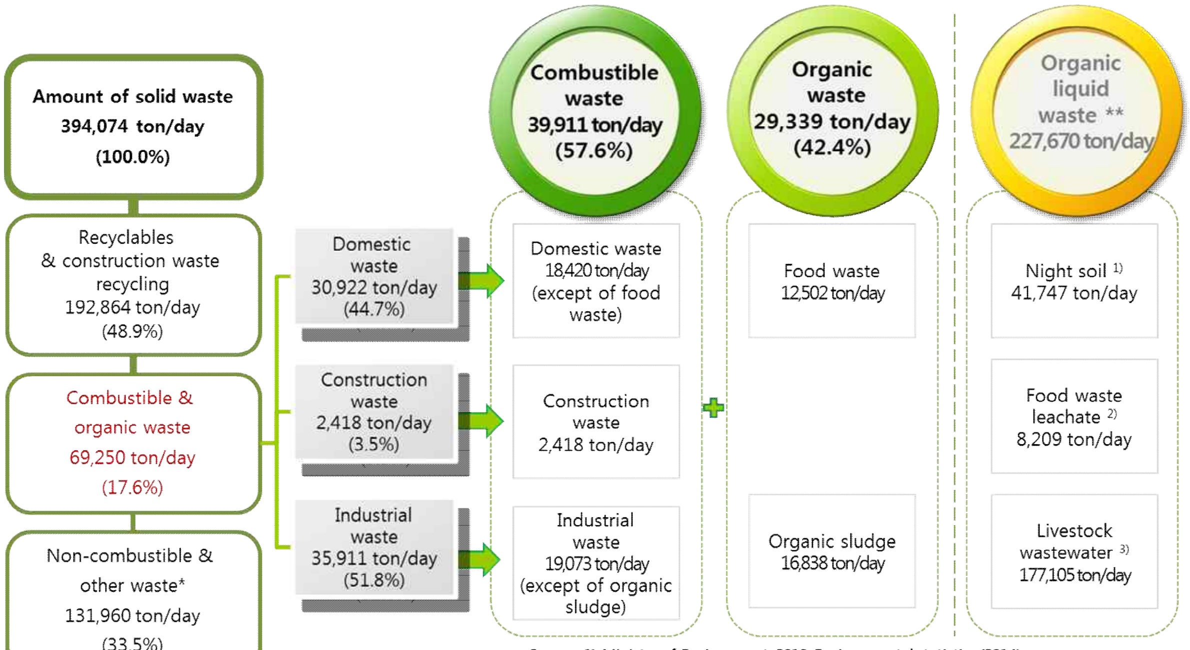
MATERIALS AND METHODS

LCA calculation tool used in this study was the LCA Software TOTAL 4.0 (Tool for type Ⅲ labeling and LCA) developed by Korea Environmental Industry & Technology Institute (KEITI). TOTAL

4.0 is a midpoint modeling including characterization, normalization, and weighting steps. The characterization factors in TOTAL 4.0 are adopted from the CML (Chain Management by Life Cycle Assessment) 2002 methodology. This study was performed to analyze entire life cycle divided by transportation, food waste treatment, and avoided impacts for eight impact categories: abiotic resource depletion; global warming potential; ozone-layer depletion; acidification; eutrophication; human toxicity; eco-toxicity; and photochemical oxidant.

System boundary includes transportation, waste treatment, and energy recovery, as shown in Figure 2. Waste treatment includes biogas, compost, and feed production processes. Avoided impacts defined as energy recovery by biogas combustion are divided into recovery and consumption on site of heat energy and production and commercial sales of electricity.

