PARTICULATE MATTER 2.5: A CASE STUDY OF MEASURES AND RISKS IN BANGKOK DURING EARLY 2019

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ฝุ่นละอองขนาดเล็กไม่เกิน 2.5 ไมครอน: กรณีศึกษามาตรการและความเสี่ยงในกรุงเทพมหานครช่วงต้นปี ค.ศ. 2019

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สถานการณ์ฝุ่นละอองขนาดเล็กมีที่มาจากหลายปัจจัย อาทิ การพัฒนาทางเศรษฐกิจ ปัญหาสิ่งแวดล้อม รวมถึงความไม่เท่าเทียมกันในสังคม ในช่วงไตรมาสแรกของปี ค.ศ. 2019 กรุงเทพมหานครถูกปกคลุมโดยฝุ่นละอองขนาดเล็กเป็นจำนวนมากหรือที่รู้จักกันในชื่อฝุ่นละอองขนาดเล็กไม่เกิน 2.5 ไมครอน ผู้ที่อยู่อาศัยในเขตตัวเมืองต่างได้รับผลกระทบจากฝุ่นละออง โดยเฉพาะปัญหาสุขภาพและการลดลงของรายได้ แม้ว่าทางรัฐบาลไทยได้มีการประกาศใช้มาตรการต่าง ๆ ในการรับมือกับปัญหาฝุ่นละอองขนาดเล็ก ประชากรกลุ่มเสี่ยงที่ซึ่งได้รับผลกระทบเป็นส่วนใหญ่กลับถูกจัดให้อยู่ในกลุ่มคนที่ไม่ได้รับความสำคัญ ในบริบทนี้ การบังคับใช้มาตรการที่ดีนั้นไม่ควรมุ่งเน้นที่การลดจำนวนฝุ่นละอองขนาดเล็กเพียงอย่างเดียว หากแต่ต้องคำนึงถึงผลกระทบที่กลุ่มประชากรอาจได้รับจากมาตรการเหล่านั้นด้วย

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ระหว่างมาตรการของรัฐในการควบคุมปริมาณฝุ่นละอองขนาดเล็กและความเสี่ยงต่าง ๆที่ส่งผลกระทบต่อประชากรกลุ่มเสี่ยงในเขตพื้นที่กรุงเทพมหานคร ในการทำความเข้าใจความซับซ้อนของปัญหานั้น ผู้จัดทำได้ใช้วิธีการศึกษาแบบข้ามสาขาวิชา ผ่านทฤษฎี “สังคมแห่งความเสี่ยง” และทฤษฎี “ความเหลื่อมล้ำทางสิ่งแวดล้อม” โดยใช้วิธีการสังเกตแบบไม่มีส่วนร่วม การสัมภาษณ์แบบเชิงลึกกับกลุ่มตัวอย่างที่หลากหลาย และการสืบค้นข้อมูลจากเอกสารในการรวบรวมองค์ความรู้เพื่อหาข้อสรุป

จากการศึกษาพบว่าสถานการณ์ของฝุ่นละอองขนาดเล็กไม่เกิน 2.5 ไมครอนในพื้นที่กรุงเทพมหานครมีสาเหตุการเกิดหลักจากการคมนาคม มาตรการการป้องกันและการลดฝุ่นละอองขนาดเล็กไม่เกิน 2.5 ไมครอนที่บังคับใช้โดยรัฐ โดยมากแล้วเป็นการป้องกันปัญหาระยะสั้น ซึ่งมุ่งเน้นไปที่การลดกิจกรรมในภาคอุตสาหกรรมและการก่อสร้างมากกว่าการให้ความสำคัญกับการป้องกันระยะยาว เช่น การปรับปรุงคุณภาพของเครื่องยนต์และเชื้อเพลิง เป็นต้น นอกจากนี้จากการศึกษากลุ่มประชากรตัวอย่างพบว่าปัจจัยที่ส่งผลต่อความไม่เท่าเทียมในการเผชิญกับผลกระทบจากฝุ่นละอองขนาดเล็ก ประกอบไปด้วย ภาระทางการเงิน มาตรการของรัฐที่อิงกับสภาพเศรษฐกิจและสังคม ราคาของอุปกรณ์ป้องกันฝุ่นละออง การเข้าถึงแหล่งที่อยู่อาศัยที่ปลอดภัยและความสามารถในการเข้าถึงการบริการของภาครัฐ รวมถึงแหล่งข้อมูลที่จำเป็น

สาขาวิชา การพัฒนาระหว่างประเทศ ลายมือชื่อนิสิต

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6181215724 : MAJOR INTERNATIONAL DEVELOPMENT STUDIES
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Thanabodee Lekprayura : PARTICULATE MATTER 2.5: A CASE STUDY OF MEASURES AND RISKS IN BANGKOK DURING EARLY 2019 . Advisor: Asst. Prof. JAKKRIT SANGKHAMANEE, Ph.D.

The increased presence of particulate matter is caused by a multiplicity of factors, such as economic development, environmental degradation, and social inequality. During the first quarter of 2019, Bangkok was covered with a large amount of fine particle, known as PM2.5. Many Bangkok residents were affected, particularly in terms of their health and income. The Thai government has announced measures to cope with the problem. However, the most effective measures should not only decrease the level of particles, but should also be able to address the impacts on risk-prone groups. In this context, the vulnerable groups seem to be those placed in a marginalized position, while they are also the group that tends to be most impacted.

The objective of the study aims to understand the relationship between the state measures and the multiplicity of risks among the vulnerable groups in Bangkok. In order to comprehend the complexity of the issue, this study utilizes a transdisciplinary approach to highlight the politics of government measures for different stakeholders. It analyzes the case of PM2.5 in Bangkok during 2019 through the conceptual lens of risk society and environmental inequality. The research combines different methodologies including non-participatory observation, in-depth interviews with various types of samples, and documentary research.

The study found that the majority of PM2.5 in Bangkok has occurred as a result of transportation activities. Most of the measures implemented by the state in response, however, were short-term solutions that focused on limiting activities in the industrial and construction sectors, rather than pursuing long-term solutions such as improving engine and fuel standards. Among the vulnerable groups, it is found that there are many factors causing their exposure to the impact of PM2.5. These factors are: economic condition, ineffectiveness of measures in regard to economic and social dependency, cost of protection, area of state service, availability of safe accommodation, and the ability to access services and sources of necessary information.

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ABBREVIATIONS

AQI	Air Quality Index
EIA	Environmental Impact Assessment
NCPO	National Council for Peace and Order
NPV	Net Present Value
PM	Particulate Matter
PRTR.	Pollutant Release and Transfer Registers
PSI	Pollutant Standards Index
WHO	World Health Organization

CHAPTER 1
INTRODUCTION

Background

The problem of particulate matter, especially PM2.5, can be considered a new phenomenon in Thailand as people have just started to notice it within the past two-to-three years. As the size of the particle is too small to perceive with the normal human eye, people in the past were not aware of the impact of particulate matter. However, when particulate matter becomes condensed, combined with the weather and high pressure system, it forces the particles to float at a lower air level, approximately 1.5 kilometers from the ground (Pongpiachan, 2019). As a result, many people are able to see haze in the sky, especially in the morning, and some of begin to concern about their health, which is believed to be consequence of the particulate matter.

In fact, Thai people have likely faced fine particulate matter, or PM2.5, before, especially the people who live in Bangkok. However, for the past few years people assumed that it was just morning fog, as they were not familiar with this type of particle. The scope of their knowledge was limited to the information of gas emission such CO2 or SO2, and PM10. A decade ago, if there was any situation of haze happening in any part of the country, the way to measure the air quality was to use the air quality index (AQI) with the safety standard set at 100; a score above 100 is considered dangerous to human health. However, this type of index can only measure particles with the size of PM10 and larger, it is not effective enough to collect the data of PM2.5 (Pongpiachan, Apiratikul, & Nasanit, 2019). However, in 2010, following the adoption of a new air quality index in many countries, such as in the United States and the European Union, Thailand started to also use the air quality index which is able to measure PM2.5 (Board, 2010).

Although the new air quality index that is able to measure the level of PM2.5 has been used in many official and public reports since 2010, many people were still not concerned about the hidden impact of the particulate matter. However, PM2.5 became well known to the Thai public at the beginning of 2019, when the city of

Bangkok was covered with a large amount of particulate matter. At that time, people paid a lot of attention to the news stories that were related to the haze issues. However, after the level of particulate matter decreased back down to the level that the human eye could not see it, the issue seems to have returned to be a topic that no one pays attention to.

In the central part of Thailand, especially in the capital city, the cause of air pollution is derived from the burning of fossil fuels and industrial activity. However, people are mainly concerned about gas emissions from these sectors rather than micro particle. Although there are a lot of similar haze issues taking place around the world, such as in Beijing or New Delhi, many Thai experts in the past believed that Bangkok would not face with a similar situation as Bangkok is located close to the Thai gulf, which allows the wind to move the floating particles away (Pongpiachan, 2018). Therefore, the measures addressing particulate matter in Thailand are weak; virtually none of them can effectively tackle the problem of particulate matter. Moreover, some policies were not created to suit all types of people, especially vulnerable groups.

To determine the impact of these measures on the vulnerable groups, it must be acknowledged that different types of people face different types of risks. In this study, the main groups of focus were the government street sweepers, the construction workers, and the motorcycle taxi drivers in Bangkok. These are the groups that primarily work outdoors, and thus it is impossible to deny that they are the groups that are more likely to be directly impacted by the PM2.5 situation. As the indirect impacts of the PM measures should also be determined, this study is intended to help the government street sweepers, the construction workers, and the motorcycle taxi drivers in Bangkok to reflect on the problems they face, with the expectation that their information can be useful for the creation of future measures that are effective enough to protect vulnerable groups from both direct and indirect impacts of particulate matter.

Research Questions

Main question

How did particulate matter related measures implemented by the state during the first quarter of 2019 lead to the multiplicity of risk among government street sweepers, construction workers, and motorcycle taxi drivers in Bangkok?

Specific questions

- What is the situation of PM 2.5 in 2019?
- What are the measures implemented by the state to prevent, reduce, and protect people from PM2.5?
- How are government street sweepers, construction workers, and motorcycle taxi drivers being exposed to particulate matter?
- What are the factors causing inequality in regard to particulate matter related risk exposure?
- What are the impacts of the state's measures regarding inequality of risk on government street sweepers, construction workers, and motorcycle taxi drivers?

Research Objectives

- To explore the situation, factors, and measures in managing the impact of PM2.5 in 2019;
- To analyze the impacts of particulate matter measures in 2019 on government street sweepers, construction workers, and motorcycle taxi drivers in Bangkok;
- To evaluate particulate matter measures that were announced during the first quarter of 2019 in terms of their equity of access by vulnerable groups.

Research Methodology

Area description

Figure 1: Air Quality of Bangkok-January 16, 2019 *(The Thaiger, 2019)*

Bangkok is the capital city of Thailand and is located between 13°45′ N and 100°31′E. The city consists of approximately six million registered residents, with an average population density of 3686-person per km^2. The inner city has a complex urban environment that mixes commercial, residential, and some industrial areas together. However, large industries are still primarily situated in the outskirts area of the capital city. According to the statistical data from Bangkok Metropolitan Administration, over five million motor vehicles were registered in Bangkok in 2003. Between November and February, predominant winds are influenced by the pressure from northeast, while between March and October, southwest monsoons are the factor that control the predominant winds. During rush hours, the city roads have an average travel speed ranging from 16.8 to 24.8 km per hour. Therefore, traffic congestion and air pollution from fossil fuel burning are the common issues that mainly impact the city (Chuersuwan, Nimrat, Lekphet, & Kerdkumrai, 2008).

