AIR POLLUTION ISSUES IN HANOI – CURRENT STATUS AND SOLUTIONS FOR AIR POLLUTION MANAGEMENT IN CLIMATE CHANGE CONTEXT

MASTER'S THESIS
NGUYEN ANH TUAN

AIR POLLUTION ISSUES IN HANOI – CURRENT STATUS AND SOLUTIONS FOR AIR POLLUTION MANAGEMENT IN CLIMATE CHANGE CONTEXT

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Hanoi, 2021
PLEDGE

I assure that this thesis is the result of my research and has not been published. The use of other research’s result and related documents must comply with regulations. The citations and references to documents, books, research papers, and websites must be in the list of references of the thesis.

AUTHOR OF THE THESIS

NGUYEN ANH TUAN
TABLE OF CONTENTS

TABLE OF CONTENTS ................................................................. iv
LIST OF TABLES ........................................................................ vi
LIST OF FIGURES ...................................................................... vii
ABSTRACT ................................................................................ x

CHAPTER 1. INTRODUCTION ......................................................... 1
1.1. Overview ............................................................................. 1
1.2. Research objectives ............................................................ 2
1.3. Structure of the thesis .......................................................... 3
1.4. Learning outcomes ............................................................. 5

CHAPTER 2. METHODOLOGY ..................................................... 8
2.1. Framework of the study ....................................................... 8
2.2. Study area ........................................................................... 9
2.2.1. Location .......................................................................... 8
2.2.2. Topography, geomorphology .......................................... 9
2.2.3. Climate .......................................................................... 10
2.2.4. Meteorology ................................................................. 11
2.2.5. Inhabitants ................................................................. 12
2.2.6. Socio-economic development situation ......................... 13
2.3. Methods of study ............................................................... 14
2.3.1. Data sources ............................................................... 14
2.3.2. The method of data collection ......................................... 14

CHAPTER 3. CHAPTER 3: THEORETICAL BASIS AND PRACTICAL EXPERTISE IN AIR POLLUTION AND MANAGEMENT MEASURES IN THE CONTEXT OF CLIMATE CHANGE .................................................. 16
3.1 Air pollution ......................................................................... 16
3.1.1 Air pollution theory ....................................................... 16
3.1.2 Causes of air pollution ................................................... 17
3.1.3 Effects from air pollution ............................................... 20
3.2 Practical air pollution management groups of measures .......... 21
3.2.1 Legal tools ................................................................. 21
3.2.2 Economic tools ........................................................... 22
3.2.3 Technical and ancillary tools ......................................... 23
3.3 Climate change ................................................................. 24
3.3.1 Definition and causes of climate change ......................... 24
3.3.2 The context of climate change in Vietnam ....................... 25
3.3.3 Climate change scenarios for Vietnam ............................. 28
3.3.4 Scenarios on climatic extremes ...................................... 30
3.4 The linkage between air pollution and climate change ......... 31
3.4.1  The foundational relation between air pollution and climate change........31
3.4.2  The new approach of air pollution management in the context of climate change .................................................................32

CHAPTER 4: CURRENT SITUATION OF AIR POLLUTION IN HANOI......33
4.1. Causes of air pollution in Hanoi ..................................................33
4.1.1. Transportation activities ..........................................................33
4.1.2. Industrial activities .................................................................34
4.1.3. Construction activities ............................................................35
4.1.4. Living activities and waste treatment .........................................36
4.1.5. Other sources from sub-urban areas .........................................36
4.2. Air pollution condition in Hanoi ..................................................37
4.2.1. Air pollution caused by PM$_{2.5}$ ................................................39
4.2.2. Air pollution caused by PM$_{10}$ ...............................................42
4.2.3. Air pollution caused by hazardous gases ....................................42
4.2.4. Air pollution caused by unpleasant odor and noise .....................44
4.3. Effects caused by air pollution in Hanoi ........................................45
4.3.1. Effects of air pollution on humans ...........................................45
4.3.2. Effects of air pollution on socio-economic development ...............45
4.3.3. Effects of air pollution-related to climate change .........................46
4.4. Current air pollution management tools .........................................47
4.4.1. Legal tool ..............................................................................47
4.4.2. Economic tool ........................................................................55
4.4.3. Technical and auxiliary tools ....................................................57
4.5. Sub-conclusion ...........................................................................59

CHAPTER 5: PROPOSED AIR POLLUTION MEASURES.................61
5.1. Practical air pollution management measures around the world..........61
5.1.1. Beijing experience ..................................................................61
5.1.2. Seoul experience .....................................................................65
5.1.3. Japan experience .....................................................................68
5.1.4. Others nations experience .......................................................71
5.2. Proposed air pollution management measure in the context of adapting to climate change .........................................................72
5.2.1. Transportation .......................................................................72
5.2.2. Industry .................................................................................76
5.2.3. Energy and fuel .......................................................................79
5.2.4. Other measures ........................................................................81
5.3. Sub-conclusion ...........................................................................85

CHAPTER 6: CONCLUSION ............................................................87
REFERENCES .................................................................................89
LIST OF TABLES

Table 2.1: Climate characteristics of Hanoi .................................................................10
Table 2.2: Average population and population density of Hanoi............................12
Table 4.1: Monthly average PM$_{2.5}$ concentration from 2013 to 2019 .....................41
Table 5.1: Euro 3 and Euro 5 emission limits ...............................................................74
LIST OF FIGURES

Figure 2.1: Framework of the research ........................................................................... 8
Figure 3.1: Particulate size of PM$_{10}$ and PM$_{2.5}$ ......................................................... 17
Figure 3.2: Changes of yearly average temperature (°C) (1958-2014) ........................... 26
Figure 3.3: Changes in yearly precipitation (%) (1958-2014) ........................................ 26
Figure 3.4: Changes in tropical cyclones (1959-2014) ................................................... 27
Figure 3.5: Changes in tropical cyclone developments with wind speeds of level 12 or higher in the East Sea (1990-2015) ................................................................. 27
Figure 3.6: Trends of sea-level rise changes ................................................................... 28
Figure 3.7: Scenario on annual average temperature change ........................................ 29
Figure 3.8: Scenario on annual precipitation change ...................................................... 29
Figure 3.9: SLR scenarios (cm) ..................................................................................... 30
Figure 3.10: Flood risk corresponds to SLR of 100cm .................................................... 30
Figure 3.11: The relationship between Air pollution in the context of Climate change ................................................................................................................................. 33

Figure 4.1: PM$_{10}$ and PM$_{2.5}$ monthly average concentration in Hanoi 2018 ............ 38
Figure 4.2: Averaged PM$_{2.5}$ concentration from 2012 to 2018 ................................. 39
Figure 4.3: Monthly average PM$_{2.5}$ concentration in the period 2013-2019 ............... 40
Figure 4.4: Annual average PM$_{10}$ concentration in Hanoi from 2013 to 2018 ............ 42
Figure 4.5: Annual average SO$_2$ concentration development at Nguyen Van monitoring station .......................................................................................................................... 43
Figure 4.6: Organization chart of Vietnam implementing the UNFCCC ....................... 52
Figure 4.7: Air quality monitoring stations distribution in Hanoi ................................... 59
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>APCA</td>
<td>Air Pollution Control Act</td>
</tr>
<tr>
<td>AQI</td>
<td>Air quality index</td>
</tr>
<tr>
<td>CC</td>
<td>Climate change</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gas</td>
</tr>
<tr>
<td>GRDP</td>
<td>Gross regional domestic product</td>
</tr>
<tr>
<td>IGCC</td>
<td>Integrated Gasification Combined Cycle</td>
</tr>
<tr>
<td>INDC</td>
<td>Intended Nationally Determined Contribution</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>NDC</td>
<td>Nationally Determined Contribution</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate matter</td>
</tr>
<tr>
<td>QCVN</td>
<td>National Technical Regulation</td>
</tr>
<tr>
<td>SLR</td>
<td>Sea level rise</td>
</tr>
<tr>
<td>TSP</td>
<td>Total suspended particles</td>
</tr>
<tr>
<td>UNFCCC</td>
<td>United Nations Framework Convention on Climate Change</td>
</tr>
<tr>
<td>VOC</td>
<td>Volatile organic compound</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENT

I would like to express my sincere gratitude to my supervisors Dr. Nguyen Sy Linh and Dr. Nguyen Van Quang for providing invaluable guidance, comments, and suggestions throughout my thesis. I am also grateful to all the lectures at the Vietnam Japan University and Ibaraki University for their support towards the successful completion of my studies.

Besides, I would also like to thank my friends and colleagues at the Institute of Strategy and policy on Natural Resources and Environment for supporting me during the entire data collection period and creating the best conditions for me to balance my work and study.

Finally, I want to dedicate my success to my family for the encouragement and support throughout my research process.

I submit this thesis of mine with great humility and regards.
ABSTRACT

Air pollution is considered as a spot-on phenomenon amongst many problems that urban areas are facing with. In Hanoi, the capital city of Vietnam, this is also unavoidable. Furthermore, climate change and its side-effects are in-turn worsen the atmospheric environment. Therefore, understanding the impacts and the relationship between air pollution and climate change is critical to the air quality management in Hanoi and its effort of striving for sustainable development down the road. To analyze the condition of air pollution in Hanoi precisely, I have collected information at national and local level (Hanoi) in dealing with the air pollution. Those are represented by lots of solutions, which are divided into groups of managerial tools. Results showed that air pollution causes a large number of negative effects both on human health, and socio-economic development. It is also indicated that climate change makes air pollution worse by increasing greenhouse gas concentration in the atmosphere. Combining all of those, the thesis has learned profound experiences in air quality management around the globe, then introduced groups of measures to reduce emissions in Hanoi, ensuring the plan to respond to CC in Hanoi.

Keywords: air pollution, climate change, air quality management, greenhouse gas, Hanoi
CHAPTER 1. INTRODUCTION

1.1. Overview

Climate change (CC) and the depletion of natural resources, environmental pollution are two main topics that are of particular interest in the world and Vietnam in recent years. Changes in the climate increase climate hazards such as natural disasters, which affect socio-economic development achievements directly (Thang et al., 2010). Simultaneously, the rapid but unsustainable development of the economy in the past few years in Vietnam has led to the decline of natural resources and environmental pollution, especially the degradation of air quality (Vietnam Ministry of Natural Resources and Environment, 2018).

One of the most visible features of CC is the increase in the concentration of greenhouse gases in the atmosphere. Greenhouse gas emissions are a direct product of socio-economic development and the global picture of greenhouse gas emissions is the irradiation of the economic and social picture on the world scale (Thang et al., 2010). These kinds of substances are also the main sources that cause air pollution. For 7 years from 2013-2019, Hanoi's atmosphere was in a polluted state. Considering PM$_{2.5}$ dust concentration parameters, all the year the dust concentration exceeds the national standard limit and many times higher than the recommendations from WHO. However, the evolution of dust concentration has changed a lot, in 2013 the dust concentration had the highest value with an annual average of 55.9 $\mu$g/m$^3$ and then continued to improve in the next 2 years with respectively, 49.2 $\mu$g/m$^3$ and 45.1 $\mu$g/m$^3$. Then again increased sharply in 2016 with a dust concentration of 50.5 $\mu$g/m$^3$ and then continued to decline in the period 2017-2019. Air pollution brings enormous damage to humans in Hanoi through the highest mortality statistics. The evidence for this is the fact that every year our country has about 60,000 deaths due to constant exposure to polluted air, this number reaches 7 million people each year worldwide. This shows that air pollution also brings a greater risk of death than malaria, cancer, and traffic accidents (Vietnam Ministry of Natural Resources and Environment, 2018).
Many pieces of research have shown that CC and air pollution share many close relations. Climate changes directly result in impacts to air quality in a specific area. The increasing of the temperature related to CC increases the ground-level ozone in many regions, which may bring challenges and difficulties in complying with ozone standards down the road. In turn, the emissions of pollutants into the atmosphere such as particular matter (PM) can have whether warming or cooling effects on the climate. At the present, researches into the impact of CC on air pollutants and in reverse is less certain, however, they underway progress to address those uncertainties. Thus, I have chosen the topic "Air pollution issues in Hanoi – Current status and solutions for air quality management in CC context" to find out the main reasons that cause air pollution, how CC and air pollution interact with each other, and how to improve the air quality management in the context of CC.

1.2. Research objectives

This research is conducted to identify a set of feasible measures for tackling air pollution in the context of current CC – one of the most significant dangerous phenomena at the present that affect all aspects include humans, social life, the economy, and the environment. My research, in detail, aims to solve three main questions:

- What is the specific current status of air quality and its managerial condition in Hanoi?

- How air pollution and CC interact with each other?

- What can be done in reality to deal with air pollution in the context of CC?

Concerning those questions profoundly, 5 key activities were conducted to address three research questions:

(1) to collect the data of Hanoi’s socio-economic development status;

(2) to collect the data of and air pollution condition in Hanoi (including data on PM$_{2.5}$ concentrations, air quality index);

(3) to analyze the current air pollution situation in Hanoi;
(4) to collect the condition of CC management in Hanoi and the correlation between CC and air pollution;

(5) to propose solutions to handle air pollution in the context of CC.

1.3. Structure of the thesis

The thesis is organized into 6 chapters as below:

**Chapter 1: Introduction**

Overview

Research objectives

Structure of the thesis

Learning outcomes

**Chapter 2. Methodology**

Framework of the study

Study area

Methods of study

**Chapter 3: Theoretical basis and practical experience in air pollution and management in the context of climate change**

Air pollution

Practical air pollution management measures

Climate change

The linkage between air pollution and climate change

**Chapter 4: Current situation of air pollution in Hanoi**

Causes of air pollution in Hanoi

Air pollution condition in Hanoi
Effects caused by air pollution in Hanoi

Current air pollution management tools

Sub-conclusion

Chapter 5: Proposed Air pollution measures

Practical air pollution management measures around the world

Proposed air pollution management measure in the context of adapting to climate change

Sub-conclusion

Chapter 6: Conclusion
1.4. Learning outcomes

<table>
<thead>
<tr>
<th>Program Learning Outcomes (PLOs) of the MCCD</th>
<th>Results of the Master’s thesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLO1: Mastering the fundamental, interdisciplinary knowledge and methodologies to assess and address actual problems (fate and features) related to CC mitigation, adaptation for sustainable development at global, national, and local levels</td>
<td>The thesis gave the fundamental knowledge and information about air pollution, climate change, and its relationship briefly. The air pollution is approached by the author considering the condition of climate change, pointing out the main causes, and proposing feasible measures to address the problem.</td>
</tr>
<tr>
<td>PLO2: Understanding and developing systematic thinking; necessary knowledge on science, technology, innovation, and governance-related to CC response for development; identifying, analyzing, assessing, and forecasting the issues related to CC and CCR; predicting the developing trend of CC science</td>
<td>The thesis found a knowledge gap between the efforts of reducing air pollution and responding to climate change in Vietnam. These are not closely related to each other. I have analyzed the air quality condition in Hanoi, along with the trend of climate change. When it comes to proposing measures in dealing with the problem, modelling tool in air pollution and climate change management appears as a significant trend afterward.</td>
</tr>
<tr>
<td>PLO3: Applying knowledge to solve the problems in CC and CCR: planning and approaching the works in the field of CC; proposing the initiatives as well as the researches on CC; implementing the</td>
<td>The thesis approached the problem in dealing with air pollution by the approach of responding to climate change. Management of air quality in the context of climate change in general needs to be</td>
</tr>
<tr>
<td>Program Learning Outcomes (PLOs) of the MCCD</td>
<td>Results of the Master’s thesis</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>solutions on science, technology, mechanism, policy and finance for CCR and development</td>
<td>carried out in a “no border” approach. Specifically, the proposed solutions must be interdisciplinary, inter-regional, and international cooperation (if any) will bring greater efficiency.</td>
</tr>
<tr>
<td>PLO4: Having skills of cooperation with personal, agencies, organizations domestically and internationally to solve the CC issues, communication in works, projects on CC; and organizing, managing and administrating advanced career development</td>
<td>In terms of collecting data, I have strong cooperation with the Institute of Strategy and Policy on Natural Resources and Environment and their network.</td>
</tr>
<tr>
<td>PLO5: Accumulating soft skills to self-directed and adapt to competitive working environment such as English proficiency (at level 4/6 according to English competencies Framework for Vietnam), Japanese communication skills; having skills on time management; using the basic computer skills proficiently; working and researching independently; having skills of research and development; and using technologies creatively in academic and professional fields</td>
<td>Studying and working at the same time give me chances to enhance my skills of time management, self-discipline, self-determination, and independent researching. Besides using English in communication and writing reports, thesis; knowing a little Japanese will make a friendly environment between student and other Japanese professors.</td>
</tr>
<tr>
<td>PLO6: Having social/community’s responsibility and professional</td>
<td>The thesis results show the relationship between air pollution and</td>
</tr>
<tr>
<td>Program Learning Outcomes (PLOs) of the MCCD</td>
<td>Results of the Master’s thesis</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>morality, especially for the scientific research results; being able to adapt to multicultural environment, ensure the harmony between the stakeholders, CCR and development; having good social morality, assist the vulnerable people to climate change; compliance with the law; discipline at work and positive lifestyle; having good attitude to their career in climate change response for sustainable development</td>
<td>climate change and the effects combined. Air pollution can affect all sectors of society. It can also worsen the condition of climate change by increasing pollutant concentration. Hence, researching and proposing solutions to address the situation indicate my social responsibilities.</td>
</tr>
</tbody>
</table>
CHAPTER 2. METHODOLOGY

2.1. Framework of the study

Figure 2.1 demonstrates specifically each stage of the whole research. Since this kind of research mainly focuses on managing aspects, the availability and sufficiency of input data is a prerequisite. The thesis bases on two main foundational data, Hanoi socio-economic situation and monitoring data collected from monitoring stations within Hanoi. These will help in analyzing the current contaminated air quality in Hanoi. This will be summarized and assessed with the information of current air pollution management in and the condition of climate change and its recent management policies in Hanoi. As regards the analysis results, a set of potential solutions will be proposed with the intention of solving and enhancing the condition of air pollution in Hanoi towards adapting to CC.

