Investigation of Air Dust and Fine Dust of an Urbanizing Environment

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Abstract. Hanoi is the capital of the Socialist Republic of Vietnam. The city is developing according to the following scheme: there is a central region and surrounded by satellites (5 cities), which are connected to the center using a transport system such as rail, road, river roads, etc. A high pace of economic development will cause environmental problems. Air quality is deteriorating due to an increase in population, means of personal transport, industrial and other sources of emissions; and all this has a strong impact on human health and the environment. According to WHO estimates, Hanoi is the city with the highest levels of dust pollution with annual average values of PM10 and PM2.5, which are both high at 73.5 μg/m³ and 47.45 μg/m³. This conference paper studies the effects of environmental pollution caused by fine dust PM2.5 during urbanization in the city of Hanoi, and some urban planning solutions to reduce pollution caused by fine dust PM2.5.

1. Introduction

Vietnam has an area of 331,690 km², located in the eastern part of the Indochina peninsula in Southeast Asia. Sharing the border with three countries, Vietnam is located next to China to the north, Laos and Cambodia to the west, and the East Sea to the east. In 2019, Vietnam's population numbered more than 95 million, ranking 13th in the world.

Hanoi is the capital of the Socialist Republic of Vietnam. On July 26, 2011, the Prime Minister of Vietnam issued decision №1259/QD-TTg, approving the general plan on construction in Hanoi up to 2030 and a vision to 2050 [1] when Hanoi will have expanded to cover a natural area of 334,470 ha, 3 times larger than before and ranked among the top 17 biggest capitals in the world. The population will continue to increase: there were 6.2 million people when the city started expanding whereas currently there are 7 million who live in 30 administrative units, 12 center districts, 17 suburban districts and 1 town [2]. Predictions suggest that the population will have grown to 10.5 million by 2050.

However, along with economic growth in urban areas, the process of urbanization also results in the major problem of higher environmental pollution. A report published by the Global Alliance on Health and Pollution in December 2019 [3] shows that more than 71,300 people have died because of environmental issues in Vietnam, of which more than 50,000 people died from air pollution in 2017.
Air pollution has a great impact on human health. According to WHO assessment, Hanoi is the city with the highest level of dust pollution [4,5] with annual average values of PM10 and PM2.5, which are both high at 73.5µg/m³ and 47.45µg/m³.

In order to contribute to approaching a very important issue, the author of the article focuses on the following three main contents: (i) Overview of Hanoi; (ii) Impact of environmental pollution due to PM2.5 fine dust in Hanoi; (iii) Proposal for some urban planning solutions to reduce environmental pollution caused by PM2.5 fine dust in Hanoi in the process of urbanization.

2 Overview of Hanoi

2.1. Geographical location
Located northwest of the center of the Red River delta, Hanoi is located from 20°53’ to 21°23’ north latitude and 105°44 ‘ to 106°02’ east longitude.

![Figure 1. Hanoi administrative map [6].](image)

2.2. History of the formation and development of Hanoi

2.2.1. The early period
In 1010, King Ly Cong Uan moved the capital from Hoa Lu to Dai La to build Thang Long Citadel, which is surrounded by the Red River, To River and Kim Nguu River. The 36 Streets of Hanoi are situated to the west of this urban construction today [6].

2.2.2. French colonial period: 1888-1945
Hanoi was the capital of the entire Indochina federation. The Hanoi Plan, implemented by the French, expanded the city to the south. In 1921, Hanoi had about 4,000 Europeans and 100,000 indigenous people [6]. Due to the introduction of Western culture, Hanoi was no longer a feudal citadel but looked like a European city (Fig 2).

2.2.3. Hanoi in the period of socialism: 1945 – present
- The period from 1945 - 1975 [1].
After peace was restored (1954), Hanoi in particular and the whole north of Vietnam embarked on the renovation of construction and economic, cultural and social development in the context of the country being divided into two regions for about 20 years.
Hanoi Master Plan: 1954 - 1960
In accordance with this plan, the city was developed on the right bank of the Red River. Ba Dinh, the Hoan Kiem area and the southern part of West Lake form Hanoi's central area of 700ha on land (Fig 3).

Hanoi Master Plan: 1960 – 1964
In 1960, the Master Plan for Hanoi was completed with the help of Soviet experts for the first time. The city was developed to the south of the Red River and a part of the north (Gia Lam, Dong Anh; Fig. 4). It now had a population of 380,000 people living on a land area of 130km$^2$ which was divided into 4 urban and 4 suburban districts.

The period 1975 to 2010 [1]

Hanoi planning before 1979
A central element of the further development of the city was building the high-speed transportation system between Hanoi and Vinh Yen.