Data Collection Method

Data was collected using qualitative methodology, including in-depth interviews and non-participant observation, in order to gather data from the sample groups. The other method of data collection was through utilization of secondary sources, including NGO and government reports, which provide background information on the measures implemented and to what extent these impacted sample groups.

In depth-interview is one of the data collection methods that requires interaction between the interviewer and the interviewee. The interviewee must answer the question thoroughly, and the interviewer should ask reasonable questions. This type of interview works well for studies focused on issues related to individual behavior, attitudes, needs, beliefs, values, and personality in various ways.

The technique of non-participant observation is a method of data collection in which the researcher observes the sample group from outside, having no interference with the sample group's activity. The advantage of non-participant observation is that it saves a lot of time; particularly the time spent building rapport with the sample group, as the researcher only observes as an outsider. Moreover, this type of data collection is suitable with a short-term study and is not as expensive as the participatory observation method.

Fieldwork Research (Total 30 samples – Between 1st-31st January 2019)

- In-depth interviews with government street sweepers: a group of government street sweepers from Bangkok Metropolitan department were selected, all street sweepers were selected from an area that was considered to be a PM2.5 red zone in early 2019 (10 samples – from Chatuchak District and Pathumwan District).
- In-depth interviews with construction workers: a group of construction workers from the construction sector were selected, both from private organizations and public organizations; MRT-Mass Rapid Transit (10 samples – from Chatuchak District and Ladprao District).

- In-depth interviews with motorcycle taxi drivers: a group of drivers from a red zone area were selected. All of them are motorcycle taxi drivers that have been legally registered with the Ministry of Transportation (10 samples – from Chatuchak District).

Document Research

- Reports from Governmental Organizations:
  - Booklet on Thailand State of Pollution 2018, Pollution Control Department Ministry of Natural Resources and Environment, February 2019 (Pollution Control Department, 2019a)
  - Origin and Guidelines to PM 2.5 in Bangkok (Pollution Control Department, 2019b)
  - 20-year Pollution Management Guidelines and Pollution Management Plan, 2017-2021, Pollution Control Department Ministry of Natural Resources and Environment, 2017 (Pollution Control Department, 2017)
- Reports from Non-Governmental Organizations:
  - Classification of Cities PM2.5 Level in Thailand, year 2018 (Greenpeace, 2018)
  - Thai Government-Particulate Measures Evaluation by Greenpeace.

Data Analysis Method

All of the data that was collected from the sample groups and secondary sources were analyzed using “analytic induction”.

Analytic induction is the interpretation of data from concrete or visible phenomena, collected from two or more data sets, such as performance, teaching behavior, or life of people. The researcher can conclude the data when they see or observe many different events. However, a conclusion that has not yet been verified will not be considered as the conclusion until it has been confirmed, thus the outcome will only be assumed as a hypothesis. Analytic induction is considered to be a necessary method to analyze qualitative data, as such method is the process by which common characteristics or patterns in concrete data can be summarized based on the principle of

"induction". It is the process of identifying facts from various sub-facts to create a set of abstract findings, which cover all of the sub-facts. Analytic induction includes three methods of analysis: analysis of data from the summary of fieldwork or descriptive note, analysis of data from classifying or grouping of factors or pattern, and analysis of data from the component that has been analyzed.

CHAPTER 2
LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

This chapter reviews literature related to the issues of PM 2.5. It is comprised of an overview of the situation of particulate matter around the world, together with the impacts and measures provided by governments of each country. Within this chapter, the data is divided into four sections. The first section is the global overview of the particulate matter situation and the solutions that each country (particularly China and Southeast Asian countries) has used to mitigate the problem. The second section is about the situation of particulate matter in Bangkok, focusing on the characteristics of the city in terms of seasons, location, and urban planning problems, which are possibly linked in contribution to the issue of particulate matter. The third section is the relationship between particulate matter and different types of people; all data in this section is aimed at understanding the factors that caused the gap in particulate matter risk exposure among different types of social group. The fourth section is about international particulate matter related measures that have been implemented in China, South Korea, India, and the United Kingdom. The last section outlines the conceptual framework, which explains the two theories that have been selected to analyze the data collection: the theory of Risk Society and the theory of Environmental Inequality.

The Global Situation of Particulate Matter

Tangshan, China can be seen as a perfect reflection of China's dilemma between economic growth and environmental degradation. Under the past strategy of "pollute first, control later", or "develop first, clean up later", the problem of air pollution has turned into a problem that many people believe is a major obstacle of the city's development in the future. The rapid increase of heavy industry and automobile traffic has worsened the situation of particulate matter. It is undeniable that the air pollution issue is associated with concern for the basic quality of life, especially the physical health and well being of families. Although the priority of the particulate matter issue ranked below many other issues, its rank was still placed above economic concerns,

including income and jobs. Since 2012, the Ministry of Environmental Protection of China has implemented a national program to lower the level of particulate matter in order to protect their citizens, however the program seems to have failed as the implementation process was not effective. Currently, people who are living in Tangshan still need to wear masks to protect themselves from the polluted air, as there is no sign of improvement regarding the levels of particulate matter. While not all residents experience equal impact from this issue due to the differences in socio-economic positions, many of them are at risk of respiratory and cardiovascular diseases (X. Li & Tilt, 2018). The case of air pollution in Tangshan is an example that clearly demonstrates the importance of policy in the direction of city development.

According to the study about "public willingness to pay" for the mitigation of particulate matter in Beijing, China, more than 80% of the urban residents were willing to pay for mitigation. However, not all residents are willing to pay the same amount of money due to differences in income, age, and health conditions. Although most of the residents had a positive reaction in terms of knowledge about and value of the mitigation of particulate matter, their income become the major barrier that limits them in paying for mitigation or even in protecting themselves individually. The majority of residents are willing to pay for particulate matter mitigation at the rate of 716.34 CNY, or approximately 3,400 Thai Baht, which accounts for 0.82% of their annual income. To clarify further, people who have a lot of knowledge about particulate matter and perception of the risks were willing to pay more for the mitigation program. Among the 80% of residents who were willing to pay for mitigation, half of them believed that the reduction of particulate matter should be the responsibility of the government. While the attitude of the residents toward government are relatively positive, half of them suggested that environmental laws, regulations, and mitigation policies should be implemented specifically by each city as not all cities have the same demographic characteristics (Dong & Zeng, 2018). From this data, it indicates that when forming policies or measures to cope with the particulate matter problem, they need to be well-designed for each location, as only one type of policy from the central government may not fit every city, and each problem in each area has its own characteristics.

In the Southeast Asia region, the level of PM2.5 has increased rapidly at the rate of 0.02 μg/m3/year, the areas with high health risks have expanded, and the proportion of population exposed to particulate matter has increased since 1999. According to the primary PM2.5 standard from the World Health Organization, the level of annual average particulate matter in the Southeast Asia region has exceeded the limit. The increase in particulate matter level is mostly a result from biomass burning and the expansion of cities with high rates of traffic congestion. In metropolitan cities, such as Bangkok and Hanoi, the level of particulate matter is directly associated with the density of the population, the larger the population and the higher its density, the higher concentration of particulate matter. Thus, without effective policies to limit the emission rates of particulate matter, it is expected that the number of cardiovascular and respiratory patients will increase continuously in the future (Shi et al., 2018).

It is undeniable that particulate matter is a worldwide issue that causes harmful impacts on human health and visibility. Many countries have adopted air quality standards for measuring, monitoring, identifying, and quantifying the root cause of PM10 and PM2.5 in order to reduce the emission rate. The large concentration of particulate matter in Southeast Asia is believed to be closely linked to land conversion and burning of secondary of forests and pastures (biomass burning). However, in the urban area, the majority of particulate matter concentration was caused by transportation activity. The effect of air quality deterioration changes the daily life of local inhabitants, as well as that of residents in the big cities. Respiratory health issues have become a common threat to the people. In addition, not only does it affect people, but the particulate matter issue has also led to an increase in the atmospheric temperature, which could result in changes in the regional hydrological cycle and crop productivity (Pani et al., 2018).

In Malaysia, as the awareness of haze increased, a lot of pressure from public and civil society was put on the Malaysian government. However, the inequalities between urban and rural communities in terms of knowledge, attitude, and practice, could be a major barrier in the promotion of haze awareness. Although both urban and rural residents have moderate knowledge in regard to the air pollution issue, the urban residents with greater average income have significantly higher understanding and

protective behaviors for haze compared to residents living in rural areas. The differences in knowledge and protective behaviors result in the different levels of exposure and impact of the haze, especially from the fine particulate matter (Vethanayagam James & How, 2017).

The Situation of Particulate Matter in Bangkok

Particulate matter is divided into two categories, fine particulate matter (PM2.5) and coarse fraction (PM10). Both fractions are different in nature and derived from different sources. Between January 2003 and December 2007, fine and coarse fractions of PM2.5 and PM10 were collected from the Chatuchak District, which is an urban Bangkok site, and Klongha District, which is a suburban site in Pathumthani province. The database shows that particulate matter concentration in the urban area had higher mass of elements compared to the results from the suburban area. Black carbon was the major proportion of fine fractions, while mass and some elemental concentration were the major content of coarse fractions. Although the wind direction plays an important role in the particulate matter issue, the major source contributing to the fine particulate matter were traffic and biomass burning (50–70% of total fine particles). For the coarse fraction, construction and soil dust were the major sources that contributed 60–70% of the total coarse particles. The results show that the overall amount of particulate matter in urban Bangkok was higher than the particulate pollution in the suburban area (W. Wimolwattanapun, P. K. Hopke, & P. Pongkiatkul, 2011).

For Bangkok, the roles of public transportation and urban planning in air pollution control need to be highlighted. With three different types of health risk assessment tests divided by exposure pathways, including ingestion, dermal contact, and inhalation, it can be said that ingestion of particulate matter causes more risk to people compared to inhalation and dermal contact. Vehicular exhaust plays a major role in the issue of particulate matter in the city; thus, the implementation of effective long-term action plans is essential to control the level of particulate matter. The promotion of electric vehicles, building cycling infrastructure, and encouraging people to use public transportation might be a solution that leads to a decreased level of dust (Pongpiachan et al., 2017).

The seasons of PM10 and PM2.5 concentration is distinct between October and February, which is dry season, and March and September, which is the wet seasons. The major source of particulate matter (PM2.5 and PM10) mass concentration in the traffic area was generated from automobiles, while the particulate matter in the residential area was generated from biomass burning. In addition, meat cooking and road dust also contributes to an increase in the level of particulate matter. The hospital admission rate in accordance with respiratory and cardiovascular illnesses increased when the level of particulate matter concentration was higher. Approximately 4000 to 5500 premature deaths occur every year in Bangkok, based on the total population of 10 million, due to issues related to particulate matter (Chuersuwan et al., 2008).

Bangkok is currently facing a severe traffic congestion problem. The patterns of urbanization and government policies have led to an increase in the number of automobiles. The street and transportation structures are complex; with some roads covered by tunnels and Sky Train platforms that result in poor ventilation. Thus, the levels of particulate matter in various areas may differ. In the case of covered and open areas (not inside buildings), people who work in covered areas, such as street vendors, have a higher potential risk in terms of exposure to particulate matter compared to workers in completely open areas. Solar intensity, temperature, wind speed, and relative humidity are some of the influencing factors that can decrease the level of particulate matter in the open areas, but cannot significantly lower the levels for covered areas (Sahanavin, Tantrakarnapa, & Prueksasit, 2016). Therefore, the measures that are issued by the state need to consider these types of conditions in the policy formation process in order to deliver the most suitable policies to mitigate the issue, as well as to protect the people who are working under those types of conditions.