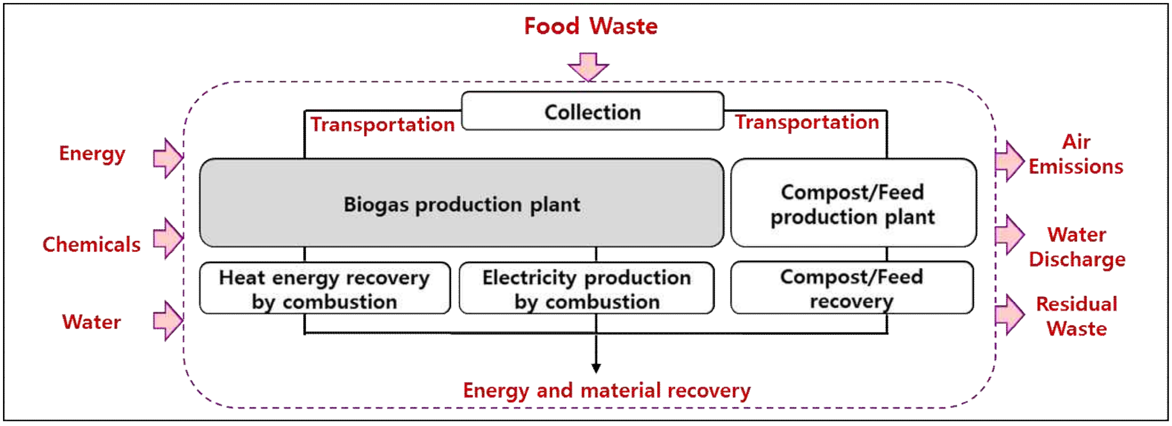
Figure 1 Generation of solid waste in Korea



Source: 1) Ministry of Environment, 2013 Environmental statistics (2014)
2) Ministry of Environment, 2013 Food waste disposal facilities operation (2014)
3) Ministry of Environment, 2012 Livestock wastewater treatment (2013)

* Industrial waste combustibles (including recycling), construction waste incineration and landfill, specified waste, etc.
** Organic liquid waste includes night soil, food waste leachate, and livestock wastewater.

Figure 2 System boundary in this study



The functional unit was defined as one ton of food waste. The characteristics of the five food waste to energy plants and one compost production plant are shown in Table 1. For the comparison of LCA results food waste to energy plants, compost plant was included in this assessment. To calculate MSW, energy, chemicals and water consumptions, and air and water emissions, all data for the year of 2013 were collected from each plant.

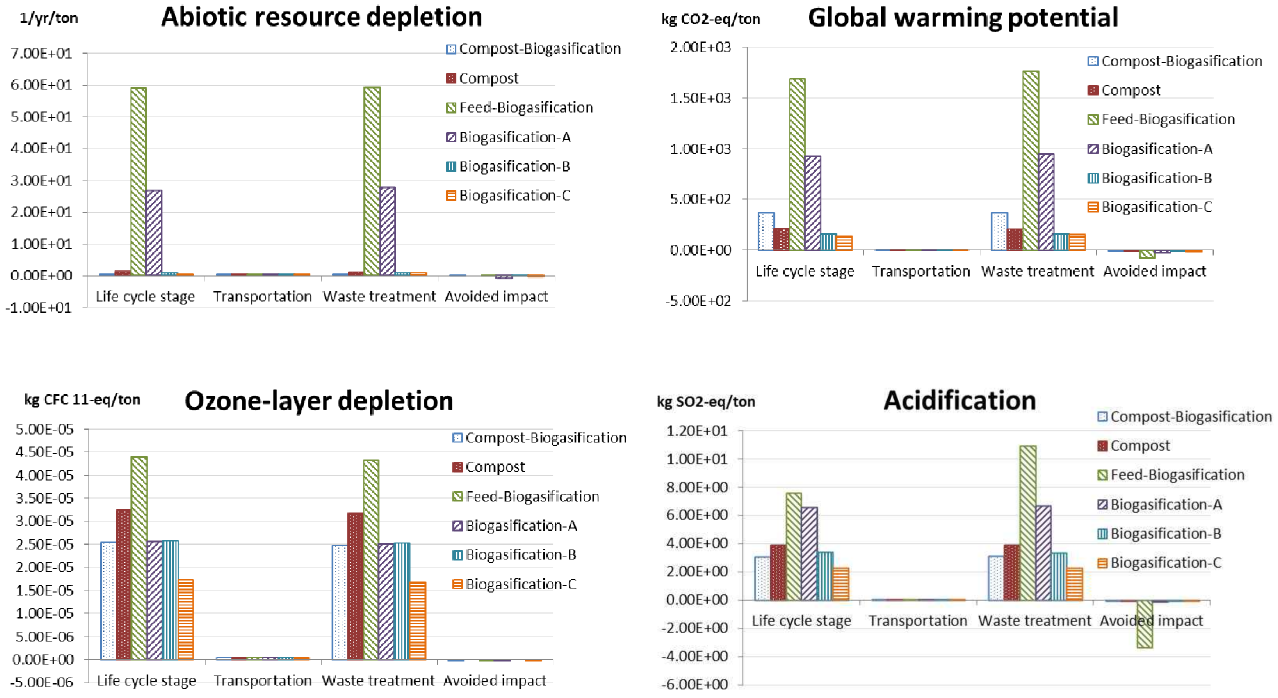
Table 1 Characteristics of food waste to energy plants in this study

