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Institute of Strategy and Policy on Natural Resources and Environment

Air Pollution in Urban Areas of Viet Nam

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Contents

BREAKING NEWS

Recently, air pollution, which is predominantly dust pollution (especially $PM_{2.5}$ fine dust) has been increasing in certain areas of Viet Nam. Monitoring shows that from 2010, concentrations of $PM_{2.5}$ at the national station located at 556 Nguyen Van Cu Street decreased between 2013 and 2017, but increased between 2018 and 2019. The comparison of $PM_{2.5}$ monitoring results by month from 2013 to 2019 reveals that from September to mid-December 2019, $PM_{2.5}$ concentrations increased considerably compared to the previous months and rose more sharply than the same period of time between 2015 and 2018.

In Ha Noi, air pollution incidents from September to December 2019 occurred more often and over several days with an average $PM_{2.5}$ exceeding QCVN standards by 2 - 3 times. Normally, $PM_{2.5}$ concentrations significantly increase in peak hours (7:00 to 8:00 and 18:00 - 19:00) and decline to their lowest levels in the early afternoon (13:00 - 14:00) and at night (23:00 - 1:00). However, during days of reported air pollution, the Air Quality Index (AQI) usually rose and maintained high levels at night and early morning, which is influenced by weather factors (calm winds, low humidity associated with temperature inversion). After that, when the temperature increases, AQI gradually decreases and usually reaches the lowest level at around 15:00 - 18:00.

At a meeting with Ministries, sectors, and Ha Noi and Ho Chi Minh cities regarding urgent solutions to control air quality in the large cities, Minister Tran Hong Ha highlighted the causes of air pollution as an initial basis for immediate and long-term solutions.

First and foremost, the number of vehicles has significantly increased releasing a large amount of pollutants. According to statistics, there are about 5.8 million motorcycles and hundreds of thousands of cars in Ha Noi. In 2019, the number of vehicles increased by 15% in comparison to the previous year. The number of vehicles registered in Ho Chi Minh City is also high with 7.5 million motorcycles. These numbers do not include the vast number of vehicles passing through these two cities, which is the biggest source of air pollution.

The second cause is construction work and road repairs. In Ha Noi, there are currently more than a thousand projects under construction. Ho Chi Minh City has a high density of buildings. The two cities are huge construction sites.

The third reason is the rapidly increasing number of suburban factories putting huge pressure on the environment. In Ho Chi Minh City there are over 900 factories producing agricultural products and handicrafts causing air pollution as well.

Moreover, another cause of pollution in Ha Noi is straw-burning, which is a seasonal source of pollution. Besides, more than 60,000 households use beehive coal stoves in Ha Noi and illegal waste incineration in the suburbs is also a significant cause of air pollution.

In response to the harmful effects of air pollution on people's health and wellbeing as well as the need for sustainable development, the Government of Viet Nam and the Prime Minister have directed ministries, sectors, and localities to deploy several solutions to control and protect the air environment. On June 1 2016, the Prime Minister issued Decision 985a/QD-TTg approving the National Action Plan on Air Quality Management to 2020 with a vision to 2025 to enhance air quality management by controlling the sources of pollutants and monitoring air quality. In conjunction with the National Action Plan, regulations will be promulgated for measures regarding air quality management in the Law on Environmental Protection 2014 and decrees guiding its implementation. In addition, regulations, standards and roadmaps in the fields of transportation and construction will be developed and implemented. Localities have gradually improved air quality, and have developed and implemented their own Air Quality Management Plans.

Source:
Ministry of Natural Resources and Environment

Resident burning straw in a suburb
Source: Quinn Ryan Mattingly - ©GIZ

Air pollution in urban areas of Viet Nam

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I. Introduction

Air pollution is now considered a leading factor resulting in major impacts on the environment and public health. In comparison to rural areas, air pollution in urban regions is much more severe and has serious consequences. Pollution has a number of sources, such as transportation emissions, industrial production, agriculture, waste treatment and management, as well as natural causes such as bushfires, desert dust, and volcanoes. The consequences of air pollution include acid rain and rising greenhouse gas emissions leading to global climate change. These consequences are affecting human health, particularly for people who suffer from respiratory diseases.

According to the Annual Report on the Environmental Performance Index (EPI, 2018) from the U.S., Viet Nam is ranked the 11th most air-polluted country in Asia. Notably, the total amount of dust in Ha Noi and Ho Chi Minh City is increasing significantly, causing the Air Quality Index (AQI) to reach alarming levels. The source of dust-pollutants in major cities is mostly transportation, construction work, roads, and industrial plants.

This study will present: (i) the status of air quality in Ha Noi and Ho Chi Minh City; (ii) the causes of air pollution; and (iii) proposed recommendations to improve urban air quality.

II. Status of air quality in urban areas of Viet Nam

Air quality in urban areas of Viet Nam varies. Most pollution is recorded in Ha Noi and Ho Chi Minh cities followed by traffic intersections in several small and medium cities. The main air pollutants in urban areas are dust (TSP, PM_{10}, $PM_{2.5}$), and other pollutants, including NO_x, SO_2, CO, O_3.

Dust

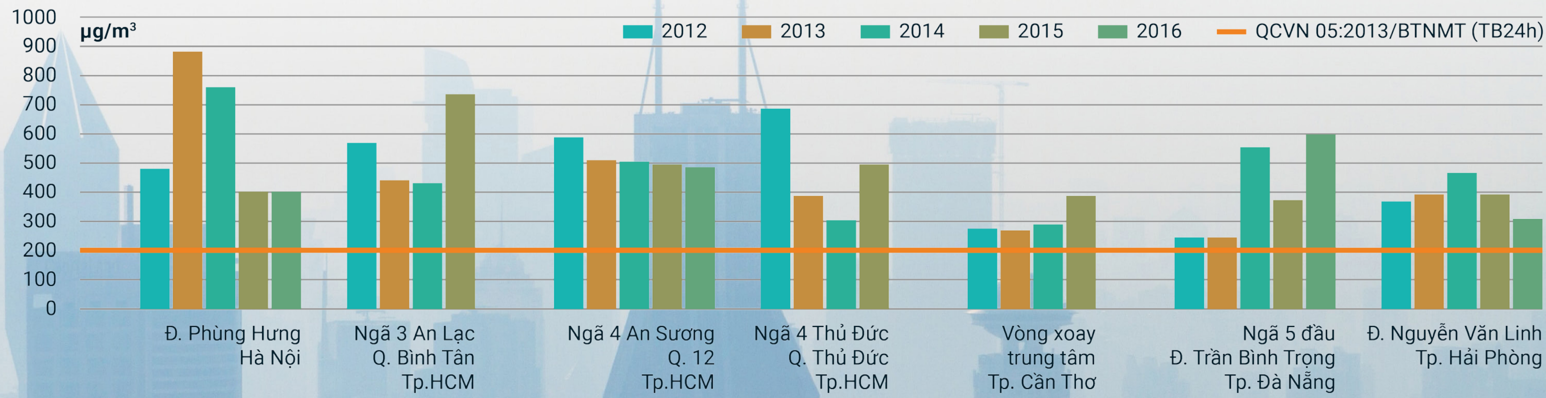
Dust pollution in urban areas is reflected by the parameters of total suspended dust of TSP, and fine dust PM_{10} and $PM_{2.5}$. Generally, PM_{10} and $PM_{2.5}$ accounts for a high proportion of dust in urban areas.

For TSP, the concentration exceeded the permissible limit of QCVN 05: 2013 by 2 - 3 times and is often highly concentrated in the roads of large cities. In areas affected by production activities, dust concentrations often maintain a high level. In particular, the level of pollution manifests itself most clearly in special-category cities followed by first class cities (Figure 1). The pollution levels for urban cities in categories II and III is lower.

For PM_{10} and $PM_{2.5}$ fine dust, the measured value at many traffic stations was higher than the annual average in QCVN 05: 2013/BTNMT (Figures 2 and 3).

Figure 1. The annual average TSP concentrations of ambient air at certain traffic routes in large cities during 2012 - 2016

Source: Viet Nam Environment Administration (VEA), 2016



Smog shrouds city
Source: Holger Link - ©Unsplash

Figure 2. Average PM_{10} concentrations in certain urban areas

Source: VEA, 2016

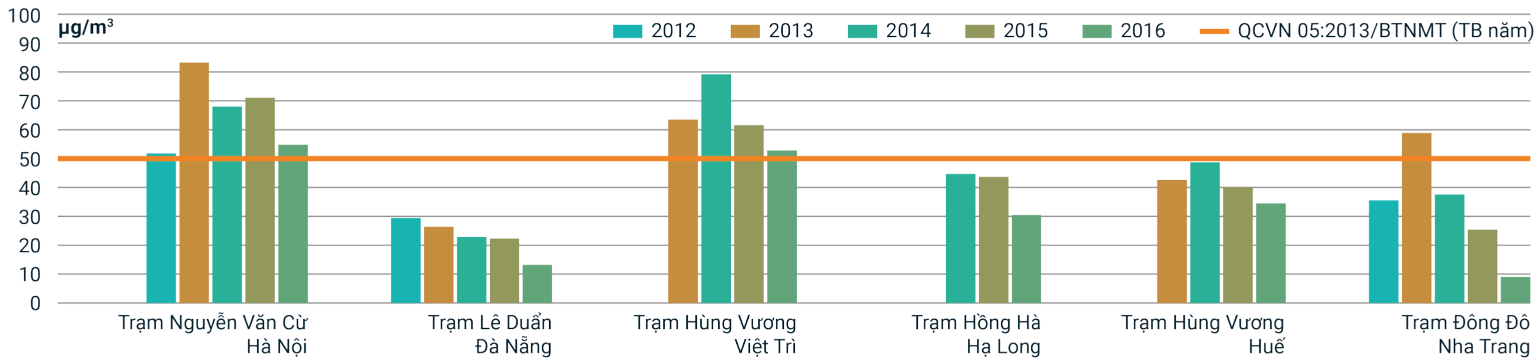


Figure 3. Average $PM_{2.5}$ concentrations in certain urban areas

Source: VEA, 2016

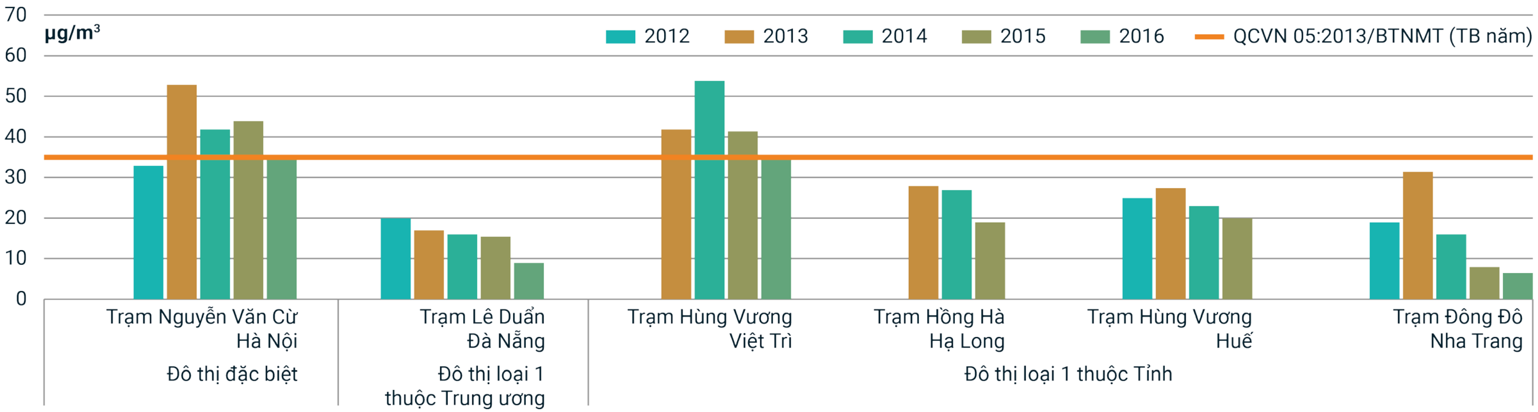
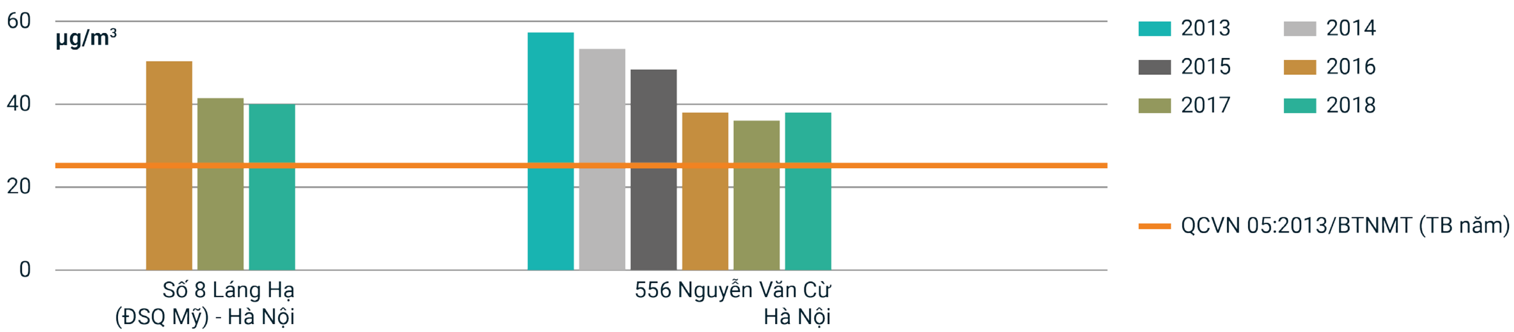


Figure 4. Average $PM_{2.5}$ concentrations measured at two monitoring stations in Ha Noi

Source: Hoang Van Thuc, Le Hoang Anh, 2019, Environment Magazine, No.4/2019



In large cities such as Ha Noi, the number of days in which PM_{10} and $PM_{2.5}$ dust exceeded the QCVN limit was high. Dust pollution (especially fine dust) usually concentrated in the winter months with little rain (November - March) in the north and north-central region. In the south-central region, which is located in the tropical monsoon climate region with year-round stable and less fluctuating temperatures, the difference between monthly PM dust concentrations was not obvious. Data measured in Danang and Nha Trang cities shows the stability of PM_1, $PM_{2.5}$ and PM_{10} in dry and rainy seasons.