Particulate Matter and Different Types of People

According to the studies of indoor and outdoor fine particulate matter in Bangkok, the outdoor PM2.5 concentration is higher than the indoor PM2.5 concentration. However, indoor residents are still at risk for negative health impacts from particulate matter, as the level of particulate matter concentration is still higher than the recommended standard compared to people who spend most of their time in

outdoor areas (Mongkhon Sompornrattanaphan, Torpong Thongngarm, Pongsakorn Tantilipikorn, Piyawut Kreetapirom, & Johnson Foo, 2018).

Indoor and outdoor particulate matter concentrations are significantly related. The personal particulate matter exposure was more closely connected with the outdoor concentrations than the indoor concentrations. The outdoor particulate matter concentration can be used as an indicator of personal exposure, even across different backgrounds and lifestyles. Although the level of concentration of particulate matter exposure was higher in the outdoor area, the average indoor particulate matter concentration on the first floor of a building was higher than that of any other floor. The variation of particulate matter concentration was found to differ from floor to floor, the lower the floor, the more exposure to particulate matter concentration. Therefore, even for people who are living in the same building, their individual exposure to particulate matter may differ. However, personal exposure is still influenced by personal lifestyles and activities, such as tobacco smoke, the season (particulate matter is more concentrated during the winter than in the summer or rainy seasons), and accommodation characteristics (living with an air conditioning system lowered the concentration of particulate matter, while staying in an open air building increased the concentration) (Watchalayann, Srisatit, J Watts, Rachdawong, & H York, 2019).

From a range of environmental health hazards in Bangkok, air pollution ranked "the most serious threat to public health". The health effects seem to be more closely linked to the small particles with the size less than 2.5 micrometers (PM2.5) and 10 micrometers (PM10) in diameter respectively. The exposure to particulate matter outdoors is at a higher particulate matter concentration than indoors. The ratio of indoor and outdoor particulate matter concentration tends to be lower in an air-conditioned environment. The sampled air-conditioned hospital area proved that it had a substantially lower particle concentration than outdoors, but this concentration was increased again with the factors of smoking and the use of charcoal stoves indoors (Tsai et al., 2000).

The study of hospital admissions for cardiovascular and respiratory diseases in Bangkok between January 2006 and December 2014 showed that there is an association between air pollution (O3, NO2, SO2, PM10, PM2.5 and CO) and health effects. Both

cardiovascular and respiratory diseases are the most common causes of morbidity and mortality, which result from exposure to air pollutants. Across all demographics, elderly people were more greatly affected by air pollution based on hospital admission. As Thailand is beginning to experience an aging population, the planning, formulating, and implementing of an appropriate health policy is necessary to reduce the number of patients and economic cost for hospital admissions (Phosri et al., 2019).

Regarding conditions in which people are exposed to environmental pollutant sources, low-income groups are the most closely linked to poor health. According to the Inadequate Ventilation Index, low-income housing tends to lack "*bathroom fan or vent, a bathroom fan with inadequate suction, no kitchen fan, or a kitchen fan that did not work or recirculated air*". This further illustrates that these residents are living in an indoor environment that is harmful to their health. Moreover, some specific activities, such as cooking on a stove with no mechanical exhaust to the exterior or kitchen fan, further generate a greater degree of health risk. Although the conditions of health problems are influenced by a combination of factors, such as building and household characteristics, environmental pollution is still one of the most important determinants of people's health, especially for residents in the low-income category (Adamkiewicz et al., 2014).

Foreign Measures

The problem of particulate matter is a global issue currently taking place in various developed and developing countries, with each country implementing different solutions. Some solutions might be working, but some are not. However, many policies are believed to be suitable for the context of Thailand. Below are some examples of short-term and long-term solutions proposed by China, South Korea, India, and the United Kingdom.

China

Chinese society has been experiencing the haze problem for a long time. Some short-term solutions have been to stop barbecuing, using drones to spray anti-haze substance, shooting rockets to create artificial rain, and installing a giant sprinkler to

spray water at the top of buildings. For the long-term solution, the Chinese government has ordered the control the emissions of particles in industrial plants; investment in environmentally friendly technology, such as electric cars; development of a mass transit system; reduction of electricity from coal power plants; promotion of wind turbines; development of applications with high precision weather measurement; and introduction of an environmental protection tax, which charges people at a rate of 12 yuan per air emissions unit (J. Li, 2016).

South Korea

The government of South Korea created a campaign to encourage people to wear masks and to reduce their outdoor activities. They also notified people of the particulate matter status using an official government application; set up air quality sensors in many public places; reduced the production hours of power plants; limited electricity production at a rate of 80%; and supplied artificial rain during the day. For the long-term solution, free transportation is provided during rush hours to help reduce the number of private cars and limit the number of old vehicles on the roads. The Korean Ministry of Environment also announced a pilot project to use drones with cameras to monitor the suburban areas of Seoul in order to discover any illegal sources of pollutants (Jang, Do, Park, Kim, & Yoo, 2017).

India

When the haze situation starts to get worse in India, the authorities will announce the protocol to reduce the construction and demolition activities that are contributing to the concentration of particulate matter. The authorities also use water-spraying measures, in which the water consists of electrostatic properties that can absorb more particles, together with temporary shutdowns of coal-fired power plants. For the long-term solution, private cars are restricted through the parking tax system, which has encouraged people to use public transportation. Additionally, large diesel engine cars (engine larger than 2,000 cc) such as SUVs have been prohibited, diesel engines in taxis are illegal, and the bus and subway routes are being expanded (Michael & Rema, 2014).

United Kingdom

During the haze situation, the British government immediately reduced the fuel consumption rate by limiting the use of wood and coal for both outdoor and indoor areas. They also announced the clean air law, resulting from the 1952 smog incident, which caused more than 12,000 deaths. Based on the British government's action, Thailand should also have clean air laws, which would be enforced by the department under the Environmental Protection Agency. There is no need to set up a new department, rather, a current one can be assigned to be independently responsible for the haze problem. Otherwise, without the delegation of a specific department, the issue will be ignored while they wait for others to deal with it. It is important to remember that the Pollution Control Department does not have the power to order factories to close, to arrest farmers who burn waste in their fields, or even to change the Euro standard. Therefore, the responsibility should belong to the department under the Environmental Protection Agency (Burns, 2016).

Without proper short-term and long-term measures implemented in the near future, the issue of particulate matter will intensify, and the risks, both direct and indirect, will increase for all groups of people, particularly the more vulnerable groups.

Literature Summary

At the local level, metropolitan areas have become an important hub for air pollution due to the large amount of pollutant gases and particulate matter (PM2.5 and PM10) that are emitted by urban residents. The linkages between particulate matter and health risks has long been studied by intellectuals, and various ailments including allergies, respiratory disease, and cardiovascular disease have been proven as consequences of high levels of air pollution. These kinds of health burdens are mainly concentrated in metropolitan areas, where they have led to a rise in mortality levels and the reduction of life expectancy rates, as well as an increase in the economic cost of health systems improvement. In non-rural areas, vehicles are one of the primary sources of particulate matter. Among all types of vehicles, heavy-duty cars with the Euro3 emission standard engine constitute a significant source of emissions, and have become

the priority strategic agenda of the government to counter negative environmental impacts. Finally, people's location and income rate is interrelated with the level of personal exposure; for example, the lower the income and floor on which they live, the more exposure they have to particulate matter. To conclude, all of these studies have focuses on risks that result from exposure to particulate matter, but none of them have addressed the new risks that have emerged from the implementation of particulate matter mitigation measures. Effective measures should not only be able to decrease the level of particles, but should be designed for the benefit of all levels of people.

Conceptual Framework

Risk Society (Beck's Theory of Risk Society of Modernity)

People are constantly needed to adjust and respond to the changes of risks which result from the development of technology and economic growth. The concept of risk society is not only limited to the area of environmental and health issues, in fact it also combines a whole set of interrelated changes under the scope of contemporary social life; e.g., the change in employment patterns, the increasing in a rate of job insecurity, the devaluation of customs and traditional influences, the shrink in traditional family role, and the democratization of personal linkage. In modern society, the source of wealth has generated various forms of risks. Its side effects have created many uncertainties, or even death-dealing, consequence for society. Based on the concept of time and space, these new forms of risks are not restricted to place (Beck & Ritter, 1992).

According to the history of risk distribution, it has illustrated that, similar to wealth, risks bonding with the class lines, only inversely; wealth accumulates at the top, risk locates at the bottom. In this context, risks tending to strengthen the class-based society, not to abolish. Poverty attracts numerous of risk, while the wealthy in regard of income, power, and education can purchase freedom and secure from the risk. After applied the argument of risk distribution to the idea of social classes, compared to the rich, poor people are more vulnerable to risk. As the rich can push many risks away as far as possible, poor people still suffer from risks. Besides, some rich can profit from

the risk they produced, particularly the one who producing and selling technologies that can prevent, stop, or solving risk's impact after once the risk occurred.

Environmental Inequality (Fielding & Burningham, 2005)

Environmental inequality has occurred from the context of the Environmental Justice promotion. Its definition can be referring to the unequal distribution of environmental risks, hazards, and access to environmental resources and protections among different type of social groups. The category of Environmental Inequality can be mainly divided in to three main subcategories, including Social Inequality, Economic Inequality, and Spatial Inequality. Normally, all categories are linked together.

Social Inequality

The "high-vulnerable group", such as children, elderly, sick, some specific genders, and low-income, must be separated from the "normal" group before the sample selection and analysis. However, for the "low-vulnerable group", the division in terms of categories must be done before the study, such as to divide in terms of its size (SME and big enterprises), or by its sectors (agricultural sector, industrial sector, service sector, etc..). However, the classification for both more- and less-vulnerable to risk groups mainly relies on the income base.

Economic Inequality

In the case that state measures are focused on stopping or controlling business activity, the impact on the "high-vulnerable group" (e.g. low-income group) should be considered in terms of how they will be affected by the measures, in what ways they can be support by the state, and the equity of the measure in terms of accessibility.

Spatial Inequality

Spatial inequality refers to the unequal amount of reliable facilities, resources, and services the area, such as medical, welfare, and state services. Some types of social groups have a greater range of resources and services, while some cannot even access their basic needs if the location in which they live does not meet with their demands.

Without the equal distribution of development, it is almost impossible to change this cycle. Space is further divided within different locations based on the clustering of various groups of people who share similar socioeconomic statuses.

To conclude, in the era of industrial modernity, society and nature are deeply connected. This implies that any changes that occur in a society also affect the natural environment and vice versa (Supriya, 2019). In order to counter various aspects of the same risk, the policies that are launched by the state to cope with the risk need to be equally supportive for all types of social groups. The concepts of Risk Society and Environmental Inequality were selected to study the impact of particulate matter related measures on vulnerable groups in Bangkok. Both concepts are used in the analysis section, as well as in shaping the direction of the outcomes. However, the concept of Risk Society plays a major role in the analysis of measures, while the concept of Environmental Inequality is mainly used to conduct the primary data analysis. Overall, the purpose of this study is to address the relationship between equal risk distribution and the improvement of particulate matter related measures for the improvement of livelihoods for all residents living in Bangkok.

CHAPTER 3
THE PARTICULATE MATTER AND MEASURES

This chapter looks at the situation of PM2.5 and explores the particulate matter related measures and regulations. The explanation will begin with the common characteristics and health impacts of PM2.5, followed by the specific measures and laws implemented in Bangkok to mitigate the problem. The last part will be a discussion of some specific measures, including the air quality index, the EURO standard, the industrial protocol, the situation of the construction sector, and the urban government workers. Finally, the chapter will conclude with an analysis of why the government is unable to solve the PM2.5 crisis.

What is PM2.5?

