EFFECTS ON AIR POLLUTION STATUS AT INDUSTRIAL AREAS IN PENINSULAR MALAYSIA BEFORE AND DURING THE PANDEMIC

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by

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"In every success there is bound to be failure". That is the word that is often expressed by successful people and I wholeheartedly agree with those words. This is due to the many shortcomings that I have encountered when preparing for this research, but those failures cannot be resolved by me without the assistance of those around me.

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This project report titled Effects of Air Pollution Status at Industrial Areas in Peninsular Malaysia Before and During the Pandemic was prepared and submitted by Rashida Binti Mohammad (Matrix Number: 171130620) and has been found satisfactory in terms of scope, quality and presentation as partial fulfillment of the requirement for the Bachelor of Engineering (Hons) (Environmental Engineering) in Universiti Malaysia Perlis (UniMAP).

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KESAN TERHADAP STATUS PENCEMARAN UDARA DI KAWASAN PERINDUSTRIAN DI SEMENANJUNG MALAYSIA SEBELUM DAN SELAMA PANDEMIK

ABSTRAK

Wabak pandemik Covid-19 adalah disebabkan oleh coronavirus yang sangat menular, mendorong pemerintah di seluruh dunia, termasuk Malaysia, untuk mengambil langkah-langkah kawalan seperti pengasingan sosial dan penguncian. Sebagai taktik kawalan penyebaran virus, Malaysia telah melaksanakan Perintah Kawalan Pergerakan (PKP) pada 18 Mac 2020, yang membatasi semua pergerakan dan aktiviti luar harian. Untuk menilai pengaruh PKP, bahan pencemar udara seperti PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, dan CO dianalisis di empat kawasan perindustrian utama di Semenanjung Malaysia sebelum dan selepas wabak tersebut. Perisian SPSS juga digunakan untuk menganalisis sifat kepekatan pencemaran udara di semua lokasi. Menurut penyelidikan ini, analisis deskriptif semua data untuk setiap lokasi selama tiga tahun telah menghasilkan pelbagai bentuk plot kotak yang berlainan. Kecuali untuk NO_2 di Pengerang dan Tanah Merah, semua lokasi menunjukkan peratusan pengurangan untuk semua parameter semasa pandemik pada tahun 2020. Semasa wabak, terdapat juga peningkatan kualiti udara yang ditunjukkan di empat stesen pemantauan udara di kawasan perindustrian Semenanjung Malaysia dengan mencatatkan frekuensi tertinggi dalam kategori baik semasa pandemik, yang memberi kesan yang baik terhadap kesihatan manusia dan alam sekitar. Kajian masa depan harus mengkaji hubungan antara pencemaran udara dan keadaan meteorologi.

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ABSTRACT

The Covid-19 pandemic was caused by a highly contagious coronavirus, prompting governments around the world, including Malaysia, to take control measures such as social isolation and lockdowns. As a pandemic containment tactic, Malaysia implemented a Movement Control Order (MCO) on March 18, 2020, which limited all movement and daily outside activities. To evaluate the influence of MCO, air pollutants such as PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, and CO were analyzed in four major Malaysian industrial areas in Peninsular Malaysia before and after the pandemic. SPSS is also used to analyze the characteristics of air pollutant concentrations at all locations. According the research, the descriptive analysis of all data for each location over three years created a variety of box and whisker plot shapes. Except for NO_2 at Pengerang and Tanah Merah, all locations indicate a reduction percentage for all parameters during the pandemic in 2020. During the pandemic, there was also some improvement in air quality shown at four air monitoring stations in the industrial areas of Peninsular Malaysia by recorded highest frequency within good category during the pandemic, which has a good impact on human health and the environment. Future studies should investigate the association between air pollution and meteorological conditions.