Of the two locations with high concentrations of PM_{10} and $PM_{2.5}$, one was in Ha Noi, where measurements were taken at busy traffic locations, and the other was in Viet Tri City, where a wide range of industrial zones are concentrated. In residential areas, the level of dust pollution was many times lower than that of traffic areas; the farther away from roads, the better the air quality. However, in residential areas located in urban regions with busy traffic, the level of dust pollution exceeded the QCVN limit. Air quality in residential areas in small and medium size urban regions was quite good.

Dust pollution in Ha Noi

The concentration of $PM_{2.5}$ in Ha Noi in 2016 was 50.5 µg/m³, which is 2 and 5 times higher than the national standard and the WHO's standard respectively. In 2016, Ha Noi recorded 123 days with $PM_{2.5}$ exceeding Vietnamese standards, and 282 days exceeding the WHO's air quality guidelines. Monitoring during 2013 - 2018 shows that air pollution in Ha Noi remained higher than QCVN 05:2013/BTNMT permitted levels (Figure 4).

In the first quarter of 2019, monitoring of $PM_{2.5}$ in Ha Noi showed that the average percentage of days in excess of the permitted limit reached about 25 - 30% (at 7/12 monitoring stations). At intersections with intense traffic density (such as the intersections of Hang Dau and Pham Van Dong), the percentage reached 56 - 60% (Figure 5).

Dust pollution in Ho Chi Minh City

According to monitoring results in 2016, Ho Chi Minh City was polluted with dust, O_3 and NO_2 at certain locations and at certain times. According to WHO statistics for the same year, annual average dust concentrations for urban areas in Viet Nam were about 28 µg/m^3 (nearly 3 times higher than the recommended annual average dust concentration level of 10 µg/m^3). Similarly, dust concentrations in Ho Chi Minh City were 4 times higher than the recommended level of 89,8 µg/m^3 for PM_{10} and 42 µg/m^3 for $PM_{2.5}$, with $PM_{2.5}$ exceeding Vietnamese standards for 14 days, and exceeding WHO air quality guidelines for 175 days. Specifically, dust concentrations recorded at monitoring stations located at major intersections in Ho Chi Minh City such as An Suong (District 12) and My Thuy (District 2) exceeded the permitted level by 8 - 9 times according to statistics from the Ho Chi Minh City Department of Natural Resources and Environment.

NO_x, SO_2, CO emissions

For urban areas, the source of NO and NO_2 emissions is mainly transportation. NO tends to increase at peak hours when vehicles are operating at high frequencies. In the air, NO_2 is the metabolism of NO; thus, NO_2 concentrations usually increase sharply right after NO is released into the environment. NO_x is a mixture of NO and NO_2 gases and reflects the level of integrated pollution of these two gases. The fluctuation level of NO_x concentrations also has an obvious differentiation in the three regions of Viet Nam: pollution levels reach their maximum in winter in the north (December to April), and are highest in the dry season in the south (October to April). Meanwhile, the central region shows very little seasonal variation.

In urban areas, NO_2 concentrations remain at the approximate threshold of QCVN 05:2013/BTNMT at an average of 1 hour and 24 hours (apart from busy crossroads in Ho Chi Minh City) (Figure 6).

Figure 5. Average $PM_{2.5}$ concentrations at certain monitoring stations in Ha Noi in Q1/2019

Source: Hoang Van Thuc, Le Hoang Anh, 2019

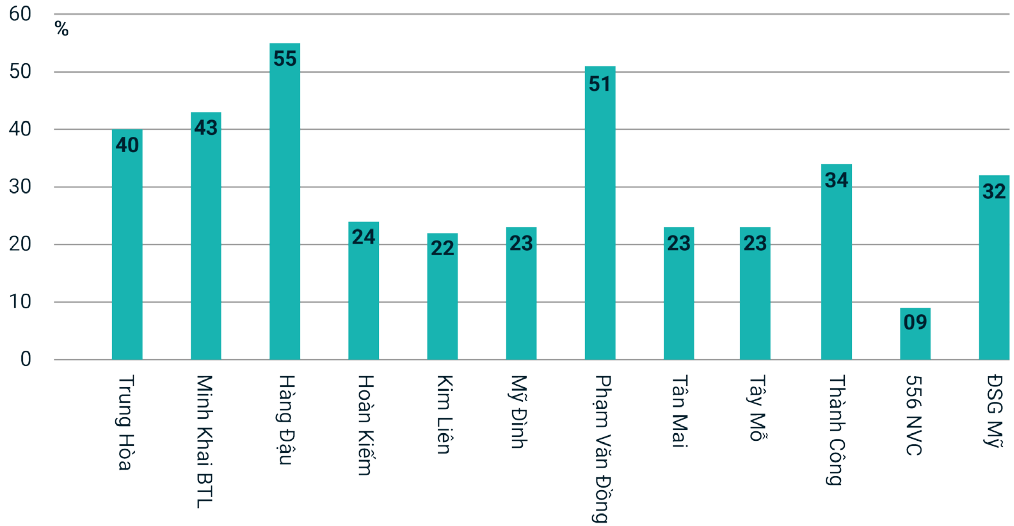
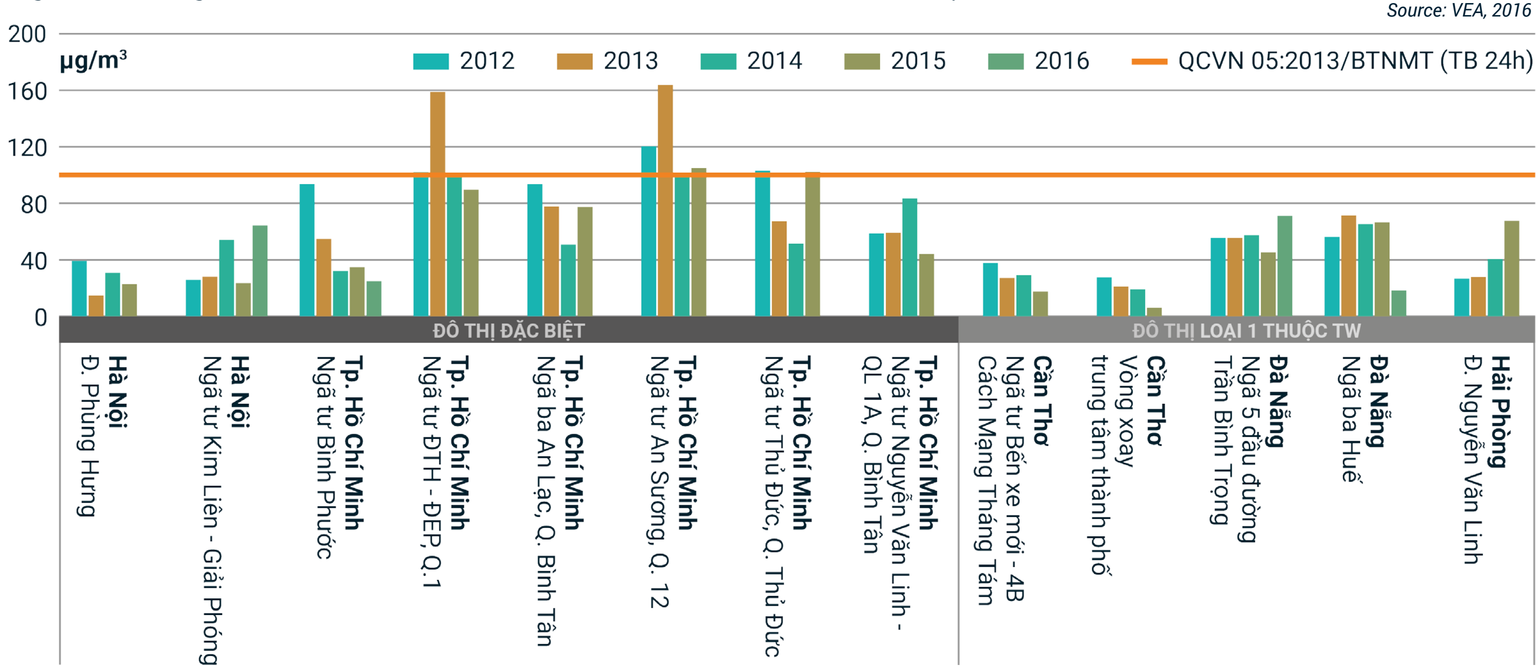


Figure 6. Average NO_2 concentrations for certain transportation routes in major cities

Source: VEA, 2016



According to the results of periodical monitoring at certain times of the day during 2012 - 2016, SO_2 concentrations tend to decrease in most provinces and cities. In most residential areas and industrial zones in urban areas, SO_2 concentrations are still within the QCVN 05:2013/BTNMT limit (Figure 7).

Nevertheless, for CO there is a difference in the level of pollution between urban areas. Large cities tend to be more polluted than small and medium cities. Some areas which are close to industrial zones in urban areas have higher CO concentrations than the QCVN 05:2013/BTNMT limit (Figure 8).

Ozone (O_3)

O_3 is a secondary pollutant generated by interactions between pollutants such as NO_x, HC, VOC and ultraviolet solar-radiation. O_3 in the air layer near the ground in urban areas usually increases sharply at noon when the solar radiation level is highest. The results from monitoring stations located near roads show that O_3 concentrations exceeded the QCVN limit for several days in the year.

Results in 2016 at the monitoring stations at Nguyen Van Cu (Ha Noi), Le Duan (Da Nang), and Dong De (Nha Trang) showed that all had more days exceeding QCVN than those at Hung Vuong (Viet Tri) and Hung Vuong (Hue) (Figure 9). This proves that NO_x, HC, VOC pollution in Ha Noi, Da Nang, and Nha Trang is much higher than it is in Viet Tri and Hue.