Particulate matter (PM) refers to solid particles and droplets of liquid that spread in the air. Some types of particles are large and dark enough to be perceived as soot or smoke. However, some other types of particle are so small that they are impossible to see with the naked eye. In general, the size of particles in the atmosphere are 100 microns or smaller and can cause adverse effects on the health of people, animals, and plants. Moreover, particles can also cause damage to buildings, obstruct visibility, and create obstacles in the transportation sector. Many countries have set particle standards as they have found that micro particles are more harmful to health than general particles as micro particles can pass into the lower respiratory system. Micro particles are divided into two types, including particles smaller than 10 micron (PM10) and particles smaller than 2.5 micron (PM2.5) (Munkong & Jinsart, 2017).

PM10 refers to “Course Particles”, or particles with a diameter of 2.5 to 10 microns, which originate from traffic on roads that are not paved with asphalt, the transportation of dust materials, and rock crushing activities.

PM2.5 refers to “Fine Particles”, or particle with a diameter smaller than 2.5 microns, which originate from engine burning, power plants, industrial plants, and smoke caused by firewood cooking. In addition, Sulfur-Dioxide (SO2), Nitrogen-Oxide

(NOX), and volatile organic compounds (VOCs) can react with other substances in the air to create fine particles.

In general, the particles can either be found in nature, such as pollen, soil dust; or as a result of human activities such as in industrial processes, transportation activities, open air burning, and fossil fuel power plants.

Where does PM2.5 come from?

The source of common particulate matter in the atmosphere can be classified into two types: dust caused by human activities such as the burning of fuels including oil, coal, and firewood, or industrial production processes; and natural particles caused by the wind's movement of soil, sand, soot, smoke from wildfires, volcano eruption, or salt dust from the sea (Wanna Wimolwattanapun, Philip K. Hopke, & Prapat Pongkiatkul, 2011).

Table 1: The Differences Between Particle Size Based on Source

	Large Size Particle	Small Size Particle
Source	- Diffusion of street dust - Diffusion of soil dust caused by mining, raising animals - Waste of organisms - Construction and demolition - Burning of coal and oil - Sea and ocean	- Burning of coal, oil, wood chips - Transformation of Nitrogen oxide gas, Sulfur dioxide and organic compounds in the atmosphere - Process result from maximum heat usage, furnace, Iron rolling mill
Process	- Crushed - Evaporation of some gases - Particle suspensions	- Chemical process, vaporization - Nucleation, condensation, coagulation - Vaporization of haze, drops of water in the clouds, in which the gas is dissolved and caused a reaction
Main components	- Diffusion particle - Suspensions caused by coals and oils - Oxides of the earth's crust elements - Salt particle, NaCI, $CaCO_3$ - Fungal spores, pollen - particle caused by vehicle tire	- SO_4^2 - NO_3 - NH_4^+ - H^+ - Organic Carbon - Metal (Pb, Cd, Ni, V Cu, Zn) - Dusty Water droplets

The sources of PM2.5 can be categorized into two types, whether it is originated from a primary source or a secondary source. For the primary source, particulate matter is created through transportation, electricity generation, open burning, and manufacturing industry, depending on the area of the original source. For the secondary source, particulate matter is created from chemical reactions in the atmosphere; normally sulfur, nitrogen, and ammonium are the substrates. Therefore, the release of sulfur dioxide and nitrogen oxide from various type of originating sources, such as fossil fuel electricity production plants or industrial factories, would also result in the creation of PM2.5 in the secondary stage.

Many people often blamed open area burning as one of the major causes of particulate matter. However, burning in open area is not the main factor that causes particulate matter concentration in the capital city. It is not correct to blame farmers, who are often accused of causing PM2.5, as a threat to the health of people living in Bangkok. In fact, the major source of particulate matter in the city is a result of transportation.

> Sonthi Kachawat, the Secretary-General of the Thai Environmental Scholars Club said that "*for the particulate matter situation in Bangkok during the first quarter of 2019, the climate was steady, the diffusion rate and wind speed were low, and the diffusion in vertical direction was minimal. In other words, the ground was consisted of low temperature and large amount fog, while up in the air the temperature started to increase due to the heat from the sun. These conditions have led to the air pollution due to substance which released from the vehicle such as the particulate matter, the benzene substance, or the carbon monoxide are hotter than the surrounding air. Therefore, it will flow up in the air (from hot to cold) for a certain extent. Then, lock up under the suitable level and finally fall down as it is unable to float any further due to the influence of humidity from the sea and heat from the sun. As a result, this cycle has causing large amount of particulate matter accumulation especially in the area that close to road.*" (Kachawat, 2018).

Bangkok is a flat area; the influence of monsoons typically helps to easily spread the dust and air pollution away from the city. However, the characteristics of PM2.5 mean that it can be easily moved from the originating source to other places hundreds or thousands of kilometers away. The originating source, such as coal-fired power plants, turn out to be the crucial factor that affect the air quality in Bangkok, particularly under the meteorological conditions (wind, temperature, air pressure, humidity).

Particulate Matter and Health Impact

Normal particles can be filtered by nose hair, but micro particles can pass through the nose hair and directly enter into the bloodstream, traveling through various organs throughout the body. To be more precise, PM2.5 is a particle that is smaller in size than $1/25^{th}$ of the diameter of a human hair; it is so small that it is only half the size of a blood cell (5 microns), thus the capillaries can directly absorb the particles and they can accumulate in the organs. The particles act like a rough cotton ball; they are a carrier for other substances such as cadmium, mercury, heavy metals, hydrocarbons and many carcinogens.

When the particles enter the lungs, they will travel through the lower respiratory tract. In Thailand, it was found that people who were exposed to a certain level of PM10 might develop asthma. However, for PM2.5, the particle is directly linked to an increase in the rate of patients with heart and lung diseases that were admitted to the emergency room. PM2.5 is also related to premature death, especially among elderly patients, patients with heart disease, patients with asthma, and children.

Large particles will fall to the ground according to gravity, but PM10 and PM2.5 can be suspended in the atmosphere for a long time, mixing with other pollutants. If these enter into the nose or mouth, some of the particles might be expelled into the sputum, but most of them will spread into the respiratory system, the air sacs in the lungs, the bloodstream, and will finally accumulate in various organs. As a result, particulate matter is associated with an increased risk in regard to chronic diseases and cancer.

Based on the study from the Institute for Health and Evaluation, Washington University, it was discovered that air pollution is a common factor in the cause of various types of diseases, as it is consists of many chemical components that are irritating to carcinogens. Therefore, the diseases, such as chronic obstructive pulmonary disease, cerebrovascular disease, ischemic heart disease, lung cancer, and acute lower respiratory tract infections, are common in the areas that have high levels of particulate matter. In Thailand, air pollution is said to result in about 50,000 premature deaths per year (IHME, 2019).

According to global medical research, it was found that if the level of particulate matter is higher than the standard value, it will result in an increased death rate caused by respiratory disease by a rate of 7%-20%, patients with respiratory diseases increased by 5.5%, systemic mortality heart and blood vessels increased by 2%-5%, patients with cardiovascular disease increased by 5.3%, elderly patients with respiratory diseases increased by 17%, elderly patients with cardiovascular disease increased by 7.6%, and causes lung problems amongst children (Wiwatanadate, 2018).

In addition, the study of particulate matter and its impact on the health of people living in Bangkok found that short-term exposure to PM2.5 is associated with 4,000 to 5,500 premature deaths each year (estimated out of 10 million people). Each day that the level of PM2.5 increases by 30 µg / m^3, the mortality rate will increase by 2-20 percent. The hospital admission rate due to respiratory disease and coronary artery disease also increases by 5-17 percent when the level of PM2.5 increases by 180 µg / m^3 in areas with high PM2.5 fluctuation rates (Ministry of Public Health, 2015).

The Situation of PM2.5 in 2019

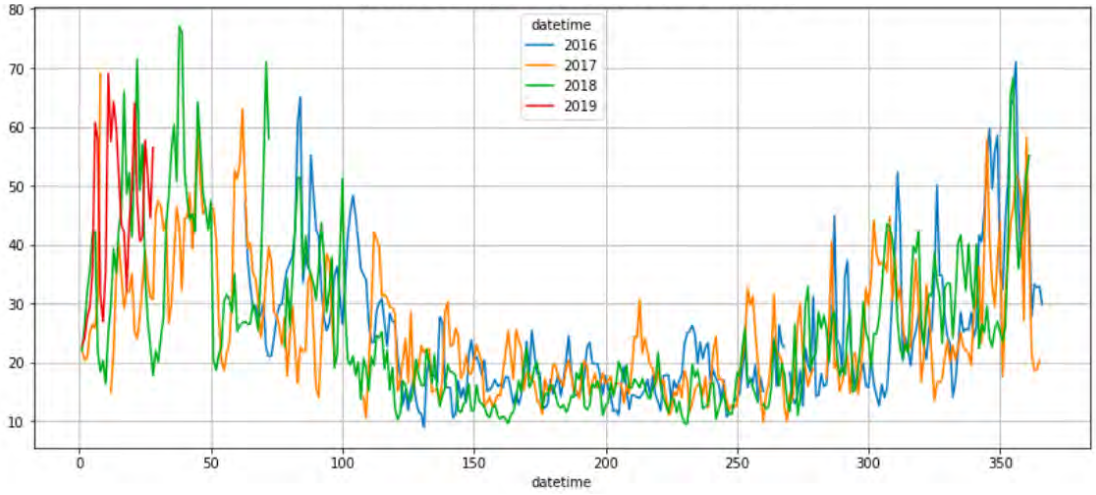
Each year between February and April, Bangkok will be faced with the impacts of particulate matter due to the result of poor weather conditions; fog caused by dry air masses clashing with cold air masses from the sea paired with mild winds leads to air stagnation. Moreover, with the infrastructure that is non-conducive to dispersion and high-rise buildings that block wind flow, the situation of particulate matter in urban areas tends to be more serious compared to that of suburban areas (Bourlerd, 2019).

According to the characteristics of PM2.5, the diameter of the particulate matter must be equal to or smaller than 2.5 micron. The source of this type of particle is usually the burning of fossil fuels, burning in the agricultural sector, or the combustion process in the industrial sector. With a size smaller than the diameter of a human hair, PM2.5 is considered to be more dangerous than PM10 as it can be directly absorbed through the human alveoli and can cause many diseases (Zhang et al., 2018).

At the end of 2018, concerns about the impact of particulate matter came to the attention of the public again due to the annual return of visible PM2.5 haze. During this time, the concern of the impact also spread to the Northern and Southern parts of Thailand where the particulate matter issue seems to be a normal phenomenon. However, instead of PM10 that used to be the major concern, PM2.5 has become the primary topic that both officials and the public are trying to solve. In fact, people who living in the Northern and Southern parts of Thailand have been exposed to the effects of PM2.5 for a longer period, but they may not have known as the air quality index in the past could only measure the PM10 particles (Padungtong, 2018).

According to Dr. Suphat Wangwattana, the ex-head of the Department of Pollution Control, nearly 51% of PM2.5 in 2019 was derived from the burning of fossil fuels in diesel engines. The average intensity of PM2.5 per year should not be over 25 micrograms per cubic meter, and within 24 hours, the average intensity should not be over 50 micrograms per cubic meter. Based on comparison of the statistical data of the levels of particulate matter throughout a period of 5 years, it was determined that the level of particulate matter increased by 25%, from 26 micrograms per cubic meter in 2013 to 35 micrograms per cubic meter in 2018, even though the Euro 4 emission standard was adopted in 2012 (Wangwattana, 2018).

Figure 2: Bangkok PM2.5 Daily Average Yearly Comparison (ug/m3)



(Weather Underground, 2019)

Since the PM2.5 measurement began in 2010 in Thailand, it can be seen that the particulate matter level is higher than 100 micrograms per cubic meter during the months of January and February. Moreover, the average concentration of particulate matter during these months tends to increase every year. This may be the result of the "First Car" policy, which started on 16 September 2011 and ended on 31 December 2011. The consequences of this policy have led to traffic congestion and an increased oil consumption rate. According to Mr. Kiattichart Maitriwong, Executive Vice President of Bangchak Petroleum Public Company Limited, the first car policy resulted in the increase of demand for gasohol by 4.5% and 3-5% for diesel fuel compared to the previous year, as the public did not use the energy efficiently due to the government's subsidy of diesel prices (Maitriwong, 2012).

