CHANGES IN $PM_{2.5}$ LEVELS AFTER COVID-19 OUTBREAK IN MALAYSIA

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SCHOOL OF CIVIL ENGINEERING
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by

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Pandemik COVID-19 disebabkan oleh coronavirus yang sangat menular, yang mendorong tindakan kawalan global seperti pengasingan sosial dan penguncian. Dengan mengurangkan aktiviti manusia, usaha pengurusan COVID-19 telah mendorong peningkatan kualiti udara di peringkat tempatan dan global dalam masa terdekat. Kami menyiasat kesan Perintah Kawalan Pergerakan (PKP) terhadap kualiti udara di 10 stesen, iaitu Alor Setar, Seberang Perai, Cheras, Petaling Jaya, Bandaraya Melaka, Pasir Gudang, Kuala Terengganu, Tanah Merah, Kota Kinabalu, dan Kuching. Kawasan yang dipilih adalah zon bandar dan perindustrian di Malaysia. Tujuan kajian adalah untuk membandingkan tahap kepekatan $PM_{2.5}$ di kawasan bandar dan perindustrian sebelum dan semasa Perintah Kawalan Pergerakan (PKP) dan untuk mengenal pasti perubahan trend harian $PM_{2.5}$ berdasarkan fasa PKP yang berbeza. Selain itu, ia juga untuk mengkaji hubungan tahap kepekatan $PM_{2.5}$ sebelum PKP dan semasa PKP dengan fasa sekatan yang berbeza. Data dikumpulkan dari Jabatan Alam Sekitar (JAS). Dari hasil kajian, didapati bahawa kebanyakan stesen mengalami penurunan tahap $PM_{2.5}$. Untuk kawasan Utara, tahap $PM_{2.5}$ tertinggi adalah semasa MCO pada 164.642 $\mu g/m^3$. Untuk kawasan Pantai Timur dan Barat, kepekatan $PM_{2.5}$ tertinggi adalah semasa fasa PRA PKP yang masing-masing mencatatkan 107,307 $\mu g/m^3$ dan 113,108 $\mu g/m^3$. Sementara untuk Kawasan Malaysia Selatan dan Timur, kepekatan tertinggi adalah pada PKPB masing-masing pada 121.986 $\mu g/m^3$ dan 155.132 $\mu g/m^3$. Perbezaan trend tahap $PM_{2.5}$ antara setiap kawasan mungkin disebabkan oleh terdapat banyak jenis industri berhampiran lokasi stesen. Industri tertentu mungkin ditutup kerana SOP, sementara yang lain mungkin tetap terbuka kerana dikenalpasti sebagai perkhidmatan perlu.

ABSTRACT

The COVID-19 pandemic was caused by a highly infectious coronavirus, which prompted global control measures such as social isolation and lockdowns. By reducing human activity, COVID-19 management efforts have led in enhanced air quality locally and globally in the near term. We investigated the impact of Movement Control Order (MCO) towards the air quality in 10 stations, which is Alor Setar, Seberang Perai, Cheras, Petaling Jaya, Bandaraya Melaka, Pasir Gudang, Kuala Terengganu, Tanah Merah, Kota Kinabalu, and Kuching. The areas chosen are the urban and industrial zones in Malaysia. The aim of the study is to compare level of $PM_{2.5}$ concentrations at urban and industrial areas before and during Movement Control Order (MCO) and to identify changes of $PM_{2.5}$ daily trend based on different MCO phase. Additionally , it is also to investigate the relationship of $PM_{2.5}$ concentration level before MCO and during MCO with different restriction phase. The data is collected from the Department of Environment (DOE). From the research, it is found that most of the stations experienced reduction in $PM_{2.5}$ levels. For North Region, the highest $PM_{2.5}$ level is during MCO at 164.642 $\mu g/m^3$. For East and West Coast regions, the highest concentration of $PM_{2.5}$ are during the PRE MCO phase which recorded at 107.307 $\mu g/m^3$ and 113.108 $\mu g/m^3$ respectively. Meanwhile for South and East Malaysia Region, the highest concentration are during CMCO at 121.986 $\mu g/m^3$ and 155.132 $\mu g/m^3$ respectively. The discrepancy in $PM_{2.5}$ level trends between each regions may be caused by the existence of numerous industries near the stations' locations. Certain industries may be closed due to government regulations, while others may remain open due to recognized as essential services.