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LIST OF SYMBOLS, ABBREVIATIONS, OR NOMENCLATURE

API	Air Pollutant Index
CAQMs	Continuous Air Quality Monitoring stations
CO	Carbon monoxide
COVID-19	Coronavirus disease
DOE	Department of Environment
GLO	Ground-level ozone
MAAQG	Malaysian Ambient Air Quality Guidelines
MCO	Movement Control Order
NO_2	Nitrogen dioxide
O_3	Ozone
$PM_{2.5}$	Particulate matter of size less than 2.5 μm
PM_{10}	Particulate matter of size less than 10 μm
SARSCoV	Severe Acute respiratory syndrome coronavirus
SO_2	Sulfur dioxide

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Air pollution can be described as when the air is contaminated with natural and anthropogenic pollutants associated with human activities, including residue pollution from consumption and industrial activities. Rapid economic growth in Malaysia has led to pollution in many sectors, such as the rise in air pollution from industrial activities (Chik, Rahim, Radam, & Shamsuddin, 2013). According to United Nations Environment Programme, (2015), Malaysia Industries that have the potential to have an effect on air quality include power plants, industrial fuel combustion, industrial production processes (electronics, rubber & palm oil processing, smelting, petroleum production & refining).The consequences of air pollution from this industrial sector can have a detrimental effect as harmful gases, dust, smoke enter the environment and make it impossible for living things to live as the air becomes polluted. Problems related to air pollution in these industrial areas also will impact the quality of air pollutant index (API) readings in Malaysia.

At the end of December 2019, one world was shaken by an outbreak of unexplained pneumonia marked by fever, dry cough, and exhaustion, and occasional gastrointestinal symptoms arising in a seafood wholesale wet market in Wuhan City, Hubei Province, China (Wu, Chen, & Chan, 2020). On March 11, 2020, the World Health Organization (WHO) declared the coronavirus pandemic 2019 (COVID-19) outbreak as pandemic (Nadzir et al., 2020). At the end of January 2020, the virus was confirmed to have reached Malaysia and reported the highest number of total COVID-19 infections in Southeast Asia at the end of March 2020. In an attempt to stem the spread of the disease, The Malaysian government announced the implementation of the Movement Control Order (MCO) with the goal of isolating the source of the COVID-19 pandemic for two weeks beginning on March 18, 2020 which was then extended until June 9, 2020 (Shah et al., 2020). During MCO, several activities, including operating business are not allowed, except for essential services (Malaysian National Security Council (NSC), 2020). As a result of the lockdown, a significant reduction in air pollution has been noticed in several countries (Kanniah, Kamarul Zaman, Kaskaoutis, & Latif, 2020). Recent research and media reports indicate that Covid-19 control not only slows the spread of the virus, but also brings about improvements in air quality at both local and short term (Seo et al., 2020). Dramatic change in global air quality has occurred and has been recorded by several studies that showed improved air quality around the globe, including China, India, Spain, Brazil and Malaysia (Habibi, Awal, Fares, & Ghahremannejad, 2020).

The improvements in air quality since pandemic due to Covid-19 control such as Movement Control Order (MCO) have provided an opportunity to evaluate air quality status before and during pandemic due to air pollutant reductions. The purpose of this research is mainly to determine the effects on air pollution status at industrial areas in Peninsular Malaysia before and during the pandemic by using secondary data. This research is focused on industrial areas in Peninsular Malaysia that involved a set of four air quality monitoring stations out of six stations in Malaysia that were strategically placed in fast-growing industrial areas resulting in a high level of air pollution in Peninsular Malaysia. This research is using daily Air Pollution Index (API) data and air pollutants concentrations data obtained from Department of Environment Malaysia (DOE) from 1 March 2018 - June 2018, 1 March 2019 - June 2019 and 1 March 2020 - June 2020. The descriptive statistics will be carried out to determine the shape, dispersion and the distributions of the data for six pollutant parameters such as particulate matter of size less than 10 µm (PM_{10}), particular matter of size less than 2.5 µm ($PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) by using SPSS software.