The Economic Impact of Particulate Matter Crisis

After the particulate matter spread across Bangkok during the first quarter of 2019, it resulted in affects on citizen health and happiness. Critical weather affects the spending, confidence, and economic activities of Thai people, which was particularly impacted following the news that ranked Bangkok as number one in global levels of particulate matter.

According to the Kasikorn Research Center's preliminary assessment, the economic impact of the particulate matter crisis for a one-month time frame will cause economic damage of a minimum of 2,600 million baht and may reach 6,600 million baht in the worst case. Most of the economic impacts are generated from health issues, loss of opportunity for spending, and tourism (Kasikorn Research Center, 2019).

Under the assumption that the situation of particulate matter may cause 50% of patients with allergies in Bangkok to visit a doctor, the combined medical expenses, transportation costs, and occupational opportunity costs average to an approximate cost of 1,000 baht per person. While the cost of a medical mask accounted for an averaged minimum of 22.50 baht per day, it is predicted that the opportunity cost caused by health issues accounts for approximately 1,600-3,100 million baht in total. For the opportunity loss in the tourism sector, both in the case of decreasing number of tourists traveling to Bangkok specifically and the case of avoiding visiting Thailand altogether, the cost is estimated at approximately 1,000-3,500 million baht.

Moreover, the particulate matter has also impacted the "local economy", particularly among the construction workers, roadside hawker stalls, and even the motorcycle taxi drivers in terms of health and income. "*Although we know that the particulate matter is dangerous to our health, but we cannot remember what the government said. At the moment, our customers are decreasing due to the haze situation. We are not afraid of PM 2.5, but we are afraid of debt. Therefore, we have no choice but to work more harder even though it is risky*". Despite concerns for their health, due to their level of income and economic status these people often have no choice but to continue working even in the midst of the particulate matter crisis.

By assessing the impact on the economy and daily life of locals, the cost of the impacts resulting from particulate matter is approximately 50-1,000 million baht. The need for people to purchase a medical mask until the levels decreased has led entrepreneurs to produce and import more masks. It is predicted that the import volume cost around 200-300 million baht, together with the money that people have to spend to cope with sicknesses.

Bangkok Government Measures

The measures that were declared in Bangkok during the first quarter of 2019 were those that were recommended by the central government and implemented by the Bangkok Metropolitan Administration. Below are the types of measures, which can be divided into three types; short-term measures for the protection of people, short-term measures for prevention of pollution source, and the long-term measures.

Short-Term Particulate Matter Measures for "Protection of People"

- Distribution of N95 masks in public areas such as public parks and government offices, prioritizing elderly, young, and sick people first
- Road cleaning every day from 18.00-06.00
- Solving traffic congestion issues by prohibiting cars to park along main public roads
- Creating artificial rain in the capital city area during 16-19 January.
- Spraying water in public areas
- Closing all schools in Bangkok from 30 January to 1 February

Short-Term Particulate Matter Measures for "Prevention of Pollution Source"

- Investigation and control of factories that release particulate matter (in addition, all factories under this measure have to report their PM emission rate to the government every day).
- Increase the number of PM checkpoints on the road from 12 to 20 in the red zone areas, such as Chatuchak, Bang Kor Laem, Bang Khun Tian, and Thonburi. Authorities will arrest any cars emitting black smoke.
- Prohibit heavy-duty vehicles from entering the capital area during rush hour, especially trucks with Euro 3 diesel engines (No enforcement).
- Speed up or suspend the construction at sites in the central capital area.
- Prevent biomass burning by increasing police patrol.
- Support campaigns to encourage people to turn off their engines while parked at government offices, hospitals, schools, and areas with high pollution.

Long-term Particulate Matter Measures (Future Plans)

- Improve the quality of fuel and engines through the adoption of Euro 5 and Euro 6 emission standards (At present Thailand has only adopted the Euro 4 emission standard).
- Encourage people to use public transportation by speeding up the transportation network projects, including BTS system, MRT system, and BRT system.
- Encourage people to use natural gas fuel, electric vehicles, or hybrid cars through the adjustment of tax systems, both for vehicle producers and consumers.
- Raise the tax rate on old vehicles that tend to release more pollutants.
- Set up city zoning to limit the number of cars that can enter each zone during morning and evening rush hours.

PM2.5 Standard Value and Environmental Laws of Thailand

The Ministry of Natural Resources and Environment Pollution Control Department has set the standard value of air quality in the general atmosphere as follows;

1.) Announcement of the National Environment Board No. 10 (BE 2538) regarding the determination of air quality standards in general issued in accordance with the National Environmental Quality Promotion and Preservation Act, BE 2551 1992, published in the Government Gazette, volume 112, episode 52 D, 25 May 1995

2.) Announcement of the National Environment Board No. 24 (BE 2547) regarding the determination of air quality standards in the atmosphere in general issued in accordance with the National Environmental Quality Promotion and Preservation act, BE 2535, published in the Government Gazette, volume 121, special episode 104, dated 22 September 2004

3.) Announcement of the National Environment Board No. 28 (2007), regarding the determination of air quality standards in general. Issued in accordance with the National Environmental Quality Promotion and Preservation act, 1992, published in the Government Gazette, volume 124, special episode 58, dated 14 May 2007

According to the announcements of the National Environment Board in regard to the three announcements mentioned above, the average standards are that the level of PM10 in a period of 24 hours must not exceed 0.12 mg / m^3 or 120 µg / m^3, and the annual average value must not exceed 0.05 mg / m^3 or 50 µg / m^3. Using the Beta Ray measurement technique, dust smaller than 2.5 microns (PM2.5) concentrated in a period of 24 hours must not exceed 0.05 mg / m^3, and the average value in one year must not exceed 0.025 mg / m^3.

Table 2: Environmental Law Related to Particulate Matter

Law	Responsible Department
Announcement of the National Environment Board No. 24 (2004) Re: Determination of the Air Quality Standard in General, issued in accordance with the Enhancement and Conservation of National Environmental Quality Act BE 2535, announced in Government Gazette, Volume 121, Special Episode 104, 22 September 2004	Pollution Control Department
National Environment Board Announcement No. 36 (2010) Re: Determination of dust standards of not more than 2.5 microns in general atmosphere Issued under the Promotion and Preservation of National Environmental Quality Act, BE 2535, published in the Government Gazette, Volume 127, Special Section 37, dated 24 March 2010	Pollution Control Department
Notification of the Ministry of Interior regarding the safety of the work relate to the environment (chemicals), relying on power under the provisions of Article 2 (7) of the Announcement of the Revolutionary Council No. 103 dated 16 March 1972	Ministry of the Interior
The Request of permission to set up factory operations under the Factory Act 1992	Department of Industrial Works

Air Quality Index: AQI

Thailand has been using an environmental measurement to monitor the situation of PM10 and PM2.5, namely the "Air Quality Index" (AQI), for the general public to easily understand the information publicized about the air pollution situation in each area and the impacts it has on health.

The Air and Noise Quality Management Bureau, Pollution Control Department originally established the air quality index that is used in Thailand. It consists of five criteria for its calculation, including one hour of average ozone gas, one hour of average nitrogen dioxide, eight hours of average carbon monoxide, 24 hours of average sulfur dioxide, and 24 hours of average particulate matter. In order to calculate the index, any the criterion with the highest value will be used as the air quality index for that day. The level of air quality in Thailand is divided into five levels, from 0 to over 300. Each level uses a color as to symbolize the level of potential impact on health. The air quality index at 100 is equivalent to the general quality standard. In the case that the air quality index exceeds 100, it indicates that the air pollution concentration has exceeded the standards that are considered safe for people's health (PCD, 2017).

Table 3: Air Quality Index of Thailand

AQI	Determination	Color used	Meaning
0-50	Good	Blue	No affecting on health
51-100	Moderate	Green	No affecting on health
101-200	Unhealthy for Sensitive Groups	Yellow	Patient with respiratory disease, children, and elderly should avoid all outdoor activities
201-300	Unhealthy	Orange	Patient with respiratory disease, children, and elderly should avoid all outdoor activities
>300	Hazardous	Red	Patient with respiratory disease, children, and elderly should avoid all outdoor activities

(Pollution Control Department, 2012)

Table 4: PSI Value: Health Impacts and Air Pollution

24-hr PSI Forecast	Healthy Persons	Elderly, Pregnant Women and Children	Persons with Chronic Lung Disease, Heart Disease
≤ 100 (Good/Moderate)	Normal activities	Normal activities	Normal activities
101-200 (Unhealthy)	Reduce prolonged or strenuous outdoor physical exertion	Minimize outdoor activity	Avoid outdoor activity
201-300 (Very Unhealthy)	Avoid prolonged or strenuous outdoor physical exertion	Minimize outdoor activity	Avoid outdoor activity
>300 (Hazardous)	Minimize outdoor activity	Avoid outdoor activity	Avoid outdoor activity

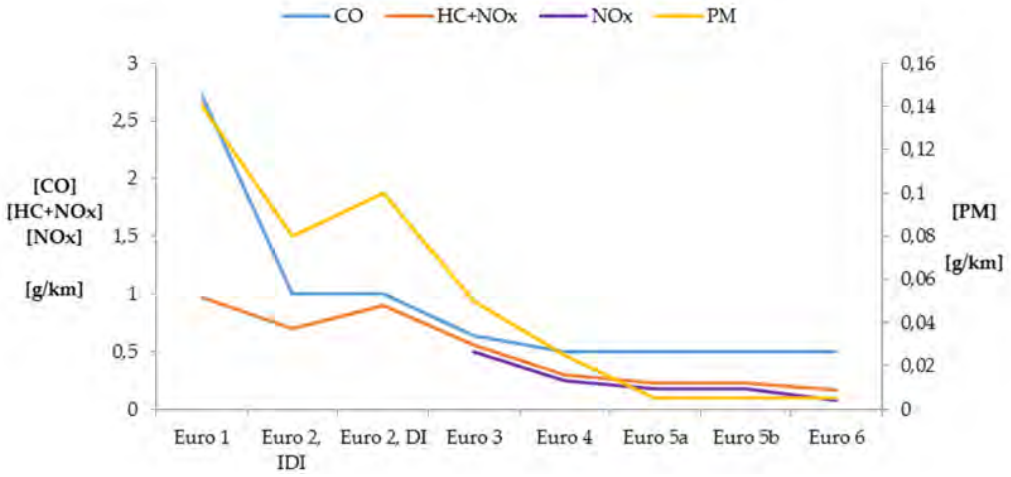
(National Evironment Agency, 2019)

Euro Emission Standards

This section focuses on the Euro standard that enforces in Thailand under the Euro Emission Standard, relating to Section 25, paragraph one of the Fuel Trade Act, BE 2543 (2000) (The Fuel Trade Act, 2000). It is the standard which aims to limit the emission of pollutant gases and particulate matters (PM10 and PM2.5) through the control of fuels and engines standard in vehicle.

In Thailand, the organization that is responsible for determining the regulations that will control the fuel quality standard is the Department of Energy Business, Ministry of Energy. Due to the adoption of Euro 4 standard for diesel and benzene fuel sold in Thailand, any fuel business or car company who produces, sells, or distributes products at a quality lower than is set by the Euro 4 emission standard will receive punishment under the Fuel Trade Act BE 2543 (2000) (DOEB, 2016).