![Figure 2.1: Framework of the research](image)

2.2. Study area

2.2.1. Location

Hanoi is the capital of the Socialist Republic of Vietnam. This city is located in the middle of the fertile Red River Delta, which soon became a political, economic, and cultural center from the dawn of Vietnam's history.
Hanoi is located northwest of the heart of the Red River Delta. It is located from 20°53’ to 21°23’ north latitude and 105°44’ to 106°02’ east longitude, adjacent to the provinces of Thai Nguyen, Vinh Phuc in the north, Ha Nam, Hoa Binh in the south, Bac Giang, Bac Ninh and Hung Yen in the east, Hoa Binh and Phu Tho in the west. Hanoi is 120 km from Hai Phong the port city, 87 km from Nam Dinh city, forming 3 main poles of the Red River Delta. After the expansion of administrative boundaries in August 2008, the city has an area of 3,324.92 km², located on both sides of the Red River, but mainly on the right bank.

2.2.2. Topography, geomorphology

Hanoi’s terrain is lower in the direction from north to south and from west to east with an average altitude of 5 to 20 meters above sea level. The hills are concentrated to the north and west of the city. Thanks to the alluvial sediment, three-quarter of Hanoi's natural area is the delta, located on the right bank of the Da River, on both sides of the Red River, and treating other rivers. The hilly area is mostly in Soc Son, Ba Vi, Quoc Oai, My Duc districts, with high peaks such as Ba Vi (1,281 m), Gia De (707 m), Chan Chim (462 m), Thanh Lanh (427 m), Thien Tru (378 m)...
urban area has several low hill mounds, such as Dong Da mound, Nung Mountain. Hanoi has four extreme points:

- The Northern side is Bac Son commune, Soc Son district;
- The Western side is Thuan My commune, Ba Vi district;
- The Southern side is Huong Son commune, My Duc district;
- The Eastern side is Le Chi Commune, Gia Lam district.

### 2.2.3. Climate

Similar to other provinces in the North, the climate in Hanoi is monsoon tropical with cold winters, sometimes with frost and little rain, lasting from November to March next year. The summer season in Hanoi is hot, combined with lots of thunderstorms and cyclones, lasting from April to October.

The annual precipitation in most places ranges from 1,500 - 2,100mm in the lowlands and from 1,600 - 2,600mm in the high mountain Ba Vi. The rain is concentrated during summer. The precipitation in the six months of summer accounts for 80-90% of the annual precipitation (Hanoi People’s Committee, 2012).

**Table 2.1: Climate characteristics of Hanoi**

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Record high °C</strong></td>
<td>32.0</td>
<td>34.7</td>
<td>37.2</td>
<td>39.0</td>
<td>42.8</td>
<td>42.5</td>
<td>40.1</td>
<td>38.2</td>
<td>39.0</td>
<td>35.5</td>
<td>34.7</td>
<td>31.5</td>
<td>42.8</td>
</tr>
<tr>
<td><strong>Average high °C</strong></td>
<td>19.7</td>
<td>20.1</td>
<td>22.9</td>
<td>27.2</td>
<td>31.4</td>
<td>32.9</td>
<td>33.1</td>
<td>32.3</td>
<td>31.2</td>
<td>28.8</td>
<td>25.3</td>
<td>22.0</td>
<td>27.2</td>
</tr>
<tr>
<td><strong>Average day, °C</strong></td>
<td>16.4</td>
<td>17.2</td>
<td>20.0</td>
<td>23.9</td>
<td>27.4</td>
<td>28.9</td>
<td>29.2</td>
<td>28.6</td>
<td>27.5</td>
<td>24.9</td>
<td>21.5</td>
<td>18.2</td>
<td>23.6</td>
</tr>
<tr>
<td><strong>Medium low, °C</strong></td>
<td>14.3</td>
<td>15.3</td>
<td>18.1</td>
<td>21.7</td>
<td>24.6</td>
<td>26.1</td>
<td>26.3</td>
<td>26.0</td>
<td>24.9</td>
<td>22.3</td>
<td>18.9</td>
<td>15.6</td>
<td>21.2</td>
</tr>
<tr>
<td><strong>Record low, °C</strong></td>
<td>2.7</td>
<td>6.0</td>
<td>6.0</td>
<td>11.8</td>
<td>17.2</td>
<td>20.0</td>
<td>21.0</td>
<td>20.0</td>
<td>16.9</td>
<td>13.0</td>
<td>10.0</td>
<td>5.0</td>
<td>2.70</td>
</tr>
<tr>
<td><strong>Precipitation, mm (inches)</strong></td>
<td>18</td>
<td>19</td>
<td>34</td>
<td>105</td>
<td>165</td>
<td>266</td>
<td>25.3</td>
<td>274</td>
<td>24.3</td>
<td>156</td>
<td>59</td>
<td>20</td>
<td>1.61</td>
</tr>
</tbody>
</table>
Average winter temperature: 16.4 °C (as low as 2.7°C). Summer average: 29.2°C (highest at 42.8°C). The average annual temperature is 23.6°C, with an average annual rainfall of 1,800mm to 2,000mm. In May 1926, temperatures in the city were recorded at a record 42.8°C (42.8°C). In January 1955, temperatures dropped to their lowest level, 2.7°C due to La Nina. In early June 2017, affected by El Niño worldwide, Hanoi suffered a week-long heatwave (31-5 to 6-6) with temperatures of up to 42.5°C, a record temperature recorded in history. Moreover, due to the influence of urban effects and the climate with high humidity, the heat waves, the actual temperature is always higher than the measurement level, can be up to 50°C. During this heatwave two people died from the heat, in the future things are even more terrible. In Hanoi in 2100, summer will last longer and there will appear a temperature of 48°C, the temperature is felt from 55-58°C. The place with snow in winter in Hanoi is Ba Vi around 6 am on 24th January of 2016 with a temperature of about 0°C.

### 2.2.4. Meteorology

The Red River is the main river of the city, starting to flow into Hanoi in Ba Vi district and out of the city in the area where Phu Xuyen district adjacent to Hung Yen, then down to Nam Dinh, the city that has been associated with Thang Long since the Tran Dynasty. Hanoi also has the Da River which is the boundary between Hanoi and Phu Tho, which is associated with the Red River in the north of the city in Ba Vi district. Also, in Hanoi, there are many other rivers such as The River, Duong River, Cau River, Ca Lo River... Small rivers flowing in the inner city such as To Lich River, Kim Nguu River, (To Lich River is processing). These are the sewage drainage routes...
of Hanoi.

Hanoi is also a special city with many lakes - traces of ancient rivers. In the inner city, West Lake has the largest area, about 500 hectares, plays an important role in the urban landscape, today surrounded by many hotels, villas. Hoan Kiem Lake is located in the historic centre of the city, the busiest area, always holds a special place for Hanoi. In the inner city can be mentioned other lakes such as Truc Bach, Tuyen Quang, Thu Le. Besides, there are many large lakes located in Hanoi such as Kim Lien, Lien Dam, Ngai Son - Dong Mo, Suoi Hai, Meo Gu, Xuan Khanh, Tuy Lai, Quan Son.

### 2.2.5. Inhabitants

Hanoi is the largest centrally-owned city in the country since the merger of Ha Tay province, and the second-largest locality in terms of population with nearly 8,053,663 people (as of 0h April 1, 2019), just after Ho Chi Minh City.

#### Table 2.2: Average population and population density of Hanoi

<table>
<thead>
<tr>
<th>Year</th>
<th>Average population (1,000 people)</th>
<th>Population density (person/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>6,713.3</td>
<td>2,031.1</td>
</tr>
<tr>
<td>2012</td>
<td>6,865.2</td>
<td>2,065.6</td>
</tr>
<tr>
<td>2013</td>
<td>6,977.0</td>
<td>2,098.8</td>
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<tr>
<td>2014</td>
<td>7,095.9</td>
<td>2,134.0</td>
</tr>
<tr>
<td>2015</td>
<td>7,216.0</td>
<td>2,171.0</td>
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<tr>
<td>2016</td>
<td>7,328.4</td>
<td>2,182.0</td>
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<tr>
<td>2017</td>
<td>7,420.1</td>
<td>2,209.0</td>
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<tr>
<td>2018</td>
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<td>2,239.0</td>
</tr>
<tr>
<td>2019</td>
<td>8,093.0</td>
<td>2,410.0</td>
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</tbody>
</table>

*Source: General Statistics Office*

Hanoi is struggling to deal with pressure from population growth pressures and mechanical population growth (Hanoi Statistical Office, 2019). On average, the capital's population increases by about 160,000 people each year, approximately one large district. The proportion of the population in urban areas increased rapidly from
36.8% to 49.2% between 1999 and 2019, proving that the pace of urbanization is going strong. Districts such as Dong Da, Thanh Xuan, Hai Ba Trung, and Cau Giay are the places with the highest population density in the city, namely: 37,347 people/km², 32,291 people/km², 29,589 people/km², and 23,745 people/km². In addition, newly established districts such as Hoang Mai, Nam Tu Liem, Bac Tu Liem, and Ha Dong have also become areas with a large population density no less than the central districts. Another problem is that population allocation in districts is also relatively disparity, the two districts with the highest population density are Thanh Tri (4,343 people/km²) and Hoai Duc (3,096 people/km²), which is 4-6 times higher than sparsely populated districts such as Ba Vi (687 people/km²) and My Duc (884 people/km²).

The population size in the period 2009 to 2019 increased by 1.66 million people, the inner city alone increased by over 1.3 million people, largely increasing the meson from immigrants. The average population growth rate is 2.22% per year, higher than the period 1999-2009 is 0.13%. Hanoi is facing the problem of ensuring a reasonable population size. Specifically, there are 32 wards and communes in Hanoi with the proportion of immigrants accounting for over 30% of the population, located mainly in areas that are very strong urbanization and unusual mechanical fluctuations such as Cau Giay, Thanh Xuan, Ha Dong, Nam Tu Liem, Bac Tu Liem. Newly built urban areas will solve the problem of accommodation for migrant flows, but this is also the reason why traffic is often overloaded, arterial roads are clogged at work and home from work, entailing many other environmental and urban management problems.

2.2.6. Socio-economic development situation

According to the General Statistics Office, in 2019, Hanoi is the 2nd administrative unit in Vietnam in terms of general products in the area (GRDP), ranked 8th in GRDP per person, 41st in terms of GRDP growth rate. GRDP reached VND 971,700 billion (US$41.85 billion), GRDP per person reached VND120.6 million (US$5200), GRDP growth rate was 7.62%. The GRDP structure in 2019 shifted in a positive direction, increasing the proportion of the service and industrial sectors, construction, reducing the proportion of agriculture, forestry and fisheries: The
agricultural, forestry and fisheries sectors accounted for 1.99% of GRDP; industrial and construction sectors accounted for 22.69%; the service sector accounted for 64.02%; product tax minus product subsidies accounted for 11.3%.

According to the General Statistics Office, in 2020, the city's economic growth slowed due to the impact of the Covid-19 pandemic. In the first 6 months of 2020, total production in the area is estimated to increase by 3.39% (same period increased by 7.12%), while the industrial production index is estimated to increase by 3.07% (same period increased by 7.4%), the total flow of goods and service revenue is estimated to increase by 4.6% (same period increased by 10%), the total number of tourists reached 4.93%, decreased by 65.4% (same period increased by 9%).

The situation of epidemic prevention of the city is also implemented effectively and quickly, ensuring the best health for residents. With the efforts of the whole political system, especially the health system, in the first 6 months of 2020, 118 cases of Covid-19 infection are cured; in the long run, there have been no out-of-community infections. The city establishes a "new normal" and focuses on implementing the "dual goal" – both disease prevention, recovery, and maintenance in the last months of the year.

2.3. Methods of study

2.3.1. Data sources

- Using secondary data: The data used related to the status of air pollution in Hanoi, including data on PM$_{2.5}$ dust concentration, air quality index, number of cases related to air pollution.

- Data source is taken from the monitoring station Nguyen Van Cu, from the air quality monitoring station at the US Embassy in Hanoi, from AirNow, from the Vietnam Environment Administration, and related reports and articles.

2.3.2. The method of data collection

- Inheritance method: summarizing and analyzing data, materials, and information related to air pollution in Hanoi:
+ The concentration of air particulate matter, the concentration of greenhouse gases, including Sulfur dioxide, Nitrogen oxide, Carbon dioxide, and Trioxide;

+ Air pollution causing agents;

+ Affection of air pollution on the environment and people.

- Methods of collecting information: collecting information from the Air Pollution curriculum, collecting data on activities that cause air pollution and parameters of air pollution, related articles, and reports.

- Comparative method: used to analyze the status of air pollution in years, the evolution of particulate concentration in the period of 2013-2019, and conclude the trend over time.

- Data processing method using tools such as Microsoft Excel, SPSS to calculate and tabulate results.
CHAPTER 3. THEORETICAL BASIS AND PRACTICAL EXPERIENCE IN AIR POLLUTION AND MANAGEMENT MEASURES IN THE CONTEXT OF CLIMATE CHANGE

3.1 Air pollution

3.1.1 Air pollution theory

Air is the amount of gas that surrounds us and plays a decisive role in human life as well as all living things on Earth. Therefore, air quality can directly affect human health and the ecosystems on our planet. Accordingly, fresh air is natural air containing very little impurity content. Living in clean, fresh air would bring a lot of benefits to humans. Many studies have shown that fresh air helps reduce allergies and asthma, enhances lung function, improves the immune system, and reduces the risk of high blood pressure. Besides, fresh air also helps people sleep better, improve mood and productivity (Huyen, 2019). However, the air is being polluted.

According to the "Air Pollution" curriculum, "Besides the main components of air, any substance in solid, liquid, gas is released into the air environment in sufficient concentrations affecting human health, adversely affecting the growth and development of animals and plants, destroying materials, reducing the environmental landscape is polluting the environment or otherwise, the air has been polluted”. In terms of pollution composition, air pollution can be divided into 02 types: particulate matter pollution and hazardous gas pollution (Thang, 2007b).

- Particulate matter (PM) pollution:

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air (United States Environmental Protection Agency, 2020). Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope. Particle pollution includes total suspended particulate (TSP), inhalable particles, with diameters that are generally 10 micrometers and smaller (PM₁₀), and fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller (PM₂.₅).
Hazardous gas pollution includes Sulfur dioxide (SO$_2$), Carbon monoxide (CO), Nitrogen dioxide (NO$_2$), and Ozone (O$_3$). In urban areas, the above gases mainly arise from the combustion of fuel (gasoline, oil) from the engines of vehicles. Besides, SO$_2$ arises from the combustion of coal and other sulfur-containing fuel sources. The concentration of parameters SO$_2$, NO$_2$, CO tends to increase in areas with high traffic density. Some of these pollutants are grouped as greenhouse gas (GHG). GHG is a gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect. The primary greenhouse gases in Earth's atmosphere are water vapour (H$_2$O), carbon dioxide (CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), and ozone (O$_3$) (IPCC, 2008).

### 3.1.2 Causes of air pollution

Air pollution is a blend of solids, liquids, gases. The causes of air pollution are divided into two groups: natural causes and anthropogenic causes.

#### 3.1.2.1 Natural causes

Natural sources of pollution include dust carried by the wind from locations with very little or no green cover, gases released from the body processes of living beings (Carbon dioxide from humans during respiration, Methane from cattle during digestion, Oxygen from plants during Photosynthesis). Smoke from the combustion of various inflammable objects, volcanic eruptions, etc. along with the emission of polluted gases also makes it to the list of natural sources of pollution (Thang, 2007a).
Volcanic eruptions are one of the worst natural disasters, causing not only great damage to air quality but also the risk of destroying nearby buildings in its operating area. The year 2020 also recorded the return of many volcanoes in the world. In December 2020, the Etna volcano erupted over the course of a week creating huge ash clouds as high as 4,600 meters around southern Italy, then being blown down by winds as far south and Eastern Europe. It makes the air quality was heavily polluted, with AQI in these areas around from 100 to 200.

Forest fires are both a source of large dust and greenhouse gases and devastate vegetation. Bushfires in Australia between late September 2019 and January next year have burned more than 4 million hectares of land. The fire also left the city of Sydney engulfed in smog. PM\textsubscript{2.5} has flown into Australian cities and caused air pollution seriously. On 2\textsuperscript{nd} January, the Australian capital Canberra achieved record bad air quality, PM\textsubscript{2.5} exceeding 200 μg/m\textsuperscript{3}. In December 2019, Sydney also recorded the worst air quality ever with PM\textsubscript{2.5} reaching nearly 400μg/m\textsuperscript{3} - the level of hazardous according to WHO ratings, meaning everyone could experience harmful health impact. The smog from Australia's bushfires also flew thousands of miles as far as New Zealand, turning neighbouring skies into orange (Guo et al., 2021).

In addition, temperature inversion is also one of the causes of air pollution in big cities. Temperature inversion occurs when the temperature of the upper atmospheric layer is greater than the temperature of the lower atmospheric layer. It blocks the atmosphere from mixing and causes pollutants to accumulate, resulting in elevated concentrations of these substances and adversely affecting the environment and human health. A recent study in Hanoi showed that there is a difference in PM\textsubscript{2.5} content between days when temperature inversions occur (usually in the cold season) and days that do not occur at about 40 to 48% depending on the monitoring station (Tham, 2018).

### 3.1.2.2 Anthropogenic causes

Transportation has always been the main cause of pollution in many developing countries. It is the source of emissions that contribute the most to total emissions, including toxic gases such as SO\textsubscript{2}, NO\textsubscript{2}, CO, and dust (TSP, PM\textsubscript{10}, PM\textsubscript{2.5}). According to statistics of the Ministry of Natural Resources and Environment (2016), 70% of
polluting smog comes from traffic activities. The emission of vehicles depends on the quality of the vehicle's machinery, fuel quality, operating speed, driver, traffic conditions such as traffic density, congestion, and infrastructure.

Industrial activity is also contributing greatly to air pollution. Smoke and dust from factories account for the largest proportion of the causes of pollution not only air but also water and food sources. In the dust from factories, there is a large amount of CO₂, CO, SO₂, NOₓ, organic matter that has not burned out (soy coal, dust) with extremely high concentrations. If the emissions are not treated well, it will adversely affect the health of the people living in that area. This is even the main cause of acid rain causing a lot of damage to people as well as crops.