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LIST OF ABBREVIATIONS

API	Air Pollution Index
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CMCO	Conditional Movement Control Order
DOE	Department of Environment
H_2O	Water
HC	Hydrocarbon
MAAQS	Malaysia Ambient Air Quality Standard
MCO	Movement Control Order
NO_2	Nitrogen Dioxide
NO_x	Nitrogen oxide
O_3	Ozone
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter (particles with aerodynamic diameter less than 2.5µm)
PM_{10}	Particulate Matter (particles with aerodynamic diameter less than 10µm)
PRE MCO	Prior to Movement Control Order
RMCO	Recovery Movement Control Order
SO_2	Sulphur Dioxide
SPSS	Statistical Packages for Social Science
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background Study

Air pollution has been a polemic that is acknowledged by the society for millennia. Currently, it is dubbed as one of the greatest hazards to humankind and political stability, alongside with global warming (Jacobson, 2009). Air pollution is a mixture of different components such as toxic gases, organic compounds and Particulate Matter. Exposure to air pollution is linked to a wide range of diseases and poor health (Lim et al., 2012) which includes retardation of neurodevelopment (Sunyer et al., 2015), behavioural, emotional, and respiratory issues (Forns et al., 2016).

Recent studies shows that one of the major contributors to air pollution in urban zones is none other than traffic (Samet, 2008). The combustion of a hydrocarbon fuel with air produces mainly carbon dioxide (CO_2) and water (H_2O). However, internal combustion engines are not perfectly efficient, so some of the fuel is not burned, which results in the presence of hydrocarbons (HC), other organic compounds, carbon monoxide (CO), particles containing carbon and other contaminants in the exhaust. In addition, at high temperatures and pressures found in the combustion chamber, the fuel and some of the nitrogen in the air is oxidised, forming mainly nitric oxide (NO) with a small amount of nitrogen dioxide (NO_2).

1.2 Air Pollutants

Air Pollutants are airborne particles, which can be either in solids, liquid, or gases form that exist in amount that is high enough to pose a threat to the health of people. This includes ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particulate (TSP), particulate matter less than 2.5 microns ($PM_{2.5}$) and 10 microns (PM_{10}) and lead (Pb). Primary particles are dispersed directly as particles while secondary particles are formed in the air through chemical reactions of gaseous pollutants. Secondary particles are mostly found in fine PM. The composition and size of the Particulate Matter (PM) depends on the location of the PM itself. In urban areas however, the major source of PM is traffic vehicular emissions (Schauer et al., 1996; Querol et al., 2001).

1.3 Problem Statement

The first case of COVID-19 were detected in Wuhan City, China on 31st December 2019 (*WHO* , 2020). Since then, it has quickly spread worldwide and were declared as a global pandemic by World Health Organisation (WHO). As of February 2021, there are over 100 million confirmed cases and over 2.3 million deaths caused by the disease (*WHO*, 2021).

Coronaviruses are large RNA viruses that generally infects a wide range of animals, which includes humans. The viruses were first identified in 1966 by Tyrell and Bynoe, who had cultivated the viruses from patients with colds (Tyrrell & Bynoe, 1966). SARS-CoV-2 had thought to be a successful transmission from animals to humans, although it is unclear which animal were behind this.

In Malaysia, thing has took a turn for the worse when the first case of the disease were first identified on 25th January 2020, becoming the first case in Southeast Asia. As an effort to curb the spread of the disease, Malaysia Government has decided to declare a nationwide cordon sanitaire namely movement control order (MCO) on 18th March 2020. At the completion of Phase I MCO (March 31, 2020), there were

2766 confirmed COVID-19 cases, and at the end of Phase II, there were 4987 cases (April 14, 2020) (Ministry of Health Malaysia, 2020). Several activities, including conducting business, are prohibited under MCO, with the exception of essential services (Malaysian National Security Council (NSC), 2020). This unexpected restricted movement caused a huge drop in traffic and reduction in human activities (*Malay Mail*, 2020). This decline in social interaction may have an impact on the air pollution levels (Abdullah et al., 2020).

Air pollution reductions have a significant and immediate impact on health. In particular, respiratory and irritant symptoms, cardiovascular illnesses, and all-cause mortality were dramatically decreased after a few weeks. Air quality improvements resulted in considerable health benefits and contributed to preventable health risks (Schraufnagel et al., 2019)

According to data from other countries, the effects of lockdown and other social distancing techniques DOEs have an effect on pollution (Singh et al., 2020;Seo et al., 2020). In South Korea, A reduction in air pollution levels was also recorded, when social distance, a somewhat milder regulation than a COVID-19 lockdown was implemented. Reduced traffic-related emissions and reductions in transboundary pollutants from neighbouring nations reduced $PM_{2.5}$, PM10, and NO2 concentrations by 45 percent, 36 percent, and 20 percent, respectively (Seo et al., 2020). In china, air quality in relation to subway density in Beijing and discovered a 7.7 percent drop in Beijing's air quality index (AQI) in regions near new subway lines, due to decreased car commuting when the COVID-19 outbreak in China caused greatly reduced transport and economic activity from November 2019 to February 2020 (Nichol et al., 2020). Thus, in this study we will investigate the impact of the implementation of MCO towards the $PM_{2.5}$ concentration in Malaysia.