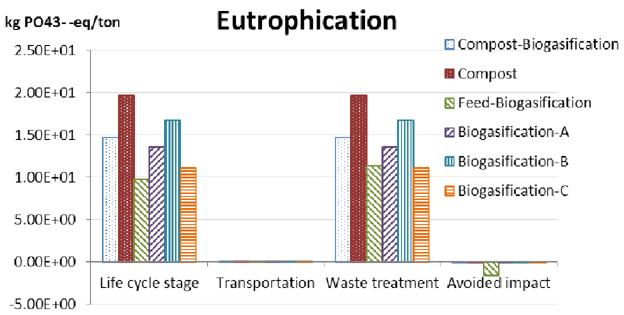
Options	Treatment capacity(ton/day)	Details
Compost-Biogasification	30	Compost and biogas production
Compost	100	Compost production
Feed-Biogasification	45	Feed and biogas production
Biogasification-A	98	Biogas production and for sale
Biogasification-B	200	Biogas and electricity production and for sale
Biogasification-C	500	Biogas production and for sale

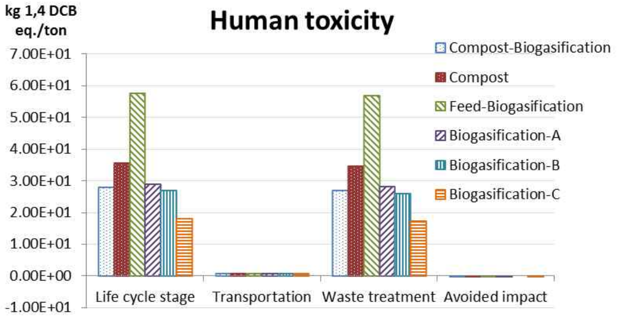
RESULTS AND DISCUSSION

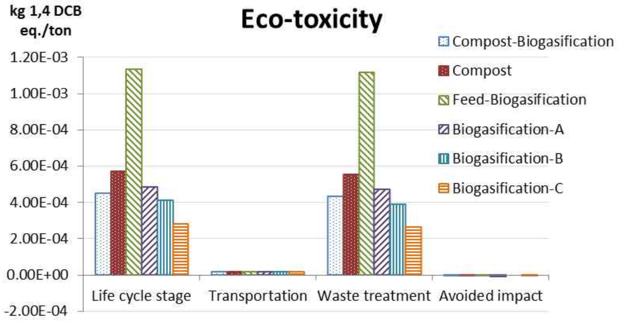
As the material and energy flow results, the compost and feed were produced 244 kg and 105 kg per one ton of food waste, respectively. Biogas was produced 25.1 kg CH_4 per ton to 49.6 kg CH_4 per ton. LCA results according to eight impact categories are shown in Figure 3. Feed-biogasification plant was worst performing due to using of liquefied natural gas for drying of food waste. Biogasification-C is demonstrating the best practice because of the adoption of large scaled and biogas used on site.

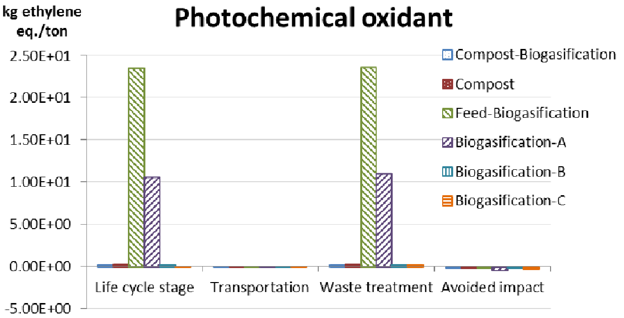
Figure 3 LCA results of food waste to energy options using a characterization model











Weighting analysis as an integration way was performed for eight impact categories. The current study found that Biogasification-C (4.58E-02 point) was the best performing, followed by Biogasification-B (7.05E-02 point), Compost-Biogasification (7.74E-02 point), Compost (8.77E-02 point), and Biogasification-A (4.11E-01 point), and Feed- Biogasification (8.24E-01 point).