The construction industry also causes air pollution through clearance activities, using diesel-powered machinery, destroying and burning solid materials. These activities are discharged into the environment with a large amount of dust. Clearance causes the air environment to receive a lot of dirt, cement dust. In addition, using diesel-powered vehicles is mainly particulate matter PM₁₀ and PM₂.₅, SO₂..., of which PM₁₀ accounts for the majority. Also, the destruction and combustion of materials discharged into the environment toxic gases such as SO₂, NOₓ, CO... More and more construction activity will increase the vehicles carrying materials to traffic, causing sandy soil from trucks, or dust on the roads under repair is also the cause of air pollution.

Waste collection and treatment are also the cause of air pollution. The main source of pollution is gas fumes from straw and other waste. At garbage collection sites, after being collected and classified by vehicles, sanitation workers will burn a large amount of garbage to reduce the amount of landfill because of an excessive amount of garbage and the burial pit was also overloaded. Burning waste not only causes emissions, but also an unpleasant smell for neighbouring residential areas. Besides that, many people have a habit of mixing chemical garbage and common garbage. When burned, this garbage does not decompose but settles into the soil and causes many other pollution problems.
3.1.3 Effects from air pollution

3.1.3.1 To humans

The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems because they can get deep into your lungs, and some may even get into your bloodstream. Exposure to such particles can affect both your lungs and your heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including:

- Premature death in people with heart or lung disease;
- Heart attacks;
- Irregular heartbeat;
- Aggravated asthma;
- Decreased lung function;
- Increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing.

3.1.3.2 To creatures

Air pollution is not only dangerous to humans but also to animals and plants. Hazardous gases such as SO₂, NO₂, CO, H₂S, or Pb in the air also seriously affect the fauna and flora system. If the animal inhales the air containing toxins, its immune system will be weakened. Plants that grow in a toxic air environment will also affect metabolism. It can be seen that plants are very sensitive to the quality of the surrounding air, especially fruit trees. Some plants will lose their leaves if they have to be exposed too much to fluidic acid (HF), as a result of which growth and development are seriously affected.

3.1.3.3 To ecosystem

Particles can be carried over long distances by wind and then settle on ground or water. Depending on their chemical composition, the effects of this setting may include:

- Making lakes and streams acidic;
- Changing the nutrient balance in coastal waters and large river basins;
- Depleting the nutrients in the soil;
- Damaging sensitive forests and farm crops;
- Affecting the diversity of ecosystems;
- Contributing to acid rain effects.

3.2 Practical air pollution management groups of measures

3.2.1 Legal tools

According to the Economics and Environmental Management curriculum "Laws and policies, also known as legal tools including documents on international law, national law, other documents under the law (ordinances, decrees, regulations, environmental standards, environmental permits...), environmental plans, strategies and policies on national, economic sectors and localities scales".

Legal tools are always important for pollution control. Specifically, environmental laws have been effective in the process of controlling and managing air pollution. Since the environment is a unified system and has no boundaries, reducing the lack of air pollution requires the participation of all countries. Any positive outcome of the national assembly, anywhere on Earth, is of equally great value in controlling air pollution. Around the world, since the 70s of the last century, many countries have also had their laws to manage air pollution to improve air quality and ensure the healthy lives of people.

International law on the environment is the overall principles and international rules governing the relationship between countries, between countries, and international organizations in preventing and eliminating damage caused to the environment of each country and the environment outside the scope of use of the country.

The National Environment Law is a combination of legal principles governing the relationships arising between the subjects during the use of or impacting one or several elements of the environment based on a combination of different adjustment methods to effectively protect the human environment. In addition, other kinds of legal tools are regulation, statute, environmental standard, environmental protection policy,
and strategy. They all serve to guiding, implementing, and identifying how the environment is protected and planed.

### 3.2.2 Economic tools

According to the "Economics and Environmental Management" curriculum, "Economic tools, also known as market-based tools, are policy tools used to influence the costs and operational interests of economic individuals and organizations to influence the behaviour of economic agents in an environmentally beneficial way."

Natural resources tax is revenue of the State Budget for enterprises on the use of natural resources in the production process. The purpose of the resource taxes: (1) Limiting the urgent need to use resources, (2) Limiting resource losses during exploitation and use, (3) Generating revenue for the Budget and conditioning the interests of the population on the use of resources.

The environment fee is an economic tool to bring environmental costs into the price of products according to the principle of "polluter must pay". Environmental taxes/fees are for two main purposes: encouraging pollutants to reduce the number of pollutants released into the environment and increasing revenues for the Budget. Currently, in many countries, revenues from environmental taxes are used for the General Budget of the Government as other tax revenues; and revenues from environmental fees will be dedicated to environmental protection activities such as waste collection, wastewater, pollution remediation, and support for victims of pollution.

Deposit - refund is used in environmental protection activities by regulating consumers of products that are likely to pollute the environment to pay an additional amount (deposit) when making a purchase, to ensure that the commitment after consumption will bring the product (or the rest of the product) back to the waste collectors or to the specified places for recycling, reuse or destruction in an environmentally safe way. If done correctly, consumers will receive a refund of the deposit from the collection organizations.

Environmental escrow is an economic tool applicable to economic activities that have the potential to pollute and damage the environment. The principle of
operation of the environmental deposit system is similar to that of the deposit-refund system. The main content of environmental margin is to require enterprises, production and business establishments before conducting an investment activity to deposit a sum of money (or precious metals, gems, or valuable papers such as money) at banks or credit institutions to ensure the commitment to implement measures to limit pollution, environmental degradation.

3.2.3 Technical and ancillary tools

Technical tools for environmental management perform the role of state control and supervision of environmental quality and composition, on the formation and distribution of pollutants in the environment. Technical tools for environmental management may include environmental assessments, environmental audits, environmental monitoring systems, waste treatment, recycling, and reuse of waste. These are considered important action tools of organizations in environmental protection. Through the implementation of technical tools, the authorities can have complete and accurate information about the current status and environmental quality developments and take appropriate measures and solutions to handle and limit the negative impacts on the environment.

The main ancillary tools include environmental modelling and communication. In particular, air quality modelling is a mathematical tool used to describe the causal relationships between pollutant emissions, meteorological conditions, pollutant concentrations in the air process. The model of air pollution plays an important role in science because of the ability to assess the relative role of the processes involved. Air pollution modelling is the only method of quantifying the relationship between emissions and concentrations, including results from past and future scenarios to determine the effectiveness of the mitigation strategy. This shows that the air pollution models are an indispensable tool in scientific research as well as state management on the environment.

Environmental communication is a two-way social interaction process that enables all those involved in the process to create and share environmental information. The purpose is to achieve a common understanding of relevant environmental topics, thereby having the capacity to share responsibility for protecting
natural resources and the environment with each other. In other words, environmental communication has a direct or indirect impact on the perception, attitude, and behaviour of people in the community. This encourages them to participate in environmental protection activities.

3.3 Climate change

3.3.1 Definition and causes of climate change

The United Nations Framework Convention on Climate Change (UNFCCC) defines CC as “CC is attributed directly or indirectly to the effects of human activities leading to changes in global atmospheric composition and contribute to the natural climate variation that can be observed for long periods” (United Nations, 1992). In this definition, the UNFCCC specifies that the cause of CC is directly or indirectly affected by human activities. This definition refers to the phenomenon of CC happening today.

According to The Intergovernmental Panel on Climate Change (IPCC), CC is defined as “a change in the state of the climate that can be identified by using statistical tests, specifically determined by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. CC may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or land use” (IPCC, 2014). This concept refers to a fact that CC has existed in the past as well as is happening at the moment and afterward. Nevertheless, in detail, the causes of CC had not been distinguished.

In Vietnam, CC has been become a hot topic and has been receiving a lot of interest from public attention. Its concept has been legalized in Vietnam’s Hydrometeorology Law (promulgated November 23, 2015). Article 3, clause 3 specifies CC as “a change of climate over a long period due to the impact of natural conditions and human activities. It is caused by global warming, rising sea levels, and increasing hydro-meteorological extreme events” (The National Assembly of Vietnam, 2015). This concept is relatively similar to the two above. CC is happening due to both natural and human causes. It is represented by changing components of the climate.
Summarizing all of those definitions above, it can be understood as climate changes when there is a change in atmospheric radiation due to various factors, including processes such as changes in solar radiation, changes in the orbit of the Earth, volcanic activity, tectonic plates transition, changes in oceans and changes in greenhouse gas concentrations. CC can be caused by natural and artificial causes.

Scientists have highly agreed that the main cause of the current CC phenomenon is caused by humans. According to the IPCC (2014), greenhouse gases such as carbon dioxide, methane, nitrogen oxides created by humans during economic development and population growth have increased unprecedented in the past 800,000 years (IPCC, 2014). Thus, this is one of the issues that need to be thoroughly addressed to minimize global warming and adapt to CC:

- Carbon dioxide (CO₂): enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical
- Methane (CH₄): is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills
- N₂O: is emitted during agricultural and industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater.
- Fluorinated gases: hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorcarbons, hydrochlorofluorocarbons, and halons)

3.3.2 The context of climate change in Vietnam

As regards the Vietnam scenarios for CC and SLR, the climate in Vietnam has relatively changed recently. They are expressed through the following manifestations and trends:

- Temperature
Temperature tends to increase in most areas of the country. From 1958 to 2014, the annual average temperature of the whole country increased about 0.62°C. Especially, from 1985 to 2014 alone, it increased about 0.42°C. On average, each decade, the temperature increased about 0.10°C. Temperatures in coastal and island areas increased less frequently than in inland areas. Temperatures are highest in winter and lowest in spring. The region with the highest temperature increase is the Central Highlands, the region with the lowest temperature increase is the South Central Coast (Vietnam Ministry of Natural Resources and Environment, 2016).

Figure 3.2: Changes of yearly average temperature (°C) (1958-2014)  
Figure 3.3: Changes in yearly precipitation (%) (1958-2014)  
*Source:* (Vietnam Ministry of Natural Resources and Environment, 2016)

- **Precipitation**

The annual average precipitation of the whole country tends to increase slightly in the period from 1958 to 2014. Precipitation increases most during the winter and spring months and decreases in the autumn months. Over the past 60 years, annual precipitation tended to decrease in the Northern regions (from 5.8 to 12.5%), the most decrease was in the Northern Delta (12.5%) and in the Southern regions (from 6.9 to 19.8%), decreasing the most in the South Central Coast (19.8%).

- **Extreme events related to temperature and precipitation**

In most regions of the country, the highest daily (Tx) and lowest daily (Tm) temperatures tend to increase significantly, with the highest increase in the period
1961-2014 reaching 1°C/decade; The number of hot days (Tx ≥35 ° C) also tends to increase, especially in the Northeast, the North Delta and the Central Highlands with the increase of 2-3 days/decade, however, it decreases in some local location in some other area. Extreme rains tend to vary from one climatic zone to another: Decreasing in most of the Northwest, Northeast, and Northern Delta regions and increasing in most other climatic regions. Unseasonal rain and unusually heavy rains occur more frequently.

- Cyclons and tropical depressions

**Figure 3.4: Changes in tropical cyclones (1959-2014)**

**Figure 3.5: Changes in tropical cyclone developments with wind speeds of level 12 or higher in the East Sea (1990-2015)**

*Source:* (Vietnam Ministry of Natural Resources and Environment, 2016)

The number of cyclones and tropical depressions operating in the East Sea that affect and land in Vietnam in the period 1959-2015 tends to be less changed. However, in recent years, strong cyclones (above the 12th level) tend to increase slightly. The cyclone season ends later and the cyclone's pathway tends to shift south with more cyclones hitting the South-side. The activities and impacts of cyclones and tropical depressions on our country in recent years have had unusual developments.

- Sea level rise

According to monitoring data, sea level at most locations along the coastal line of Vietnam tended to increase from 1993 to 2014 with an average increase of about 3.34 mm/year, of which, the strongest was approximately 5.58 mm/year (Phu Quy)
and least was 1.33 mm/year (Bach Long Vi). However, in some locations, sea level tends to decrease such as Co To (1.39 mm/year) and Hon Ngu (5.77 mm/year).

![Image: Trends of sea-level rise changes](image)

**Figure 3.6: Trends of sea-level rise changes**

According to satellite data, the sea level of the entire coastal strip of Vietnam tends to increase with an average growth rate of about 3.5 mm/year. Specifically, the largest increase is in the South Central Coast region (5.6 mm/year) and the least increase in the coastal area of the Gulf of Tonkin (2.5 mm/year) (Vietnam Ministry of Natural Resources and Environment, 2016).

### 3.3.3 Climate change scenarios for Vietnam

According to the CC scenario for Vietnam, in recent years, Vietnam's climate will witness significant changes, reflected in these following manifestations and trends below (Vietnam Ministry of Natural Resources and Environment, 2016):

- **Scenarios for temperature**

  Temperatures in all regions of Vietnam tend to increase compared to the base period (1986-2005), with the largest increase being in the North.
According to the medium scenario (RCP4.5\(^1\)), the temperature by the end of the century will increase by 1.9±2.4°C in the north and 1.7±1.9°C in the south. According to the high scenario (RCP8.5\(^2\)), by the end of the century, the temperature will increase by 3.3±4.0°C in the north and 3.0±3.5°C in the south. The average minimum and maximum temperature in both scenarios have a clear trend of increasing (Vietnam Ministry of Natural Resources and Environment, 2016).

- Scenario for precipitation

Annual precipitation tends to increase nationwide. According to the RCP4.5 scenarios, in the middle of the next century, the rainfall will increase from 5 to 15; By the end of the century, rainfall had a similar distribution as in the middle of the century, but the region with an increase of over 20% will be wider. According to the RCP8.5 scenario, precipitation at the end of the century will increase as much as 20% in most of the North, Central, and Central, part of the South and the Central Highlands (Vietnam Ministry of Natural Resources and Environment, 2016).

- The scenario for sea-level rise

The SLR scenario was developed for 9 coastal and island areas including (i)

\(^1\) RCP4.5 is the scenario of 2.4°C increase compared to the period 1986-2005 and CO\(_2\)e reaches 650 ppm in 2100

\(^2\) RCP8.5 is the scenario of 4.9°C increase compared to the period 1986-2005 and CO\(_2\)e reaches 1370 ppm in 2100
coastal area from Mong Cai to Hon Dau; (ii) The coastal area from Hon Di to Deo Ngang; (iii) The coastal area from Deo Ngang to Hai Van Pass; (iv) Coastal area from Hai Van Pass to Cape Dai Lanh; (v) The coastal area from Cape Dai Lanh to Mui Ke Ga; (vi) The coastal area from Mui Ke Ga to Cape Ca Mau; (vii) coastal area from Cape Ca Mau to Kien Giang; (viii) The Paracel Islands of Vietnam; (ix) The Truong Sa archipelago of Vietnam.

Figure 3.9: SLR scenarios (cm)  
Figure 3.10: Flood risk corresponds to SLR of 100cm

Source: (Vietnam Ministry of Natural Resources and Environment, 2016)

According to the RCP4.5 scenarios: By the end of the 21st century, the highest SLR in the Hoang Sa and Truong Sa archipelago is 58cm (36 ÷ 80cm) and 57cm (33 ÷ 83cm) respectively; Ca Mau - Kien Giang area is 55cm (33 ÷ 78); Mong Cai - Hon Dau and Hon Dau - Ngang Pass area has the lowest SLR of 53cm (32 ÷ 75cm). According to the RCP8.5 scenario: At the end of the 21st century, the highest SLR in the Paracel archipelago and Truong Sa archipelago is 78cm (52 ÷ 107cm) and 77cm (50 ÷ 107cm) respectively; the area of Ca Mau - Kien Giang is 75 cm (52 ÷ 106cm); Mong Cai - Hon Dau, Hon Dau - Ngang Pass area has the lowest SLR of 72cm (49 ÷ 101cm) (Vietnam Ministry of Natural Resources and Environment, 2016).

3.3.4 Scenarios on climatic extremes

The number of cyclones and tropical depressions tends to be less variable, but
distribution is more concentrated at the end of the cyclone season, this is also the period when cyclones operate mainly in the South. Strong upon very strong cyclones tends to increase.

The number of hot days (Tx> 35°C) tends to increase in almost all parts of the country, the largest in the North Central, South Central, and South. Droughts may become more severe in some regions due to increased temperatures and the possibility of decreasing precipitation in the dry season such as in the South Central Coast in the spring and summer, the South in the spring, and the North in the winter. The number of extremely cold days also tends to decrease, however, the number of cold periods fluctuates sharply from year to year (Vietnam Ministry of Natural Resources and Environment, 2016).

3.4 The linkage between air pollution and climate change

3.4.1 The foundational relation between air pollution and climate change

Air pollution and CC are all assumed as international issues and are also inevitably related to each other. They all have the ability to make huge impacts on the environment and people's health. First of all, sectors in almost the national system around the globe that contribute to the sources of GHGs increase the CC are also the foundation of air pollution. The consumption of fossil fuels creates both contaminated components into the atmosphere and also increases the concentration of the total GHGs (Liu et al., 2019). In general, CC can affect air quality, and conversely, air pollution can impact CC.

The relationship is presented by two main components, which are the concentration of ground-level ozone (O₃), and particulate matter (PM). On the one hand, the changes in climate make a negative effect on air quality. Specifically, increased atmospheric temperatures related to global warming have the potential to increase the concentration of O₃, which will put a threat in compliance with the O₃ standards down the road. On the other hand, changes in the climate also resulted in the increase of pollutants emitted into the atmosphere. While O₃ can warm the climate, other different components of PM may have either warming or cooling impacts on the climate. For instance, while black carbon emitted from combustion warms the Earth,
particulate sulfates cool the atmosphere.

3.4.2 The new approach of air pollution management in the context of climate change

Firstly, CC and air pollution are closely connected since greenhouse gases and air pollutants originate from the same source, fossil fuel combustion. Then, the relationship is represented by 3 sub-linkages (Figure 3.11).