Noise pollution

In urban areas, noise pollution is typically concentrated in traffic axes with high vehicle densities. Noise thresholds measured in major streets in large urban areas exceeded the QCVN 26:2010/BTNMT permitted noise level

Figure 7. Average concentrations of SO_2 in ambient air in certain industrial zones in urban areas during 2012 - 2016

Source: VEA, 2016

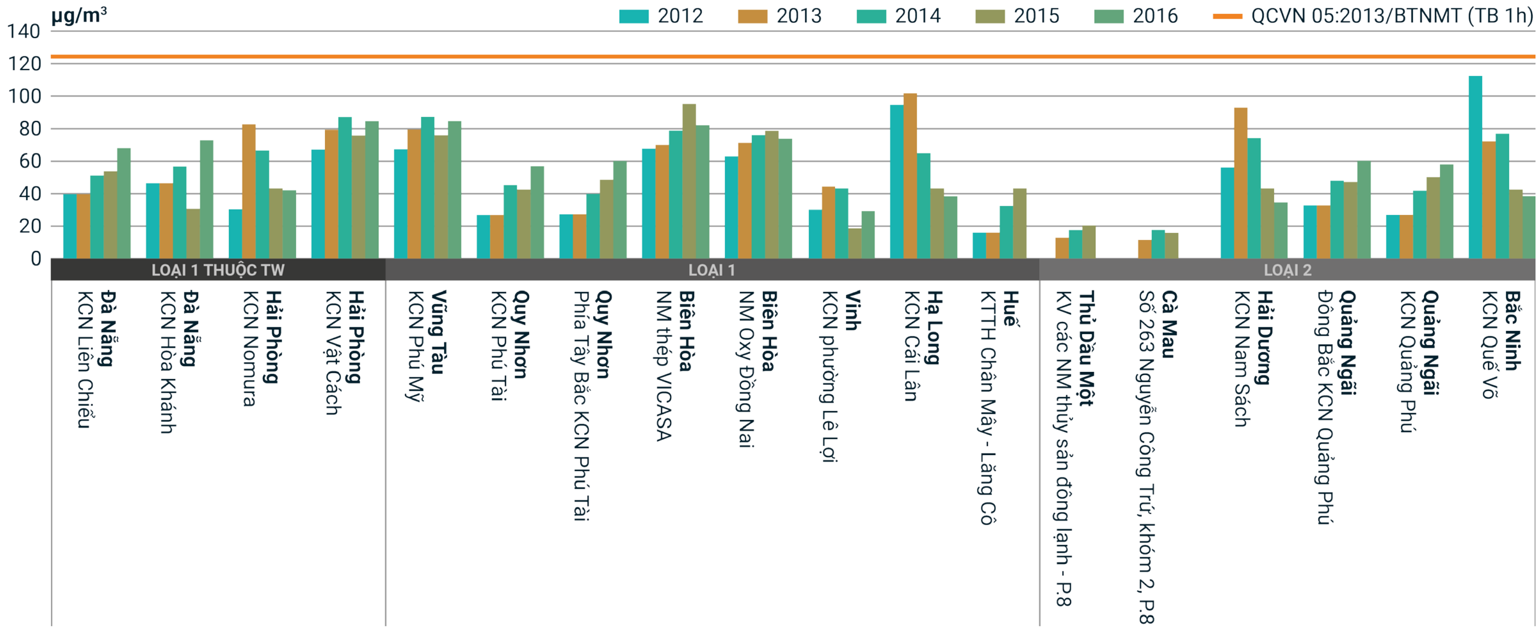
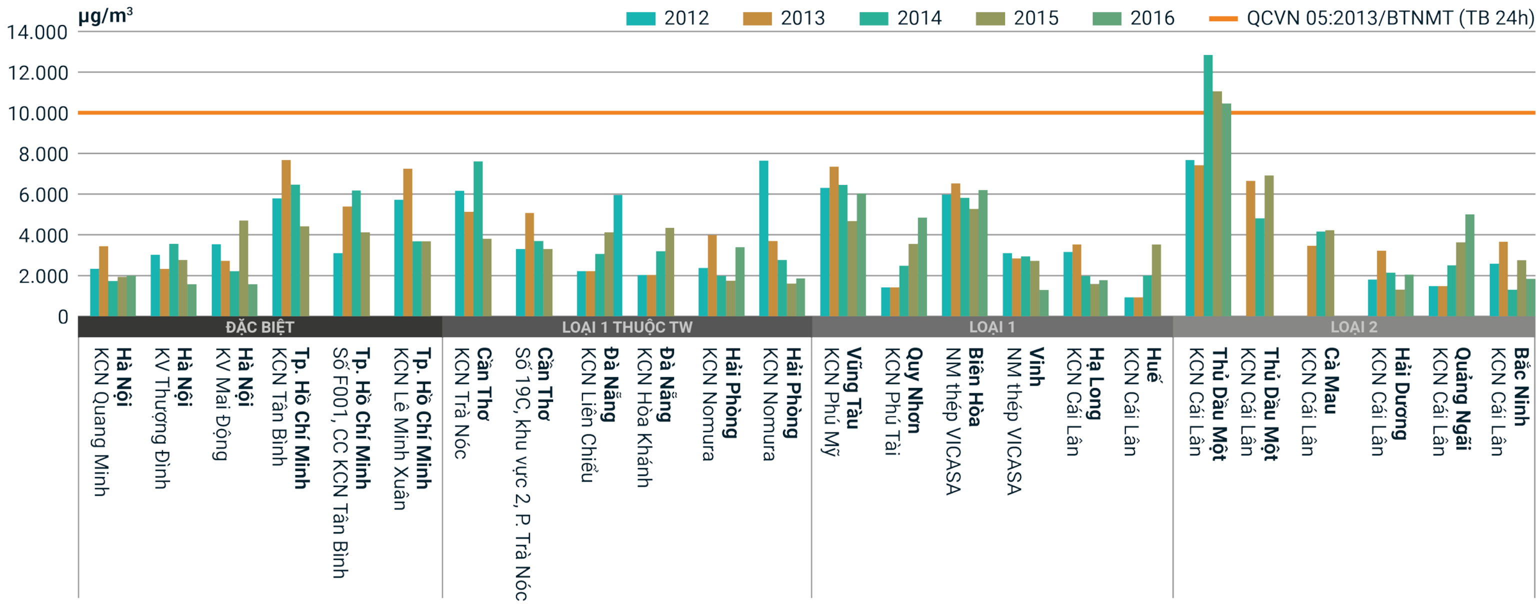


Figure 8. CO concentrations of ambient air in industrial zones in urban areas during 2012 - 2016

Source: VEA, 2016



between 6:00 to 21:00 (70 dBA). For small and medium-sized cities, noise levels measured at transportation routes did not vary greatly and did not exceed QCVN limits (Figure 10). For measurement spots in residential areas, noise levels were generally within permitted levels.

III. Causes of air pollution in urban areas

The major sources of air pollutants in urban areas of Viet Nam are from various activities including transportation, industry, construction, craft villages, and waste treatment.

Transportation:
The rise in the number of vehicles, particularly cars and motorcycles while the quality of roads remains unsatisfactory, is one of the main causes of air pollution in urban areas. The air pollutants are mainly generated by emissions from the use of diesel, gasoline or fossil sources including CO, NO_x, SO_2, gasoline vapours (CnHm, VOCs), PM_{10}, $PM_{2.5}$ and dust from soil and sand rising from roads (TSP). Motorcycles account for a major proportion of CO, VOC, and TSP emission. Cars accounted for a large proportion of SO_2 and NO_2 emissions.

In Ha Noi, as of Quarter 1/2019, Ha Noi Traffic Police were managing 6,649,596 vehicles. This includes 739,731 cars, 5,761,436 motorcycles, and 148,429 electric bikes. The review report 2014 - 2019 shows that in 2017 the number of vehicles increased by 5.3%; in 2015, this number increased by 4.2% and in 2019 by 1.5% compared to 2018. According to statistics, motorcycles account for 86% of vehicles operating in Ha Noi (Minh Duc, 2019).

Figure 9. Numbers of days with O_2 exceeding QCVN 05:2013/BTNMT at 5 monitoring stations in 2016

Source: VEA, 2016

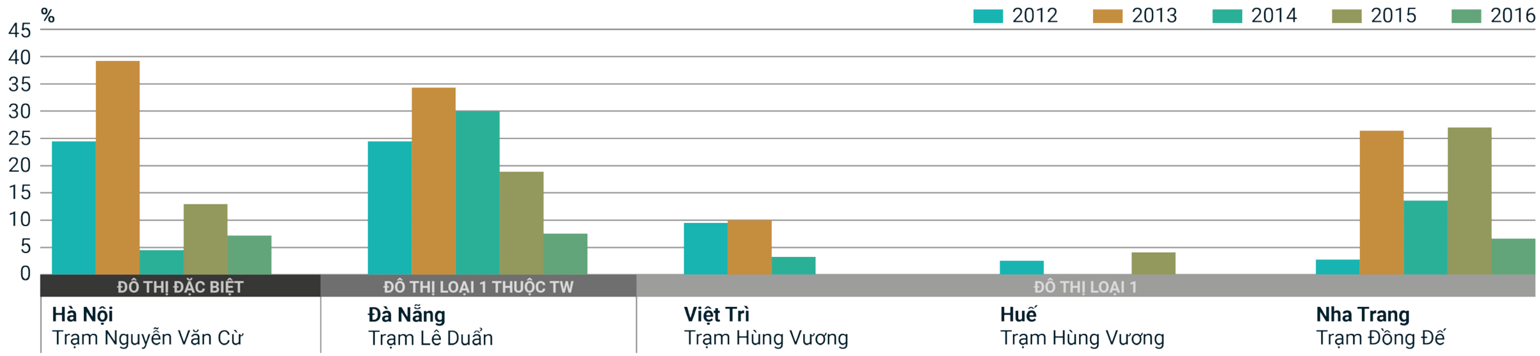
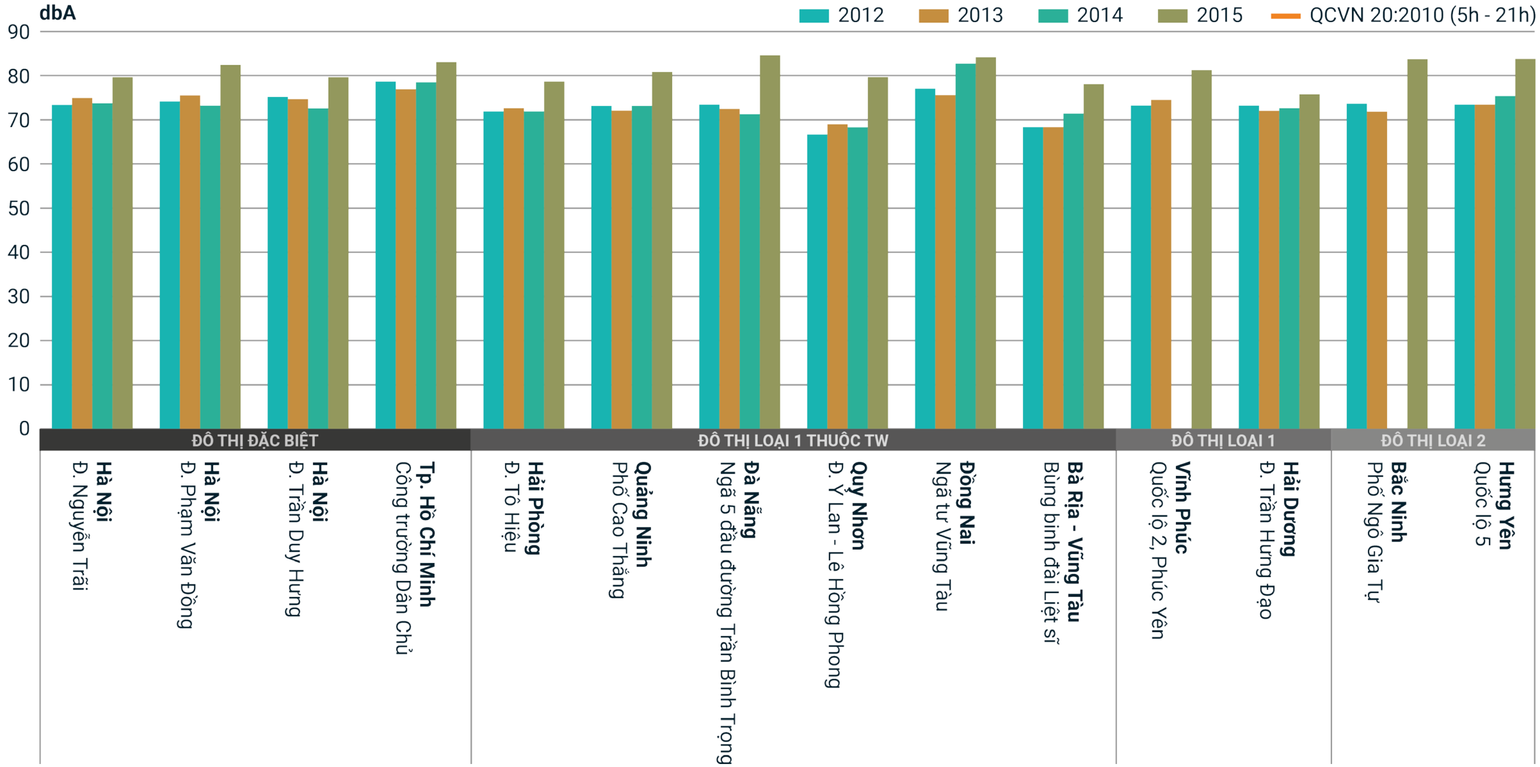


Figure 10. Noise parameters measured in ambient air at certain traffic routes in urban areas

Source: VEA, 2016



Transportation is also a main source of dust, air and noise pollution in Ho Chi Minh City. According to statistics from the Ho Chi Minh City Department of Transportation, there are currently 8.5 million vehicles in the city. The number of motorcycles account for nearly 95%, consuming 56% of petrol but emitting 94% HC, 87% CO and 57% NO_x. It is predicted that the number of vehicles will increase to 9 million motorcycles and nearly 800,000 cars in 2020. Moreover, this number will include millions of motorcycles (especially second-hand motorcycles and self-made vehicles) along with various kinds of cars and trucks emitting toxic gases and generating dust, causing severe impacts on human health.