CONCLUSION

This study considered the characterization and weighting models as LCA results. The aims of this paper are to analyze the flow of materials and energy and to evaluate food waste to energy plants using LCA and compare them with combined compost or feed plants. As the material and energy flow results, the compost and feed were produced 244 kg and 105 kg per one ton of food waste, respectively. Biogas was produced 25.1 kg CH_4 per ton to 49.6 kg CH_4 per ton. Feed-biogasification plant was worst performing due to using of liquefied natural gas for drying of food waste. Biogasification-C is demonstrating the best practice because of the adoption of large-scale and biogas consumption on site, followed by Biogasification-B, Compost-Biogasification, Compost, and Biogasification-A, and Feed- Biogasification. Thus, the improvement of the energy options could reduce significantly the environmental impacts. When a new food waste to energy plant is introduced, it is need to benchmark the plants that have good performance in terms of fossil fuel use among current existing plants and to reflected the options in the design.

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Demolition/Construction Waste Management in Vietnam- The Necessary for Development of Recycling Policy

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ABSTRACT

The rehabilitations within urban areas in Vietnam have generated a large quantity of demolition and construction waste.

There is no regulation in collection, transportation, reuse and disposal of the demolition and construction waste in Vietnam.

The lacking of facilities and responsible entities to manage demolition wastes have caused serious pollution situation to the environment and the recovering of valuable materials were not well organized yet.

In order to overcome this situation, an investigation on quantity, composition and as well as status of reuse/ recycle and disposal of demolition waste have been conducted in some cities of Vietnam.

The needs for construction and demolition waste management in Vietnam in the future are how to maximize the materials recovery, minimize waste and reduce total waste management cost?

The presentation will shows the current situation of demolition/construction waste and the needs for development of a recycling policy for this type of waste in Vietnam in Vietnam for future.

Keywords: Demolition/Construction waste management, landfill management, waste recovery; waste recycling.

INTRODUCTION

Rapid urbanization has become an important factor for the country's socio-economic development. In addition to socio-economic benefits, rapid urbanization has created a large quantity of wastes including Demolition (D) & Construction (C) waste;

At present, there are lacking of studies on D&C generation and compositions and the regulation in collection, transportation, reuse and disposal of the demolition and construction waste in Vietnam is still not established yet. Lacking of facilities and responsible entities to manage D&C wastes have caused serious pollution situation to the environment. The recovering of valuable materials from this type of waste is not well organized yet.

MATERIALS AND METHODS

- Questionnaire surveys and site surveys
- Sampling and analyzing of component of D&C samples
- Desk study the concerning previous reports and researches

Surveyed Areas:

- Ha Noi and Ho Chi Minh City (representative for the special category cities)
- Da Nang, Can Tho, Hue, Qui Nhon (representative for the first category cities)
- Ha Long (representative for the second category cities)
- Bac Ninh (representative for the third category cities)

RESULTS AND DISCUSSION

There is no specific definition for C&D Waste in Vietnam. However, according to the Vietnamese Standard (TCVN 6705-2009- Non hazardous solid wastes -Classification), C&D wastes are classified as the wastes arising from construction/demolition activities.

Status of C&D waste management:

Generation sources: According to the study, the major generation sources of C &D waste are: Excavation activities, Destroying old constructions/ buildings and site clearance, the surveyed data shown that percentage of C&D generation from site clearance activities is ranging from 27.0% to 33.7%, while the percentage of C&D generation from excavation is ranging from 27,3 % to 40.2% and percentage of C&D generation from destroying of old buildings and construction of new buildings is ranging from 32.8% to 44.5 % . .

Components of C&D waste: Figure 1. Shows that the components of C&D waste are varying from cities by other cities due to the development levels in the city are different.