The correlation between climate and air quality is noteworthy for ozone. Ozone levels are directly driven by weather since ozone-generating photochemical reactions of air pollutants (nitrogen oxides; methane; volatile organic compounds, VOCs) need high temperatures and bright sunshine, conditions typical of summer months. High temperatures are often associated with dry weather conditions, which significantly contribute to high ozone levels during heatwaves through a drought stress on vegetation that inhibits stomatal uptake of ozone;

Climatic factors affect particulate matter concentrations to different extents depending on the PM chemical components. On the one hand, high temperature results in an increase in sulfate aerosols due to faster SO2 oxidation, and on the other, it brings about a reduction in nitrate PM concentrations due to increased gas phase transition. However, under climate change the nitrate burden is predicted to increase along with all other aerosol species, except sulfates;

Another important link between climate and air quality is that primary products of combustion processes (i.e. carbon monoxide, non-methane VOCs, nitrogen oxides, sulfur dioxide, black carbon and organic carbon aerosols) and some secondary pollutants (i.e. ozone) have the potential to increase global warming directly or indirectly. Carbon monoxide, non-methane VOCs and nitrogen oxides cause a reduction in the oxidant power of the atmosphere increasing the lifetime of methane, one of the most important warming agents and a precursor to ozone. Nitrate particles, as well as organic carbon aerosols, instead have a cooling effect on the climate. Sulfur dioxide partly converts to sulfate particles, which also have cooling potential, and partly reacts with black carbon, which has a strong warming effect.
CC in general is happening with an extremely complex trend. It comes in many different forms. In fact, it has become a phenomenon that is of great interest to people and governments worldwide. It can be confirmed that CC has become a "no border" issue. Countries have also promptly approached this issue by linking together and offering solutions to respond to climate change not only for their own but also inter-sector, inter-regional, and international. Because of that inevitable trend, the management of air quality in the context of climate change in general needs to be carried out in a “no border” approach. Specifically, the proposed solutions must be interdisciplinary, inter-regional, and international cooperation (if any) will bring greater efficiency.

CHAPTER 4: CURRENT SITUATION OF AIR POLLUTION IN HANOI

4.1. Causes of air pollution in Hanoi

4.1.1. Transportation activities

Amongst all the causes of air pollution, transportation is the most polluting. Emissions from this source are contributing the most to the total emissions; the main exhaust gases include SO₂, NO₂, CO, particulate matter (TSP, PM₁₀, PM₂.₅). According to the Vietnam Ministry of Natural Resources and Environment (2016), up to 70% of the particulates causing pollution are caused by traffic activities, of which 85% of the CO₂ and 95% of the VOCs. Vehicle emissions depend on the quality of the
vehicle's machinery, the quality of the fuel, the operating speed, the driver, the traffic conditions such as the volume of traffic, the congestion, and the road infrastructure (Vietnam Ministry of Natural Resources and Environment, 2018).

As of the first quarter of 2019, Hanoi had 6,649,596 vehicles, including 739,731 cars, 5,561,436 motorbikes (86%), and electric scooters 148,429 units... (Hanoi Statistical Office, 2019). Among those vehicles, motorbikes are the largest emission source. The number of means of transport increases by about 15% annually equivalent to about 27 thousand units per month. To meet the travel needs for such a large number of vehicles, it is required Hanoi have to arrange a land area for traffic about 23% of the city area, but this figure in Hanoi only reaches one third. This is the cause of daily congestion in Hanoi, prolonged local congestion that not only causes economic damage but also makes air quality increasingly polluted.

In terms of public transport, at present this type of traffic in Hanoi is mainly composed of buses. Although the quality has been improved and increased in quantity, these are not enough to meet the travel demand of the residents. Furthermore, buses are also a significant source of air pollution since the buses in Hanoi are still in their old state and do not meet emission standards. Bus routes in Hanoi are still cramped; its quality has not met the travel needs of the residents along with the low awareness of people participating in traffic causing traffic congestion.

Not only causing air pollution, but transportation activities also degrade the inner city roads. Most of the roads in the city are narrow, lack planning, and do not meet the travel needs of the residents. The main roads in Hanoi are continuously under repair and construction, making the concentration of particulate matter even worse. The traffic demand of the trucks packed with construction materials also increases, the traffic of these types of vehicles also makes the dust from the truck, or dust on the roads being repaired increase. This is also the cause of air pollution.

4.1.2. Industrial activities

The main source of emissions from industrial zones is from the burning of fossil fuels from more than 100 industrial clusters that have been operating in the inner city. On the other hand, enterprises' scale in Hanoi mainly consists of extremely small,
small, and medium, thus most of them do not have a system to treat harmful emissions before being discharged into the environment. Moreover, technology is out of date and mainly uses fossil fuels. Businesses still use coal and oil due as the most two types of input materials due to their low cost, despite the growing trend of converting to clean energy. Their main exhaust gases are NO₂, SO₂, total suspended particles (TSP). Otherwise, suburban industrial areas in nearby provinces comprised of meteorology factors also deliver a large number of polluted particles towards Hanoi, which made its air pollution more serious.

4.1.3. Construction activities

Along with the urbanization process, construction activities in Hanoi are taking place more and more with dense density, especially construction activities of new residential areas, bridges, roads, transportation of materials and wastes carried a large amount of dust. Although there is Circular 05/2015/TT-BXD on the management of shielding at construction sites to ensure environmental hygiene during construction, or regulations to wash vehicles before leaving the site with vehicles carrying construction materials, washing roads, however, dust and particles continue to increase, affecting residents in traffic.

The construction industry causes air pollution through clearance activities, the use of diesel-powered machinery, destruction and burning of solid materials. These activities all release a large amount of dust into the environment. Site clearance causes the air environment to receive a lot of particles and cement dust. The use of diesel-fuelled vehicles, which emits mainly particulate matter PM₁₀ and PM₂.₅, SO₂..., in which PM₁₀ accounts for the majority. The activities of destroying and burning materials release to the environment harmful gases such as SO₂, NOₓ, CO.

Also, in Hanoi, there is often a situation of prolonged construction, typically the Cat Linh-Ha Dong railway, or Truong Chinh route (finished), making the air environment always in a state of dust pollution, affecting road users and people in the area.
4.1.4. Living activities and waste treatment

Activities that pollute the air environment are mainly cooking with coal stoves, domestic wastes that generate odors, and activities from craft villages. Currently, households in Hanoi use various types of cooking such as gas stoves, induction cookers, electric cookers, and infrared stoves. Many of them still use coal stoves, mainly small families. However, to limit the negative impact of coal stoves on the environment and human health, Hanoi has had a policy by 2020 to eliminate the city's honeycomb charcoal stove. Hoan Kiem is one of the inner-city districts first to eliminate coal stoves. On the spread of propaganda pamphlets of the Hanoi Department of Natural Resources and Environment, which were posted around the area of Hoan Kiem district, it had written "Heat a honeycomb charcoal stove once by smoking 40 cigarettes".

With a population of more than 8 million people, the amount of daily domestic waste in Hanoi is up to 6,500 tons, the city currently has 17 waste treatment plants, but most of them have not been implemented, also have not received the consent of the citizens or stopped working. The reason is that those disposal and burial sites all generate odors and pollute the air environment and greatly affect the residents around the area. Treating waste emits a lot of harmful gases into the environment, from the first step is the collection to the last step is burning or burial. The garbage collection step generates many harmful gases, especially methane due to the rot of food, leaves. Then, the process of transporting garbage that generates dust due to the long-distance circulation. Most of them are always in congestion and the roads are degraded, in addition to waste scattered during transportation and odor pollution. The process of waste burial or incineration also emits harmful gases, most of the waste is usually paper, wood, rubber, nylon, cloth, and plastic, so the gases discharged into the environment are mainly $\text{SO}_2$, $\text{NO}_x$, CO, $\text{CO}_2$, HCl, ash...

4.1.5. Other sources from sub-urban areas

The nearby area of Hanoi consists of key industrial development, attracting a large amount of foreign investment and building a lot of export processing zones such as Bac Ninh, Hung Yen, Hai Duong, Quang Ninh... Factories produce and also emit a
large number of toxic gases, particulate matter... although the distance is quite far from Hanoi, these polluted contaminates can be blown to Hanoi by the wind.

According to an analysis by the Green Innovation Development Centre (GreenID) based on air monitoring data from the US embassy, particle pollution in Hanoi is worse than in Indonesia's capital Jakarta. Dust pollution in Hanoi is even more difficult to improve when our country is still planning to build more coal-fired power plants, one of the main pollution causes. In the North of Hanoi, there are 20 coal-fired thermal power plants in operation, although the factories far away from Hanoi, PM$_{2.5}$ fine particle has the ability to spread very far. Otherwise, agricultural sources such as straws burned in the seasons also cause a large amount of ash that affects the air quality of the city.

4.2. Air pollution condition in Hanoi

The air pollution situation in Hanoi has never been as alarming as in recent years, when annually, it receives a large number of emissions from about 6.7 million vehicles, more than 100 industrial zones with specific emissions of about 80 thousand tons of smoke and dust, 46 thousand tons of CO$_2$. Air pollution in Hanoi is reflected through the monitoring data about PM$_{10}$, PM$_{2.5}$, SO$_2$, NO$_x$, CO$_2$, CO, TSP.

Particle pollution is one of the most prominent environmental problems in Hanoi. Fine particle concentration is usually high at major intersections, during times of traffic congestion such as 07 to 09 A.M or 5 to 7 P.M. Considering the times of the year, the dust concentration usually increases in the dry season when the weather is less rainy, usually in the last months of the year, when the atmosphere in Hanoi is of poor quality and due to both weather factors and increased traffic pace at the end of the year. During the past 6 years, Hanoi's atmosphere has always been in the state of dust pollution with the dust concentration parameters all exceeding QCVN 05: 2013 (25 $\mu$g/m$^3$) and WHO recommendations (10 $\mu$g/m$^3$).
Figure 0.1: PM$_{10}$ and PM$_{2.5}$ monthly average concentration in Hanoi 2018

Source: Based on data collected from Nguyen Van Cu monitoring station and Airnow

Dust pollution in Hanoi is analyzed by two particulate indexes PM$_{2.5}$ and PM$_{10}$. The evolution of the concentration of PM$_{10}$ and PM$_{2.5}$ in Hanoi in the period 2010-2018 calculated according to the average annual value ranged from 46.2 to 100.8 μg/m$^3$ and 35.5 to 59.4 μg/m$^3$, respectively. These two types of particulates concentration have an increasing trend at the end of the year. The reason is explained by the weather in Hanoi is usually dry and less rain in these months. As shown in Figure 0.1, PM$_{10}$ and PM$_{2.5}$ concentrations in 2018 were lowest in July and highest in December. PM$_{2.5}$ is more dangerous than PM$_{10}$. The proof for this is that PM$_{10}$ can only penetrate the lungs, but PM$_{2.5}$ can go deeper into the human body and penetrate the blood.

Other types of emissions such as CO, NO$_2$, SO$_2$, and O$_3$ originate from vehicles, thus areas with high traffic volumes will be the most polluted. The concentration of these pollutants in Hanoi is still within the limits of QCVN 05: 2013 (Vietnam Ministry of Natural Resources and Environment, 2018).

In addition, the changes in air quality in Hanoi recently showed that this change is closely related to the change in weather. Weather in Hanoi, the temperature in winter is usually higher than that in summer. The cause of this phenomenon is the difference between climatic characteristics in each season of the year. One of those characteristics of air quality is that it is strongly influenced by climatic and meteorological factors such as wind, wind direction, temperature, humidity,
precipitation, and sunlight. Specifically, in the winter, low heat, less light, and rain, along with the northeast monsoon lead to the movement of pollutants from the North.

In addition, during this time, heat inversions appeared. Usually, the higher it gets, the lower the atmospheric temperature. However, when the heat inversion occurs, this law is reversed. This unusual temperature difference creates an inversion layer like a barrier. This membrane prevents the dispersion of contaminants along both the longitudinal and transverse axes. As a result, airborne pollutants accumulate in one area, increasing the pollution concentration. In the summer, the temperature is high, the ground and the atmosphere are heated. At the same time, with the characteristic of frequent rainfall and thunderstorms, pollutants are more likely to be washed away or dispersed into higher altitudes. However, with such weather characteristics in summer, pollutants easily dissolve in the air and cause pollution concentrations not as high as in winter.

4.2.1. Air pollution caused by PM$_{2.5}$

Along with the industrial revolution, the 4.0 current trends in the world are sustainable development and building a green economy. Developed countries, USA, Korea, Germany, have been using advanced technologies intending to green the economy, reduce emissions. The trend of environmental protection is getting stronger as countries respond to World Environment Day 2019 with the theme of Air Pollution and Vietnam is not an exception. The proof is the evolution of the air quality based on the PM$_{2.5}$ criteria in the period 2012-2019.

![Figure 0.2: Averaged PM$_{2.5}$ concentration from 2012 to 2018](image)

*Source: Calculation results from PM$_{2.5}$ concentration data in Hanoi provided by AirNow*
The period 2012-2018 showed that the concentration of PM$_{2.5}$ in years was higher than QCVN 05:2013 values, it can be seen that after the enacting of the regulation, the air quality has been improved in 2014 and 2015 compared to 2013, but tends to increase sharply in 2016 with PM$_{2.5}$ concentrations up to 50.5 μg/m$^3$. However, the air quality continued to improve in the following years. For an overview of PM$_{2.5}$ pollutions in Hanoi during this period, based on data from AirNow and Nguyen Van Cu monitoring station, we have a chart of the monthly average PM$_{2.5}$ concentrations from 2013 to 2019.

![Figure 0.3: Monthly average PM$_{2.5}$ concentration in the period 2013-2019](chart.png)

*Source: Calculations from PM$_{2.5}$ concentration data in Hanoi provided by AirNow*

Through the chart, we can see that the air quality in Hanoi, in general, is improving. In 2013, the worst air quality in the whole period when the average monthly concentration in this year was mostly higher than the corresponding value of the remaining years. However, in the last months of 2019 Hanoi had a much higher increase in PM$_{2.5}$ concentrations compared to the same period last year. During the period, PM$_{2.5}$ concentrations tend to increase sharply during the Tet months and decrease in the months of 6,7,8. The cause of this phenomenon is believed to be because the weather in the last months of the year is usually dry, less rain, heavy traffic.

Not as of December 2019, the average PM$_{2.5}$ concentrations in the 11 months of this year falls to about 30.4 μg/ m$^3$ although December is usually the time when PM$_{2.5}$ concentrations rise and the average PM$_{2.5}$ concentration of the year will also increase.
significantly from 30.4 μg/m³. However, if the air developments in Hanoi in December continue in accordance with the rules of the last 4 years (51 μg/m³ in 2015, 50 μg/m³ in 2016, 48 μg/m³ in 2017, and 26 μg/m³ in 2018, the average concentration in 2019 are likely to continue to decrease compared to previous years. If the average PM₁₅ concentrations in December 2019 is predicted to be 50 μg/m³ and 102 μg/m³ (the highest level in the same period in December 2019), the average PM₁₅ concentrations in Hanoi in 2019 is 32 μg/m³ and 36.3 μg/m³. Lower than in 2013-2018.

**Table 0.1: Monthly average PM₂.₅ concentration from 2013 to 2019**

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*Source: Calculations based on monitoring data at Nguyen Van Cu monitoring station and U.S. Embassy monitoring station*

Through the analysis of the air pollution situation in Hanoi in the period 2013-2019, we can see positive signs when the PM₂.₅ concentration continues to decrease in recent years. However, there are still many difficulties in improving air pollution in
Hanoi and the situation of air pollution is also increasingly unpredictable and dangerous to human health than ever before.

4.2.2. Air pollution caused by PM\textsubscript{10}

According to the national technical regulations on ambient air quality, PM\textsubscript{10} has an average 24-hour due value of 150 μg/m\textsuperscript{3} and an average of 50 μg/m\textsuperscript{3} per year.

![Figure 0.4: Annual average PM\textsubscript{10} concentration in Hanoi from 2013 to 2018](image)

Source: Fluctuations over time of PM\textsubscript{10} dust, Environmental Journal

PM\textsubscript{10} concentrations in Hanoi generally tend to decrease throughout the period. However, PM\textsubscript{10} concentrations have mostly exceeded the limit according to QCVN 05:2013, during this period only in 2017 PM\textsubscript{10} concentrations are within the permission threshold at 47 μg/m\textsuperscript{3}.

From the above analyses, we can see that the annual concentrations of PM\textsubscript{2.5} and PM\textsubscript{10} dust in Hanoi exceed the limit in QCVN 05:2013/BTNMT. According to observational data, it can be seen that the concentration of PM\textsubscript{2.5} dust exceeding the permission allowed limit between 2013 and 2018 has been between 10.31 (in 2017) and 51. 25% (in 2013). Meanwhile, the rate of PM\textsubscript{10} concentrations exceeding the lower limit, the highest was only about 9.19% in 2013, even the figures in 2016 and 2017 reached the permission standard.

4.2.3. Air pollution caused by hazardous gases

Air pollution due to SO\textsubscript{2}, NO\textsubscript{2}, CO, O\textsubscript{3} gases in Hanoi is still within the permissible limits of QCVN 05:2013/BTNMT which means that Hanoi’s atmosphere
has not been polluted by hazardous gases. CO, NO₂, SO₂, O₃ emissions are derived mainly from motor vehicles, so areas with high traffic density are the places with the highest concentrations of pollution. According to the "National Environmental Status Report 2016", the concentration of CO, NO₂, SO₂ in Hanoi’s air is still within the limits of QCVN 05:2013. However, NO₂ concentrations tend to increase. CO levels usually rise during peak hours. For example, data at the Nguyen Van Cu Monitoring Station (Gia Lam, Hanoi) in 2015 showed that the highest CO concentration of the day was at 8-9 am, up to over 3,500µg/m³. The average annual SO₂ concentration also at Nguyen Van Cu Station tends to increase gradually, from less than 10 µg/m³ in 2012 to 30 µg/m³ in 2015, then decreased to about 22 µg/m³ in 2016.

The concentration of NO₂ in the city still reaches the standard, but tends to increase in recent periods, NO₂ often increases sharply in areas with high traffic density of Hanoi such as the crossroads of The Department, Pham Van Dong area, Truong Chinh ... Due to this feature, NO₂ parameters increase sharply during peak hours such as 7-9 am and 5-7 pm. Similar to NO₂, CO parameters in Hanoi will also increase during peak hours in traffic areas.

The concentration of SO₂ is also still within the limit according to QCVN 05:2013. As well as the parameters of other gases at certain times, SO₂ will also increase beyond the norm, especially often occurs in locations near enterprises using coal, oil containing sulfur when burning arises into the environment. But in terms of the average annual target, it still reaches the standard.

Figure 0.5: Annual average SO₂ concentration development at Nguyen Van monitoring station
According to data from the monitoring station Nguyen Van Cu, SO$_2$ concentration in Hanoi increased in the period 2012-2015 but decreased in 2016. The reason why SO$_2$ in Hanoi increased is believed to be due to the rapid urbanization and population growth, the main reason is the increase in the number of vehicles, emissions to the environment of large emissions including SO$_2$.