1.4 Objectives

The objectives of this study are:

- To compare level of $PM_{2.5}$ concentrations at urban and industrial areas before and during Movement Control Order (MCO)
- To identify changes of $PM_{2.5}$ daily trend based on different MCO phase
- To investigate the relationship of $PM_{2.5}$ concentration level before MCO and during MCO with different restriction phase

1.5 Scope of Work

Analyzing of the $PM_{2.5}$ of the chosen stations in Malaysia. All of the stations are either located in urban or industrial areas. The period of observation is throughout MCO period of 2020 which is from 1st of March 2020 until 30th of June 2020 to see the impact of the pandemic on the air pollution at the selected areas. The raw data is obtained through requesting from Department of Environment (DOE). The $PM_{2.5}$ concentration then were analyzed using SPSS software.

1.6 Dissertation Outline

Chapter 1 (INTRODUCTION): it begins with a research background of air pollution, then moves on to the issue statement, aims, scope of this study, and finally the chapter layout of this study.

Chapter 2 (LITERATURE REVIEW): Air pollution and $PM_{2.5}$ are fully examined in this part in accordance with the study topic. More information about the research issue, such as the characteristics and sources of air pollution, is being gathered for use as a reference in this study.

Theoretical aspects of research methodology will be addressed in Chapter 3 (METHODOLOGY). To collect data for this study, a variety of techniques were employed.

Chapter 4 (RESULTS AND DISCUSSION): This section will provide the results of data collection and analysis. The consistency of the results will be assessed and discussed, as well as appropriate literature reviews. For ease of comprehension, the results were provided in the form of a table, figure, and graph.

The conclusion of the analysis will be carried out in Chapter 5 (CONCLUSION AND RECOMMENDATION). Finally, some comments and ideas for future investigations are offered in light of the findings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This literature review is an analysis of multiple existing work of knowledge in the areas relevant to this research; based on journals, articles, and other educational sources.

2.2 Air Pollutants in Malaysia

Air pollution is contamination of the either indoor or outdoor environment by natural or anthropogenic pollutants. Anthropogenic pollutants mean any pollution that is from human activities. This includes the burning of fossil fuels, deforestation, mining, sewage, et cetera.

The emissions generated are dispersed into atmosphere and then concentrated on the localized area, which is a result of different contributing meteorological factors such as wind direction. Air pollution has become a serious environmental issue in the ASEAN nations, especially in Malaysia. Malaysia has ranked as the 55th worst country among 180 nations worldwide in terms of air quality (EPI, 2020) with the major sources of air pollutants includes open biomass burning, vehicular emissions and industries (Afroz et al., 2003; Hyer et al., 2013; Alias et al., 2014; Khan et al., 2016a).

2.3 Air Pollutant Index

The measurement of ambient air quality in Malaysia is done using the Air Pollutant Index (API). Instead of using actual concentrations of air pollutants, the API is established in easily understandable ranges of values as a manner of reporting air quality. This score also shows its impact on human health, ranging from positive to negative, and can be classified according to the National Haze Action Plan's action requirements. The Malaysian API system closely resembles the United States Environmental Protection Agency's (US-EPA) Pollutant Standard Index (PSI)1 (*Department of Environment,2020*). API is classified according to a scale that varies from country to country according on its level of danger. The scale used in Malaysia is as follows:

API	Status
0-50	Good
51-100	Moderate
101-200	Unhealthy
201-300	Very Unhealthy
≥301	Hazardous

Figure 2.1 Air Pollution Index Flow Chart

2.4 Criteria of Air Pollutants

The Department of Environment has published the Malaysia Ambient Air Quality Standard (MAAQS) for a total of seven substances: ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), total suspended particulate (TSP), particulate matter less than 2.5 microns ($PM_{2.5}$) and 10 microns (PM_{10}) and lead (Pb). These compounds are known as criteria air pollutants. The presence of these pollutants in ambient air is caused by multiple sources of emissions. The average time listed in the guideline is varies from 1 hour to 24 hour for different type of air pollutants which represents the period of time over which measurement is monitored and reported for the assessment.