The plan 1979-1981
After 1979, toxic substances started to accumulate in the southern region of the Red River. Hanoi continued growing and covered an area of 13,550ha, inhabited by a population of 1.5 million in 2000. The suburban area was extended to include Ba Vi and Vinh Phuc, so that the total area was expanded to 2130km$^2$

Hanoi planning in 1981
In combination with Soviet experts of Lening Planning Institute (1961), the master plan of Hanoi up to 2000 was completed and approved at decision №100/TTg. on April 24, 1981. It included a detailed vision for changes in Hanoi over the next 20 years during which the city grew to cover 13,500 ha and the population increased to reach 1.5 -1.7 million, so that there were 90m$^2$/person in the inner city area (Fig 5).
Hanoi planning in 1996

Hanoi is considered as a key point to create the structure of the northern economic region. However, in the late 80s and early 90s, planners determined that the size of the city was too large and incompatible with the socio-economic situation of the capital, and that its general condition did not invite investment in construction, so that the technical infrastructure remained basic. Hanoi is ranked as one of the major urban areas in Asia. Its population size was 1.3 million people in the first stage and 1.5 million people by 2010, with more land available in case the population would further grow to 1.7-2.0 million people.

The developed city mainly sells along the main roads which are the gateway with an open structure, creating alternating areas of greenery, water surface going deep into the center, improving urban ecological environment.

Hanoi Planning in 1998

The long-term direction of the development of Hanoi city is mainly to the west, forming the urban chain of Mieu Mon - Hoa Lac - Son Tay (Ha Tay province); in the North are the Soc Son urban cluster (Hanoi City) - Xuan Hoa - Dam Lai - Phuc Yen (Vinh Phuc province) and other urban areas which have been established in order to exploit the advantages of this geographic location. In the immediate future, the direction of expansion will be northwest, southwest and north, though development north of the Red River will be a priority. (Fig 6)

The population of the central city is 2.5 million, of which 1 million live in the western urban chain area and 0.5 million in the northern urban cluster.

Hanoi planning in 2010 (Fig 7)

Hanoi developed following the model of an urban cluster, including 1 central urban and 5 satellite urban areas, ecological urban areas, townships and rural areas. It is connected by a ring road system with radial axes, which is connected to the road network of the capital region and the nation. The central urban area of Hanoi is separated from its satellite towns by a green corridor.

Forecasts predict that the population size of the whole city will be around 9.0-9.2 million by 2030, and a maximum of around 10.8 million by 2050.

\* It can be said that the history of formation and development of Hanoi is associated with the process of urbanization. The rapid urbanization process combined with high economic growth led to the process of migration from rural areas to the city and the flood of people moving from neighboring provinces to Hanoi became uncontrollable, breaking regulations.

\+ Uncontrolled population growth, especially in the central area, puts increasing pressure on the social and technical infrastructure systems of the urban area.

**Figure 5.** Hanoi Master Plan 1981-2000.

**Figure 6.** Planning map of Hanoi to 2020.

**Figure 7.** Planning map of Hanoi to 2030.
Increasing urbanization also means increasing the challenges facing managers and policy makers every day, such as prevention of overcrowding, traffic congestion, inundation, pollution, dust, noise, air, water resources are increasingly urgent.

3. Impact of environmental pollution due to PM2.5 fine dust in Hanoi city

3.1. Sources and some monitoring results of PM2.5 in ambient air in Hanoi

According to reports, the environmental status of the air in big cities like Hanoi has deteriorated in recent years due to rising dust levels which cause great harm to people’s health [7]. PM2.5 dust concentration has exceeded the permissible limit of it’s annual average as specified in QCVN 05:2013/BTNMT by 2-3 times. The frequency of days with dust concentration higher than the allowed limit is quite high, especially in the roads of big cities. The report also stated that the main sources of urban air pollution are transportation, construction, urban production, residential activities and waste treatment.

As the diagrams below show, the average annual PM2.5 dust concentration measured at two different automatic air environment monitoring stations exceeded the permissible level specified in QCVN 05:2013/BTNMT on ambient air quality from 2015 to 2017 (Fig. 8, Fig. 10 and Fig. 11).