1.2 Problem Statement

In many countries in the Southeast Asia region, air pollution has been an ongoing problem and Malaysia is one of the worst affected. For the past decades, the major sources of air pollution in Malaysia are power plants (85 %), motor vehicles (10 %), industrial activity (3 %) and other sources (2 %) (Sentian, Herman, Yih, & Hian Wui, 2019). In industrial activity, factories result in the emission of pollutants, including carbon monoxide, ozone, nitrogen dioxide, sulphur dioxide, lead and particulate matter. This industrial activity led to a change of the Air Pollutant Index (API) trend because the quality of air can be affected by air pollution. Air pollution in these industrial areas is due to the emission of hazardous fumes emitted by factories and industries where inefficient or less enforcement filtration, mining operations, agricultural activities, and indoor air pollution. Air pollution can affect nature and human health. For human health, air pollution can cause respiratory health problems when directly inhaled by toxic agents and skin damage from the direct incidence of ultraviolet light rays on the skin due to the decreasing ozone layer. For nature, it can cause global warming, acid rain, climate change, smog effect and extinction of animal species. Thus, uncontrolled industrial activity can cause a big impact on air pollution at the same time affecting humans and nature. During the pandemic, Malaysia and foreign media claimed an immediate improvement in air quality as a result of the lockdown. Movement Control Orders (MCOs) are a preventive measure used by several countries, including Malaysia, to reduce the dangerous spread of this disease (Kanniah et al., 2020). The Air Pollutant Index (API) reported by the Department of Environment (DOE) stated that the air quality in Malaysia is currently better compared to before the MCO (Nadzir et al., 2020). However, data on the effects of Pandemic Covid-19 to the air pollution status are still sparse. As such, the goal of this research is to study the effects of air pollution status at industrial areas in Peninsular Malaysia before and during the pandemic.

1.3 Objective

The major goal of this research is to determine the effects on air pollution status at industrial areas in Peninsular Malaysia before and during the pandemic. In-depth, the specific objective of this research are:

i. To determine the characteristics of air pollutants concentration data at industrial areas in Peninsular Malaysia from 1 March 2018 – 30 June 2018, 1 March 2019 - June 2019 and 1 March 2020 - June 2020.
ii. To compare the air quality status before and during the pandemic at industrial areas in Peninsular Malaysia by using daily Air Pollutant Index (API) and air pollutants concentration data.
iii. To determine the effects on air pollution status at industrial areas in Peninsular Malaysia before and during pandemic by using Air Pollutant Index (API) from Department of Environment Malaysia (DOE).

1.4 Scope of Research

The main scope of research is focused on the industrial areas in Peninsular Malaysia in order to determine the effects on air pollution status before and during pandemics. This research is using daily Air Pollutant Index (API) data and air pollutants concentrations data obtained from the Department of Environment Malaysia (DOE). The secondary data will be used from 1 March 2018 – 30 June 2018, 1 March 2019 - June 2019 and 1 March 2020 - June 2020. The research involved a set of four air quality monitoring stations out of six stations in Malaysia that strategically placed in fast-growing industrial areas resulting in a high level of air pollution in Peninsular Malaysia. The four air quality monitoring stations are located at Tanah Merah (Kelantan), Petaling Jaya (Selangor), Paka (Terengganu) and Pengerang (Johor). The characteristics of air pollutants concentration such as particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) also included.

1.5 Significant of Project

In Malaysia, industrial activities are one of the contributors to air pollution. Air pollution may have a significant effect both on human and nature. During the pandemic, Malaysia has implemented 'Movement Control Order' (MCO) as a preventive measure to reduce the number of pandemic cases which at the same time have improved the air quality status. Thus, this research is very important to study the effects of air pollution status before and during a pandemic at industrial areas in Peninsular Malaysia. From this research, the status of air pollution before and during the pandemics Covid-19 will be evaluated. This research may provide useful information for other researchers and also provide some ideas for the next researcher. Since the research on this topic is still sparse in Malaysia, it also will provide baseline study for the reduction of the main air pollutants emitted by industrial activity during pandemic phenomena. The findings of this research also will redound benefit of society, considering that can provide information to the public about the impact of pandemics on air quality status in industrial areas.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Air Pollutant Index (API) describes measurements of ambient air quality in Malaysia. Rather than using the actual concentration of air pollutants, the API can be easily viewed as a method of tracking air quality. This Index level also reflects its impact on human health, ranging from good to harmful, and can be graded using the Action Criteria outlined in the National Haze Action Plan. However, over the pandemic, air quality has shown a deteriorating increase. As a result, several researchers started to perform studies comparing air quality before and during a pandemic all around the world.

A plethora of findings from numerous studies provides information about air quality across the world. However, not much research has been conducted throughout all Malaysian regions. As a result, studies on air quality in each of these three major sectors such as fuel combustion from motor vehicle, industrial facilities, heat and power generation must be increased, especially in industrial areas since the studies on that sector is still less in order to obtain more reliable and accurate information about air quality in our country.