The Recommended Malaysian Air Quality Guidelines (RMAQG) established by the Department of Environment (DOE) were used to configure the concentration of pollutants in contaminated air in this research. The guidelines for the concentration of air pollutants in Malaysia are shown in Table 2.1.

Table 2.1 Recommended Malaysia Ambient Air Quality Guidelines

Pollutant and Method	Averaging Time	Malaysia Guidelines	
		(ppm)	(uμg/m^3)
Ozone	1 hour	0.10	200
	8 hour	0.06	120
Carbon Monoxide	1 hour	30	35
	8 hour	9	10
Nitrogen Dioxide	1 hour	0.17	320
Sulfur Dioxide	10 minute	0.19	500
	1 hour	0.13	350
	24 hour	0.04	105
Particles TSP	24 hour		260
	1 year		90
PM_{10}	24 hour		150
	1 year		50
Lead	3 Month		1.5

2.4.1 Carbon Monoxide

Carbon monoxide is a colourless, odourless, and non-irritating but extremely dangerous gas. Vehicular exhaust is a major source of carbon monoxide for it is a by-product of incomplete combustion of hydrocarbon (Prockop & Chichkova, 2007). Carbon monoxide survives in the atmosphere for a period of approximately one month but is eventually oxidised to CO_2 (The Environmental Yellow Pages 2010).

2.4.2 Sulfur Dioxide

The main sources of sulfur dioxide emissions are from combustion of fossil fuel and volcanic activity. Sulfur dioxide is dangerous to human as it irritates the skin and mucous linings of the eyes, nose, throat, and lungs. Exposure to high level of SO_2 can cause inflammation of the respiratory system. The symptoms include pain when taking a deep breath, coughing, irritated throat, and breathing problems. This gas is highly reactive with other chemicals in the air and able to change to other small particles that can breathe into the lungs and cause similar health effects (Stieb et al., 2011).

2.4.3 Nitrogen Dioxide

Nitrogen dioxide is typically produced through the combustion of fuel. This gas is produced as a result of the emissions of vehicles such as cars and trucks, as well as buildings such as power plants. This gas is toxic to humans because it irritates the respiratory system and causes undesirable health effects such as coughing or difficulty breathing (Faustini et al., 2014).

Not only is it harmful to humans and animals, but it also has a negative impact on the ecosystem. Acid rain is formed when NO2 and other NOx groups combine with the water and oxygen in the atmosphere. This eventually has a detrimental effect on ecosystems such as forests and lakes (Grennfelt et al., 2020).

2.4.4 Ozone

Ozone is extremely vital in our atmosphere since it shields all living species on Earth's surface from damaging solar UVB and UVC radiation. However, because of its impact on humans and the environment, ozone at ground level is a hazardous air pollutant. (Staehelin et al., 2001). According to current research, prolong exposure to ozone can weaken the lung functions (Gryparis et al., 2004).

2.4.5 Particulate Matter

Particulate matter (PM) is a term that refers to a collection of various solid or liquid particles suspended in air that are frequently seen in accumulation (Pope and Dockery, 2005). These particles are often invisible to the naked eye on their own (Zereini & Wiseman., 2010). $PM_{2.5}$ is the most reliable and consistent predictor of health effects in research of long-term air pollution exposure (Health Effects Institute 2018). In fact, several studies conducted in Europe have found that short and long-term exposure to $PM_{2.5}$ is linked to a variety of health concerns, including lung cancer. 9 The findings of these research served as the foundation for the International Agency for Research on Cancer (IARC) to categorise PM as carcinogenic to humans (O et al., 2015)

PM is classified in a variety of ways. To begin, they are composed of primary and secondary particles, depending on the nature of their formation. Primary particles are spread directly as particles, whereas secondary particles are formed in the atmosphere by the collision of precursor gases. It is natural for particles to undergo continuous transformation, as secondary material can emerge on the surface of existing particles (Guevara, 2016).

These suspended particles formed in various sizes, composition and origin. The particles are classified by their aerodynamic properties because: (WHO, 1987) they govern the transport and removal of particles from the air; (Friedlander & Lippman., 1994) they also govern their deposition within the respiratory system; and (Clark,1992) they are associated with the chemical composition and sources of particles.

These properties are conveniently summarized by the aerodynamic diameter, which is the size of a unit-density sphere with the same aerodynamic characteristics.