Transportation is the biggest source of pollutants which emmits 99% of total CO emissions in Ho Chi Minh City, 97% NMVOC, 93% NO_x, 78% SO_2, 46% dust and 64% CH_4. For SO_2, motorcycles are the major source of emissions, which account for 39.5% of the total, followed by harbours at 15% and cars at 10.7%. For CH_4, transportation is the largest source of emissions accounting for 64% followed by biological sources, which account for 32% (Ho Quoc Bang, 2017)..

Industrial production in urban areas: The source of air pollution from industrial activities in urban areas is often from light industrial enterprises such as textiles, craft villages and assembly factories. The pollutants include dust, Clo, SO_2, colourings, formaldehyde, HC, NaOH, and NaClO. Other pollutants from mechanical production and metallurgical manufacturing groups include: dust, heavy metal vapours, CN-, HCl, SiO_2, CO, and CO_2. The manufacture of metal products causes the following types of emissions: specific metal dust, chemical vapour, organic solvent vapour, SO_2, NO_2. Emissions from chemical production include: H_2S, NH_3 dust, organic solvent vapour, specific chemical dust, SO_2, CO, and NO_2.

According to the Ha Noi Industrial and Export Processing Zones Authority, Ha Noi has 19 industrial zones and high-tech zones covering 2,250 ha as well as 107 industrial clusters covering 3,000 ha. For sustainable industrial development, Ha Noi People's Committee is focusing on high-tech and environmentally-friendly projects, manufacturing high value-added and competitive export products; thus, the industrial zones in Ha Noi have not caused harmful air pollution.

In Ho Chi Minh City, the total number of industrial sources is about 812, of which 764 emission sources employ gas emissions treatment systems. Industrial activities account for 22% of the total SO_2 emissions of the city, 21% of dust, 1% of NMVOC, 5% of NO_x, 1% CH_4, and 1% CO. Harbours contribute 15% of total SO_2 emissions, 11.5% NO_x and 5% dust (Ho Quoc Bang, 2017). In addition, the number of factories near the city is increasing rapidly putting intense pressure on the surrounding environment, specifically in Ho Chi Minh City. Nine hundred agricultural production and handicraft firms close to Ho Chi Minh City also cause air pollution.

Construction activities:
Construction activities are carried out at apartment buildings, new urban zones, bridges, roads, and for house repairs. Along with activities such as demolition and renovation, construction materials spilled during carriage usually cause dust pollution. In addition to dust, construction equipment (excavators, bulldozers) also emit other pollutants such as SO_2, CO, and VOC.

The main polluting agents from craft villages:
Air pollution in craft villages is mainly derived from the use of coal for fuel (low-quality coal is popular), and the use of raw materials and chemicals for production. The pollutants containing typical components are dust, CO_2, CO, SO_2, NO_x and volatile organic matter.

However, the craft villages in suburban or urban areas in Ha Noi or Ho Chi Minh cities are all traditional ones with unique handicrafts, using small-scale and advanced production processes along with limited use of fossil fuels (coal); thus the levels of air pollution are not high.

Burying and treating waste:
In open-landfills under the effects of temperature, humidity and micro-organisms, organic solid waste decomposes and produces gases (CH_4 - 63.8%, CO_2 - 33.6%, and other gases). It is estimated that the amount of CH_4 and CO_2 accounts for 3 - 19% of the total generated gases from open waste and landfills. For landfills, it is estimated that 30% of the gases generated from decomposition can escape to the surface without causing any impact. The process of transporting and storing solid waste also generates odours from the decomposition of organic substances which pollute the air. The gases generated from the decomposition of organic matter in solid waste include: stanched ammonium, rotten egg smelling hydro sulphur, rotten cabbage organic sulphur, stinking mecaptan, rotten fish smelling amine, mouldy meat smelling diamine, stanched chlorine, and snail-odour phenol. Currently, in peri-urban villages, irresponsible waste incineration activities have occurred. Rubbish in landfills (paper, wood, rubber, nylon, plastic, cloth, and other substances) when burned discharges gases

Street smog in the early morning
Source: Hannah Tims - ©Unsplash

into the environment such as: NO_x, CO, CO_2, SO_x, HCl, HF, Dioxin, Furan and ash.

In Ha Noi in 2019, over 4,000 tons of waste generated was every day, of which a small amount was treated and recycled in the Nam Son solid waste treatment complex (Sóc Sơn district), and Xuan Son (Son Tay town). Most of the remaining was untreated or buried in unsanitary landfills (these sites accounted for 85 - 90% of the total landfills - Dieu An, 2019) and burned in incinerators. Most of the solid waste incinerators do not meet gas waste treatment requirements, causing severe impacts on the air environment.

Straw burning and beehive coal cook stoves:
Straw burning mainly occurs in peri-urban districts of Ha Noi. Burning straw after harvesting covers both suburbs and inner city areas with a dense layer of straw smoke. For several days, this dense smoke layer restricts visibility on a large number of roads, even when the streetlights are on. Straw burning not only wastes energy and affects traffic safety, it also adversely impacts on the environment (in generating CO_2, CO, $PM_{2.5}$, PM_{10} dust, SO_2, CH_4 and other gases) and endangers human health.

Burning beehive coal cook stoves also contributes to air pollution by generating dust, including $PM_{2.5}$ and other gases such as CO_2, CO, SO_2, and PAHs. Moreover, these gases that cannot be dispersed in narrow areas make air pollution more serious. According to the Ha Noi Department of Environment Protection, as of 31/12/2019, the total number of beehive coal cook stoves has reduced by 58% compared to 2017, but over 23,000 remain in operation. Most of these stoves are used at street restaurants and bars around the inner city (Son Ha, 2020).

Other factors:
climate, topography, forest cover
Air quality, especially dust concentrations, is influenced by various factors including climate, topography, and greenery coverage. The fluctuation of PM_{10} and $PM_{2.5}$ in the cities in the north of Viet Nam depends heavily on climatic conditions. For instance, in dry and cold months in Ha Noi, the high concentration of dust is caused by the phenomenon of temperature inverse (hot air at the top and cold air at the bottom) which prevents air pollutants diffusing so that the concentration of pollutants in the air increases compared to the rainy and hot months. Topography also greatly influences the wind direction, affecting the spread of dust. Trees absorb CO_2, emit O_2 and absorb heat. Thus, the denser the greenery, the better the air quality.


Beehive cookstove being used on the sidewalk
Source: Quinn Ryan Mattingly - ©GIZ


Resident burning straw in a suburb
Source: Quinn Ryan Mattingly - ©GIZ


Waste being burnt along the roadside
Source: Quinn Ryan Mattingly - ©GIZ

A rare morning with a moderate amount of traffic
Source: Markus Winkler - ©Unsplash

IV. Recommendations for air quality management in urban areas

Based on the current situation and the causes of air pollution as mentioned above, the following technical, economic and policy solutions are proposed to improve air quality in urban areas, reduce pollution and enhance management effectiveness.

1. Control and limit the sources of dust pollution in urban areas:
Monitor construction works and encourage communities to consume clean fuel for cooking. Upgrade the quality of urban roads. Strictly control the transportation of goods and construction materials. Expand green areas in urban areas.

2. Control and limit the sources of dust/gas pollutants in suburbs/rural areas:
Control sources of emissions including minimising emissions from solid waste treatment (burning) and straw burning. Organise collection and treatment of solid waste, produce compost from crop waste and animal-raising activities, and develop a system to treat/reuse waste from husbandry. Promote communication, education, and awareness raising on the dangers of air pollution. Organise propaganda so people do not burn straw after harvests but dispose of waste in designated places. Instruct/recommend farmers to use pesticides at the right time and in the right way.

3. Control emissions from vehicles:
Promote the development of vehicles that use clean energy and non-motorised transportation. Continue to apply measures that reduce and improve traffic congestion. Effectively implement the application of Euro 3, Euro 4 standard; encourage factories to produce vehicles according to new standards; check vehicle models are in compliance with waste standards; implement inspection and maintenance programmes; restrict and then prohibit the circulation of vehicles that cause noise and emit various air pollutants into the environment.

4. Strictly control energy-intensive industries polluting the environment with dust and emissions:
The owners of industrial production firms must strictly follow emissions standards and strictly control emissions of dust and toxic exhaust (dioxin/furan, mercury, VOC). Production firms, businesses and service enterprises that generate large amounts of industrial gas emissions must install systems to reduce them before operation to meet air quality management standards. In addition, authorities need to provide guidance to control emissions from industrial production processes, and continue to adjust mechanisms and policies to create favourable conditions for businesses to access preferential capital sources for investment, installation and operation of waste treatment systems (including gas emissions). Authorities must also develop policies that encourage the import of gas exhaust treatment equipment and automatic and constant monitoring devices.

5. Encourage the use of Best Available Technology (BAT), Best Environmental Practice (BEP), and cleaner production in all industries:
Newly built production and business establishments must use BAT, or be restricted or prohibited from using outdated and backward production technologies in order to reduce energy consumption and mitigate air pollutants. Ongoing business establishments that emit large amounts of air pollutants must apply cleaner production methods and best environmental management as well as gradually upgrade their technologies to obtain BAT.

6. Add/revise the environmental technical standards (QCVN) for ambient air quality and specific industries:
The permitted thresholds in the Vietnamese technical standards on emissions of air pollutants for specific industries and on ambient air quality need to be revised to be stricter and more appropriate for monitoring. The standard system must be scientific, reasonable and close to international standards. Depending on each particular case, cities/provinces should be allowed to make more stringent requirements for air quality parameters compared to QCVN.

Using mobile phone app to monitor air quality
Source: ©GIZ

7. Strengthen the role of the management, monitoring and sanctioning authority of local authorities (communes, districts) and communities in areas where air polluting establishments are located. Local communities living near production sites are constant and close supervisors. Any changes in the environment in general and air quality in particular are recognised first by the local community. Therefore, if they are mobilised in environmental monitoring networks, enterprises will be compelled to comply with environmental protection measures more strictly.

8. Formulate regulations on responsibilities of agencies, officers and inspectors:
Develop inspections and specific sanctions for violations. At the same time, develop incentivising regulations and economic incentive policies for firms that properly apply measures to minimise air pollution and reduce emissions to below 30% compared to permitted national standards.

9. Develop regulations and evaluation tools to identify responsibilities and levels of damages for cases with multiple sources of pollution in the same area and trans-border impacts across districts and provinces. Develop regulations on penalties for actions that cause air pollution that impacts the economy and public health.

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Emissions from industrial factories
Source: Patrick Hendry - ©Unsplash

Economic benefits of improved air quality in urban areas from the perspectives of Ha Noi citizens

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I. Introduction

Air pollution is the most pressing environmental issue for cities across the world. According to the World Health Organization's (WHO) database on air pollution in 2018 , more than 80% of people living in urban areas suffer poor air quality. In Viet Nam, air pollution caused by dust is an emerging environmental issue in large urban areas (MONRE, 2017). The WHO's database 2018 on air pollution shows that dust concentrations in Ha Noi are higher than other Vietnamese cities. In 2009, pollution from vehicles emissions in Ha Noi caused 3,200 deaths, which is more than the number of traffic fatalities (Hieu et al., 2013).

Ha Noi is facing an increasingly worrisome issue. In comparison to other cities in Viet Nam, air pollution, particularly dust pollution, is considered to be more serious (Luong et al., 2017). The sources of pollution in Ha Noi include emissions from vehicles, construction, people's activities, and industrial production activities. According to Ha Noi's Department of National Resources and Environment, 70% of dust and smoke causing pollution in Ha Noi is from transportation (box 2.1. MONRE, 2017).

Dust pollution is one of the most conspicuous environmental issues in Ha Noi. PM (Particulate Matter) dust is a mixture of solid and liquid particulate matter. PM_{10} is fine dust with a diameter of 10 µm or less. $PM_{2.5}$ is fine dust with a diameter of 2.5 µm or less. According to Blume et al. (2017), and Thu and Blume (2018), the average $PM_{2.5}$ concentration in 2016 recorded at the US Embassy monitoring station (on Lang Ha Street, Ba Dinh, Ha Noi) reached 50.5 µg/m^3. In 2017 it was 42.6 µg/m^3, which was much higher than the national standard (25 µg/m^3) and the WHO's recommended limit (10 µg/m^3).