Figure 3: The Euro emission standards for the regulated car pollutants



(Hooftman, Oliveira, Messagie, Coosemans, & Mierlo, 2016)

According to the Euro 4 emission standard, the decrease of the Brimstone ratio in diesel and benzene has led to a reduction in level of particulate matter by the rate of 4.05 micro grams per cubic meter, together with the decline in number of patients at approximately 284-810 people per year. Based on this number of patients, it is estimated that the government can save 22,680-56,700 Baht per year from supporting the public health cost (TCIJ, 2019).

However, for the government to respond with the rising of particulate matter issue while simultaneously avoiding negative backlash for policy implementation, each time an updated Euro regulation is passed such as during the update of Euro 3 to Euro 4, the policy maker must to release the announcement of future regulation first without making it legally binding for at least 5-7 years to give companies time to adjust

In present, the Thai government has still not clearly stated a plan or proposed timeframe to adopt Euro 5 emission standard Act, only a roughly prediction that the Euro 5 will be implemented by law within 2023. According to Ruenglaikram, the reason for this uncertainty may be associated with the car producer companies, especially the Japanese automobile producers. Based on the reason that Thailand is one of the popular automobile production bases that produce and export vehicle throughout the world, the update of Euro emission standard from 4 to 5 could possibly post some impacts toward automobile production industry. It is predicted that every move of the Euro emission

standard has always affects the capital investment of automobile producer in regard of the need to upgrade the production lines. With automobile production accounting for one of the biggest sources of income for the Thai economy, if Japanese automobile companies were to leave due to unsuitable business environments, this would create a severely negative impact (Ruenglaikram, 2018). As a result, this might be one of the key factors that answer the question; why the new Euro emission standards in Thailand tend to take a lot of time to be adopted and regulated in the country?

Although it seems that the Thai government has equally regulate the same Euro 4 emission standard toward every type of vehicle, 80% of heavy-duty trucks and public buses that running on the road still use Euro 3 diesel engine with 6 cylinders since 2007 (Ruenglaikram, 2018). Running on a standard that is more than 11 years old, it is not surprise that this type of vehicles is likely to be one of the biggest pollution sources that leads to the problem of particulate matter in Bangkok.

Industrial Pollution Control

In the middle of the particulate matter crisis, the industrial factory has become one of the victims to be blamed as an originating source of pollution. According to Mr. Utama Saonayon, the Minister of Industry, the Ministry has already solved the offhand problems and is looking into future solutions to prevent problems from happening again (Saonayon, 2019).

The Ministry of Industry has established a committee to prevent and solve the PM2.5 problem by formulating a plan to monitor and supervise all industrial plants, especially the factories that have more possibility of emitting these particles. If any violations are found, action will be taken immediately under the scope of the law.

The Department of Industrial Works has been ordered to measure the air quality and to be responsible for controlling large factories in terms of pollutant emissions. Moreover, the department has been assigned to measure the air pollution in areas that consist of many factories and to randomly check the high-risk factories in 12 provinces, including 20 factories in Bangkok, Nonthaburi, Pathum Thani, Samut Prakan, Samut Sakhon, Nakhon Pathom, Phra Nakhon Si Ayutthaya, Saraburi, Chonburi, Rayong,

Prachin Buri and Ratchaburi. The Department of Industrial Works has also enacted laws to enhance their power of control and force high-risk factories to install automatic, 24-hour air pollution monitoring systems (CEMS) (there are 600 factories that must comply with this law).

Furthermore, the ministry is also monitoring the level of air pollution in the Special Economic Development Zone (EEC). However, most of the factories in this zone use fuel from natural gas, which is considered to be clean energy. The fuel is combusted in systems with high temperatures, resulting in complete burning. Therefore, no increment of dust is released from the industries operating in the EEC zone. It can be said that industries in the EEC are the industries of future in terms of innovation and pollution-free production. All factories in this zone are operating under strictly enforced emission protocols,

Construction Sector

The construction sector is the group that the state considers as the main source of the pollution problem, and has announced measures to strictly force them to control the emission of particulate matter. Many construction companies have to invest more financial capital to set up mesh sheets or water sprinklers at their construction sites (Authaisaengsuk, 2019), while some have had to pause their construction process due to the recommendation by state authorities (The Mall, 2019). In the construction of the MRT and BTS Skytrain, although they did not suspend their construction process, most of the activities during the announcement of this measure were limited to non-heavy activities that would not cause the emission of particulate matter (Naewna, 2019). Therefore, after the end of the measure, the contractors have to work harder and faster in order to finish the project before the deadline.

Urban Government Workers

The Deputy Governor of Bangkok has stated that the Ministry of Public Health has identified the occupational groups that are at risk of being affected by particulate matter problems in the Bangkok metropolitan area, including street sweepers. At the

moment, according to the original Bangkok ordinance, there are about 20,000-30,000 people responsible for maintaining cleanliness and orderliness in capital area. Formerly, Bangkok had a policy for such employees to wear hygiene masks for the prevention of germs and dust, and to reduce the risk of various diseases, particularly for garbage collectors who, as they collect solid waste in the streets, houses, shelters, alleyways, and canals, are found to be the most vulnerable group. Apart from direct contact with diseases, they are also exposed to particulate matter when moving to various locations across the city. In response, there is a policy for employees to receive free hygienic masks from the Public Health Service Center of Bangkok, (Total 60 places) to wear while working in the field. However, it was later found that most of the employees do not wear the masks so Bangkok ordered the relevant authorities to encourage all staff to wear the masks (Piungam, 2018).

Why is the Government Unable to Solve the PM2.5 Crisis?

After the crisis of PM2.5 in early 2018, the Pollution Control Department created the "Project to study the PM origin and the plans for managing PM2.5 in Bangkok and metropolitan areas". It was made as a guideline for managing the PM2.5 crisis and aimed to cope with, and reduce, the problem of PM2.5, which was expected to occur again during January - March 2019 and the following years.

The purpose of this section is to answer the question "Why was the government unable to solve the PM2.5 crisis that occurred in Bangkok and the metropolitan area between December 2018 and January 2019, even though they already had plans and measures in hand?" The analysis and observation are as follows:

Neglect of the Crisis

When an incident occurs, often the following phrases are used in response: "*the situation is still not critical*" (Lertpraphan, 2019), "*although the amount of dust exceeds the safety level, it is normal for the change of season*" (Petsuwan, 2018), or "*the situation is not in crisis, the AQI is only 70-100*" (Karnchanarat, 2019). These attitudes

reflect the perception that air pollution is not a regular occurrence, but is rather consistently ignored by policymakers in many countries around the world.

Part of this neglect is due to the belief that “air pollution must be concentrated to a certain extent before it can pose some threat to health”. In the case of Thailand, “*if the PM level exceeds 100 micrograms per cubic meter for more than three consecutive days, then it will be considered as critical state*” (Damrongtai, 2019). According to the data collected during the month of January 2019, Bangkok residents were living their life under the shade of PM2.5 that exceeds the Thai safety and WHO levels for approximately 20 days, however the government still ignored the situation and did not consider it as a crisis (Bourkamsri, 2019).

Although the resolution of the meeting of the National Environment Board on 4 February 2019 established a three-step approach to follow during a PM2.5 crisis in which the average concentration of PM2.5 level for 24 hours has exceeded 50 micrograms per cubic meter (Ministry of Natural Resources and Environment, 2019), the operations are still based on the authority of "every government department", which so far has proven ineffective. In addition, according to the WHO, “*there is no evidence of a safe level of exposure or a threshold below which no adverse health effects occur*” (WHO, 2011), thus the issue must be considered as a mission of government agencies to improve by strictly implementing the air quality standards.

Non-Effective Policies, Plans, and Measures

The neglect of the crisis has resulted in a lack of opportunity to effectively cope with air pollution problems. The belief that "*the situation of PM 2.5 this year has not yet reached a critical stage and it is under the government control*" (Dumrongtai, 2019a), the announcement to the people that "*please remain clam because the situation was not as severe as in the year 2018, where the highest value touched 120 -130 micrograms / cubic meter*” (Dumrongtai, 2019c), or the comforting words from the government that “*if the situation of PM2.5 is really critical, rising 2-3 days in a row, the government will issue a warning and introduce new measures that better than the current one*” (Dumrongtai, 2019b) have led the public to question the measures

implemented, such as spraying water along the roads which was confirmed by the environmental agencies as virtually useless in the reduction of the concentration of PM2.5 (Panyametekul & Pannasawat, 2018). The most suitable solution is the reduction of emissions from the originating sources. Therefore, when the air pollution crisis takes place, the government should set up emergency response teams for each specific aspect of the problem.

Missing Gap Between Policies, Knowledge, and Practice

The government has often drafted elegant policies to manage air pollution but does not actually put them into practice.

The controversy of benefits and costs of PM2.5 prevention

On the international scale, it was found that the investment for control and prevention of particulate matter provides more benefit compared to the capital cost. In the United States, the review of the 1990 Clean Air Act Amendment, in terms of cost-effectiveness for the past 30 years (1990-2020), found that the establishment of air quality standards will have prevented the deaths of 230,000 people by the year 2020, and most of the benefits (85%) are derived from the reduction of particle levels.

In the case of Thailand, all measures under the Particulate Matter Control Strategy Project in Bangkok and the Metropolitan Area, 1997, are considered positive in terms of net present value. The value within five years is between one hundred million dollars and ten billion dollars. In other words, the benefits of reducing the rate of illness and death from particulate matter related causes are worth the costs used to reduce the particles according to the study of origin and guidelines for managing PM2.5. The government has clearly stated that investing in measures to control PM2.5 seem to be successful based on the amount of investment.

However, when considering investment promotion policies and other related policies that currently exist, the aspect of investing to control and prevent PM2.5 is completely ignored. For example, the announcement of the Ministry of Natural Resources and Environment No. 7/2558 allows an exception of EIA in all sizes of waste power plants; or the Section 44 orders that ignore the enforcement of city plans for

some certain types of businesses (ENLAW, 2016) including 1) electricity power plants, 2) non-natural gas production plants, 3) waste water treatment plants / incinerators, 4) waste separation plants, and 5) recycling factories.

The delay to adjust the PM2.5 standard in the atmosphere

In the report of the study of origin and guidelines for managing PM2.5 in Bangkok and metropolitan area, the Pollution Control Department clearly stated that legal measures to control the source of particulate matter are clearly effective methods as they are easy to implement and have continuously long-term effects. The enforcement of air quality standards with higher goals will provide greater benefits, as well as shorten the timeline of implementation.

In the meeting of the National Environment Board on 4 February 2019, the agenda was expected to adjust the average concentration of PM2.5 in a 24-hour period from 50 micrograms per cubic meter to 35 micrograms per square meter through the adjustment of the 95th percentile format. However, the National Environment Board did not adjust the PM standard with the reason that before the announcement of the future criteria, the transportation system must be completed, while the average level of particles within the next 6-7 years must not exceed the current standard level in order to prevent the particle from affecting the country in the long run (Simachaya, 2019). In other words, this means that the new standard for PM2.5 and other type of air pollutants will have to wait another 6-7 years.

The lack of a legal framework and systematic collection of PM2.5 data

Although Thailand possesses the knowledge and technology essential to obtaining PM2.5 data, the more significant issue is the right of the community to access that data (Community Right to Know).

Over the years, the public sector has driven *"the Law on Pollutant Release and Transfer Registers"* (PRTR), which is a framework for the development of pollution reporting and emission information systems (Saetang, 2016). This PRTR law is different from *"the Announcement of the Ministry of Industry regarding the preparation of reports on the type and quantity of pollutants released from the factory,*

2015"(Ministry of Industry, 2015) in terms of public participation and creation of database systems that are publicly accessible.

If the PRTR law becomes effective, it will be an important measure to help the government systematically manage the PM2.5 data, strengthen the government agencies' PM2.5 situation assessment, improve the availability of information to support environmental and health protection planning, and enhance the industrial sector's monitoring system and production process, leading to more efficiency in business operations and trade competition.