Fine particulate matter (fine PM) is defined as particles with a diameter ranging between 0.1 and 2.5 m and is referred to as $PM_{2.5}$ when combined with the ultra-fine mode. In the fine mode, primary combustion particles and secondary combustion particles that have formed through coagulation and condensation make up the bulk of the combustion. Because of their ability to penetrate into the alveolar gas exchange region of the lungs, $PM_{2.5}$ is sometimes referred to as respirable particles or respirable particles. This mode contains particles with a diameter more than 2.5 m (it is worth mentioning that studies assessing the toxicology of coarse PM often specify a fraction of PM10–2.5 or, on rare instances, PM15–2.5). They are available in sizes ranging from 0.1 to 100 microns, with larger particles being too heavy to persist in the atmosphere for an extended amount of time.

Particulate matter (PM) in this category includes the most visible or obvious kinds, such as black smoke, dirt, dust from highways and construction sites, large salt particles from sea spray, mechanically generated particles, and some secondary particles, among others. Pollen, mould, spores, and other plant components are all classified as coarse particles as well. While larger particles account for only a small proportion of total particle count, they account for the vast majority of total particle mass.

Generally speaking, PM10 refers to any ambient PM (i.e. ultra-fine, fine, and coarse particles) having a diameter smaller than 10 microns (m). As a result of their ability to penetrate the nose and throat's initial line of defence and deposit along the airways in the thorax, these particles are sometimes referred to as "thoracic" particles.

The size distributions of numerous types of particulate contaminants are depicted in Figure 2.2.

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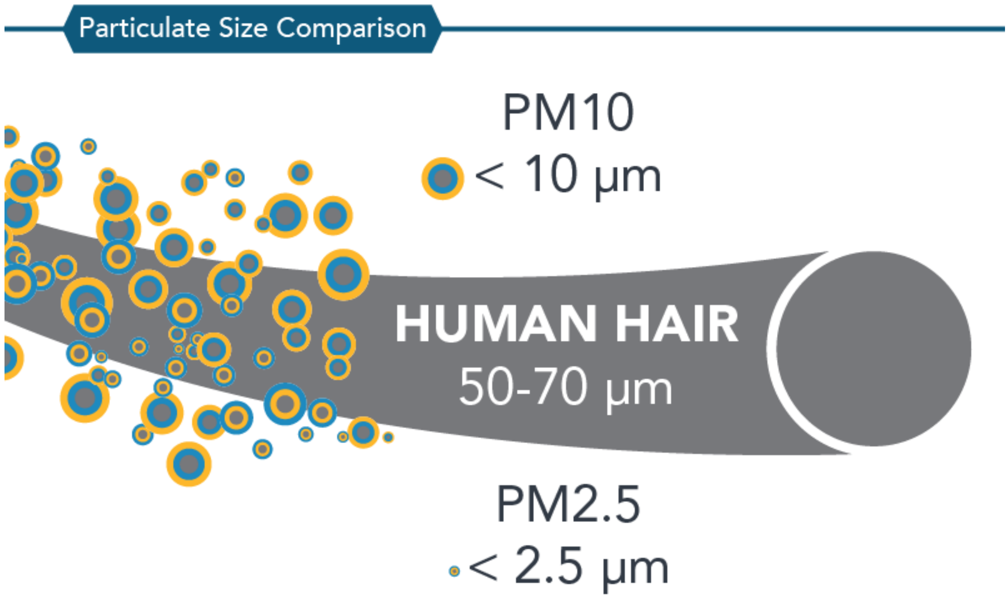

Figure 2.2 The Comparison between PM_{10} And $PM_{2.5}$ To Human Hair.

PM is a very common air pollutant. Indicators describing PM that are relevant to health refer to the mass concentration of particles with a diameter of less than 10µm (PM_{10}) and of particles with a diameter of less than 2.5 µm ($PM_{2.5}$). Since PM is a mixture with physical and chemical characteristics varying by location, the components that made up this pollutant changes depending on the source of emission. Common chemical constituents of PM include sulfates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal material; particle bound water, metals (including cadmium, copper, nickel, vanadium and zinc) and polycyclic aromatic hydrocarbons

(PAH). It is also not uncommon to spot biological components such as allergens and microbial compounds in PM. (WHO., 2013).

2.5 Meteorological Parameters

Meteorological parameters are one of the important factors to influence the urban air quality (Dey et al., 2017; Zhang et al., 2018; Manju et al., 2018). The greater the distance from the pollution source, the greater the effect of meteorological conditions (Zhou and Levy, 2007). They also are extremely important in the transport and dispersion of pollution in the atmosphere.

2.5.1 Temperature and Relative Humidity

Humidity is the concentration of water vapour in the atmosphere. This means that humidity affects the quality of the air humans breathe in. Relative humidity influences the particle movement and it can cause PM settlement on the ground. Therefore, with increase of relative humidity of an area, the concentration of air pollutants become lower (Giri et al., 2008). However, the absence of rainfall during winter in seasonal nations may cause water vapors in the air facilitates ventilation effects of $PM_{2.5}$ (Kayes et al., 2019).