The forms of CO, NO_2, SO_2, O_3 emissions are derived mainly from motorized vehicles; thus the areas with intense traffic density are the places with the most intense pollution. According to the National Environmental Situation Report 2016, the concentrations of CO, NO_2, and SO_2 pollutants in Ha Noi were within the limits of QCVN 05:2013. However, the concentration of NO_2 has tended to increase in recent years. The concentration of CO often increases at peak hours. For instance, data from the monitoring station in Nguyen Van Cu Street (Gia Lam, Ha Noi) in 2015 showed that the highest concentration of CO for the day was at 8:00 - 9:00 in the morning with up to above 3,500 µg/m^3. The average SO_2 concentration in Nguyen Van Cu station has gradually increased, from below 10 µg/m^3 in 2012 to a high of 30 µg/m^3 in 2015; it then decreased to about 22 µg/m^3 in 2016.

The health impacts of air pollution on Ha Noi citizens are considered to be serious. Hieu et al (2013) calculated the number of fatalities due to PM_{10} pollution from transportation was 3,200, more than the number of traffic-related deaths. During 2010 - 2011, PM_{10}, $PM_{2.5}$ rose to 10 µg/m^3 in Ha Noi, and the number of children's hospitalisations of respiratory-related diseases increased accordingly (Luong et al., 2017). During the period 2007 - 2014, if the average concentration of NO_2 for 7 days increased to 21.9 µg/m^3, the number of hospitalisations for pneumonia rose by 6.1% (Nhung et al., 2018).

In order to minimise air pollution, in June 2016 the Government of Viet Nam issued the National Action Plan on Air Quality Management. In recent years, Ha Noi has made efforts to deploy several measures to minimise

[1] *The WHO's database on air pollution provides information on dust pollution to 4000 cities in 108 countries during 2008 - 2017 (http://www.who.int/airpollution/data/cities/en/, viewed on 10/8/2018)*

Emissions from industrial factories
Source: ©Pexels

air pollution, including piloting buses using compressed natural gas CNG, planting one million trees by 2020, and installing more air monitoring stations. However, air pollution is still a worrisome issue for people in Ha Noi, and requires more effective measures.

This article will present the results of a survey of 1,028 households in Ha Noi on measures to minimise air pollution that people expect to be prioritised. At the same time, the paper also shows an estimation of economic benefits based on people's willingness to pay for an improvement in air quality. The data on people's wishes might be useful for the development of policies to improve air quality that serve the needs of the people.

II. Survey of Ha Noi citizens on minimising the impacts of air pollution

Introduction

The people's opinions are a crucial source of information to develop feasible policies. Based on a review of international experience, the research team designed the options for solutions, and conducted a survey of Ha Noi residents' opinions on measures to reduce air pollution, which they then prioritised. In June and July 2019, the survey was organised with direct interviews at households in Ha Noi. A total of 1,028 people (heads of households) were interviewed.

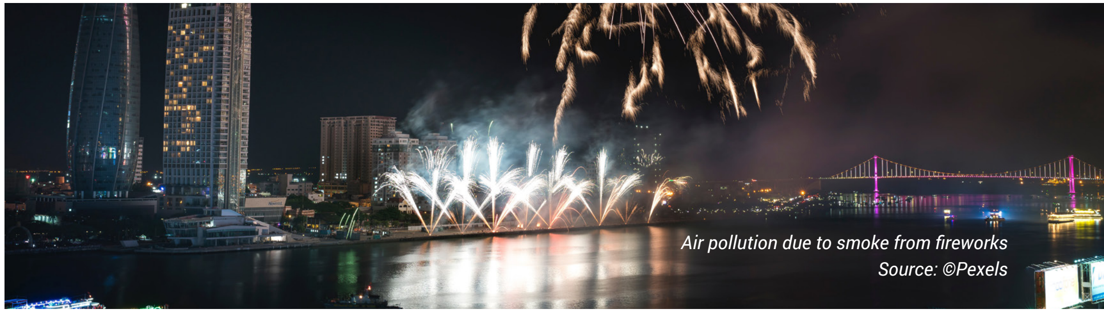
a. Prioritised solutions chosen by residents

The interviewees were asked to prioritise three options in the list of solutions to reduce air pollution. The solutions that Ha Noi residents prioritised are presented in Table 1. The groups of three solutions Ha Noi residents prioritised are: (1) increasing the number of trees; (2) switching to clean fuel that causes less pollution; and (3) improving public transportation.

b. International experience on measures favoured by Ha Noi residents

Table 1. Percentage of preferred measures to improve air quality

No	Solutions	Ratio of selection
1	Increasing the number of green trees	73%
2	Switching to clean fuel that causes less pollution	50%
3	Improving public transportation	43%
4	Strictly applying standards on motor vehicle emissions	33%
5	Developing advanced air quality monitoring systems	30%
6	Applying measures to control traffic, such as speed limits and restriction of traffic in inner cities	16%



Air pollution due to smoke from fireworks
Source: ©Pexels

In this section, existing international experience on implementation of the measures preferred by Ha Noi citizens is considered. This will help strengthen the credibility of people's opinions for consideration in policy making.

Urban green spaces, such as parks, rooftop gardens, roadside greenery and tree walls provide a wide range of ecosystem services for cities (Wolch et al., 2014). Several major cities in the world are making efforts to expand green space. Seoul has recently developed gardens; Melbourne plans to double its green areas to reach 40% by 2040; and Milan plans to extend its green space by planting three million trees (Whiting, 2018). Recent studies indicate that green space can protect residents from some pollutants. Pollutants such as PM_{10} (Gómez-Moreno et al., 2019; Rafael et al., 2018), $PM_{2.5}$ (Yang et al., 2015), NO_x (Klingberg et al., 2017; Yli-Pelkonen et al., 2017) and O_3 (Klingberg et al., 2017; Sicard et al., 2018; Yli-Pelkonen et al., 2017) can be reduced at locations near green spaces. In Strasbourg urban trees remove one ton of CO, 14 tons of NO2, 56 tons of O_3, 12 tons of PM_{10}, 5 tons of $PM_{2.5}$ and 1 ton of SO_2 each year (Selmi et al., 2016). However, the development of green space should take the dimensions of green tree-fences into account, directions and speed of wind, as well as the density of tree species (Abhijith et al., 2017; Janhäll, 2015).

Switching to consume fuel that emits less carbon and to electric vehicles (EVs) is also one of the most popular solutions. Brazil made a significant change to ethanol – a lower carbon fuel produced from sugarcane – in 1975; nowadays, Brazil has a large fleet of cars using sugarcane-based ethanol (Cortez and Baldassin, 2016). Norway set a target to end sales of vehicles powered by fossil fuels by 2025 (Reuters, 2018). France intended to obtain a similar goal by 2040 (Reuters, 2019) and China aims to electrify 20% of new vehicles by 2025 (Reuters, 2017). Switching to compressed natural gas (CNG) is popular for public transportation. The Los Angeles Metro completely transferred to CNG buses in 2013 and New Delhi implemented a similar policy in 2001 (Chong et al., 2014). The implementation of such policies has a significant impact on vehicle emissions. A recent review article concludes that the switch to electric vehicles has the potential to reduce emissions that cause air pollution (CO, NO_x, VOC, SO_2) (Requia et al., 2018). Other studies show that the switch to electric vehicles probably reduces emissions of $PM_{2.5}$ (Pan et al., 2019) and O_3 (Schnell et al., 2019). In comparison to buses using diesel, some studies show that CNG buses have lower CO emissions, NO_x (Geng et al., 2013; Vojtíšek-Lom et al., 2018), SO_2 and PM dust (Geng et al., 2013).

Public transport systems, which carry large loads of passengers daily, is an environmental-friendly option. Among public transport systems, the bus rapid system (BRT) has been deployed throughout Latin and South America, Southeast Asia, China, and Australia (Deng and Nelson, 2011), and has become more popular in Europe (Ingvardson and Nielsen, 2018). Several studies show that BRT can reduce emissions of CO, NO_x, $PM_{2.5}$ and PM_{10} (Bel and Holst, 2018; Chen and Whalley, 2012; Zheng et al., 2019). Increasing the frequency of services can make positive impacts on the reduction of CO_2, NO_x (Lalive et al., 2013). Nevertheless, it should be noted that if there is no change in regulations for urban transportation (for example, restriction of private vehicles), public transport may not improve air quality (Beaudoin and Lawell, 2017; Rivers et al., 2017).

III. Estimated economic benefits for Ha Noi residents from improved air quality

Air quality is a non-marketed goods, so the market price is not available to measure its value to consumers. In order to estimate the economic benefits of improved air quality to residents, a survey on public opinions was conducted. The respondents made decisions based on a hypothetical market, which was designed to collect information on people's willingnesss to pay (WTP, Willingness-To-Pay) for different levels of air quality improvement. The level of WTP selected is a measure of the economic benefit they feel represents air quality improvement. In this study, economic benefit is estimated by WTP levels for health improvement levels (particularly, reduction in the risks of air polltion-related motalities and diseases) and the levels of improvements for expanding urban green areas. This is an approach adopted by Choice Experiment (CE, Choice Experiment). An example of an alternative question is shown in Figure 1. Respondents can choose Option A or Option B or Disagree with both A and B.

Each respondent was asked to answer 6 questions with 12 different options. The options represent different levels of improvements on reducing health risks and increasing green areas. The levels of improvements are shown in Figure 2.

Figure 1. An example of an alternative question

	Option A	Option B
HEALTH RISKS of air pollution related diseases:	Among 100.000 people, it includes: **150 people** hospitalised (**200 people less** than current status)	Among 100.000 people, it includes: **350 people** hospitalised (**0 people less** than current status)
Among 100.000 people, it includes: Number of sick people hospitalised Number of deaths Others	**35 people** died (**15 people less** than current status) 	**35 people** died (**15 people less** than current status) 
URBAN GREEN areas	**18m²** per person (**10m²** larger than current status)	**13m²** per person (**5m²** larger than current status)
FEES must be paid via electric invoices from 2020	**15 thousand VND/month** (=180 thousand VND/month)	**85 thousand VND/month** (=1.020 thousand VND/month)

Open waste-burning along the roadside
Source: Quinn Ryan Mattingly - ©GIZ

Figure 2. Levels of air quality improvement

Properties	Status	Levels of improvement
Health risks of air pollution related diseases:	**Among 100.000 people, it includes:**	
Number of sick people hospitalised due to air pollution related diseases	350 people	350; 250; 150 people
Number of deaths due to air pollution related diseases	50 people	50; 35; 20 people
Urban green areas	8 m^2 per person	8; 13; 18 m^2 per person
Fees must be paid via electric invoices from 2020	Not applicable	15; 50; 85; 120 thousand VND/ month = 180; 600; 1020; 1440 thousand VND/year

Figure 3. Results of the Choice Experiment survey by Ha Noi residents

	Coefficient (β)	Deviation
Constant	0.46378***	0.06421
Risk of hospitalisation due to air pollution	-0.00306***	0.00026
Risk of death due to air pollution	-0.02364***	0.00177
Area of urban greenery	0.05526***	0.00523
Fee charge	-0.01509***	0.00057
Coefficent R^2	0,09	

Figure 4. Results of WTP (VND/month) of Ha Noi residents for each type of benefit from improved air quality

	WTP	Deviation
Reduced 1/100,000 sick people hospitalised due to air pollution	203***	0.01835
Reduced 1/100,000 deaths due to air pollution	1566***	0.12974
Area of urban greenery (1m^2/person)	3661***	0.35802

Figure 5. Results of WTP (VND/month) of Ha Noi residents for each programme from improved air quality

	WTP	Deviation
Medium improvement programme	62.084***	3.74299
Maximum improvement programme	124.169***	7.48598

*Note: *** is statistically siginificant at the significance level of 0,01 (adapt for Figure 3, 4 and 5)*

1,028 households were surveyed. The results estimating the econometric model of people's choices are shown in Figure 3. The variables in the model are statistically significant and are as expected. The interviewees preferred to select the improvement options with low health risks (particularly, the number of sick people hospitalised and the number of dealths per 100,000 people are low) and the area of greenery per capita was high. The low cost improvement options were also more likely to be chosen by the respondents.

People's WTP level for each type of benefit from improved air quality, such as reduced risk of hospitalisation, reduced risk of dealth from air pollution, and increased areas of greenery is shown in Figure 4. Total WTP for a comprehensive (simultaneous improvement of all types of benefit) is presented in Figure 5. The WTP level in Figure 5 is estimated for the two following types of comprehensive programmes:

+ Medium level: the number of sick people hospitalised was 250 people/100,000; the number of deaths was 35 people/100,000; and the area of greenery was 13 m^2 per capita.