PRTR law will guarantee people's right to access to information and will promote participation in the protection and maintenance of environmental quality, accordingly to the Constitution of the Kingdom of Thailand. It is also an effective tool in reducing health risks from air pollution and PM2.5.

At the moment, there is only a pilot project for PRTR; the laws have not yet been established to enforce these regulations legally (PCD, 2009).

The Backwardness in Process of Public Participation

The recommendation regarding the PM2.5 situation as issued by the Pollution Control Department clearly states, in the topic of "*the participation of people*", that:

> "*The public's interest in air pollution is a new phenomenon. With an access to social media and information from abroad, it is a driving force for government agencies to create correct understanding and encourage people to improve air quality. Because the number of air quality monitoring stations are limited, some may not be in the area where people are interested, therefore with a cheap air pollution meter that people can buy, the government agencies should allow people to participate in air pollution monitoring by giving advice on where to buy and how to use the device.*" (Nuttripob, 2019)

Apart from the government including communication specialists and communication consultants in the Emergency Response Team, they also need an

effective communication channel that is fast and accurate to explain the current situation to the public. However, based on the previous situation, the government still fails to deliver successful communication, and this must be supplemented by public participation in terms of self-AQI-reporting and recommending protection to one another (Panyametekul & Pannasawat, 2018).

The Air Quality Index

The Air Quality Index (AQI) is the numerical value used to report daily air quality, to know how clean or dirty the air is, and how people's health might be impacted as a result. The air quality index focuses on the impact on people's health within 2-3 hours or days after inhaling the polluted air. The higher the AQI, the larger the percentage of the population that is likely to be affected in terms of health issues.

When comparing the Air Quality Index (AQI) used in Thailand to the AQI recommended by the World Health Organization (WHO), the annual AQI of PM2.5 used in Thailand is 25 micrograms per cubic meter, which is 2.5 times higher than the World Health Organization's AQI, and the average for 24 hours is 50 micrograms per cubic meter, which is two times higher than the World Health Organization's standards. As Thailand is a developing country, the AQI must be based on economic and social factors; if it were defined as equal to the World Health Organization, the state may not be able to control the amount of particles to not exceed the standard.

In Thailand, the Pollution Control Department is responsible for the environment while health matters are taken care of by the Ministry of Public Health. Therefore, as the environmental standards are set by the Pollution Control Department, the discussion of the PM2.5 index is a matter of environment more so than health. In fact, the responsibility of establishing the air quality standard should be the role of the Ministry of Public Health, as it typically issues health standards based on the World Health Organization recommendations. However, the power to issue such standards was given to the Pollution Control Department so concerns regarding social and economic growth must be considered. Therefore, these standards become "environmental standards" rather than "health standards".

In practice, the World Health Organization views health as the priority issue, but for Thailand, the state combines social and economic issues together with health. This has resulted in the AQI standard in Thailand to be higher than that of the World Health Organization, as the Thai government is afraid that they could not meet the higher standards and may need a lot of capital for investment. As a result, the air quality standards are not equal: the WHO has set the standard at the level before health is afftected whereas Thailand's standard is set at a level where health is already being affected. This has led to many people in Thailand choosing not to wear a medical mask due to the reason that the situation has not reached the level that is considered dangerous to health, as per the Thai standard. Consequently, though, not wearing the mask will cause many health effects in reality.

The PM2.5 crisis has revealed the ineffectiveness of decision-making, policy design, and internal government processes in Thailand. Therefore, the capacity of these institutions needs to be updated in order to improve effectiveness, while the public sector will continue to seek their own health security while hoping for positive change in the future.

CHAPTER 4
PM2.5 RISK EXPOSITION AND INEQUALITY OF MEASURES

This chapter presents the findings of primary data collection from the methods of non-participatory observation and in-depth interview, together with the analysis of each sample group's condition and the state measures. It should be noted that the measures discussed in this section will relate particularly to the sample groups, i.e. government street sweepers, construction workers, and motorcycle taxi drivers. All sample groups were selected from the Chatuchak, Pathumwan, and Ladprao districts and interviewed between the 1st and 31st of January 2019.

The PM2.5 Exposure Among Sample Groups

Government Street Sweepers

Since the government street sweepers work outdoors six day per week, inhaling toxic air and particulate matter is inevitable. Although the PM2.5 crisis raised the concerns of the general public, more than half of the street sweepers do not consider it as a priority issue. One of the street sweepers stated that "*Just finding money is hard enough, I have no time to concern about the dust.*" Some of them realize that heavy air pollution will cause a great impact on their health and result in long-term sickness, but they continue working, as they have no other choice. The factor of income is far more immediate than the issue of dust and health.

During the haze situation at the beginning of 2019, eight of the street sweepers from this sample were sick. The major symptoms of sickness were nosebleeds, coughing, eye irritation, and sore throat. Most of them believe that PM2.5 is one of the main factors that made them sick. While the presence of PM2.5 increased their awareness about health risks, the majority of the government street sweepers believed that all types of dust are the same. "*We don't know how each type of dust is different, no one has told us.*" Only two of them could differentiate between PM2.5 and other common air pollutants. They do not have a deep understanding of the characteristics

and impacts of this specific type of particle. The government provided the N95 masks for their safety, but did not adequately inform them about the dangers of PM2.5.

However, as the N95 mask is thicker than the normal mask, when the street sweepers wore it, they felt that it was difficult to breath while they are working and almost all of them decided to use a scarf or normal mask instead. Most of them mentioned that wearing the N95 mask all the time could cause them faint. In fact, the street sweepers do not really recognize the differences between the N95 mask and the normal mask, only that the N95 mask is more expensive and very hard to find in the market. "*Actually, we want to wear a mask when we work, but when we wear it, we felt very tired.*" Even though the department that they work for has provided a free mask for them, after receiving the recommendation that they should wear the mask the whole time that they are working, most of them decided not to collect the mask from their department office and instead still use the normal mask or scarf, which they believe is enough for protection. However, after receiving some information on the impacts of PM2.5, some of them expressed that the government should have provided more information about PM2.5 through their chief and that the mask provided for them should specifically suit with their job, such as a mask designed for long term outdoor activity.

Construction Workers

Construction work is paid on a day-by-day basis; skipping one day will result in the lack of income for that day. According to the labor law, the minimum income per day in the Bangkok area is 325 baht (Ministry of Labour, 2018), while in reality the average daily income is around 400-450 baht. During the haze situation, before the government ordered the construction activity in the capital area to stop, concern about particulate matter among construction workers was not a priority. Most construction workers do not wear a mask for protection as the team leaders or companies do not distribute it to them. Moreover, it is too expensive for the workers to buy their own masks, as the price of one mask could be the same as a meal. One group of workers expressed, "*We are not rich as the other, the cost of mask can support our lives for a day.*"

However, after the implementation of the state order to stop all construction activity, life for construction workers was more difficult. Without any income for almost a week, living in the capital area became a challenge for the workers. The cost of living is extremely expensive compared to their income base. Each day, during mealtime, all workers gathered together and shared their food. This food sharing method helped them to cut huge costs for their meals. Their accommodations were randomly provided, with some receiving a room inside a container or some living in a tent. Of course, none of these accommodations offer air conditioning facilities or air purifiers, thus throughout the night when they were sleeping, it was impossible to avoid exposure to particulate matter. Some nights it was very hard to sleep, as the weather was very hazy, making it difficult to breathe.

> "*During the day we have no work, during the night we cannot sleep, all of this is because of stupid dust.*"

Although some of the construction workers heard the news about the haze, it is very difficult for them to understand the data that is presented. Some technical terms and English words are too hard for them to understand. Most of the data that they receive is via smart phone, as the nature of their occupation is usually to move from place to place, buying a television or radio is considered a burden. However, not all of the workers have a smart phone, only some do. Therefore, sometimes the warnings and recommendations did not reach every worker equally. To be more specific, Facebook is the main channel through which the workers received the information, but to fully understand such information the data receiver needs to be literate. Out of the entire number of workers, only few have the ability to read.

In the middle of the construction break, the workers admitted that they have heard the state's announcement to distribute the masks, but for them to travel to receive the mask was written off as "*nonsense*", as the cost of transportation is much too high compared to their income.

Motorcycle Taxi Drivers

Motorcycle taxi driver is the type of occupation that will normally encounter with the particles released from vehicle exhaust. However, during the PM2.5 crisis, they could perceive that the concentration of particles was more intense. When they were driving, visibility was significantly decreased compared to the days on which the sky was clear. Thus, sometimes the motorcycle taxi drivers had to turn down customers for safety reasons. In addition, during the haze period the number of customers decreased to half of the normal amount. The reason for the lack of customers was that during this time people preferred to use taxi cars or the public bus with air conditioning instead.

> "*We know that the dust is dangerous, but we have no choice, this is the job that we only have.*"

Normally all motorcycle taxi drivers wear a mask for dust protection, but the N95 masks are not very popular among this group. It was observed that almost none of them use the N95 mask. There are two reasons that can explain why they did not use this type of mask. The first reason is that it is expensive and they do not want to replace the mask every two days. The second reason is that the N95 mask is not suitable for driving, as the masks do not provide sufficient air circulation making it very difficult to breath. In fact, the product warning recommends that the mask be worn for only 30 minutes at a time; if it is worn for more than half an hour the user could suffocate from a lack of Oxygen. A lack of Oxygen while driving could potentially lead to an accident for the motorcycle taxi driver and their customer. In response, some of the drivers mentioned, "*we know that wearing a mask is good, but the safety of the customer must come first.*"

It is not surprising that motorcycle taxi drivers typically receive data, information, and warnings regarding the issue of particulate matter from their smart phones, as they normally use their phones to communicate with their clients. While they did hear about the short-term measure that the state would distribute the masks, most chose not to go get it due to the mask's characteristics. What they need from the state is a mask that includes a ventilation fan, which would allow them to breath more easily;

but the mask that the state provided did not include this feature. In addition, they do not know where to buy the N95 mask with a ventilation fan and of course this type of mask would still need the filters replaced frequently, which means they would have to spend more money.

Respiratory complications, such as coughing and sneezing, were more popular among the motorcycle taxi driver group, together with the symptom of eye irritation. Sometimes, some motorcycle taxi drivers had to skip their place in the queue to take a break in order to rest and cope with the health issues that had occurred as a result from the particulate matter.

Table 5: Comparison of Data Collection from Sample Groups

	Government street sweepers	Construction workers	Motorcycle taxi drivers
Number of Samples	10 people	10 people	10 people
Approximate number of real populations	10,000 people	150,000 – 200,000 people	100,000 people
Average age	35 years old	36 years old	32 years old
Area of Working	Chatuchak/Pathumwan	Chatuchak/Ladprao	Chatuchak
Working hours/week	54 hours/week	48 hours/week	30 hours/week
Average income/month	12,000 baht/month	11,000 baht/month	14,000 baht/month
Rate of N95 mask user	40%	0%	50%
Accessibility to PM data: Internet/television	60%	20%	80%
Accommodation	100%-No Air condition/Air purifier	100%-No Air condition/Air purifier	90%-No Air condition/Air purifier
PM2.5 Health Impacts	- Respiratory disease - Eye irritation - Nose bleed - Chronic cough	- Respiratory disease - Eye irritation - Nose bleed - Chronic cough	- Respiratory disease - Eye irritation - Nose bleed - Chronic cough

(Between 1st-31st January 2019) / (Total 10 samples = 100%)

Factors of Inequality in Risk Exposition

The factors resulting in the inequality of exposure to the risks related to particulate matter based on the data received from the sample groups can be divided into five categories including the state measure, the cost of protection, the ability to receive and access effective medical care, the ability to understand and access sources of information and warnings, and the conditions of accommodation.