The data at the monitoring stations showed that the O$_3$ concentration also exceeded the limit according to QCVN for several days of the year. Specifically, in 2012 there were 24 days, in 2013 increased to 38 days and then fell sharply in 2014 with 4 days exceeding the norm; in 2015 and 2016, 13 and 7 days of O$_3$ parameters exceeded the permitted standards, according to the regulations. However, the average annual O$_3$ concentration is within the threshold.

4.2.4. Air pollution caused by unpleasant odor and noise

In Vietnam, there is no law on this issue, so odor pollution has been causing many adverse effects on the lives of Hanoi citizens, Especially people living around the waste collection area of Nam Son, Soc Son district, according to the supervision of the Hanoi People's Council, the total amount of household waste per day is about 6,500 tons per day, of which nearly 90% of this waste is treated by landfill method, not treated so odor pollution at landfill points is getting more and more serious. In Hanoi, odor pollution from the To Lich River greatly affects the lives of people around, so that the city government must devote large budgets to renovate the river.

Noise pollution is regulated in QCVN 26:2010/BTNMT - National Technical Regulations on Noise. Accordingly, the maximum allowable limits in special zones and regular areas from 6 hours to 21 hours are 55 and 70 dBA, of course. This limit between 21:00 and 6:00 is 45 and 55 dBA, and 55 dBA, of the same time. The level of noise measured in Hanoi is mostly within the permitted standards, but in some places such as construction site, the main traffic points, the noise level at 75 - 79dBA exceeds the permitted level, this is a loud noise level and equivalent to the noise level of other cities in the world, adversely affecting the living life of people. Noise affects human hearing, can cause headaches, dizziness, fatigue.
4.3. Effects caused by air pollution in Hanoi

4.3.1. Effects of air pollution on humans

As mentioned above, human health is easily affected by environmental changes, especially air. Although the atmosphere in Hanoi has improved, the diseases related to air pollution have continuously increased recently. Hanoi residents are very susceptible to respiratory diseases, pneumonia, or more serious diseases such as lung cancer. The longer people live and work in Hanoi, the more likely they have the potential of affecting by air pollution. Furthermore, the most susceptible group are children, pregnant women, and the elderly. Research has shown that air pollution is also the cause of an increase in miscarriage, the fetus is also more likely to have birth defects if mothers are exposed to a lot of polluted substances during the time of pregnancy.

PM$_{2.5}$ particulates are the air pollutant with the most negative impact on human health. Humans breathe about 10,000 litters of air every day, so if the PM$_{2.5}$ fine particulate concentrations in the atmosphere are high, the risk of related diseases is greater. There are many studies done around the world that show that exposure to PM$_{2.5}$ particulate increases the risk of illness and death. For example, exposure to PM$_{2.5}$ increases the risk of asthma, lung disease, chronic obstruction, pneumonia, respiratory diseases, cardiovascular diseases, diabetes, and lung cancer (Uysal and Schapira, 2003; Ghio and Huang, 2004).

Some studies by environmental experts also show that the number of people dying from air pollution in Hanoi could double what is now or more by 2035 and for children living in 3 the capital city of Beijing, Jakarta, and Hanoi. Air pollution increases the risk of death from respiratory infections by 40% and asthma by 20%. For adults, the risk of lung cancer increases by 25-30%, and the risk of stroke is doubled (Kagawa, 1985; Balmes, Fine and Sheppard, 1987).

4.3.2. Effects of air pollution on socio-economic development

The World Bank has estimated the economic burdens on the effects of air pollution. This estimation shows that the costs associated with this are enormous. Air pollution causes cost damages such as costs of medical examination and treatment,
loss of income due to force-stop working for medical treatment. They are also shown in the decline of crop productivity, leading to a decline in profits earned from trade or displacement of people from polluted areas, costs of pollution treatment, and control. These costs are hereinafter referred to as pollution costs. Most of the causes of these cost losses come from secondary impacts, giving rise to a series of socio-economic problems. The estimated loss rate is up to 20% of income (World Bank, 2018).

The current population of Hanoi by the end of the first quarter of 2019 is about more than 8 million people, the Ministry of Natural Resources and Environment said that, on average, each person in Hanoi spends more than 1,500 VND (0.07 USD) on respiratory treatment due to air pollution every day. The total population of Hanoi spends about 4.38 trillion VND (equivalent to 18.25 million USD) per year on medical treatments.

On a national scale, Mr. Le Viet Phu - an economist at Fulbright University Vietnam said that the total economic loss due to air pollution premature death is about 5-7% of Vietnam's GDP, equivalent to 11.4-15.9 billion USD.

Air pollution in Hanoi makes the sky of the city always gray, affecting the landscape of Hanoi, causing loss of beauty for tourists, and affecting tourism and relaxation activities. Hanoi is always an ideal destination to attract tourists with nearly 15 thousand visitors per year (Hanoi Statistical Office, 2019). Although the number of tourists has increased over the years, a part of tourists said they find that Hanoi is very polluted. If Hanoi's atmosphere is not improved, it can greatly affect the tourism industry of the city.

4.3.3. Effects of air pollution-related to climate change

CC occurs due to the contribution of many factors, but the main reason comes from humans such as burning fossil fuels (coal, oil ...) to create greenhouse gases. Accompanying air pollution phenomenon is always a rapid increase in CO₂ and CO parameters due to transportation activities, this is the gas causing the worst environmental pollution, and is the main cause of the greenhouse effect., which causes CC. Currently every year, Hanoi has to receive about 46,000 tons of CO₂ from different emission sources, making the CC situation increasingly serious.
Air pollution causes CC and the direct consequence of this phenomenon is that the temperature in Hanoi has continuously increased over the years. The summer of 2019 is identified as the time when Hanoi has had record heat with the highest temperature in the past 100 years. There are times when the outdoor temperature in Hanoi reaches up to 45 to 50°C and lasts for consecutive days. The temperature is constantly rising and divided into many prolonged heat waves, which greatly affect the health of people and their jobs, especially those who work outdoors. Besides, such hot weather makes the demand for air-conditioners increasing, causing harmful gases emitted from air-conditioners and refrigerators to increase the air pollution situation.

4.4. Current air pollution management tools

In Vietnam, by 2008, the political commitment to climate change must be integrated into the development of new policies and strategies embodied in the National Target Program to Respond to Climate Change. Thus, it can be said that 2008 was a milestone in the process of responding to climate change in Vietnam. From here, the decision-making is studied and considered in the context of climate change, in which it is impossible not to mention pollution control solutions in big cities.

4.4.1. Legal tool

- According to Vietnam Environmental Protection Law 2014: In the current system of legal documents, from laws to decrees and guiding documents, there are regulations on-air environment protection, including the urban air environment. Vietnam Environmental Protection Law 2014 has supplemented the provisions of on-air environment protection. In particular, for urban areas, there are regulations on environmental protection for industries with high air pollution activities such as transportation, construction, industry... Specifically, in Section 4 “Protection of the air environment” of chapter VI, there are 03 following articles (The National Assembly of Vietnam, 2014):

- Article 62: General provisions on the protection of the air environment;

- Article 63: Managing air quality;

- Article 64. Air pollution control.
The provisions in this law do not mention sanctions, mainly provisions on the process of evaluating and approving projects before they are built. It regulates that after the construction if these organizations and enterprises made impacts on air quality, there must be mitigation and treatment measures to ensure compliance with the provisions of law. Nevertheless, it does not mention management measures and sanctions if there are violations of the regulations.

In section 5, Chapter IX: Waste management has regulated about "management and control of dust, exhaust gas, noise, vibration, light, radiation". Article 102. "Dust and gas emission management and control". This stipulates that organizations and individuals engaged in production and business activities, if having excessive dust emissions, must treat them to meet regulations. Furthermore, vehicles and equipment when emitting dust also must be shielded and installed with dust filters.

• “Decree No.38/2015/NĐ-CP regulating industrial emission management: Regarding the type of exhaust gas, the main sources in our country include: traffic, industry, construction and residential, agriculture and craft villages, burial and substrate treatment. The control and handling of dust and exhaust gas are regulated in Vietnam Environmental Protection Law 2014 and Decree No.38/2015/NĐ-CP. However, the implementation of regulations in the control and treatment of dust and emissions is currently facing many difficulties. Up to now, traffic emissions have not been monitored and controlled for registered vehicles many years ago; Emission from craft villages, industrial clusters has not been controlled yet. Therefore, environmental pollution from these activities is continuing (The National Assembly of Vietnam, 2014; The Government, 2015).

• The National Action Plan for Air Quality Management - Decision No. 985q/QĐ-TTg approving “National Action Plan for Air Quality Management to 2020, Vision to 2025” approved by the Prime Minister in 2016. “Accordingly, the management agency must focus on dust control during construction and transportation of materials and wastes at construction sites; investing and renovating advanced technologies, production processes and production equipment in industrial production establishments to limit emissions generation; continue to invest in the construction, installation, and operation of gas treatment equipment systems arising from industrial
establishments, ensuring no pollution of the air environment; have to complete the implementation of regulations on the roadmap for application of emission standards to new manufactured, assembled and imported cars and motorcycles. Strengthening national capacities for greenhouse gases (GHG) control, contributing to the implementation of Vietnam's national commitment to GHG emissions reduction. Strengthening the surrounding quality monitoring through increasing the number of automatic continuous surrounding air monitoring stations in urban areas compared to 2015 following the national environmental monitoring network plan. Monitoring air pollutant parameters regularly according to environmental technical regulations and parameters VOCs, HC...” (Prime Minister of Viet Nam, 2016).

In Vietnam, there is currently no separate legal document applicable to the air environment, however, due to awareness of the importance of air quality management, the Prime Minister has issued several related regulations, standards of the surrounding atmosphere, including:

- National technical regulation on ambient air quality, QCVN 05:2013/BTNMT. This regulation specifies the concentration of substances in the air, replacing the QCVN 05: 2009/BTNMT;

- QCVN 06:2009/BTNMT regulates several toxic substances in the surrounding air, replacing the TCVN 5938:2005;

- QCVN 26:2010/BTNMT regulates the noise, replacing the TCVN 5949: 1998;

- Decision on the approval of the national action plan on air quality management to 2020 with a vision to 2025. The decision includes 3 articles to control emissions sources, identifying the current state of pollution PM$_{10}$ and PM$_{2.5}$ particulates in urban areas; strengthening national capacities for greenhouse gas control; contributing to the implementation of Vietnam's commitment to reduce greenhouse gases, and strengthen monitoring of ambient air quality.

Besides, many environmental technical regulations on emissions regulated in Vietnam Environmental Protection Law 2014 include emissions techniques of mobile and fixed sources. Includes the following regulations below:
- QCVN 51: 2013/BTNMT: National technical regulation on industrial emissions of steel production;

- QCVN 02:2008/BTNMT: National technical regulation on the waste gas from medical solid waste incinerators;

- QCVN 19:2009/BTNMT: National technical regulation on industrial emissions for dust and inorganic substances;

- QCVN 20:2009/BTNMT: National technical regulation on industrial emissions with a number of organic substances;

- QCVN 21:2009/BTNMT: National technical regulation on industrial emissions of chemical fertilizer production;

- QCVN 22:2009/BTNMT: National technical regulation on industrial thermal power emissions;


In addition to domestic standards and regulations, Vietnam also participates in international conventions on the protection of the air environment such as the "United Nations Framework Convention on Responding to Climate Change" (UNFCCC), Kyoto Protocol on Responding to Climate Change, Paris Agreement on Responding to Climate Change".

4.4.1.1 Vietnam participates in the United Nations Framework Convention on Climate Change.

Vietnam participated in the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and the Kyoto Protocol in 2002. As a non-Annex I member of the UNFCCC, Vietnam has actively implemented the Joint Service of the UNFCCC and the Kyoto Protocol. On 8 June 2015, Vietnam ratified the Doha Amendment to the Kyoto Protocol to contribute to the establishment of a global legal basis for controlling and reducing GHG emissions during the second commitment period of the Kyoto Protocol (2013-2020) and the goal of keeping global temperatures
from rising more than 2°C by the end of this century compared to the pre-industrial era.

In order to facilitate the implementation of the UNFCCC and the Kyoto Protocol, the Government of Vietnam has issued many important documents. Examples are the Prime Minister's Directive on organizing the implementation of the UNFCCC, Kyoto Protocol and CDM; Plan to organize the implementation of the Kyoto Protocol under the UNFCCC; National target program to respond to CC; National Strategy on Climate Change; National Green Growth Strategy; National action plan on CC for the period 2012-2020; Scheme of management of GHG emissions; management of carbon credit business activities to the world market. It can be seen that the GHG emission reduction target is one of the central goals.


The organizational apparatus of the Government of Vietnam participating in the implementation of the UNFCCC consists of 3 core ministries, departments, and branches: The Vietnam Ministry of Natural Resources and Environment, the Standing Committee of the National Committee on Climate Change, and the Steering Committee of the UNFCCC. In particular, other relevant ministries will also provide information, data, and suggestions in coordination with the Vietnam Ministry of Natural Resources and Environment; With guidance from the Steering Committee, the Department of Climate Change will consolidate reports from working groups and national contexts, GHG inventories, mitigation activities, technology, etc., together with the coordination and consultation support of domestic and international research institutes, universities, and scientific and technological consulting organizations; Relevant departments, general departments, and institutes send them to the Steering Committee. Following that, the Standing Committee of the National Committee on Climate Change will send the BUR to the UNFCCC Secretariat. Thereby, the Vietnam
Ministry of Natural Resources and Environment will send the Advisory Council of the National Committee on Climate Change and finally submit it to the Government of Vietnam for the approval of the BUR.

Figure 0.6: Organization chart of Vietnam implementing the UNFCCC

4.4.1.2 Vietnam participates in the Paris Agreement on climate change

In December 2015, at the 21st Conference (COP21), all Parties of the UNFCCC approved the Paris Agreement on Climate Change. This is a historical agreement binding the responsibilities of all parties to respond to CC. Vietnam signed the Paris Agreement on April 22, 2016, and approved the Paris Agreement through the Government's Resolution No.93/NQ-CP dated October 31, 2016, and submitted its approval document to the United Nations on November 3, 2016. The Prime Minister has approved the Plan to implement the Paris Agreement on CC through Decision No.2053/QD-TTg dated October 28, 2016. The plan includes 68 main tasks to be
implemented from now to 2020 and 2030 to actualize Vietnam's commitments at COP21 and implement the Paris Agreement on CC.

Vietnam has completed and submitted its Intended Nationally Determined Contribution (INDC) in September 2015. Vietnam's committed emissions reductions compared to the normal emissions scenario (BAU - as of the base year 2010) are 8% with its resources and potentially up to 25% when receiving international support. Currently, the INDC has been renamed NDC (the word “intended” is ruled out) after the Paris agreement on CC response was approved by Vietnam. In Vietnam's NDC, the base year used is 2014. The total GHG emissions in the base year 2014 were 283.9 million tons CO$_2$e compared with the INDC, the total GHG emissions in 2010 were 246.8 CO$_2$e. A total of 82 options were identified for GHG emission reduction. They focus on such sectors: energy, industry, waste, forestry sector, and industrial processes. With domestic resources, by 2030, Vietnam will reduce 9.4% of its total GHG emissions compared with BAU. The above target could be increased to 27.3% when international support is received through bilateral and multilateral cooperation and implementation of new mechanisms under the Paris Agreement on CC.

It can be seen that Vietnam shows a very large and clear ambition in GHG emission reduction (although it only belongs to groups of countries that voluntarily implement it). The level of commitment to reducing emissions will be higher with the help of international organizations. These actions demonstrate the careful preparation of Vietnam in terms of legal efforts to reduce emissions and adapt to CC. Vietnam's NDC approved by the Prime Minister will be disseminated to localities to update and incorporate into the Socio-Economic Development Plan for the period 2021-2030, which includes Hanoi capital.

4.4.1.3 Hanoi’s actions

Particularly for Hanoi, the Vietnam Ministry of Natural Resources and Environment has issued two technical regulations on the air environment to tighten the regulations on industrial exhaust emissions in the capital area, which are industrial emissions standards for dust and inorganic substances and industrial emissions standards for cement production.
- Technical regulations on industrial emissions for dust and inorganic substances in the area of Hanoi Capital - QCTĐHN 01:2014/BTNMT;

- Technical regulations on industrial emissions of cement production in the area of Hanoi Capital - QCTĐHN 03: 2014/BTNMT.

At the same time, the city's efforts to limit pollution and protect the capital's environment are also reflected through the issuance of many orientation documents. Hanoi Party Committee issued Resolution No.11-NQ/TU dated May 31, 2017, on "Strengthening environmental protection in Hanoi city to 2020 and the following years", Hanoi People's Committee issued Plan No.160/KH-UBND dated July 3, 2017, to implement Resolution No.11-NQ/TU dated May 31, 2017, of the Hanoi Party Committee, Plan No.124/KH-UBND dated June 1/2017 on overcoming shortcomings and limitations; organizing the implementation of urgent tasks and solutions to protect the environment of the city, in which the city has focused on implementing solutions to manage waste sources, overcome pollution, and strengthen capacity for quality management, environmental air quality, raising public awareness about environmental protection and CC.

Moreover, in 2019, the People's Committee of Hanoi issued Directive no.15/CT-UBND and Directive no.19/CT-UBND related to the air environment. Specifically, the former is on replacing and exclusion of the use of coal as fuel, the latter is on improving the Air Quality Index (AQI) in Hanoi. In which, there is a need to focus on promoting propaganda and raising awareness of the community about the negative impacts of air pollution on human health (Hanoi People’s Committee, 2019).

4.4.1.4 Revised environmental protection law 2020

The law was reorganized compared to the 2014 Law on Environmental Protection, bringing regulations on the protection of environmental components to the top, clearly showing the cross-cutting goal of protecting environmental components, protecting people's health. This matter is assumed as the central and decisive content for other environmental protection policies (Vietnam, 2020).

The law also synchronizes environmental management tools for each stage of the project, starting from the stage of investment policy review, project appraisal,
project implementation until the project goes into official operation and project completion. These include national environmental protection strategy, environmental protection planning, strategic environmental assessment, preliminary environmental impact assessment, environmental impact assessment (EIA), environmental license, and environmental registration.

The above differences bring some new points in the way of managing environmental components as well as related objects. To solve this pressing problem, the Law has regulated the formulation and implementation of an air environmental quality management plan to improve the quality of protection of environmental components.