+ Maximum level: the number of sick people hospitalised was 150 people/100,000; the number of death was 20 people/100,000; and the area of greenery was 18 m^2 per capita.

IV. Conclusions

In the study, the respondents expressed their willingness to pay, thereby reflecting the economic benefits that they felt represented improvements in air quality in Ha Noi. Ha Noi residents expressed a strong interest in expanding green spaces and reducing the number of deaths related to air pollution. The average WTP for an increase of 1 m^2 of green area per capita is estimated at 3,661 VND per month, and in order to reduce 1/100,000 deaths from air pollution, WTP is about 1,566 VND per month. Ha Noi people seem to be willing to pay 124,169 VND monthly for the maximum benefits of air quality, which is approximately 0.9% of household income.

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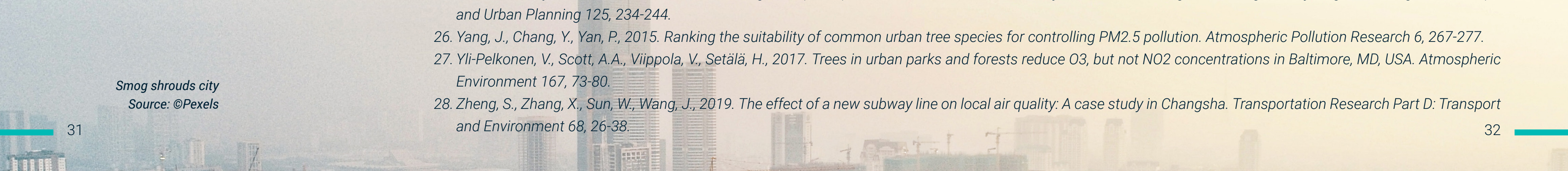

Smog shrouds city
Source: ©Pexels

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Efforts to control urban air pollution in Beijing, China and some policy implications for Viet Nam

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I. Background

Facing environmental issues, especially increasing air pollution, the Government of China has implemented a variety of measures. The pollution control programme is implemented by the State Council, the Law on Air Quality was fully revised in 2015, and several new sanctions have been legislated; particularly, allowing the government's environmental agency to apply strict penalties and confiscate the assets of polluters. Companies that violate the law will be "named and charged" and the companies' leaders can be sentenced to 15 days in prison. Especially, there is no ceiling imposed on sanctions, but depending on the seriousness of violations, different levels of sanctions are applied. This has dealt with the previous situation where due to the ceiling of sanctions, several violating companies paid fines rather than invest in emissions treatment systems and controlling measures. The new Law on Air Quality consists of 70 articles replacing 47 articles as regulated in the previous law. The new law also lists more than 300 groups of organisations and individuals who can initiate lawsuits on behalf of those affected by pollution in order to strengthen the capacity to enforce and monitor the law on environmental protection, especially controlling air pollution. Based on the national law, localities, especially Beijing, have implemented specific measures to control air pollution. According to a report by the United Nations Environment Programme (UNEP), in 1998, Beijing was known as the world's most air polluted city (UNEP, 1998). To deal with air pollution, Beijing implemented several programmes and projects including a comprehensive air pollution control programme in 1998. This programme was financially and technically resourced, especially with political will and the participation of the whole of society (Jiang et al., 2015; Zheng et al., 2018).

For over 20 years (2019), Beijing has simultaneously implemented a wide range of measures to control air pollution, such as: (1) optimizing energy infrastructure; (2) controlling pollution from coal-burning; and (3) controlling emissions from vehicles. Beijing's efforts have been successful in reducing air pollution. For 5 years from 2013 - 2017, fine dust pollution ($PM_{2.5}$) in inner city Beijing was reduced by 35% and in suburbs by 25% (UNEP, 2019). For further information on Beijing's measures and implementation approaches during the last 20 years, this article will focus on analysing emissions control solutions and present policy recommendations for air pollution control in Viet Nam, especially for large cities such as Ha Noi and Ho Chi Minh City.

II. Beijing's Air quality protection programme

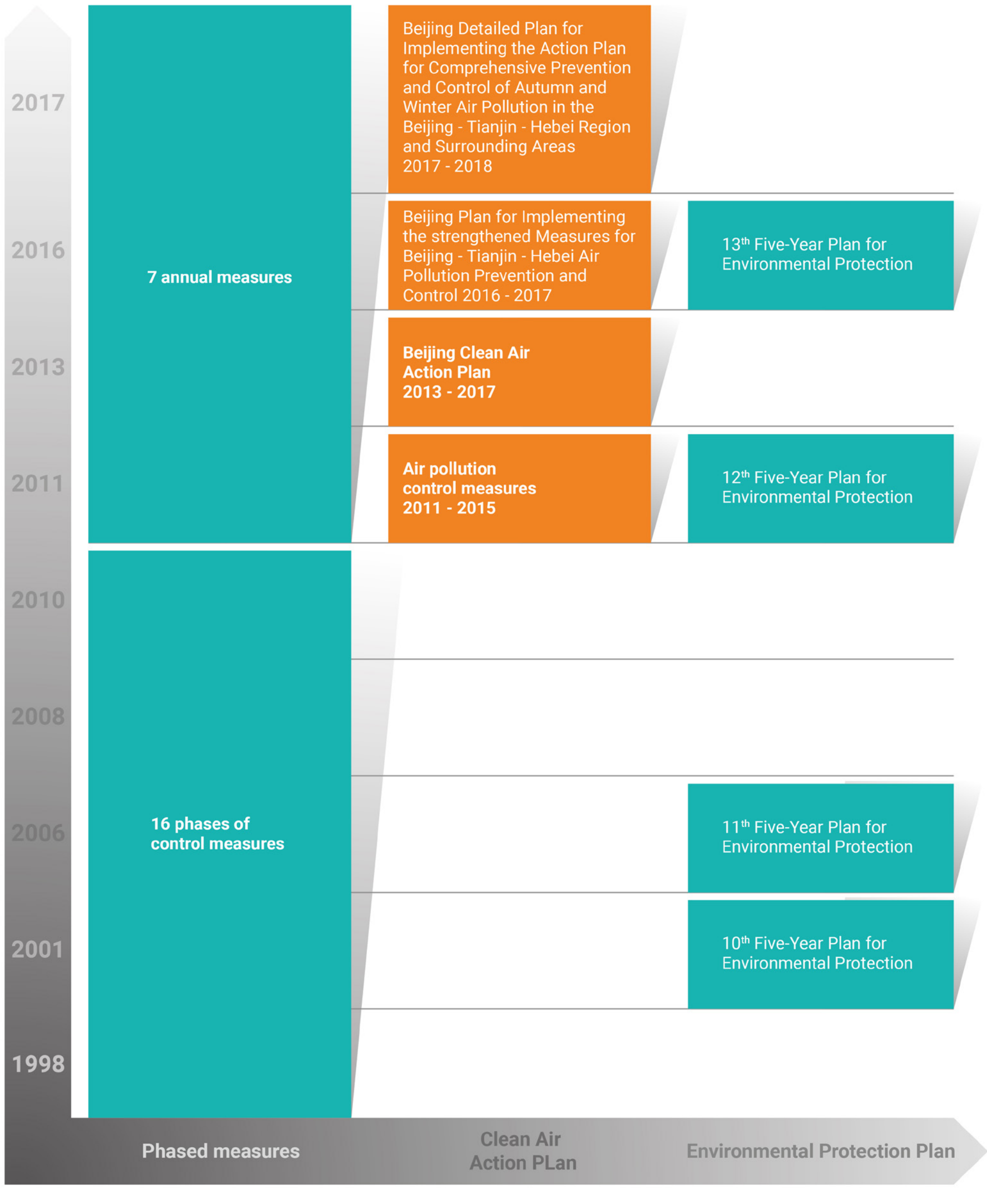
Since 1998, air quality data and forecast results have been published. Firstly, Beijing publishes its weekly air quality report. The city has improved the quality of air quality data (the coverage of data by place and time) through upgrading the air quality monitoring network. According to the United Nations Environment Programme (2013), in 2001 Beijing started publishing daily air quality reports and forecasts focusing on 3 main pollution parameters: SO_2, NO_2 and fine dust PM_{10}. Air quality forecasting became a crucial task during preparation for the Olympic Games in 2008. To ensure air quality and attract athletes and tourists, Beijing expanded and improved its air quality monitoring network and strengthened its capacity to monitor, analyse and use data. The air quality forecasting system was developed with three main components: (i) a statistical forecasting model; (ii) a numerical forecasting model; and (iii) experts of modelling in order to give results on time and with high credibility. Air quality control activities are implemented by the Beijing Municipal Bureau of Environmental Protection[1].

[1] *Its name is has been changed to the Beijing Municipal Ecological Environment Bureau*

Emissions from industrial factories
Source: ©Pexels

Figure 1. The process of developing Beijing's Air Pollution Control Plan from 1998 to 2017

Source: UNEP, 2019



From 1998 to 2017, Beijing carried out various tailored measures to fit specific periods of time. Accordingly, from 1998 to 2010, Beijing focused on implementing 16 basic measures to control air pollution. In 2011, Beijing implemented the Clean Air Action Plan along with the 12th five-year environmental protection plan (2011 - 2015) and the 13th five-year environmental protection plan (Figure 1). This clearly shows that, in the early stages, Beijing focused on monitoring, forecasting and gradually improving air quality without taking the issues of clean air or large-scale investment into account. This is obviously reflected in the investment budget to control air pollution in Beijing: before 2011, annual investment was only RMB 3 billion, but from 2013, the investment increased by many times. By 2017, Beijing was spending approximately RMB 18 billion on air pollution control (Figure 2).

Measures to control air pollution in Beijing

To control air quality, Beijing introduced some major groups of measures such as adjusting energy structure and controlling emissions from coal-burning; adjusting transportation structure and controlling mobile emissions sources, and other measures such as improving the quality of fuel, especially oil and combustion gases.

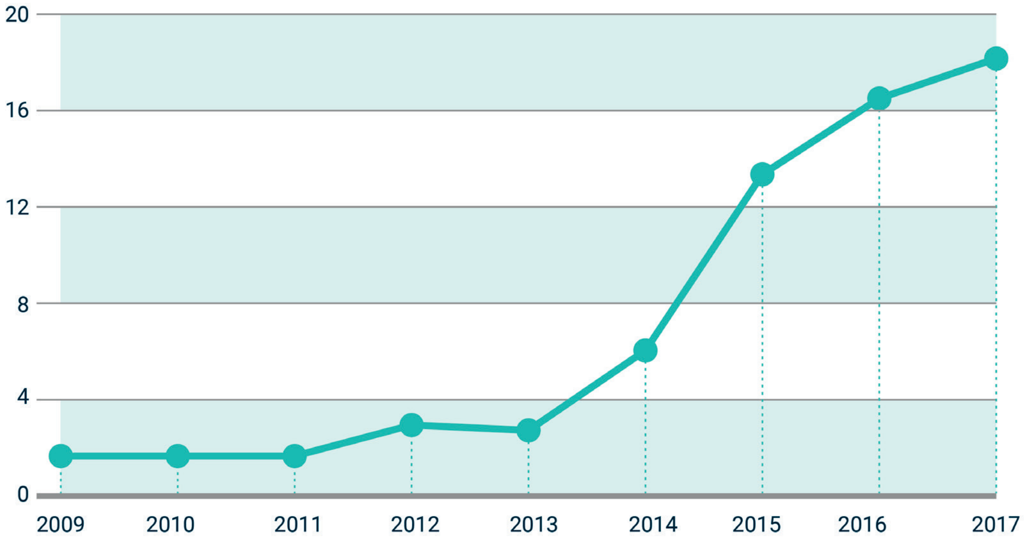
Adjusting energy structure and controlling emissions from coal-burning

Coal has been a crucial source of energy for Beijing for so long, especially for coal-fired power plants, industrial production plants, cooking and heating. Since 1998, Beijing has made efforts to upgrade the End of Pollution (EOP) and adjust the energy-use structure. Accordingly, the use low-sulphur coal was prioritised and the use of alternative clean energy sources such as natural gas and electricity was increased. Beijing made great strides adjusting the energy structure. For example, during 2013 - 2017, coal consumption reduced from 28 million tons to below 5 million tons and use of alternative clean energy increased by more than 90% (UNEP, 2019).