2.5.2 Wind Speed and direction

The direction of the wind has an impact on air pollution. If the wind is coming from an industrial area towards an urban location, pollution levels in the town or city are likely to be higher than if the wind is blowing from another direction, such as open farmland. Meanwhile, increased wind speed was found to contribute significantly to a reduction in PM_{10} and $PM_{2.5}$ concentrations in the air (Radzka, 2006)

2.6 Legal Requirements

In Malaysia, there are standards regarding air pollutions that must be abide. Malaysian standards regarding the Ambient Air Quality stemmed from the legislative requirement of Malaysia Ambient Air Quality Standard, MAAQG.

The chemical parameters are:

- $PM_{2.5}$
- PM_{10}
- Sulfur Dioxide, SO2
- Nitrogen Dioxide, NO_2
- Ground Level Ozone
- Carbon Monoxide, CO

In addition, three physical parameters are:

- Temperature
- Relative Humidity
- Wind Direction

2.7 Sources of Particulate matter

A paramount portion of PM sources can be traced from a variety of human (anthropogenic) activity. PM comes in different forms and chemical combinations, which fully depends on the surrounding areas. Some are comes straight from a source, for an example, construction sites, unpaved and unmarked roads, dry fields, or open fires.(Afroz et al., 2003)

Most particles found in the atmosphere is a result of complex reactions of chemicals pollutants such as sulfur dioxide and nitrogen oxides, which are generated from power plants, industries and vehicles. (Guevara, 2016)

2.7.1 Traffic

Vehicular particle emissions are the result of a great many processes, for an example combustion products from fuel and oil, the wearing of products from brake linings, tyres, bearings, car body and road material, and the resuspension of road and soil dust (Laschober et al., 2004).

The combustion of a fossil fuel with air produces primarily carbon dioxide and water vapour, according to theory. In practise, however, combustion engines are inefficiently built, resulting in some of the fuel not being properly burned, resulting in the existence of hydrocarbons (HC), other organic compounds, and carbon monoxide (CO). Furthermore, given the high temperatures and pressures occurring in the combustion chamber, the fuel and some of the nitrogen in the air are oxidised, resulting primarily in nitric oxide (NO) and a minor amount of nitrogen dioxide (NO_2).

Traffic is an effective pool of both fine and coarse mode primary particles, organic gases, and a major source of nitrogen oxides, which then form secondary nitrate aerosols. Particles of carbonaceous material are formed mainly by diesel vehicles, such as trucks and unmaintained petrol vehicles, like old cars (Vardoulakis et al., 2003).

2.7.2 Stationary Sources

The most significant stationary air pollutants sources comprises of industrial facilities such as municipal power plants, waste incineration, and factories. The variety of characteristics of the particles produced from these sources depends on the combustion process itself, and the type of fuel used during the process (solid, liquid, or gas).the combustion processes and properties of particulate matter emitted from these sources have been comprehensively reviewed (Morawska and Zhang , 2002).

2.7.2(a) Industries

Air pollution is an inevitable byproduct of the modern industrial economy that cannot be entirely eliminated, although it may be reduced with stringent measures. Production in industries results in environmental degradation due to emissions of significant quantities of particulates and gaseous pollutants. With the introduction of Industry 4.0 on the way, heavy polluting industries will be the primary source of pollution as well as the key actors in assuming environmental responsibility (Lin et al., 2021).

2.7.2(b) Open Burning and Forest Fires

Burning banned materials is damaging to the environment because they emit poisonous compounds that contaminate our air. Polluted air may be breathed by humans and animals and deposited in the soil, surface water, and on plants. CO is the most prevalent air pollutant formed by forest fires and is a direct threat to human health. These destructive flames, as well as the ensuing air pollution, harmed the health of tens of millions of people (Borrego et al., 1999)

2.7.2(c) Power Generation

Energy consumption and generation play a significant role in both direct and indirect causes of air pollution, and linkages between the two have been demonstrated across a wide variety of disciplines (Hu & Guo, 2020). As coal-fired power plants are the largest source of air pollution in the power industry, it is critical to acknowledge their contribution to air pollution as coal is the largest contributor to the human-made increase of carbon dioxide in Earth's atmosphere (Sahu et al., 2021).