**Figure 8.** Preliminary estimates of PM2.5 (thous.tons) precursor emissions for year 2015 [11].

**Figure 9.** The average evolution of PM2.5 dust concentration by months at General Department of Environment in 2017.

**Figure 10.** Average PM2.5 dust content in 2017 at 02 automatic air monitoring stations.

**Figure 11.** PM2.5 monitoring data at the US Embassy automatic station from 2016 to present.

PM2.5 dust concentration data was continuously collected at the following two automatic air monitoring stations: one station is located at the Regional Environmental Monitoring Center at №556 Nguyen Van Cu, and the other monitoring station belongs to the US Embassy in Vietnam located at № Lang Ha (Fig10). As the diagrams above show (Fig. 9 and Fig. 10), the General Department of the Environment registered PM2.5 content exceeding 1.02 times the permitted standard, whereas PM2.5 levels at the US Embassy station exceeded safe conditions by 1.7 times [12] (Fig11).

* The speed of urbanization in Hanoi is quite fast and strong, the city is like a big "construction site". Currently, there are more than 1,000 construction projects, big and small, in the city, including dozens of renovation projects, and the building of intersections and new urban areas on a large scale.
The construction period lasts for years, causing dust pollution in a large area. For residential areas located in the inner city affected by traffic and industrial development, the pollution level still exceeds the permissible limit of QCVN. In contrast, in residential areas in suburban areas, air pollution levels are lower.

3.2. Impact of air pollution due to PM2.5 fine dust in Hanoi city. Impacts of air pollution on human health

In 2015, PM2.5 dust caused 42.2 thousand deaths in Vietnam, according to estimates of the Global Burden of Disease Report. Among them, there are 4.9 thousand cases due to lower respiratory diseases in children under 5 years old; 5.3 thousand cases of lung and bronchial cancers; and 26,000 cases of cardiovascular disease in adults [13].

Meanwhile, a study in Hanoi showed that PM1, PM2.5 and PM10 increased by 2.5%, 2.2% and 1.4% of hospitalizations for respiratory diseases in general [14]. Another study [15] also showed that when NO2 increased by 22 mg/m³, the number of hospitalizations due to pneumonia of Hanoi children increased by 6.1% and asthma, bronchitis increased by 5.5%.

Also according to research by Guo and colleagues in Hong Kong showed that the PAHs (Polycyclic Aromatic Hydrocarbons) accounts for 50% -82% in PM2.5 and PM10 dust, mainly found in PM2.5 [16]. PAHs and related compounds have been shown to be carcinogens, gene mutations and teratogens, which can cause various toxic effects on humans and animal.

Economic losses due to air pollution affecting health include expenses for medical examination and treatment, loss of workdays due to sick leave, and loss of caregiver time. Taking care of sick people ... in Hanoi city is quite large.

4. Proposing some urban planning solutions to reduce environmental pollution caused by PM2.5 fine dust in Hanoi, Vietnam in the process of urbanization

Air pollution is an issue related to many economic, social and environmental aspects, so finding solutions is not simple. In order to give effective measures to prevent pollution and improve urban air quality, it is necessary to first accurately identify the sources of waste and major causes of environmental pollution:

- Firstly, the composition of vehicles in Hanoi, most of them 85%, is motorbikes, while motorbikes are not of good quality, public transportation are very few.
- Secondly: the road surface area in Hanoi is too small compared to the total area, which means that the area for vehicles is very small. Prior to 2008, this area accounted for only 1.9% of the inner city area, which is very low compared to the world, so vehicles had to squeeze each other.
- Thirdly, in the urban structure of Hanoi, there is little space for trees, lakes, and all are concrete is generally very crowded.

So to find effective solutions is not simple, many solutions need to be implemented synchronously. In particular, the urban planning solution closely related to urban management and urban development is one of the leading important solutions:
Table 1. Proposed a number of solutions to reduce environmental pollution Hanoi city.

| No. | Urban areas | Land for urban construction (%) | Forecast for 2030 (thous) | Solutions to reduce environmental pollution |
|-----|-------------|---------------------------------|---------------------------|---------------------------------------------|
| I   | The central urban area consists of subdivisions: Zone A, Area B, Area C, Area D, and Green Belt | 51.700 | 56.63 | 4606 | 74.07 |
|     | 1. Economical use of land fund |
|     | 2. Modernizing uniform and unified infrastructure, especially the transport system |
|     | 3. Relocation of a number of industrial establishments, ministries’ offices, universities, colleges and medical establishments |
|     | 4. Expanding and building more green parks and entertainment areas |
|     | 5. Reduce excessive population concentration in accordance with tolerability. Limiting the construction of more high-rise apartment buildings to increase population density. |
|     | 6. Improving drainage system, minimizing air pollution, noise. |
| II  | The satellite urban area covers the following urban areas: VT1-VT5 | 35.200 | 38.55 | 1.377 | 22.14 |
|     | 1. Building a settlement corridor - transport infrastructure according to Eco2 City model |
|     | 2. Adaptive agricultural agriculture; |
|     | 3. Renovating and building isolated park and green areas. |
| III | Area of towns includes towns from: TT1-TT10 | 4400 | 4.82 | 235.4 | 3.79 |
|     | 1. Building models of Eco city and Agro city. |
|     | 2. Shifting from a natural production model to an eco-agricultural model associated with small handicraft tourism services. |
|     | 3. Zoning urbanized villages to create harmonious transition spaces, adapting to modern urban spaces with a green space system. |
| Total | 91.300 | 100 | 6.218.4 | 100 |