In order to achieve energy structure adjustment, Beijing implemented several concrete measures such as reducing emissions and replacing clean energy sources in power plants, which was a major source of coal consumption. Before 2005, Beijing implemented projects that enhanced control of End of Pollution (EOP) for thermal power plants to reduce SO_2 emissions, dust and other pollutants. Since then, Beijing has begun to switch from coal to gas for thermal power plants and gradually increased the consumption of natural gas. This has contributed considerably to the reduction of coal consumption in the energy sector while the amount of electricity produced has increased to meet demand. According to UNEP (2019), the amount of coal used in energy (thermal power), which reached a peak in 2005 (nearly 9 million tons per year), decreased to approximately 6.43 million tons in 2013. In spite of decreased coal consumption, however, in order to meet electricity needs, the amount of consumed natural gas increased to 1.85 billion m^3 in 2013 accounting for 35% of total fossil fuel use in energy sector. The energy structure adjustment was strengthened after the implementation of the Beijing Clean Air Programme 2013 - 2017 (Beijing Municipal Government, 2013). From 2013 - 2017, Beijing built 4 large thermos-electric centres to replace coal-fired power plants, helping to cut consumption by nearly 8.5 billion tons of coal every year.

Figure 2. Budget for air pollution control in Beijing from 2009 - 2017 (billion RMB[2])

Source: Beijing Municipal Bureau of Finance, 2018



By 2017, the energy sector had almost eliminated coal-use; instead 7.4 billion m^3 of gas was consumed. As a result, the share of natural gas in the total amount of fossil fuel consumed in the energy sector increased to 85%. The reduction of coal consumption in thermal power plants helped significantly decrease the emission of pollutants. Besides, the long process to improve coal-boilers became a crucial responsibility for Beijing in controlling air pollution. Beijing has carried out several activities to develop non-coal technology since 1998, making an effort to replace coal-fired boiler technology with gas. During 2013 - 2017, the total amount of 27,300 MW of electricity using coal-fired boilers was replaced; annual coal consumption decreased to about 8.5 million tons. Coal-fired boiler technology was improved in four stages by region and priority. In 2007, coal consumption was basically replaced in the entire metropolitan area of Beijing.

In addition to eliminating the use of coal at coal-fired power plants, Beijing implemented measures to end the use of coal in daily activities. Specifically, from 1998 - 2017, Beijing continuously upgraded central heating systems to reduce the majority of coal consumption by replacing coal with natural gas, electricity and other kinds of clean energy in household heating systems. So far, Beijing has completed the replacement of heating systems for about 700,000 households and achieved the objective of a city centre without coal at the end of 2015 (UNEP, 2019). In addition, since 2015, the control of coal consumption has expanded to the suburbs and rural areas and the use of coal for heating and cooking has been replaced with clean energy. As a result, coal consumption has been reduced by nearly 1 million tons and the use of coal in 6 central districts and in southern suburbs has basically been eliminated.

Adjusting transportation structure and controlling mobile emission sources

Since 1998, Beijing has considered controlling emissions from vehicles a crucial responsibility and reviewed more than 30 emissions standards for new vehicles, vehicles under operation, and petrol quality (UNEP, 2008). In 2008, an integrated system of vehicle emissions controls at petrol stations was developed and continuously improved during 2013 - 2017. Accordingly, the programme to remove old vehicles through subsidies was established and in 2016 all vehicles with yellow-label certificates (those vehicles that did not meet emissions standards) were withdrawn. There were policies to restrict the use of motorcycles, large trucks and vehicles that did not meet the emissions standards (yellow-labelled vehicles), and to encourage the use of LPGuses, and electric buses and taxis. One policy banned the use or cars one day per week. Besides, Beijing implemented the fuel quality standards 'China 5/V' in June 2012 and 'China 6/V' in January 2017.

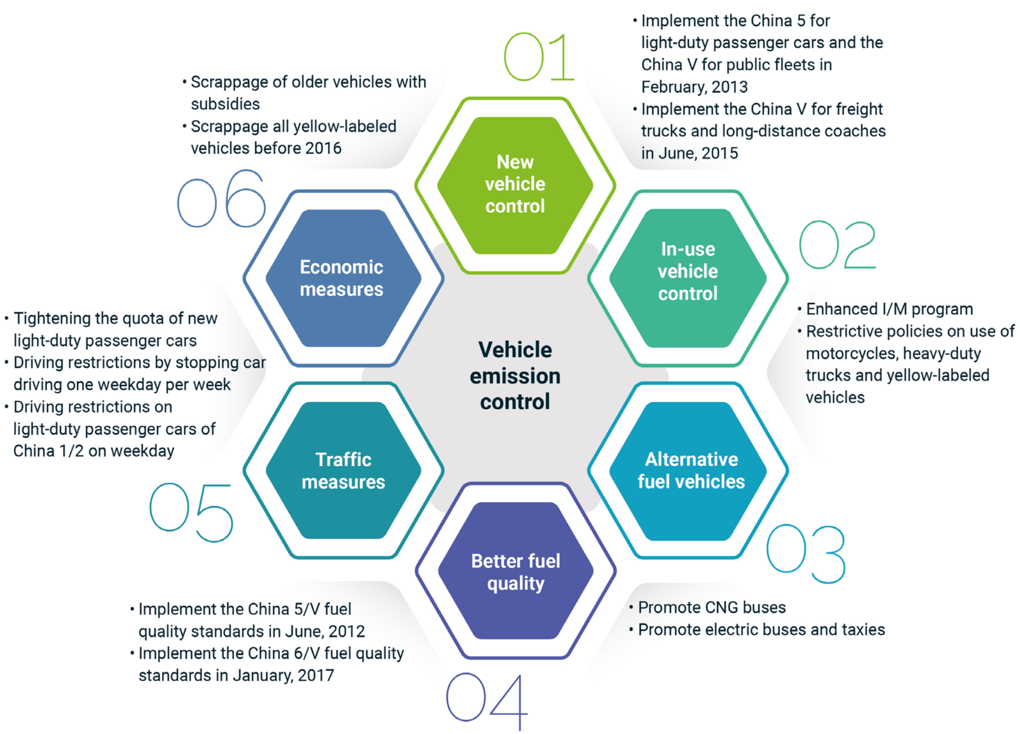
To control air pollution from mobile sources, especially from vehicles, Beijing simultaneously carried out 6 groups of solutions which included: (1) controlling new vehicles; (2) controlling vehicles in operation; (3) vehicles using alternative energy; (4) fuel quality; (5) regulating traffic; and (6) economic measures (Figure 3). Those groups of solutions include technical measures such as emissions standards (for new vehicles, vehicles in operation, alternative fuel, or regulating traffic) or economic measures such as assistance to eliminate old vehicles and vehicles with high emissions coefficients. Among the above-mentioned solutions, the specific measures are as follows:

(1) Adopting strict emission standards and improving vehicles: In January 1999, Beijing became the first city in China to adopt 'China I' emission standards for vehicles using light gasoline. In February 2013, Beijing was the leading city to adopt emission standards 'Beijing 5/V' (equivalent to emission standards Euro 5/V) and closed the gap in emission standards for vehicles in the developed cities of Europe and North America. Over the past two decades, Beijing has made great strides in controlling emissions of new vehicles and has promoted the advance of energy-saving technology in the Chinese car industry. Along with tightening emission standards, Beijing has also added several measures to reduce emissions from motor vehicles. Within 20 years, the improvement process for public transport was implemented in 4 stages.

In 1999, Beijing began to address the reduction of CO, THC, and NO_x emissions of vehicles using gasoline, and nearly 200,000 cars were upgraded. In 2008, the furnished Diesel Particulate Filter (DPF) cleaner was implemented with a total of 10,000 upgraded vehicles. In 2015, 8,800 China IV/V diesel buses were equipped with NO_x reduction systems. Since 2016, 8 groups of public service vehicles (including: public transport, sanitation, postage, scrap trucks, school

[2] *Exchange rate in 11/2019, 1 yuan = 3,320 VND*

Figure 3. Measures to control emissions from vehicles



buses, tourist buses, airport shuttles, garbage trucks) have been equipped with diesel particulate filters. By the end of 2017, a total of 17,000 vehicles were equipped with Diesel Particulate Filtering cleaners (UNEP, 2019).

(2) Removal of outdated and polluting vehicles: In Beijing, yellow-labelled vehicles have been restricted from operating on Ring Road 2 since 2003. During the Olympic Games, this kind of vehicle was banned throughout the city. In 2010, the limit for yellow-labelled vehicles was expanded to the 6th Ring Road and has been banned throughout the city since December 2015. Since 2017, the emissions standards China I and China II have restricted vehicles using petrol. Light oil can only be used outside the 5th Ring Road. Heavy diesel trucks have also been restricted from operating inside Ring Road 6. Since 2009, to promote the replacement of high emissions vehicles, Beijing has implemented a government subsidy programme to remove outdated and highly-polluting vehicles. During 2013 - 2017, Beijing removed 1.7 million outdated vehicles, which was higher than the original target.

(3) Other solutions

The solutions controlling mobile sources also include upgrading fuel quality, encouraging the use of gasoline and diesel, encouraging the use of vehicles using new energy, optimising transportation infrastructure, restricting the purchase of new vehicles, and strictly controlling transportation. For example, regarding upgrading fuel quality, Beijing began to improve fuel quality in the late 90s and became China's top city consuming unleaded gasoline in 1998 and the first city adopting fuel quality standards China II to V associated with upgrading fuel standards for new vehicles. In January 1997, Beijing once again took the lead in adopting fuel quality standards China VI with strict environmental criterial for consuming gasoline and diesel. For new vehicle development, since 1999, Beijing has introduced natural pneumatics technology to the Bus Association and encouraged the Association to switch to clean energy and new energy-sufficient buses.

With 2,306 buses upgraded in 2016, of which 1,368 electric buses account for 59%, optimising transportation infrastructure, optimising urban planning and public transport development such as buses and subways, transportation infrastructure has been significantly improved during recent years. Particularly, the number of people using trams increased considerably from 1 - 2% in 2000 to over 20% in 2016. Meanwhile, the number of people using private cars reached a peak in 2008, and then gradually decreased accounting for only 30% of passenger transportation. The improvement of the transportation system structure has been effective in mitigating emissions and reducing traffic congestion during peak hours.

In 2016, monitoring methods were improved and integrated with new technology, such as combining with new-generation remote sensing materials with high resolution, vertical radar networks, and meteorology monitoring systems with high accuracy. The new technology allows the mainstreaming of air-land measurement systems into the monitoring network with greater analytical capacity. At the same time, based on big data technology, Beijing has analysed and developed independently smart air quality sensors associated with building new networks and air quality control models. With these technologies, Beijing has developed a network of more than 1,000 air sensors to monitor ultra-fine dust $PM_{2.5}$ at a low cost and high surveillance density. The system can accurately identify $PM_{2.5}$ concentrations and support the assessment of air quality in 325 areas in Beijing.

Controlling air quality in other sectors

a. Restructuring the industrial sector and controlling industrial pollution

Focusing on the functional direction of the city, Beijing has taken comprehensive measures to optimise the structure of the industrial sector and reduce pollution from industry including tightening environmental requirements for new projects, removing outdated manufacturing technologies, treating polluting enterprises, promoting clean production, and enhancing end-to-end of production (EOP) control. Since 2006, a wide range of new large-scale industrial factories such as Beijing Cup and Chemical Factory, Shougang Shijingshan Factory, Beijing Steel Group and Dongfang Chemical Factory have been closed and relocated; the number of cement production factories decreased from 19 to 2, with the remaining factories only used for integrated treatment of harmful waste. Since 2013, more than 1,900 polluting businesses from printing, molding and furniture industries have been closed or relocated, and 11,000 polluting enterprises have been identified and treated in various ways. More than 400 projects have been

Figure 4. Beijing Ring Road Map

implemented with a focus on controlling the pollution of NO_x and VOC. Besides, Beijing has actively promoted the development of high-technology industries and services, increasing the proportion of these industries from 67.4% in 2001 to 80.6% in 2017, equivalent to the average level of developed countries.

b. Controlling dust pollution

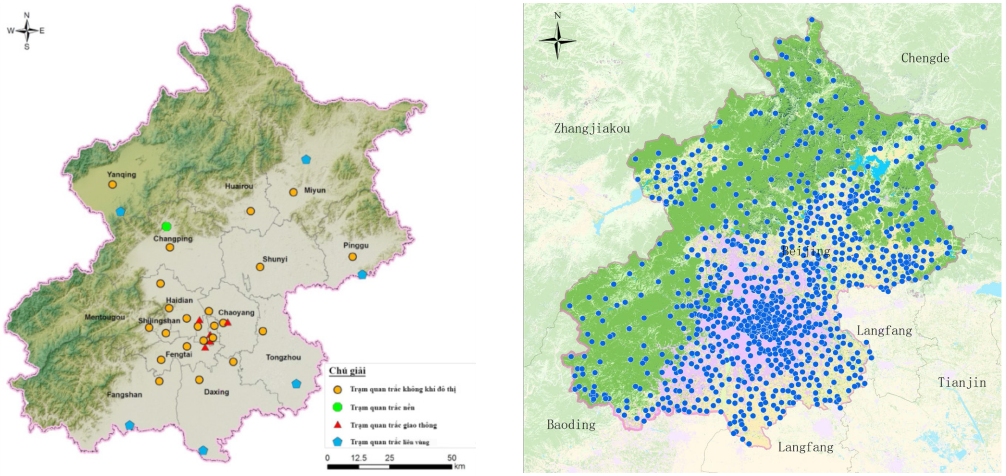
Over the last 20 years, the urbanisation rate for Beijing has grown rapidly; dust pollution has become obvious due to the increasing number of large-scale and wide-scale construction activities. Beijing has continued to improve its pollution control system and focused on bare land, construction sites, and dust-on-road to control pollution more effectively. A video surveillance system for dust pollution has been installed in more than 1,700 construction sites and 155 concrete batching plants across the city. Those concrete batching plants that could not meet the requirements were closed.