4.4.2. Economic tool

In Vietnam, the Vietnam Environmental Protection Law 2014 has detailed regulations on the application of economic tools to protect environmental components in general, including the air environment. In which, Article 147 clearly states the spending of the state budget on environmental protection (The National Assembly of Vietnam, 2014):

1. Expenditures on environmental protection include:

a) Developing strategies, plans, technical processes, technical instructions, economic and technical norms, environmental technical regulations, programs, and schemes on environmental protection;

b) Evaluation of environmental protection planning, strategic environmental assessment report;

c) Environmental monitoring activities; building environmental information systems and environmental reporting;

d) Supporting the inspection and examination; controlling environmental pollution, treating environmental pollution, preventing, responding, and overcoming environmental incidents; waste management and biodiversity conservation; training and communication on environmental protection; disseminating and evaluating the
implementation of the law on environmental protection; international cooperation on environmental protection;

e) Other environmental protection management activities.

2. Expenses for investment in the development of environmental protection include expenditures on construction projects, renovation of waste treatment works, construction and equipment of environmental monitoring and analysis stations managed by the State; investment in means and equipment for the prevention, response, and overcoming of environmental pollution, degradation and incidents; responding to CC; biodiversity conservation; rehabilitate polluted water sources, planting and taking care of trees in public places, public areas.

3. Estimating and managing the use of state budget for environmental protection complies with the law provisions on the State budget.

Some methods belong to the group of economic management tools, including environmental protection tax, environmental protection fee, and environmental protection fund. These are all methods of controlling environmental pollution based on a focus on economics. For example, the environmental protection tax in Vietnam is seen as an indirect tax, the collection of products and goods that are determined to be used will cause negative environmental impacts (The National Assembly of Vietnam, 2010).

Furthermore, the revised environmental protection law 2020, just approved by the Prime Minister, also has many new points related to economic management tools. In particular, the Law's point of view tends to use more economic tools, based on market principles for environmental protection activities.

The law for the first time regulates the organization and development of the domestic carbon market. This is considered as a tool to promote the reduction of GHG emissions, contributing to the implementation of contributions to reducing GHG emissions by Vietnam committed to the parties involved in the Paris Agreement on Climate Change. On the basis that Vietnam has just completed and is one of the first countries to submit NDC to the secretariat of the UNFCCC, Vietnam is one of the few countries to increase the contribution of mitigating emissions in the updated NDC.
pursue this effort, the pathway in the coming period depends heavily on the development of the carbon market. Vietnam will initially assess carbon, including proposals on carbon markets and detailed regulations on carbon pricing develop a system to exchange GHG emissions quotas, domestic carbon credits in the revised environmental protection law 2020. Based on such a development orientation, the construction of a complete carbon market will help accelerate activities in the air environmental management that Vietnam is lacking, specifically the activities of collecting and managing data on monitoring of the air quality and inventory of GHGs nationwide.

4.4.3. Technical and auxiliary tools

4.4.3.1 Reducing air pollution through planting trees

Green space development in Hanoi city has always been a top concern. Every year, Hanoi issues a lot of guiding documents on the improvement, replacement, or new planting of greenery areas in the city. To solve problems related to the lack of green space, the Ministry of Construction and the People's Committee of Hanoi approved the implementation of the project "One million new trees" for the period 2016-2020. With the main policy of building 25 more parks (05 parks of international standards). As a result, from 2016 to 2020, Hanoi has grown 50% higher than the original plan (Hanoi develops a system of green trees: Thickening the ‘shield’ to protect the environment, 2020). The number of trees is enormous; however, the plan is not specific about the location as well as the types of trees. Besides planting new trees, the management of trees still has many shortcomings. Especially, the inspection and detection of dead trees, decaying trees, dangerous research has not been regularly carried out. This has many potential risks of branch breakage and tree fall in the next rainy season.

4.4.3.2 Environmental modelling

In the past 10 years, the application of environmental modelling methods in management and research in Vietnam has been popular. Especially in the field of air environmental quality assessment, The Community Multistage Air Quality Modelling System (CMAQ) is widely used. In addition, the research also develops, combines the application of the CMAQ model with meteorological models and emission models.
This combination has created a new research methodology, which will increase the reliability, accuracy, and reasonableness of the research result.

In 2008, the Vietnam Institute of Meteorology, Hydrology, and Environment carried out the project "Building air quality forecast bulletin for key economic regions in Vietnam" (Son, 2008). The research objective is to generally research the air quality in key economic regions of Vietnam. The authors use traditional monitoring methods together with the CMAQ air quality modelling system to evaluate the air environment quality through parameters SO\textsubscript{2}, NO\textsubscript{2}, CO, and PM\textsubscript{10} particulate. Regarding the results of the study, it has built a database for calculating gas emissions for 3 key economic regions through collection and field survey. At the same time, the research approached and solved the air quality problem by modelling methods using WRF, CMAQ, and SMOKE models. The error in the results of the topic was evaluated at an acceptable level. However, regarding some shortcomings, the research has not considered dry deposition issues in the study area such as sedimentation speed, sedimentation capacity, and dry deposition distribution. At the same time, it is recommended to continue to invest in the application of the CMAQ multi-substance, multi-scale air quality model system in the daily forecasts of air quality for researches and studies in Vietnam Institute of Hydrometeorology and the Environment as well as in Vietnam down the road.

4.4.3.3 Air quality monitoring

Currently, the automatic air quality monitoring network in Hanoi includes 10 stations under the management of the Hanoi Department of Natural Resources and Environment (put into operation in 2017) and 1 station under the management of the Vietnam Environment Administration (operated since 2010) and some private monitoring stations such as the US Embassy air monitoring station.

It can be said that the number of air quality monitoring stations in the city these days is quite small and not rationally distributed. Most of the monitoring stations are located in the inner city area (Figure 0.7). Simultaneously, the observed data obtained from those stations are not consistent and synchronized with the period and monitoring factors. Nevertheless, those collected data also provided information on the air quality in the city promptly.
4.5. Sub-conclusion

Air pollution in Hanoi comes mainly from transportation, industry, and construction, and has become more and more serious in recent years. In which, fine dust pollution is the most prominent environmental problem. The best evidence is that the measurement results show that the particulate matter concentration in the capital over the past 6 years always exceeded the permitted level of QCVN and WHO's recommendation. Fine dust pollution affects the health of the capital's dwellers as they increase the risk of respiratory diseases, stroke, and lung cancer. Not only that but also air pollution contributes to accelerating CC. This is considered to be the direct cause of the continuous increase in the city’s temperature over the past few years, making the difference between summer and winter temperature increasing. The high temperature also causes the demand for fuel to increase and consequently increases the emission of harmful gases into the atmosphere. In order to improve air quality, many measures have been enacted to control air pollution; however, their integration in the context of CC has many limitations. The legal measures focus on providing responsibility for waste generators to control their emissions, but there is no clear mechanism for regulatory agencies, causing difficulties in implementation. Besides, economic tools are focusing on developing the domestic carbon market to reduce total greenhouse gas
emissions nationwide, not paying attention to the application of fees to minimize local pollution. Thus, it can be seen that, among the causes of air pollution in Hanoi, traffic activities have not yet had effective and determined policies compared to other causes.
CHAPTER 5: PROPOSED AIR POLLUTION MEASURES

5.1. Practical air pollution management measures around the world

5.1.1. Beijing experience

Beijing has had its first aggressive campaign against air pollution since 1998, although air environmental protection has been in place since the 1970s. The priority should be to find ways to improve air quality effectively and sustainability. Over the past 20 years, many other challenges have been addressed, so far, Beijing has shown many manifestations of air pollution control as the air quality here has improved significantly. The city's response to CC has left many valuable lessons learned, as well as an improved roadmap for other cities to follow.

Beijing's roadmap for improving air quality is divided into two phases. Phase 1 began from 1998 to 2013. Experts identified the main cause of air pollution originating from burning coal and motor vehicles, with the concentration of major pollutants all exceeding the limits of national standards. During these 15 years, Beijing implemented a series of measures focused on improving and upgrading infrastructure, energy control coal, and emissions from motor vehicles. At the end of phase 1 in 2013, some contaminants such as CO, SO\textsubscript{2} were within the limits of the standard. The average annual CO emissions for the period 1998 - 2013 decreased from 135 μg/m\textsuperscript{3} to 48 μg/m\textsuperscript{3}. Measurements of SO\textsubscript{2} from 120 μg/m\textsuperscript{3} decreased to less than 10 μg/m\textsuperscript{3} during the same period. Phase 2 began in 2013 and ended in 2017 by Beijing's "Clean Air Action Plan 2013 – 2017" is considered the most comprehensive and systematic pollution control program. The plan has brought many landmark results in the fight against air pollution.

Beijing's external achievements are the result of reasonable investment in the time, resources, and efforts of all walks of life. This improvement mainly comes from good control of coal-fired boilers, which use more than clean raw materials along with industrial restructuring. Not only PM\textsubscript{2.5}, during this period, the concentration of air pollutants has also decreased significantly, specifically, SO\textsubscript{2} decreased by 83%, from more than 40 μg/m\textsuperscript{3} to less than 10 μg/m\textsuperscript{3}, NO\textsubscript{x} also decreased by 43%, volatile organic matter decreased by 42% and PM\textsubscript{10} concentration decreased by 55%.
5.1.1.1 Legal measures

Beijing's air pollution management system has contributed greatly to the success of the whole campaign. This is the result of 20 years of efforts to build and improve. This system has the following characteristics:

- Have complete enforcement and enforcement mechanism
- Systematic planning
- There are base standards
- There are detailed monitoring and monitoring centres
- There are strict regulations on environmental management

Beijing's air pollution management system includes the following legal documents:

- The "Law on Air Pollution Prevention and Control" (first enacted in 1987) was amended in 2015 and came into effect on January 1, 2016.
- Beijing Municipality's internal ordinance on "Air Pollution Prevention and Control" (2014) is based on lessons and experiences accumulated in the previous 15 years. This also marks a change in air pollution control, from pipeline end treatment to process control
- The national system of technical regulations on air pollutants
- The Law on Environmental Protection Tax was promulgated on December 25, 2016, and took effect on January 1, 2018. The act was enacted to replace the old tax system, which has been in place since 1979. Subjects of the Law on Environmental Protection Tax include emissions, wastewater, waste, and noise. Regarding the subject of emissions, the Law on Environmental Tax applies to 44 types of substances causing air pollution, calculated according to the volume of discharge into the environment.

The environmental protection tax law enacted shows the Chinese government's tough measures in controlling pollution. 44 types of air pollutants are regulated as taxable objects such as SO₂, NOₓ, fog, Pb compounds, carbon dust, ... The tax rate applies between 1.2 and 12 yuan and is paid monthly or quarterly. Tax revenues will be paid into the state budget for use for purposes such as economic development, support, or subsidies for activities and projects to improve air quality.
5.1.1.2 Economic tools

A system of economic incentive policies was also developed in addition to a strict air pollution management system. To control air pollution from controlling gas emissions from coal-burning, industrial activities, traffic activities, this system is implemented by enacting many attractive subsidy packages, supports, and incentives.

Economic support measures focus on reducing coal-fired use, increasing the use of clean energy, supporting vehicle owners to change old vehicles to environmentally friendly vehicles, or improving dust handling mechanisms for diesel vehicles. There are also many support packages for high polluting manufacturing enterprises to find ways to reduce their emissions.

Economic incentives for the management of enterprises in the industry were launched very early, in 2007 Beijing introduced closed subsidies for enterprises consuming water, energy, high pollution emissions. By 2013, there were two types of subsidies: subsidies for environmentally friendly technology transformation and increased closure subsidies for polluting businesses.

The use of electric vehicles was also introduced by Beijing as an economic incentive in 2010, with a series of subsidies: subsidies for procurement of electric vehicles, assistance in leasing and charging electric buses and electric street cleaning facilities; Subsidy of passenger vehicles and powered vehicles; Subsidies for individuals who purchase other electric vehicles and electric battery-powered vehicles. By 2015, Beijing continued to adjust subsidies for individuals buying electric passenger cars.

Another measure to protect Beijing’s air environment is the removal of vehicles using old engines. The measure was first introduced in 2006 to subside the early removal or transfer of old vehicles, by 2011 China had increased the subsidy level for early removal and continued to increase this subsidy for the second time in 2014. Promote new energy-use. In 2008 China introduced this economic incentive through support for solar energy collections. Continuing to develop this measure, China launched support for heat pump construction works in 2012.
Besides that, measure included in the economic incentive tool is mass coal control with the first subsidy for procurement of thermal power equipment in 2009. In 2015 the city government introduced subsidies for family procurement of wall gas furnace equipment to reduce the amount of CO$_2$ born from coal burning. The last measure is to improve the boiler; in 2014 Beijing increased subsidies for the improvement of coal-fired boilers in the suburbs, in 2016 subsidies for low Nito emission equipment, until 2017 subsidies for the improvement of gasoline-fired boilers.

Revenues from Environmental Protection taxes were spent on economic incentives, so financial investment in Beijing's air pollution control soared in 2013-2017, from 3.6 billion NDT in 2013 to 17 billion NDT in 2017. This is also the phase of the application of Beijing's Clean Air Action Plan 2013-2017

5.1.1.3 Other measures

In addition to a complete legal system and a comprehensive system of economic measures, Beijing has developed an automated air monitoring system to ensure the "Clean Air Action Plan" is completed. The city's first monitoring system was built in 1980 consisting of 8 monitoring stations; monitoring indicators are polluting gases such as SO$_2$, CO, NO$_2$, and TSP. In the following years, the number of monitoring stations was increased to 35, and added new targets of PM$_{10}$, PM$_{2.5}$, and O$_3$.

Besides, Beijing has developed an "Emergency Response System for Serious Pollution". In combination with the existing air quality monitoring system, Beijing residents will be notified at least 1 day in advance through the mass media if there is a serious pollution phenomenon.

Community involvement in air environment protection is also of interest to the city government and improved policies. The city gradually enhances the quality of educational institutions and performs more environmental events. Environmental campaigns are strongly promoted through media such as radio, TV, social networks (Weibo, WeChat) contributing greatly to increasing the participation of the city's people in environmental protection.
5.1.2. Seoul experience

The main sources of emissions in Korea come from industrial parks, transportation activities, energy extraction activities, and residential activities (heating, cooling, using equipment). In addition, an objective cause comes from China, when the spread of particulate matter from neighbouring countries is also making the situation of air pollution in South Korea worsening. South Korean experts believe that their air is polluted with PM$_{2.5}$ dust from China, usually accounting for about 30-50% of the output, cold days with many slow airflows, this number is up to 60-80% of the amount insured.

Based on the development situation, Korea's largest source of emissions according to experts from 3 sectors, in turn, traffic activities, industrial parks, and thermal power plants. Traffic in Korea has a very high number of cars, about 500 million vehicles, and always tends to increase the demand of people. In addition to personal vehicles, other vehicles such as trucks, ships, trains all use energy from diesel engines, gasoline. Thereby, the emissions outside the environment are very large. Industrial parks and thermal power plants also use a large number of fossil fuels (oil accounts for 38%, coal accounts for 29%, and gas accounts for 15%). According to research by Michael Zschiesche and his fore works, between 2000 and 2012, South Korea's PM$_{10}$ emissions increased four-fold and other gases such as SO$_x$, NO$_x$, CO, and VCO also increased significantly.

5.1.2.1 Legal tools

Both the People and the Government of South Korea take action to deal with air pollution. People use devices such as pollution masks and air purifiers to limit the adverse effects of air pollution. The South Korean government has also intervened and enacted regulations to control air pollution.

- "Emissions Standards for Air Pollutants"
- "Seoul's 2005-2014 Urban Air Quality Control Plan"

In 2016, South Korea signed the "Paris Agreement" with the goal that by 2022 domestic emissions will be reduced by 30%. To implement this commitment, the Government of South Korea issued several regulations as follows:
- Closing coal plants using old technology and replacing them with new ones using nuclear power;
- At the same time promulgate plans to provide air purifier systems for schools, hospitals, and public places;
- Banning large-volume trucks and vehicles using old diesel engines in days of severe air pollution;
- In 2018, the government gave free use of the cluster transportation system in Seoul during the 3-day peak of air pollution. The aim of the ruling elite is to reduce the number of cars circulating in the city to reduce pollution levels. However, the results of this option did not achieve the expected effect (Poon, Linda);
- Using the initiative of the Ministry of Natural Resources and Environment of Korea is to use drones to monitor and observe the burning of fossil fuels, illegal activities that disperse contaminants (fine particulates, SO$_2$, CO, NO$_2$,...);
- Plan to use the aircraft to spread some substance into the air, thereby creating artificial clouds to create rain to wash away pollutants in the atmosphere;
- Strengthen cooperation with countries such as China and India in international plans to reduce air pollution.

Besides, the Government of South Korea promulgates the evil standard not to control the concentration of contaminants:

- Korea's first ambient air standard in 1978 regulated SO$_2$ gas content;
- Standards for CO, NO$_2$, Total Suspended Particulate (TSP), and O$_3$ were issued additionally in 1983, after which PM$_{10}$ was added in 1995;
- Benzene and PM$_{2.5}$ dust targets were added in 2010 and 2011, PM$_{2.5}$ was introduced in 2011 and came into effect in 2015;
- PM$_{2.5}$ standards are adjusted, the average daily target is 35 μg/m$^3$ and the annual average is 15 μg/m$^3$ in 2018;

5.1.2.2 Economic tools

South Korea's economic measures are primarily government subsidy packages aimed at supporting and encouraging organizations and individuals to reduce polluting gas emissions and increase the use of alternative energy sources. During this period,
Korea has continuously promoted investment in many energy sector development projects towards environmental friendliness, promoting the restructuring of the sector to clean energy and renewable energy. This creates a positive change for the clean energy sector, some typical actions can be mentioned as:

- In 2010, Seoul city invested USD 8.2 billion to build a wind farm with a capacity of 2,500 MW to gradually change the old energy types in the city.

- In 2011, the South Korean government continued to promote the development of the gas renewable energy sector with plans to increase 1.5 million jobs in the clean energy sector with the aim of accounting for 18% of the global clean energy market by 2030.

- In 2014 the South Korean government spent USD 1.9 billion to build 6 clean energy enterprises.