The interaction between coal and air during burning creates carbon oxides, notably CO_2, an important greenhouse gas, SO2, and different nitrogen oxides (NOx). Because of the hydrogenous and nitrogenous components of coal, carbon and sulphur hydrides and nitrides are also generated during coal burning in air (Sahu et al., 2021)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter entails the detailed explanation of the methodology used to conduct and complete the research project. In order to achieve the objectives of this study, a flowchart is created for a more organized process. Figure 3.1 shows the flowchart of the methodology.

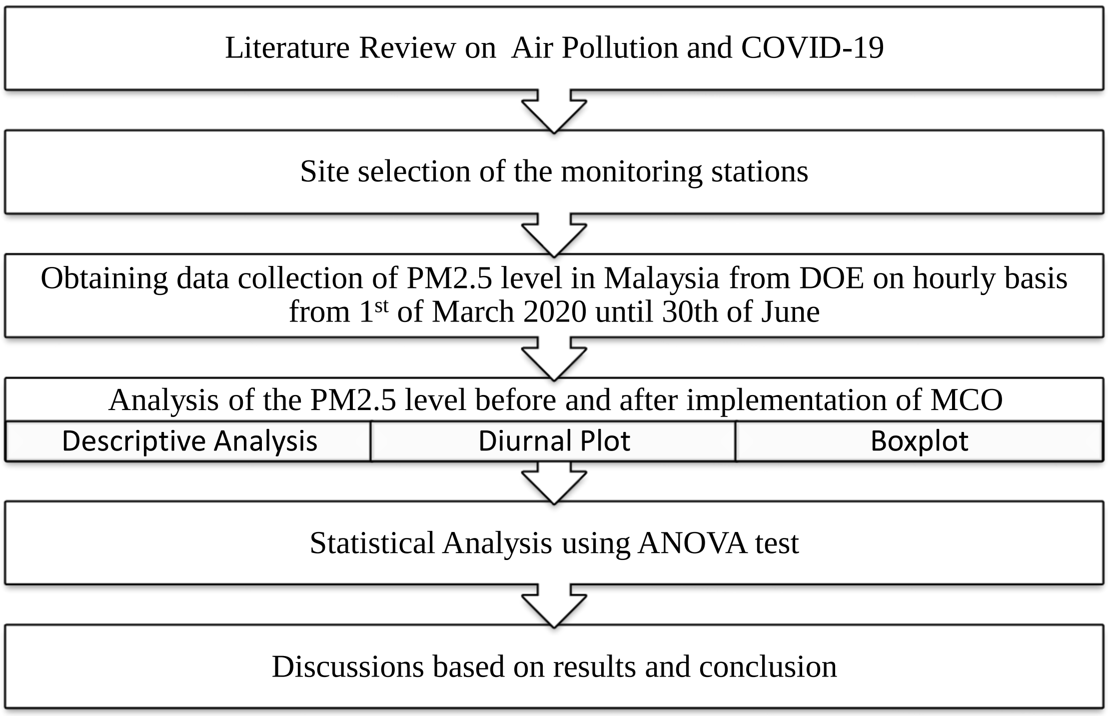

Figure 3.1 Flowchart of the Methodology

3.2 Study Area

The Department of Environment (DOE) uses a network of 51 stations to monitor the country's ambient air quality. These monitoring stations are deliberately placed in residential, commercial, and industrial locations to identify any major change in air quality that may be hazardous to human health and the environment. Automatic monitoring is intended to collect/measure data constantly (24 hours a day) during the monitoring period.

The selected air monitoring stations are picked depending on the station's location. Each station is located in either an urban or industrial region. The reason for this is because the increment in air pollution caused by the pandemic will be more visible in urban regions because these are the locations that were worst impacted during the COVID-19 outbreak, whilst changes in rural areas are assumed too minor to be included in the research.

The chosen Air Monitoring Stations are as follows:

Table 3.1 Chosen Air Monitoring Stations

Station	Region	State	Location	Type
S1	North	Kedah	Alor Setar	Urban
S2		Pulau Pinang	Seberang Perai	Industrial
S3	West Coast	W.P. Kuala Lumpur	Cheras	Urban
S4		Selangor	Petaling Jaya	Industrial
S5	South	Melaka	Bandaraya Melaka	Urban
S6		Johor	Pasir Gudang	Industrial
S7	East coast	Terengganu	Kuala Terengganu	Urban
S8		Kelantan	Tanah Merah	Industrial
S9	East Malaysia	Sabah	Kota Kinabalu	Urban
S10		Sarawak	Kucing	Industrial

Figure 3.2 Location of the Chosen Sites

3.3 Measurement Method

In this research project, the $PM_{2.5}$ data were obtained from the Department of Environment (DOE), Malaysia

3.4 Period of Observation

The data for this study is evaluated from the first of March 2020 to the 30th of June 2020. These date periods were chosen because they range from the PRE-MCO phase to the RMCO phase. Additionally, DOE can only provide $PM_{2.5}$ levels during the time period specified above. From the Table 3.2, it shows the phase in the period of observation and the regulations enforced by the government in each phase differs. The difference in regulations reflect the amount of air pollution emitted, which can be computed using SPSS software.