The management model of green and civilized construction has been developed with new and effective washing and dust removal technology. For the control of road dust, in 2013 more than 8,000 garbage trucks were renovated and covered, and the amount of dust in main roads was monitored with results published monthly. New technologies in dust vacuum, sweeping and collection were applied in 88% of the city's streets, which helped reduce dust emissions in the city. Besides, to enhance and expand environmental resilience, Beijing launched a tree planting programme of 66,667 ha increasing green coverage by more than 66%. In addition, Beijing tried to expand its surface water areas of the Vinh Dinh River (Yongding), Chao Bach River (Chaobai) and the canal system in the north, creating a natural ecosystem including green shields in the mountains, green buffers in the suburbs, and greening urban areas (UNEP, 2019; Zhang et al 2018).

In addition to the above-mentioned technical measures, in order to enhance effectiveness and efficiency of air quality control regulations, Beijing has carried out a series of communications programmes to raise awareness and encourage the participation of society. Since 2013, Beijing has published information relating to air quality including current concentrations of six major parameters of air pollution from 35 automated air monitoring stations, as well as publishing the results of evaluations, health guidelines, and air quality forecasts. Platforms publishing the information include new media: webpages, Weibo, Wechat and other mobile applications, as well as traditional media such as television and radio (UNEP, 2019).

Acknowledging the importance of community participation in environmental protection, especially air pollution, Beijing has strengthened environmental communication and education centres. These centres have been equipped with both traditional and modern media such as newspapers, radios, internet, Weibo, and WeChat. At the same time, Beijing has promoted the development of online and live activities with the participation of the community, such as Beijing Environmental Culture Week and Beijing Green Media Conference. According to the Beijing Environmental Protection Department, more than 38 environmental education centres have been developed. Various forms of communications have been used to update environmental activity reports, interpret environmental policies, disseminate knowledge and propagate green ideas, as well as significantly raise awareness of the community

Figure 5. Beijing's automatic air quality monitoring network



through delivering information through scientific books, special television programmes and cartoons, and drama on the environment in general and air pollution in particular.

Different activities and events to raise awareness have been developed for different target groups. For youth and children, a series of environmental protection events; for example, a Debate Contest on the theme "I love the Earth" for primary and secondary schools and the Environmental Protection Art Festival for Beijing children. For photographers and animation enthusiasts, the launch of photo contests on the theme "Hand in hand in the blue sky, you and me" or design contests on animation have inspired participation. For those with cars, a series of activities with the theme "Green steering" was organised. Beijing began to appoint community environment ambassadors in 2013; so far there have been 10 ambassadors, 5 of which have been females acting as role models for the community.

Beijing has also established a system to receive feedback and recommendations on the environment such as a hotline, and an online mailing box. Those who report environmental violations, especially regarding the air environment, can receive a reward of up to RMB 50,000 (approximately VND 164 million). This is to encourage the community to participate in discovering and reporting environmental violations.

Therefore, it can be seen that to solve the issue of air pollution, Beijing has implemented several measures, including: controlling emissions sources, strengthening education and communication, developing automatic air monitoring systems, and greening the city. Accordingly, priority sectors have been identified and a roadmap, including the revision and supplementation of stricter legal regulations to control pollution, have been implemented. Beijing's achievements after 20 years implementing comprehensive air pollution control programmes conveys a clear message that if the whole political system and the entire society participate in solving environmental pollution, especially air pollution, success will come, bringing health benefits and the trust of the community.

IV. Policy implications for Viet Nam to enhance the effectiveness of air pollution control

The success of Beijing suggests Viet Nam should develop a comprehensive air control programme, especially in large cities.

- Before implementing an air quality control programme, the cities need to identify and prioritise the main sources of pollution to implement synchronous solutions. In addition, statistics and documentation of major emissions sources causing air pollution and information on air quality need to be promptly disseminated in order to strengthen monitoring by stakeholders.

- The establishment of air quality networks needs to study density, location and monitoring parameters. For instance, Beijing set up a basic system of monitoring stations, transportation, urban air, inter-regional stations, and intense density of $PM_{2.5}$ monitoring sensors in order to strictly control the sources causing air pollution using data analysis models to disseminate information. Also, visual monitoring systems for hotspots of high fine-dust emissions should be set up; for example, at construction sites and urban areas with high population densities.

- Large cities should also consider controlling vehicles, especially those that do not meet emissions standards, and installing emissions monitoring systems on buses using different kinds of fuel. In the next 5 - 10 years, it is necessary to develop and implement a regulation on traffic circulation days for certain central areas (for example, at least one day per week when private vehicles are not allowed to circulate).

Gate of Manifest Virtue, Forbidden City, Beijing
Source: Gigi - ©Unsplash

- Establishing a public data portal on the number of vehicles and the correlation of air quality as well as warnings on air quality on different media is essential. At the same time, a multimedia communications programme should be developed with timely dissemination of information to stakeholders, especially groups vulnerable to air pollution.

- Research to revise and supplement the Law on Environmental Protection 2014 and related legal documents should be conducted. Accordingly, it is necessary to complete legal provisions on ambient air standards and regulations for emissions consistent with international standards – sanctions need to be diverse and appropriate to the level of violation. Fines should be levelled depending on the severity of violations; fine ceiling levels should be removed. More specific provisions on the recall and disposal of old vehicles that do not meet technical standards on emissions should be imposed with subsidies for vehicle owners. In addition, regulations on the right to sue polluters (i.e. a representative of an organisation has the right to sue on behalf of an affected community) and specific provisions on promoting the application of industrial revolution 4.0 technologies to detect and solve air pollution should be developed. Legal regulations strengthening the role of civil society organisations, community and social communication in air pollution control should also be designed and implemented. Municipal governments can base legislation on environmental protection to issue detailed regulations that are applicable in accordance with local conditions.

In order to reduce emissions from private vehicles, municipal governments need to change the transportation structure and enhance public transport capacity (for example, highway systems, rapid bus routes, etc.).

Air pollution on the Nhat Tan Bridge, Ha Noi
Source: ©GIZ

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Expert's opinions about air pollution and solutions

There has been some information that environmental experts assert and raise warnings that air quality in Ha Noi and Ho Chi Minh City is at an alarming level and has a severe impact on people's health, which is making people living in Ha Noi worried.

To find out more, we interviewed **Ms. Luu Thi Thanh Chi - Deputy Director of the Environmental Protection Agency at the Ha Noi Department of Natural Resources and Environment.**

Reporter: Madam, can you please tell us how air protection measures are currently being implemented?

Ms. Luu Thi Thanh Chi: Since 2017, Ha Noi has called for socialisation on the environment, including air environment protection. Based on that policy, several enterprises have cooperated with the Ha Noi Department of Natural Resources and Environment to improve air quality, including VinGroup, which has supported the city to install automatic air quality monitoring stations. After installation and operation, these stations have provided stable and accurate data. These provide 24-hour monitoring data, which is published on the Ha Noi City and Ha Noi Department of Natural Resources and Environment websites, where residents can easily access the data.

Air quality in Ha Noi is currently calculated based on AQI regulated by the Ministry of Natural Resources and Environment and we still comply with these regulations. Those data are reliable for people to refer at this moment in Ha Noi city.

Reporter: There are 10 air quality monitoring stations in Ha Noi; some NGOs also have data from other stations. Can we use the data collectively?

Ms. Luu Thi Thanh Chi: We are expecting to expand the monitoring network. The project developing the network of monitoring stations will be completed by 2020 and has been approved by the People's Council and is currently in the investment process. By 2020, this project will be completed and integrated into the current network of 10 stations. The data will be transmitted to the Data Processing Centre at the Department of Natural Resources and Environment, which is located at the Environment Protection Agency.

Data sensors that are installed by individuals or organisations from different sources have not been verified. Several organisations send documents and devices to the Environment Protection Agency for calibration at the standardized monitoring station of the EPA. After calibration, these sensors will give reliable data.

And we will also expand that network on smart phone applications so that people can access the data. After calibration, the data are reliable and so the city's automatic monitoring network can be expanded.

Reporter: So are the data sources given by NGOs reliable, Madam?

Ms. Luu Thi Thanh Chi: I cannot confirm if the data from their monitoring stations are accurate or not; for example, the US Embassy has their own station but uses American standards. We comply with Vietnamese standards, so we have different ways of calculating AQI. In addition, the location of the stations is also important as it affects the data. For example, if the monitoring station is located in a residential area or green park area, the data is different to those located along roads. And we cannot take the data extracted from the monitoring station at a road to assess that Ha Noi's air quality is poor. We monitor air quality at different times and in different weather conditions. We have to keep track of the data for a long period of time and evaluate a series of data to give accurate results.

Exhaust gases from manual factories
Source: ©Pexels

Reporter: The rapid and hot economic development process is also one of the reasons causing air quality to worsen. In your opinion, what breakthrough solutions should we have to reduce air pollution and improve air quality?

Ms. Luu Thi Thanh Chi: From my point of view, Ha Noi has drawn a very detailed roadmap, which we are implementing as planned. We cannot rush to cut air pollution right away, and we need to follow the roadmap. Over the past two years, we have achieved the objective of planting 1 million trees, which has created a shade and air purifier system. We have communicated and advocated that people should not use beehive coal stoves and not burn straw in the fields. To minimise this behaviour, we will remove the risks of air pollution affecting human health and the community.

Reporter: Can you please tell us some solutions in the coming time to ensure air quality and improve the living environment of the capital's residents?

Ms. Luu Thi Thanh Chi: In the coming time, the City will invest in developing an automatic environmental monitoring network that is constantly synchronised throughout the city. With such a complete and comprehensive system of facilities and tools, the City's specialised agencies will have complete data, thereby helping us to accurately and scientifically assess environmental quality, especially the air environment. Specialised agencies will assess, analyse and identify the factors, levels, trends and the evolution of pollution to provide timely mechanisms and policies to control and improve air quality.

In addition, the City is also synchronising several measures to improve issues relating to transportation, such as planning, re-managing transportation (regulating the traffic flows of cars, motorbikes; restricting trucks, taxis in busy streets, increasing public transport). Currently, the City is researching to develop a roadmap to restrict motorbikes in some streets at peak hours to reduce traffic congestion.

Reporter: Thank you very much!

Resident burning dry grass along the road
Source: Quinn Ryan Mattingly - ©GIZ

Production of percussion tools at carpentry establishments
Source: ©ISPONRE

Vehicles circulating on dirt roads
Source: ©ISPONRE

Carpentry production worker on the sidewalk
Source: ©ISPONRE

Air pollution at the end of the day in urban areas
Source: ©GIZ

PHOTOS

Air pollution from human production and living activities in Ha Noi

1. De La Thanh area

Wood-trading shops on the side of the road, in addition to sawing and routing woods, produce wooden goods on-site.

The stench from both wood dust, created from all stages of wood processing such as routing and sanding, as well as from painting makes the small De La Thanh street already burden with a high volume of traffic suffer

2. Linh Nam area

Linh Nam road starts from Kim Nguu river to Ring Road 3 at the end of Thanh Trì bridge. This is a road with a very high level of traffic.

Although there are a great number of roadside eateries and shops, this area has received little attention from the city's urban planners. The residents freely make a living and dump their wastes and used water on the road, obstructing traffic and causing both damages to the surface and air pollution

Mr. Nguyen Van Khac

Thanh Tri District, Hoang Mai Province

Mr. Khac travels across Linh Nam area very often.

This populous area with a frequently high volume of traffic is very dusty when sunny and dirty when rainy. Due to the high number of roadside eateries and markets, people tend to sweep up the rubbish near the sides, causing the road to be flooded with rubbish when it rains.

He recommends to the People's Committee of Thanh Tri District a promotion of greater responsibility in rubbish collection and disposal in designated areas or waste carts in a timely manner. People should also refrain from fly tipping, causing road as well as city pollution.

Mr. Nguyen Van Khac
Source: ©ISPONRE

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