- By 2030, implement the plan to meet 20% of the total electricity produced from renewable energy sources through solar and wind energy.

Also, in recent years, Korea has made great strides in the renewable energy technology industry. A 4 GW high voltage transmission line was built connecting other provinces with Seoul with an investment of USD 320 million. This promises to improve energy production. South Korea's time and money investments have helped them reach out to powers such as the United States, Germany, Japan, and the European Union, becoming one of the world's leading manufacturers of clean technology inventions confirmed by the United Nations Climate Change Conference. The positive changes in the energy sector have also contributed to improving air quality in Korea.

In addition to investing in the transition from fossil fuels to clean energy and providing positive signals in the process of improving air quality, South Korea also plans to subsidize people when purchasing products that contribute to reducing air pollution such as air purifiers.
5.1.3. Japan experience

5.1.3.1 Legal tools

The Japanese government enacted the Air Pollution Control Act (APCA) in 1968, and then amended in 1966 and 2006. APCA consists of 6 chapters, 37 articles, enacted to protect the community health, and the living environment against air pollution. The law regulates the control of emissions, dust, and smoke, volatile organic compounds, floating particles from production and business activities, factories, and manufacturers. In addition, there are emissions control regulations during construction, standard regulations for some air pollutants such as SO2, NO2, particulate matter, and emission standards for cars. The content of APCA focuses on:

APCA states that it is the responsibility of the Ministry of the Environment to establish a National Standard of Air Quality, or permissible concentrations in outdoor air, for common pollutants: SO2, CO, particulate matter, suspended dust, NO2, etc. APCA also regulates that, in addition to the National Standards for Air Quality, if the Minister of the Environment deems it necessary to control emissions and preventing air pollution in any province, the Minister of the Environment can ask the President of that province to modify existing emissions standards or issue a set of air quality standards in that province to control the exhaust gas, dust, smoke, volatile organic substances, particulate matter from factories; At the same time, the provincial chairman must have measures to control the amount of dust during construction in their province. In the case of the provincial chairman consider that the current emissions standards in accordance with the law on emissions and hazardous substances are insufficient to protect public health, natural - social conditions, and the living environment within their province, the Chairman of the province can issue stricter emissions regulations and standards than those of the Government.

From the National Air Quality Standards, if the Minister of the Environment finds that air pollution has occurred or may occur to an extent exceeding the prescribed limits in all or some of the practice areas that concentrate equipment that released emission gas into the atmosphere, the Minister of Environment may issue Circular prescribing special emission standards for all or some of these areas. This Circular is applied instead of emissions standards according to the National Standards for Air
Quality. For establishments that install equipment to discharge pollutants into the air, before operating, they must register the polluting sources, measure, statistic, and inventory; install automatic emissions monitoring equipment, and must be licensed by the competent state management.

APCA stipulates that the Minister of the Environment details the maximum allowable limit for emissions from motor vehicles into the atmosphere. The provincial president is responsible for checking and monitoring the number of emissions from motor vehicles in the area under his management, in case of detecting that the amount of emissions from motor vehicles exceeds the emission standards prescribed by regulations. According to the regulations, the President of the province requires the Traffic Safety Committee of that province to take measures under the provisions of the Road Traffic Act (Law No. 105 of 1960) to prevent and overcome the consequences of air pollution.

APCA requires the Chairman of the province to be responsible for checking and monitoring the AP status and must regularly report the air pollution status to the Minister of Environment. If it is found that air pollution status is serious that could harm human health and living conditions, the Chairman of the province should coordinate with the facilities that emit emissions and coordinate with the Traffic Safety Committee of that province to take necessary measures to reduce air pollution and announce air pollution status in the province.

APCA stipulates that in the case of human health or live damage due to the release of hazardous substances from factories, the director or operator of the factory must be responsible for liability compensation. If the number of emissions caused by the factory or workshop caused negligible damage, the court may review the cases to determine the person's compensation amount.

In addition, the law provides for strict legal liability for acts that cause air pollution: Organizations and individuals that cause pollution, degradation, environmental incidents, cause damage to other organizations and individuals must respond to overcome pollution, restore the environment, compensate for damage, and depending on the nature and severity of the violation; consequences of acts which have
caused damage to organizations and individuals. APCA stipulates 05 levels of penalties for violations of air pollution legislation as follows: Imprisonment up to 1 year or a fine of up to 1,000,000 yen; Imprisonment for up to 6 months or a fine of up to 500,000 yen; Imprisonment for up to 03 months or a fine of up to 300,000 yen; A fine of 200,000 yen; Fine up to 100,000 yen

5.1.3.2 Economic tools

Japan uses a variety of taxes to control air pollution. This solution stems from the advantage of being highly preventive by hitting directly on the economic benefits that the business world is aiming for. Tax is considered the most effective solution and is applied consistently and flexibly in Japan.

Japan proceeds to collect carbon tax on crude oil products, petrochemical products, and coal and this revenue has increased gradually from 2012 to the present. The carbon tax levied in Tokyo for gasoline is 1.9 yen/litter, and diesel fuel at 2.1 yen/liter. For households in urban areas, the carbon tax rate is 100 yen/month. In traffic, people use green traffic tax for different types of vehicles, different technologies will have different tax rates. The lowest tax rates are for green transport such as trains, trams, or energy-efficient vehicles. Besides, to minimize solid waste and reuse auto parts and components, Japan collects the recycling fee. From January 2005 to March 2009, 92.77 million cars had to pay recycling fees with a total value of up to 912.1 billion yen. Moreover, the payment of taxes and fees is quite simple, through the tax administration system of the local government, or the network, so people do it easily. Tax supervision is assigned to tax authorities and local authorities, while the use of fees and environmental protection taxes are publicly and transparently announced.

Every year, the Japanese Government spends a certain amount of budget on environmental management, disaster management and allocates it to provinces, branches, and agencies across the country. Financial support may be included in this budget allocation package or other additional sources within and outside the Government. In order to efficiently use energy sources, especially electricity, the Government grants certain grants to power generation companies or private enterprises with separate power generation systems and production line systems. These supports
have been implemented since the establishment of the environmental management agency. To develop comprehensive solid waste treatment and recycling facilities, in 2005, Japan set up a subsidy system to promote the establishment of a sustainable material cycle society. In 2008, 40 projects were approved for funding. In addition to funding from the Government, local authorities, businesses also support environmental protection projects, or for production facilities. Thus, financial support is a quite positive solution for Japanese businesses, helping businesses reduce costs when building factories and waste treatment systems at the same time.

5.1.4. Others nations experience

Many solutions have been adopted by countries to reduce air pollution, but mainly focus on the source of emissions from traffic activities. In Europe, the emission standards system with motor vehicles has been adopted, which is understood to be the maximum emission limit allowed for motor vehicles to be exchanged and traded between countries of the European Union. This method caused emissions to plummet since the early 1990s despite a 26% increase in the amount of fuel consumed by vehicles. By 2005, CO emissions were only 20% higher than non-intervention scenarios. NO<sub>x</sub> is 60%, PM<sub>2.5</sub> is 40%.

The city of Barcelona and 19 nearby cities imposed vehicle speed restrictions in the city limiting motor vehicles in urban areas to 80 km/h in 2007 (previously the maximum limit was 120 km/h). This policy reduces emissions by 4%. Air quality is improved by 5-7% for major pollutants. Similarly, in the Netherlands, the government has regulated a top speed of 80 km/h for urban vehicles since 2005. This policy is strictly implemented and causes NO<sub>x</sub> emissions to decrease by 5-30%, PM<sub>10</sub> decreased by about 5-25% in Amsterdam and Rotterdam (Thanh, Hoa and Hang, 2018).

Porto (Portugal) plans to restrict/prohibit the circulation of some motor vehicles with high emission levels. Specifically, the government has established a "Low Emission Zone" (LEZ), where certain types of vehicles are prohibited or restricted from entering. Duque and his partner (2016) assumed that only vehicles that met Euro 3 or higher were allowed to enter LEZ and concluded that the air NO<sub>2</sub> content in LEZ decreased by 3 % per year (Thanh, Hoa and Hang, 2018).
A simple but highly effective solution is to develop an urban greenery system. In Strasbourg (France), from July 2012 to June 2013, trees in the public sector have eliminated about 88 tons of pollutants, including CO (1 ton), NO₂ (14 tons), O₃ (56 tons), PM₁₀ (12 tons), PM₂.₅ (5 tons) and SO₂ (1 ton) (Selmi and his partner, 2016). Throughout the United States, using the above model for results, the urban week green system decreased by 1%, the health benefits were enormous, equivalent to USD 4.7 billion (Thanh, Hoa and Hang, 2018).

Some cities charge for peak-hour traffic in the inner city of London (UK) has been applying peak hour traffic since 2003, Stockholm (Sweden) since 2007. There is also Copenhagen (Denmark), Lyon (France), and Singapore. Accordingly, motor vehicles must pay a fee every time they pass through the toll point when entering or entering the city center, except for some time as prescribed. Research shows that in the area of paid vehicles, PM₁₀ and CO decrease. However, the NOₓ content does not change significantly.

5.2. Proposed air pollution management measure in the context of adapting to climate change

Based on an analysis of the current status and experience of air pollution management in Hanoi and other countries around the world, the thesis has proposed groups of measures focusing on solving the following key problems:

5.2.1. Transportation

Emissions from vehicles such as cars and motorbikes are always mentioned by experts as the main cause of air pollution in big cities. The greater the traffic flow, the worse the air quality. If monitoring the development of air quality in big cities during the period of social isolation effect due to covid-19 pandemic will see the effect of vehicle traffic on air quality. Hanoi’s traffic volume decreased sharply from 1st April to 15th April, comparing air quality evolution from 1st January to 10th April 2020 with the same period of previous years, air quality tends to improve. Hourly AQI of the day at Hanoi’s stations between 22nd March and 7th April, most of the day, air quality remains good and moderate level. Particularly on 8th April – 9th April, air quality declined at a bad and very bad level. These are also the days when the number of vehicles participating in traffic in the inner city increased significantly higher than in the
previous days. So to reduce air pollution, it is necessary to improve traffic activity, starting from controlling the number of vehicles and the emission of such vehicles

5.2.1.1 Applying taxes and charges for vehicles in the city

In the way of managing vehicles in London and some cities in Europe, Hanoi may apply a similar fee to T-Charge. This fee promises to be suitable for the current situation in Hanoi because there are still many motorbikes and cars using too old engines still circulating in the city. This can be seen as one of the first steps towards removing out-of-town vehicles. Instead of prohibiting the circulation of used vehicles, car owners will have the right to choose between investing money to change to new vehicles or continuing to use old vehicles and pay for that every day. The solution will be more flexible and easier to apply than the solution to prohibit the circulation of old vehicles because people have the right to choose and can change their habits gradually. This solution will be more effective if it can be combined with the car purchase support packages of businesses, in the same way, that Vingroup launches packages to support people to buy their VinFast cars.

The application of tariffs on vehicles in the city will first begin with the enacting of traffic emission regulations. This has also been added in the draft law on environmental protection amended in Clause 3 article 92 on management and control of dust, emissions, specifically " The Ministry of Natural Resources and Environment promulgates environmental technical regulations on emissions of vehicles... ". Thus, the responsibility for developing environmental technical regulations on emissions of vehicles will be carried out by the Ministry of Natural Resources and Environment, while the inspection will be managed by the Ministry of Transport integrated through the operation of the registry agencies. The development of this norm can be formulated through Euro standards according to decision No. 49/2011/QD-TTg on the regulation of the roadmap for the application of emission standards for cars, two-wheeled motorbikes producing, assembling, and importing new emissions, emission standards have also been introduced to correspond to Euro standards. Specifically, in accordance with article 3 of this decision, "Emission standards level 3, level 4 and level 5 are standards for testing and limiting contaminants in emissions corresponding to Euro 3, Euro 4 and Euro 5 as stipulated in the technical regulations on motor vehicle emissions
of the European Economic Commission of the United Nations or in the European Union directive applicable to motor vehicles producing, assembling and importing new vehicles. " New manufactured, assembled and imported cars must apply standard 5 from 1st January 2022. Two-wheeled motorbikes manufactured, assembled, and imported must apply emission standard level 3 from 1st January 2017. Thus, environmental technical regulations on emissions of vehicles must be issued and applied from 01 January 2022, based on Euro 5 standard for cars and Euro 3 standard for motorcycles.

**Table 0.1: Euro 3 and Euro 5 emission limits**

<table>
<thead>
<tr>
<th>Standard</th>
<th>For gasoline engines</th>
<th>For diesel engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 3</td>
<td>CO - 2.3 g/km</td>
<td>CO - 0.64 g/km</td>
</tr>
<tr>
<td></td>
<td>HC - 0.20 g/km</td>
<td>HC + NOx - 0.56 g/km</td>
</tr>
<tr>
<td></td>
<td>NOx - 0.15</td>
<td>NOx - 0.50 g/km</td>
</tr>
<tr>
<td></td>
<td>PM – unlimited km</td>
<td>PM - 0.05 g/km</td>
</tr>
<tr>
<td>Euro 5</td>
<td>CO - 1.0 g/km</td>
<td>CO - 0.5 g/km</td>
</tr>
<tr>
<td></td>
<td>HC - 0.10 g/km</td>
<td>HC + NOx - 0.23 g/km</td>
</tr>
<tr>
<td></td>
<td>NOx - 0.06 g/km</td>
<td>NOx - 0.18 g/km</td>
</tr>
<tr>
<td></td>
<td>PM – 0.005 g/km (direct injection only)</td>
<td>PM - 0.005 g/km</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PM – 6.0×10^11/gkm</td>
</tr>
</tbody>
</table>

Inspections of vehicles will also have to be carried out as soon as the new regulations come into force. Vehicles that do not reach will be labelled and charged at toll pegs before entering the inner city. This fee can be charged from 7 a.m. until 6 p.m. on Mondays through Fridays of the week. In terms of fees, more large-scale and surveys are needed to determine the most suitable rates for the country's economic conditions. In London, the same fee is currently valid at $18 per day. The proposed fee ranged from VND 50,000 to VND 100,000 per day.

**5.2.1.2 Development of public transport systems**

The development of public transport systems is essential and will be stable and long-term for the city to limit the number of smog emissions from personal sources such as cars and motorbikes. Currently, Hanoi's public transport system is mainly bus systems and a high-altitude railway system is about to put into operation in 2021.
For the high-altitude railway system, the Cat Linh – Ha Dong urban railway project began to test the entire system for safety assessment, serving the test before being put into commercial operation for 20 days, starting from 12th December 2020. In order to put the system into operation in the next year, it is necessary to prepare strong support solutions to change habits, attract people to use. One of the important issues to solve is to connect the existing bus system with the railway to be able to gather passengers and improve the convenience. The fact that the railway is put into practice will undoubtedly affect the habits of a section of the people of the capital but is the right thing to do to ensure the goal of pollution control. The city government should abandon buses that coincide with the route of the over-high-altitude railway, adding new routes to serve people's shuttles. Bus stops must also be arranged appropriately, ensuring that people's distance to the train stations is shortest. Another solution to implement e-ticket for the project can integrate with the ticket card of urban railway systems with the existing bus system, especially fast bus system to ensure the most convenience for passengers.

As for the bus system, which has been used for a long time, but the quality is still limited, there are many old buses still circulating on the street. The solutions will focus on improving the quality of existing buses and attracting people to ride buses. To improve bus quality as well as reduce emissions, it is necessary to introduce electric buses into the system. Because of the use of electric fuel, electric vehicles do not emit pollute environmental gases such as cars or motorbikes and do not cause noise when moving. To be able to quickly implement this solution, the Hanoi government needs to have mechanisms, incentives, cooperation with Vingroup to order electric buses and put them into the pilot as soon as possible. This solution is highly feasible because it is in line with the guidelines of the central government and the city of Hanoi, as well as the development projects of Vingroup. Specifically, at the end of December 2019, Vingroup also sent a written request to the Hanoi People's Committee to propose the form of "Vehicle investment scheme, organizing the operation off-air passenger transport of clean energy buses (trams) with subsidies in the city of Hanoi in the form of order" and some documents reported to the Hanoi People's Committee. The target audience will first of all be adults and young people, they have ideals for environmental protection and natural ecology, both those with minimalist lifestyles,
minimizing shopping, owning property, vehicles, and these people often choose walking, bicycles and buses (public transport) to travel.

Specifically, the most attractive solution is to apply technology to the management and operation of bus transport. This solution is considered a breakthrough solution and has the potential to combine with the over line rail system. Accordingly, the transport industry needs to replicate the smart e-bus card project on the main bus routes, have a route through the university, and have a high number of frequent passengers. When using this type of card, the City Department of Transportation can aim for passengers to pay without cash, even without presenting a student card. Once people are used to using it, the city will no longer use extra vehicles. This will improve the quality of services, attract people to use buses, contribute to reducing congestion and traffic accidents in the city. Some vehicles may pilot this solution as routes 05, 39, 61 passes through the Academy of Policy and Development and the University of Natural Resources and Environment of Hanoi, routes 12, 18, 23 passing through the Banking Academy, routes 26, 28, 31 passing through the Academy of Finance and Hanoi Polytechnic University.

5.2.2 Industry

Industrial activity has always been a major source of air pollution emissions in any country. It can be seen that in recent years, the new regulations of Vietnamese environmental law are increasingly concerned about the management of emissions arising from industrial production activities because these climate sources account for the majority of GHGs and CC. Therefore, in order to have effective air pollution control system, stronger solutions are needed to manage the operation of production plants in the area, as well as around Hanoi. Some solutions Hanoi government may apply some measures that other countries around the world are also implementing.

5.2.2.1 Use of integrated licenses for industrial parks

In the revised draft Law on Environmental Protection, the Ministry of Natural Resources and Environment has proposed to integrate the types of wastewater discharge permits. Accordingly, it will have a type of environmental permit, including the content of licensing the discharge of wastewater into irrigation works. This license
replaces seven types of environmental licensing administrative procedures. The integration of the License into an Environmental License is a step reform of administrative procedures and unified environmental management, specifically; it will create maximum favourable conditions for businesses to perform their environmental protection obligations. If an environmental license is put into use, the state agency may decide whether a production facility can be built based on certain standards. State agencies can also control the operation and closure of enterprises, as well as have the right to decide whether these industrial facilities can impact the environment.