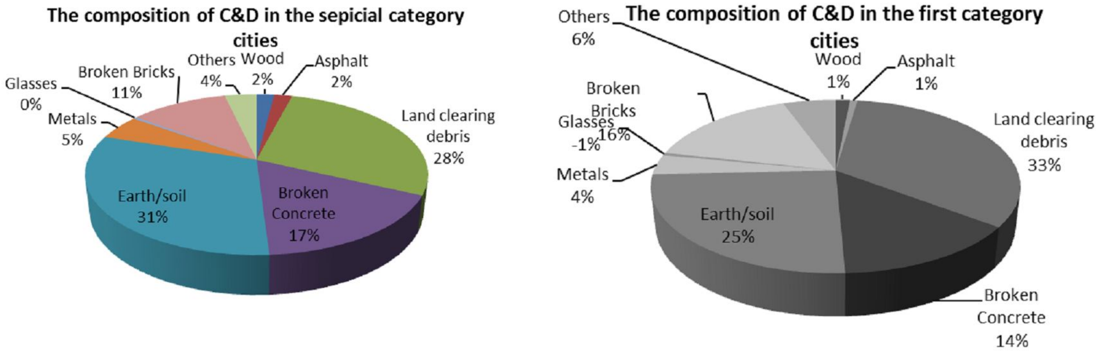

Figure 1. The components of C&D waste Surveyed cities-
Special and First Category Cities

Source: Surveyed data by INEV, 2012

Collection and transportation: C&D waste are collected and transported by both public sector (URENCO, CITENCO..) and private sectors. The vehicles used for transportation are heavy trucks with big sixe while the roads/streets in the cities are narrow and corowded, that have caused serious problems in the cities.

Recovery and Reuse of materials from C&D waste: Recovery and Reuse of materials from C&D waste are implemented through the following ways:

- Reuse for filling to the ponds/low elevation places: 47 %
- Uncontrolled disposal in the illegal dumping sites 32.5 %
- Recycling as material for producing construction products: 20.5 %;

The application of Recyclable Materials from C&D waste is showed in Table 1.

Table 1. The application of Recyclable Materials from C&D in Vietnam

Waste components can be Recycled	Application
Broken Concrete	Base of the urban /Rural Roads
	Filling materials
Asphalt	Road layer line
Wood	Raw materials for producing sawdust
Metals	Metalic products
Cardboard	Paper products

Source: Surveyed data by INEV, 2012.

Disposal of C&D Waste: There is few cities such as Hanoi city, Ha Long City which have solid waste management planning oh which the sites for disposal of C&D waste are located. Most cities/provinces in Vietnam has no facilities for disposal of this type of waste.

Policies for C&D waste management: There is no specific legal regulation for management of C&D waste in Vietnam, some regulations are concerning with solid waste management in generally such as: Law on Environmental Protectiom, Law on Construction; Law on Urban Planning..

In 2009, the Government of Vietnam has approved the “ National Strategy for Integrated Solid Waste Management in Vietnam by 2025, vision to 2050” with aims to enhance environment quality, ensure public health and contribute to sustainable development of the country. In this strategy, the specific objectives were set up including of C&D waste but the targets are ambitious and give no specific suggestions for implementation.

CONCLUSION

In Vietnam, C&D wastes are mainl generated from three sources: Excavation activities, destroying old constructions/ buildings and site clearance for preparing the development of urban technical infrastructure. The quantity of C&D waste is increasing according to the different level of the development of cities. The components of C&D waste can be reuse, recycle for other purpose with the appropriate ways but so far, only small percentage of C&D

waste are reuse as material filling and recycling for reproducing of raw material for other purposes. Exept, Hanoi, Ho Chi Minh and Da Nang Cities, most of cities in Vietnam have no proper landfill for disposal of C&D waste.A large quantity of C&D waste are illigally disposing.

There is no legal documents and instructions/guideline for management of C&D waste in Vietnam. The planning and investment for Research & Development on C%&D waste management is still lacking. Especially hazardous component in this type of waste is still in darkness.

It is very important for Vietnam to develop a new policy on C&D waste management in which the potential for reuse and recycling activities should be more encouraged.

ACKNOLEDGEMENT:

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ORGANIZATION

ORGANIZERS: Institute of Strategy and Policy on Natural Resources and Environment (ISPONRE), Viet Nam Environment Administration (VEA), Department of Science and Technology under Ministry of Natural Resources and Environment (MONRE)

CO-ORGANIZERS: Japan Society of Material Cycles and Waste Management (JSMCWM), Korean Society of Waste Management (KSWM) Society for Solid Waste, Chinese Society for Environmental Sciences (SSW-CSES), Technical Infrastructure Agency under Ministry of Construction Vietnam, and other regional and global academic networks

SUPPORTERS: UNCRD (United Nations Centre for Regional Development), ISWA (International Solid Waste Association), IGES (Institute for Global Environmental Strategies), JICA (Japan International Cooperation Agency), MOEJ (Ministry of the Environment, Government of Japan) and others

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