5. Conclusion
Today in Vietnam, as elsewhere in the world, the importance of transforming and reviving urban structures is recognized. This study evaluated the current situation of environmental pollution, including 2.5 torture in the city of Hanoi, Vietnam, in the process of urbanization, without affecting the socio-economic development of cities.

The main conclusions can be made: Firstly, on a national scale, the influence of urban morphology on PM2.5 concentration is mainly reflected in the number and size of the urban population. Secondly,
the concentration coefficient PM2.5 in urban areas is gradually changing depending on the population. Urban density tends to be useful in decreasing PM2.5 concentrations in large populations.

The city of Hanoi is currently facing a number of challenges in its natural ecological environment due to rapid urbanization and rapid industrialization. At the same time, sustainable economic and social development is an important task for the Vietnamese government. As shown in this study, we strongly support the fact that building smart urban forms through urban planning and spatial optimization is one of the ideal ways to lower PM2 levels in Hanoi.

6. References
[1] Prime Minister, Decision No 1259 QD-TTg, dated July 26 2011 on Approving the General Planning on construction of Hanoi Capital up to 2030 and a vision to 2050
[2] National Assembly, Resolution No 22/2003 QH11 of November 26, 2003 on the division and adjustment of administrative boundaries of some provinces (2003) Resolution No 15/2008 QH12 of the National Assembly on amendments administrative boundaries of Hanoi
[3] Global Alliance on Health and Pollution (GAHP) Pollution and Health Metrics: Global, Regional and Country Analysis report 2019
[4] Anh L H, Nam D T, and Luan V N 2018 Particulate matter pollution in some cities in Vietnam - Temporal variations and spatial distribution of ambient PM10 and PM2.5 concentrations in North Center for Environmental Monitoring
[5] BTNMT (2013a) QCVN 05: 2013 BTNMT National technical regulation on ambient air quality
[6] https://vi.wikipedia.org/
[7] 2017 Ministry of Natural Resources and Environment "Report on the current state of the environment in 2016 Chapter 2: Air environment" vol 2 pp 25-45
[8] GSO 2020 Statistical Yearbook 2019, 2018, 2015, 2009, 2005 General Statistics Office (Hanoi, Vietnam)
[9] Huong Thu 2012 “Hanoi’s atmosphere is ‘dirty first-class in Asia’” VnExpress Retrieved
[10] Hung T Đ et al Application of Gis technology and monitoring satellite of PM2 dust change 5 in Northern Vietnam (2000–2005-2010)
[11] Markus Amann (et al) Forecast of air quality in Hanoi and the northern region of Vietnam VAST-IIASA Project 2018 (Hanoi) 44 p
[12] Trinh Thi Thuy et al 2018 Researching the effect of inverse temperature phenomena on PM2.5 dust concentration in the air environment in Hanoi VNU Science Journal: Earth and Environment Sciences 3
[13] Cohen A J et al 2017 Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015 The Lancet
[14] Luong L M et al 2016 The association between particulate air pollution and respiratory admissions among young children in Hanoi (Vietnam) Sci Total Environ
[15] Nguyen T T Nhung et al 2017 Acute effects of ambient air pollution on lower respiratory infections in Hanoi children: an eight-year time series study (Under-review)
[16] Guo H et al 2003 Particle-associated polycyclic aromatic hydrocarbons in urban air of Hong Kong Atmospheric Environment 37(38) pp 5307-5317
[17] Oanh N T K, Phuong M T T, and Permadi D A 2012 Analysis of motorcycle fleet in Hanoi for estimation of air pollution emission and climate mitigation co-benefit of technology implementation Atmospheric environment 59 pp 438-448
[18] WHO 2016b WHO Global Urban Ambient Air Pollution Database (update 2016) In: WHO http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ Accessed 12 May 2016
[19] World Bank 2016 The cost of air pollution: strengthening the economic case for action The World Bank Group (Washington, D.C.)
[20] World Bank 2009 Potential climate change mitigation opportunities in waste management sector in Vietnam