Therefore, the topic proposes plans to integrate industrial emission discharge permits into environmental permits. Currently, project owners on the list of large traffic emission sources specified in The Appendix of Decree No. 38/2015/ND-CP must register the owner of industrial emissions unless the waste source owner has co-treatment activities of the subject of the grant of hazardous waste treatment license or the subject is confirmed to ensure environmental protection requirements for domestic solid waste treatment facilities or ordinary industrial solid waste. The registration of industrial emission source owners is conducted when the production facility operates officially or when the facility plans to change the source of industrial emissions, such as increasing emissions, the number of sources of emissions. Therefore, in order for the integration of discharge permits into the same environmental permit to be implemented quickly, it is necessary to consider the licensing right in the process of appraising and approving the environmental impact assessment report. Finally, the process will be completed when the facility goes into operation after the evaluation examinations of the authorities. That is, the determination of scale and emissions is carried out based on the data in the environmental impact assessment report and will be tested for accuracy based on the actual data after the project is put into operation.

The target of this solution will give priority to thermal power plants around Hanoi because there are currently 20 coal thermal power plants concentrated mainly in the Northeast. the cooperation project between the Vietnam Academy of Science and Technology (VAST) and the International Institute of Applied Systems Analysis (IIASA) of Austria, announced in October 2018, 2015, the cause of contributing to the concentration of PM$_{2.5}$ in the air in Hanoi comes from high thermal power and
industry is about 20%. The study estimates that only one-third of Hanoi’s air PM$_{2.5}$ pollution levels come from within the city. Besides, the "Burden of Disease from Rising Coal-Fired Power Plant Emissions in Southeast Asia" study conducted by experts from Harvard University using 2011 data estimated that thermal power plants contribute 5 micrograms/ m$^3$ to the average PM$_{2.5}$ in Hanoi, and this number increases to 12 micrograms/ m$^3$ by 2030.

5.2.2.2 Applying new technologies to reduce emissions

Currently, many coal thermal power plants in Vietnam are using modern technology not inferior to other factories in the region and the world, ensuring environmental requirements. However, a new technology that Vietnam can develop in the future is IGCC technology (coal gasification technology) just like in Japan is applied. Using IGCC technology will allow coal-fired plants to minimize CO$_2$ emissions. Specifically, compared to USC (on super-dues), IGCC can improve power generation efficiency by 46-50%. Using IGCC technology, CO$_2$ does not escape to the environment and is buried in the ground. The stages in the IGCC process include:

- Coal, water, and oxygen are put into a gasifier, in which the coal is partly oxidized and turned into a vapour called syngas.

- Syngas passes through steam according to the equation: Syngas + steam remove CO$_2$ + H$_2$.

- CO$_2$ will be separated and buried (CCS - carbon capture and storage, separation and burial of CO$_2$).

- H$_2$ was burned and used to run gas turbines.

- The remaining hot air (residual heat) escaped from the gas turbine is heated in the steam turbine (generator).

In order to apply this technology in the future, Vietnam needs to strengthen cooperation with Japan to build a typical coal thermal power plant in the environment. Then, replicate this factory model to the whole country. Some factories such as Vinh Tan 4, Vinh Tan 4 expansion, Coastal 3 expansion, applying super-due technology SC and on super-due USC to improve power efficiency and reduce CO$_2$ emissions can
also be considered upgrading existing technology to fewer emission technologies while proceeding to close factories using too outdated technology.

For the cement industry, traditional technology is the heating of clinker; cement grinding has created dust and CO₂, CO, NOₓ, SOₓ emissions, greatly impacting the ecological environment as well as air quality. Therefore, the innovations and inventions of new generation cement production technology are expected to be breakthroughs, fundamentally changing the current technology, forming the production line of Zero Emission - Natural Cycle cement (zero emissions - natural circulatory, live circulatory). Accordingly, there are 5 important foundation issues in a manufacturing plant and also 5 key areas for industry and human life are mentioned:

- Cement production will not emit the emissions affecting the environment and rotation; gas re circulatory according to nature, the rules of the habitat.

- Maximum use of fossil fuels in the production of clinker and cement such as limestone, clay, silicon, iron ore and replaced with materials taken from the waste of other economic sectors as well as waste in the daily activities of society (waste, sludge, ash slag, waste of building materials, and all ash after combustion...).

- Burning fuel from coal, oil is gradually replaced by burning industrial waste, domestic waste, potentially heat-reactive waste that people are discharging daily.

- Amniotic fluid optimization and improved thermal energy efficiency, electricity is also taken into account through new technology solutions for power generation to both use in the production of the plant and can provide more electricity to society.

- Applications and algorithms in the field of computing are also applied to set up intelligent control systems to meet the rotation of gas circulation, use of alternative fuels, waste treatment, improve the efficiency of use and power generation.

5.2.3 Energy and fuel

From the case study of Beijing (China), the researchers assumed that this is a typical air quality improvement model and may be effective in all cities despite the
difference in economic experience, politics and economics. Therefore, Hanoi can apply the same economic subsidy and support tools as Beijing.

- Subsiding for organizations and enterprises transitioning from old technology to environmentally friendly technology. In addition, the subsidies for closed businesses results from pollution in the city.

- Promoting the development of electric vehicles. Recently in Hanoi, the demand for electric vehicles has been increasing, businesses and agents also constantly change models and designs to suit the tastes of customers. A successful and very popular electric vehicle development company is the electric bike product from VinFast. Electric cars are growing; the city has not had many policies to promote this eco-friendly product, though. Some proposed measures are product subsidies, construction of charging stations, subsiding for individuals buying electric vehicles.

- Allowing vehicle owners to use old engines so that they have an incentive to remove their old vehicles early and replace them with eco-friendly ones.

From the Korean case study, it can be seen that the tools they use to improve the air environment are long-term measures, thus these measures are largely related to the problem of replacing chemical fuels of using renewable energy.

- Hanoi can increase investment in the renewable energy sector by building power plants using clean energy instead of continuing to build coal-fired power plants. Specifically, they can build wind or solar power plants in the neighbouring provinces nearby Hanoi, thereby gradually eliminating the old types of polluting energy that are currently being used.

- Increasing job creation and take measures to support workers in the clean energy industry.

- Creating conditions to attract foreign investment to develop the clean energy industry. Furthermore, it is necessary to have strong and thorough treatment policies and measures for polluting facilities that do not have treatment systems or have no standards. This leads to the promotion of investment in advanced dust treatment with
highly effective technologies. Supportive policies are needed for advanced, high-yield, and dust-reducing technologies.

Changing material in the cooking process of the residents in Hanoi. Most households in Hanoi these days do not use the honeycomb charcoal stove but use gas stoves, electric stoves... However, Hanoi has many small restaurants, where they mainly use honeycomb for cooking as the number of statistics up to 55 thousand charcoal stoves. However, Hanoi has an active action. Their administrator has promulgated "The policy to eliminate coal stoves by 2020" and Hoan Kiem is an important urban district for implementing this policy.

5.2.4 Other measures

- Planting trees

According to research results of scientists around the world, trees are capable of absorbing half of the radioactive dust, the number of toxic vapors emitted from industrial production, daily living activities, and air conditioning. Trees also minimizing the effect of GHGs and can increase the beauty of the landscape of Hanoi. In Hanoi, the urbanization process takes place at a fast and great pace in terms of both population and surrounding land areas. However, the land area for greenery does not keep up with the urban development. According to statistics, urban green trees in Hanoi have not met the standard of coverage. According to green urban standards, each person must have 10m² of green trees to absorb the gas emitted by them. Currently, the standardized land area for green trees in Hanoi needs to reach 12-15 m²/person, but the reality is only 2 m²/person, while this figure in Washington is 40 m²/person, in New York it is 29.3 m²/person or in London, it is 26.9 m²/person (Vietnam Ministry of Science and Technology, 2012).

“The One Million Trees Fund Program for Vietnam” is a joint activity between the Vietnam Environment Administration and the beverage brand Vfres of Vietnam Dairy Products Joint Stock Company - Vinamilk, launched in 2012. This program works towards the natural environment by calling on the community to join in planting more trees in Vietnam. The program's planting site criteria are extended to areas where trees provide practical benefits to the community such as residential areas, public
areas, central roads, and schools in the city nationwide. Accordingly, the program aims to plant one million trees in major cities across the country. In the first year of implementation, it is expected to organize planting trees in four major cities: Hanoi, Ho Chi Minh, Hai Phong, and Da Nang. Then, the number of green trees will be increased annually and expanded to other cities towards the goal of planting one million trees for Vietnam. Up to 2013, the program organized planting trees in 8 provinces and cities: Ho Chi Minh, Quang Ninh, Da Nang, Tien Giang, Hanoi, Hoi An, Quang Nam, and Hai Phong with nearly 70,000 types of trees. After two years of implementation, the program has received much supports from the state agencies and localities. The enthusiastic response and participation of many famous Vietnamese characters, thousands of volunteers who are youth union members, residents living in the greenery area.

Implementing this program, within 2 years of 2016 and 2017, Hanoi has planted nearly 500,000 trees throughout the city streets. However, trees are planted according to the criteria of landscape, cooling, and highlighting the streets, not paying attention to the goal of reducing the diffusion of exhaust gas or filtering dust. Therefore, to improve the atmosphere of the city, planting trees is not enough, but also studies on height and distance suitable for meteorological conditions are needed.

- Supervising construction sites

Hanoi needs to strengthen supervision of shielding at construction works to minimize dust dispersion affecting the traffic participation and daily life of the residents. For instance, the areas of Giai Phong– Truong Chinh, Cau Giay, Kim Ma...

Although there are regulations on shielding at construction sites, vehicles transporting construction materials... however, in fact, there are still many works in the process of demolition that are not covered. For example, route Minh Khai - Dai La - Truong Chinh.

- Control open burning waste activities

In Hanoi, there is still a phenomenon of open burning waste. Although the scale is minor but spontaneous, so it is difficult to control. This action not only causes a loss
of urban beauty but also emits a lot of dangerous air pollutants and a high potential risk of fire and explosion. To control this open burning waste activity, it is necessary to coordinate with many organizations and related parties in the city. Specifically, the propaganda and dissemination of the harmful effects of open burning waste on health and the environment will be carried out by the Department of Natural Resources and Environment in coordination with the Department of Information and Communication. The encouragement of residents to collect their waste for sanitation units instead of bringing their waste to burn will be chaired by the Department of Finance and coordinated with the Department of Taxation, the Department of Natural Resources and Environment, and the Department of Labor, Invalids, and Social. The inspection, monitoring, detection, and sanctioning of organizations and individuals that indiscriminately burn trash causing air pollution will be carried out by the Hanoi Police force. Along with that, the direct implementation of tasks and plans to localities will be responsible by the People's Committees of districts, towns in the city area. Finally, the MONRE needs to improve waste collection, increasing collection frequency in areas with high demand.

- Educational propaganda measures

By learning from studies of international experiences, it is clear that those countries that have high achievements in the "war" against air pollution are all supported by their residents. It all about their effort of propaganda, advocacy, and awareness-raising that each country has put into the process of learning, working, and living of the residents. Unless there is a high level of citizens’ awareness, the policies made by the authorities will improve air quality effectively.

In Hanoi in particular or our country in general, people's awareness of environmental issues, especially to the air environment, is not high. This is reflected in the fact that the majority of residents do not care about particulate matter, they are not aware that particulate matter can penetrate deep into the body, or do not know what AQI index is. Even patients related to lungs, asthma... heavily affected by air pollution do not know these two indicators. Even they still do not believe that air pollution is a higher cause of death than traffic accidents. That is why it is necessary and urgent to raise public awareness about the current situation of air pollution in urban areas. Only
knowing how dangerous air pollution is, people can actively prevent it, and also cooperating with state authorities.

In order to implement this measure in Hanoi, we need television programs and official articles to appear in the national media such as the websites of state agencies. Installing slogan banners on the streets with short quotes, but concise and attractive to the residents. Furthermore, providing lessons, seminars, and extracurricular sessions on environmental protection in the lecture halls, at elementary schools, secondary schools, or high schools within the city. Providing that information to the next generation is fundamentally vital for our effort of protecting the atmosphere and the environment.

- Environmental modelling

The deterioration of the air quality in Hanoi capital is getting worse, directly affecting the life and living activities of the capital's residents. In addition to controlling the air environment quality through advocacy and promulgation of regulations, traffic, and construction, forecasting and estimating the quality of the air environment is a critical task. It can be designed to build Hanoi capital into a modern international cultural and tourist centre.

In those air quality forecasting studies that have been presented in section 4.4.3.2, forecasts are often formulated for specific air quality environmental quality factors, with results are mostly used by scientists and the authorities. Therefore, the applicability into real life is not high, the forecast results are often in the form of specialized reports, have not reached the residents.

With advanced technology nowadays, mathematical models show outstanding advantages in simulating air spreading. By using simulated mathematical models, it is possible to determine the air environment at any location in the area without depending too much on the expensive and sparse monitoring network. The air pollutant dispersion simulation model has a close relationship with the regional meteorological model as well as the Hanoi sub-region. Therefore, the connection of the simulation model with the meteorological model and the weather forecast will be close to the development of current science and technology. The pilot study of short-
term air quality forecast for the Hanoi city area will be a potential new research direction in modelling the air environment afterward. On that basis, forecasts are expected to broadcast daily, assess current air quality, and forecast average daily air quality for the consecutive coming days. The output of the bulletin is the AQI index, which will provide easy-to-understand qualitative comments that help people make decisions about daily activities.

5.3. Sub-conclusion

Those typical experiences above were taken in countries such as China, Korea, and Japan that have been referred to propose solutions for Vietnam. They are all Asian countries, have experienced and controlled serious air pollution problems.

According to the world's experiences in controlling air pollution and the context of CC, control solutions were proposed and focused on traffic, industrial activity, and energy. The proposed solutions include mechanisms for coordination among regulatory bodies, as well as among other relevant organizations. In the transport sector, the thesis focuses on proposing a fee based on the traffic emission regulations issued to the owners of old traffic in the city to control emissions and encourage people to switch to public transport or new vehicles. Also, the development of new public transport systems such as buses and overhead railways should be focused to attract more people to participate. In the industrial sector, solutions focus on improving administrative procedures in integrated discharge licensing for businesses and investing in the development of new technologies for high-emission industries in Hanoi are coal-fired thermal power and cement production. In the energy and fuel sector, use subsidy packages to promote clean energy development. Businesses are supported to switch to new and more environmentally friendly technology or to compensate for the costs of closing polluting factories. Domestic and foreign organizations are also encouraged to invest in new energy development. People are subsidized to buy electric vehicles, while small restaurants and cafes are given support to replace charcoal stoves. Other measures are also proposed such as tree planting to improve the urban landscape, control of construction activities in the city, and environmental communication.
Among the above measures, developing public transport systems and applying modelling in air pollution management and forecasting is highly feasible. Hanoi has already done on building the sky train (being tested prior to its commercialization). Furthermore, air quality forecasting has been a hot topic for a long period. Hence, this brings a high potential of having an official AQI forecast bulletin shortly.
CHAPTER 6: CONCLUSION

Vietnam is considered a developing country with impressive annual economic growth in Southeast Asia. However, the focus on economic development has degraded the quality of environmental components. There are many remarkable environmental problems that Vietnam must be confronting, including the problem of air pollution in urban areas. In Hanoi, now, besides the weather bulletins, AQI forecast is also a topic that people are interested in and updated every day. The reason is that Vietnam regularly has high AQI and is often in the top polluted cities in the world.

This thesis had collected, synthesized, and analyzed the current state of air pollution in Hanoi. Through reference to the air environment management of countries around the world, especially countries with similar air pollution status, several management solutions have been proposed. These solutions are a combination of world experience and suitability for conditions in Hanoi. However, to be able to promote their effects, it is necessary to have an asynchronous and flexible combination between solutions to maximize efficiency.

The thesis will mention some methods of connecting solutions to increase management efficiency. Currently, the first priority solution is always to implement legal tools. Laws include rules that force the application's subjects to take it seriously. However, to spread and increase the deterrence of this tool, the law must be linked with the economic method and the method of communication.

Besides, the contribution of scientists in drafting legal regulations is indispensable. Based on the development scenarios, the evolution of air pollution, and CC collected by scientists, the managers have proposed relevant socio-economic development plans. The promotion of forecasting models in all sectors will help the formulation of well-built development plans, balancing economic development and protecting the air environment.

It can be said that legal tool-focused management is an optimal approach. In particular, legal measures should be the centre of management tools; other tools will be supporting tools to maximize effectiveness and efficiency of implementation.
Although the air quality in Hanoi in the period 2013 - 2019 has been improved, the concentrations of PM$_{2.5}$ and PM$_{10}$ still exceed the standard values in QCVN 05: 2013/BTNMT. In particular, the percentage of PM$_{2.5}$ concentrations exceeding the highest limit was 51.25% in 2013, the lowest was 10.31% in 2017. The percentage of PM$_{10}$ concentrations exceeding the maximum limit was only 9.19% in the year 2013 and within the permissible value of the regulation in 2016 and 2017. About hazardous gases such as SO$_2$, NO$_2$, CO, O$_3$, the monitoring results show that the content of these substances is still within limits allowed by the standard. However, the concentration of these gases has tended to increase in recent years and usually has the highest concentration of pollution in high traffic density areas due to the source mainly from the vehicle.

The solutions proposed in the thesis also focuses on the main causes of air pollution in Hanoi, namely means of transport, industrial activities, and the fields of energy and fuel use. These are all sources of not only particulate matter but also major sources of GHG emissions, which both pollute the environment and contribute to accelerating the global CC process. In particular, to prioritize the development of appropriate mechanisms and policies to manage air pollution, thereby serving as the basis for the application of other management tools such as economic and auxiliary tools to improve effectiveness. Besides, among those proposed measures, it is possible to continue to develop recent public transportation systems and thoroughly apply the environmental modelling method in forecasting and warning of air pollution.

Some of the limitations that the topic encountered include the availability of observed data collected at the monitoring stations in the city. Besides that, the data series is not abundant and it is difficult to access the data sources. The AQI index according to Vietnamese regulations is heavily depended on the availability of monitoring results. Because the data source is limited, especially data on GHG in Hanoi, an interview is required to collect more primary data for increasing the convinces for research.

The measures given are largely based on practical experiences of countries in the world, as well as enhancing many solutions applied in Vietnam. However, the above selection is mainly based on the author's findings and understanding. Evaluating the effectiveness of these measures will need further research with great effort down the road.
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