The State Measures

Although the state has distributed N95 masks in highly accessible public areas in Bangkok, the area of distribution and the number of masks stand as major barriers that prevent the sample groups from accessing the safety measure that they should receive. According to the state's announcement, there were only seven areas in which the state decided to distribute the masks: Suan Lum District, Chatuchak, Bang Kho Laem, Bang Khun Tian, Thonburi, Bangkapi, and Ratchaprasong. Therefore, any citizen who wants to receive a free mask has to travel to one of these seven areas. Comparing the price of the mask to the cost of transportation, it is not worth traveling to receive the mask. Furthermore, the total combined number of masks provided only accounts for 100,000 pieces, which is absolutely not enough to fill the demand. According to the news, the masks that were distributed by the state ran out of stock within the first ten minutes of the distribution (Ippoodom, 2019).

Cost of Protection

During the haze situation, there were two main types of protection: the N95 mask and the air purifier machine. The N95 mask costs approximately 40 Baht in Thailand and the main company selling this type of mask is 3M (Investerest.co, 2019). Based on the characteristics of the mask, it can protect the user from PM2.5 particles, however the lifetime of the mask is only two days and the user can only wear the for 30 minutes at a time, otherwise it will lead to a lack of oxygen. While the air purifier machines appear to be a reasonable investment as they can be used several times, the price of the machine is much too expensive for the sample groups to afford. Additionally, the air purifier machine also requires the filters to be changed every week.

As a result, the sample groups chose the only forms of protection that were viable with their rates of income: normal medical masks that cannot protect from PM2.5, or using N95 masks continuously for more than two days.

Comparison of the price of air pollution prevention equipment

- Price of medical mask is 10-20 baht per piece (cannot prevent PM2.5 dust)
- Price of N95 masks is 30-35 baht per piece (recommended to change every two days)
- Price of air purifier machine is 3,000 baht per unit or more
- Price of PM2.5 detector 2,000 - 10,000 baht per unit

The Ability to Receive and Access to Effective Medical Care

Although in Thailand there is a universal health care program that aims to subsidize medical costs for the public, the chronic respiratory diseases that are caused by exposure to particulate matter are not yet covered by this program. According to the regulations of the universal health care program, the coverage does not include chronic diseases (NHSO, 2013). As most of the diseases that result from the impacts of particulate matter are chronic diseases, such as chronic cough and asthma, those who contract these types of diseases have to be responsible for their own medical costs.

The Ability to Understand and Access to Source of Information and Warning

Most of the data that has been announced by the state via television, radio, and Internet is too complicated to be understood by the selected sample groups. Many times, the sample groups received the information about particulate matter, but they did not understand as it is either written in English (the sample groups do not speak English) or uses scientific terms that they are not familiar with. Moreover, almost half of the informants do not have access to all of the sources of information, as they may not own a television or smart phone. With this in mind it can be understood why their knowledge regarding the impact of particulate matter is extremely limited.

The Condition of Accommodation

The majority of the sample group's accommodations were in buildings that do not have air conditioning or air purifiers, as these facilities add significant costs. In fact, these places were designed with ventilation features, especially the bedrooms, to decrease the temperature during the night (the average temperature in Bangkok is relatively hot compared to that of a suburban area, approximately 30-35 °C). Therefore, during the night all of the sample groups were exposed to similar levels of PM2.5 as they were during the day. In addition, at night the concentration of particulate matter tends increase as the lower temperature forces the particles closer to the ground. In other words, living in non-air conditioned accommodation results in a higher exposure to particulate matter compared to accommodation with air conditioning.

Politics of PM2.5

When the haze of PM2.5 is covering the city of Bangkok, people become very keen to protect their health. One thing that is illuminated by this situation is the disparity between qualities of life, in terms of economic and social conditions, also notable in the cost of protection. In just one month the daily life of people in Bangkok had changed; people bought N95 masks that can filter PM2.5, portable PM2.5 air quality monitors, and air purifiers for indoor use after they were notified that the particles could also impact the indoor area. These are temporary solutions for people to protect their health and their families, but they are not sustainable solutions.

Over the period of five years since 2014, the solution that the government under Prayuth Chan-O-Cha has decided to implement seems to focus on the tale end of the problem. This is completely different from the promise of "reform" that was promised by the government at the beginning of the coup. At that time, the reform of civil servants and the issue of inequality were prioritized by the government (Aukkarasomcheep, 2019). However, the problems of "low quality" work by Thai government officials still continues, together with the expansion of the gap between rich and poor. Furthermore, the general public still receives poor social services. According to the CS Global Wealth Report over the past two years under the military government, Thailand ranked No. 1 with the highest inequality in the world (Credit Suisse, 2018); the top 1% of the

wealthiest Thai people across the country holds a combined total of up to 58% of the whole country's property. The issue of poor government services and unequal wealth distribution plays a major role in many sectors, even in the case of PM2.5. The PM problem is complex and clearly cannot be solved overnight, as various political, economic, and social factors are considered to be at the base of the issue.

Is air pollution really affecting people at all levels equally?

PM2.5 is known as the dust that can generate negative impacts on our health and the air quality measurement stations can help people to receive updates. However, the increase in public awareness also influences people to seek more protection. Although the sample groups are not a primary contributor to pollution compared to those who drive private cars or own an industrial factory, they have to deal with air pollution directly in various aspects, including their work outdoors, their accommodation characteristics, and their low-income. Moreover, it is necessary to have a smartphone and Internet connection to check the air quality hour by hour in the place where they live; without these technologies it is not surprising why most of them are not concerned about their health.

Even though air pollution threatens everyone's life and the protection measures are to wear a mask or use an air purifier, for some groups of people these solutions are not accessible due to their financial limitations and the lack of supply in the physical market. Therefore, in order to obtain the mask, it is often necessary to go through online channels that require a smartphone and/or Internet connection. In other words, access to resources and services is limited for certain groups of people. Base on the theory of risk society, the poor groups are more vulnerable to risks, while the rich are able to push many risks as far away as possible. The lack of income and education has become the main problem that leads to the inequality of risk distribution, as safety and freedom from risk require money to access. Moreover, the rich can profit from the risks they produce, as some can produce and sell technologies that help prevent such risks from occurring or help to cope with their adverse effects. In addition, apart from social and economic inequality, spatial inequality has played a major role in the context of the particulate matter crisis in Bangkok, particularly in the aspect of the unequal amount of

social services provide by the state, including medical and welfare. Some types of social groups have a greater range of available resources and services, while some are not able to access even their basic needs. Without equally distributed development, it is nearly impossible to break this loop. Space is further divided within different locations based on the clustering of various groups of people who share similar socioeconomic statuses.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

Summary of Findings

The implementation of particulate matter related measures in 2019 impacted not only particulate matter itself, but also vulnerable groups including (1) Government street sweepers, (2) construction workers, and (3) motorcycle taxi drivers.

Based on the study, it can be concluded that the originating sources of the particulate matter are mainly resulting from human activities including traffic congestion, fossil fuel burning, and various type of construction. Most of the measures implemented by the state were short-term solutions that focused on reducing activities in the industrial and construction sectors and distributing PM2.5 protection equipment, rather than focusing on long-term solutions to prioritize improvement of the quality of engines and fuels in accordance with the updated Euro standards. Although the N95 masks and air purifiers have been recommended and distributed by the state, not every group people can access to those products equally. All of the sample groups have contracted chronic coughs and respiratory diseases as a result from their exposure to PM2.5 due to their lack of suitable social, economic, and spatial status; these groups simultaneously were faced with the problem of income reduction due to the state's order to stop construction activities and the reduction in the number of customers during haze situation. The factors that directly impacted risk inequality were the state measures, cost of protection, accommodation conditions, and the ability to access effective medical care and sources of information. Finally, from assessing the impact of measures that were enforced by the state in preventing and reducing the amount of PM2.5 on the sample groups, the study found that the state measures should focus more on vulnerable groups in terms of improving access to protection and data sources, as well as providing compensation for health expenditures and income reduction during the crisis.

The promotion of rapid economic development and inefficiency of government administration has led to the issue of PM2.5 in Bangkok. Both aspects have influenced changes in the environment, society, economy, and behavior of people. These changes

also forced some people into social vulnerability through factors such as limited ability to receive crucial information, limited access to resources and state services, lack of education, and the problem of poverty. In other words, this was the path that led to the "risk society"; a concept that assumes that social risks will occur in late modern societies. Moreover, the economic status of the of the vulnerable group, along with their living areas and social conditions, have further contributed to their inevitable exposure of most of the risks, especially those generated by the ineffective measures implemented by the non-democratic government.

Effective Public Transport, The Solution of Risk Inequality

In Thailand, items that indicate social status, such as cars, are promoted by the government with the motivation to support the automobile industry. Together with unclear traffic and urban planning, buses and public transportation become the forms of transportation for low-income groups, especially with the characteristics of low quality and inconvenience. Moreover, the expansion of the mass transit train system has increased the price of accommodation along the train route. These issues have together contributed to inequality in transportation and the air pollution problem, which is a result of millions of private cars. Again, people who receive most of the impact are those with lower income, who do not drive their own cars and are responsible for very few emissions of particles.

While the best way to reduce the problem of particulate matter is to decrease the number of vehicles running on the road, this solution seems to be impossible to achieve during this time due to the value Thai people place on private cars and their belief that the public transportation is not supportive enough (ARCADIS, 2017). Therefore, the way to mitigate the situation of air pollution from vehicles is to improve the fuel and engine quality standards, not only for small vehicles but also heavy-duty vehicles. However, the more sustainable solutions are to improve the standard of buses and public transport networks, develop a mass transit system that suits more groups of people, encourage people to use public transportation, and turn public transportation into the primary preferred method of transportation.

A truly livable city is a city that is equally conducive to all types of people. A basic right in life is to have clean air to breathe, and people should not have to pay for it. Urban development that considers the health of people as the first priority, regardless of their income, is considered as sustainable development. Otherwise, we will continue to observe social status from the type of protective mask that people wear.

Measure Recommendations

Environmental solutions must consider three main elements, including: 1. Mechanisms that control behavior (forced or motivated), 2. The level of pollution control, and 3. The control variables such as price, quantity, technology, and sources of pollution. Some recommendations are as follows:

- Raise awareness of the dangers of PM2.5 and the ways people can protect themselves and their families.
- Increase the number of air quality monitoring points, link the data with the applications to deliver real-time information, and increase public participation in monitoring the level of PM2.5.
- Control the price and lower the tax on PM2.5 protection products (e.g. N95 mask and air purifier).
- Increase the area of N95 mask distribution or deliver it via postal service.
- Create a health service program that specifically covers the health related impacts of PM2.5, including chronic diseases.
- Support research that aims to assess the impact of particulate matter on health.
- Adjust the Air Quality Standards to cohere with the standards of the World Health Organization.
- Strictly detect and control black smoke and engine modifications in all types of vehicles through an annual vehicle inspection program.
- Improve the standard of public transportation and lower the price to encourage more people to utilize it.
- Solve traffic congestion by strictly enforcing the traffic plans and city zoning.
- Collect environmental and health taxes from private car users.

- Raise oil and exhaust standards from Euro 4 to Euro 5, or Euro 6, in both small and large vehicles.
- Promote and prepare for the use of EV trains by supporting the necessary infrastructure and reducing the rate of EV vehicle taxation.

Research Prospect

Although this thesis has addressed the situation of the vulnerable groups living in Bangkok, it was conducted with only three selected vulnerable groups: the government street sweepers, the construction workers, and the motorcycle taxi drivers. There are many other vulnerable groups who are also living in Bangkok that should also be afforded the opportunity to express their opinions, situations, and needs. In fact, Bangkok is not the only city in Thailand that annually faces issues with particulate matter; there are many other cities that are currently encountering similar problems. Deeper understanding of particulate matter and the impacts of related measures will definitely be useful for the improvement in the quality of life for all people, not just those of the vulnerable groups.

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