Table 3.2 The Phases during the COVID-19 Outbreak and the Regulations

Phase	Date	Description
PRE-MCO	1st of March – 17th of March	• No restrictions on movement were implemented to the public
MCO	18th of March – 3rd of May	• Restrictions on movement nationwide • Gatherings for any purposes were prohibited • All educational institutions nationwide were required to close. • travelling together are allowed in pairs only
CMCO	4th of May – 9th of June	• One is allowed to travel for work purposes • Funeral attendance with a limit of 20 people is allowed • Private vehicles is allowed to carry up to four persons in the same household
RMCO	10th of June- 30th of June	• Travel from one place to any other place within Malaysia for work purposes is allowed. • House visits and gatherings are also allowed for public holidays. • Travel by air to and from Peninsular Malaysia, and Sabah and Sarawak are allowed for work and supply of essential services • Congregations at places of worship are allowed

3.5 Data Analysis

In data analysis, several method was used to achieve the objectives of this study. The data is analysed using SPSS software. The primary goal of data analysis is to discover relevance in data so that the resulting knowledge may be utilised to make educated decisions.

3.5.1 Descriptive Statistics

Descriptive statistics try to describe the relationship between variables in a sample or population. They provide simple summaries about the sample and the measures. (Satake., 2015). Descriptive Statistics are used to present quantitative descriptions in a form that is easier to digest. Most of the statistics encountered in daily life, in newspapers and magazines, and in television, are descriptive in nature (Salkind., 2010). In this research, the descriptive analysis were used to determine the maximum, minimum, mean, median, standard deviation, skewness and kurtosis. The average or mean (X) is defined as the following:

$$X = \sum Xi/n \quad (3.1)$$

where X_i is an individual observation and n is the number of observations.

The standard deviation (s) is a statistic that indicates the degree of variance among the observations in a sample. The greater the standard deviation, the more variety there is in the observed data. The lower the standard deviation, the less variance there is in the data. The standard deviation of the observed values is calculated as follows:

$$s = \sqrt{\frac{x_i - \bar{x}^2}{n-1}} \quad (3.2)$$

The skewness and kurtosis of a distribution are two measures that describe the form of the distribution. The skewness of a distribution is a measure of the symmetry of the distribution. Skewness will be equivalent to zero in a symmetrical dataset, and vice versa. As a result, the skewness of a normal distribution is equal to zero. Skewness is a measure of the magnitude difference between the two tails, and it is essentially a quantitative measure of it (Groeneveld & Meeden, 1984).

In probability theory, kurtosis is a variable that reflects the sum of the two tails. It expresses the probability of occurrence in the tails. The value is commonly compared to the kurtosis of a normal distribution, which is equal to three in this case. If the kurtosis value is more than 3, the dataset has a more noticeable tail than a normal distribution, as opposed to a normal distribution (Groeneveld & Meeden, 1984).

3.5.2 Box plot

Box plot has become the industry standard for displaying the 5-number summary, which includes the minimum and maximum range values, upper and lower quartiles, and the median. This set of numbers is a simple approach to summarise a dataset's distribution. Furthermore, the 5-number summary's condensed format allows for a simpler comparison of datasets, as only five distinctive values must be examined. (Potter, 2006).

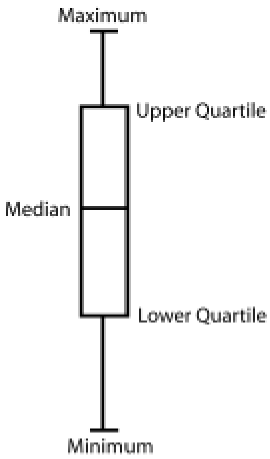

Figure 3.3 Anatomy of a Box Plot

The box plot's typical construction, as illustrated in Figure 3.3, divides a data distribution into quartiles, or four equal-sized subsets. A box is used to represent the upper and lower quartiles; the interior of the box represents the innerquartile range, which is the area between the upper and lower quartiles and accounts for 50% of the distribution. To eliminate extreme outliers, lines or occasionally referred to as whiskers are extended to the distribution's extrema, either the dataset's minimum and maximum values, or to a multiple of the innerquartile range, such as 1.5. Frequently,