2.2 Pandemic Covid-19

In December 2019, individuals in Wuhan, the capital of the province of Hubei and a major transport hub in China, began presenting serious pneumonia of unknown cause to local hospitals (Singhal, 2020). A high number of early cases share a connection to the Huanan Seafood Wholesale Market in Jianghan District, Wuhan, Hubei, China, which sells exotic foods other than seafood such as snakes, marmots, bats, and birds. On December 31, 2019, China notified the World Health Organization of the outbreak and the Huanan Seafood Market was closed on January 1, 2020. Acute respiratory infection in humans has been caused by the nCoV present on the market in animals. On January 7, the virus was described as a coronavirus with more than 95 % homology to the bat coronavirus and more than 70 % similarity to Severe Acute respiratory syndrome coronavirus (SARSCoV) (Singhal, 2020). The first studies discovered that cought, fever, and myalgia were the most common symptoms in the early stages of the disease (Arregocés et al., 2020). SARS-CoV2 transmission can easily occur through respiratory droplets and through direct and indirect contact with the mucous membranes of the eyes, nose and mouth (Shah et al., 2020). Singhal (2020) in his article agreed that the virus can remain viable on the surface for days under favorable atmospheric conditions but is killed in less than a minute by common disinfectants such as sodium hypochlorite, hydrogen peroxide, etc. Figure 2.1 shows the image of virus that causes a pandemic disease named Covid-19.

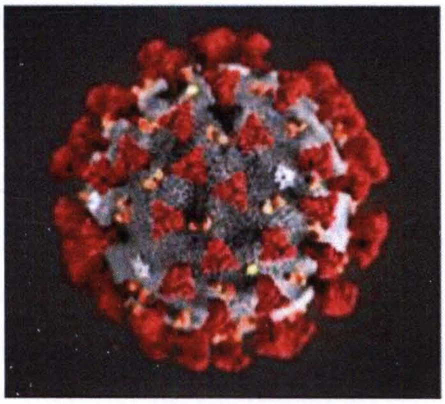


Figure 2.1: The image of SARS-CoV2 which caused the Covid-19 (Shah et al., 2020)

The World Health Organization (WHO) declared the outbreak of Covid-19 a pandemic on March 11, 2020 (Nadzir et al., 2020). It is supported by (Shah et al., 2020) stated that the world is currently facing a devastating infectious disease called Covid-19, which is caused by a coronavirus. The disease Covid-19 later affected many countries in Asia, Europe, Africa and the United States (mainly the United States) and became a pandemic (Kanniah et al., 2020). This claim can be supported by similar research done by Shah et al. (2020) when the threat of Covid-19 start raised its head in Malaysia after the neighboring Singapore reported its first imported Covid-19 case from Wuhan, China, on January 23, 2020, which was also the first positive case in the Republic. Researchers from the International Journal of Infectious Diseases Study explained that the situation in Malaysia is getting worse as a result of a religious meeting in the Seri Petaling Mosque. The authorities have therefore confirmed that one of the action plans is recognized as the Movement Control Order (MCO) in Malaysia to stop the spread of Covid-19 (Abdullah et al., 2020).

2.2.1 Movement Control Order (MCO)

According to Tang (2020), in response to the Covid-19 pandemic, the Malaysian federal government implemented the 2020 Malaysian Government Movement Control Order (MCO) to control the spread of viruses. The Malaysian government has established various levels of Movement Regulate Order (MCO), ranging from high-risk to low-risk locations, to effectively control the present Covid-19 situation which are Movement Control Order; Recovery MCO, Conditional MCO, Enhanced MCO; and Targeted Enhanced MCO. The first phase of MCO is from the 18th of March until the 30th of April 2020 which is a statewide lockdown. According to the research, the MCO comprises a comprehensive prohibition on movement and social gathering throughout the country, including religious, athletic, social, and cultural activities (Sarifin & Yusoff, 2020). Phase 2 was introduced through a special announcement by the Prime Minister on March 25, 2020, with the extended MCO phase 2 beginning on April 1st and ending on April 14th, 2020. The government has announced that permits for commercial premises and individual movement will be limited to a distance of no more than 10 kilometres (km) from the residence. Following an order from the Malaysian Ministry of Health, the Prime

Minister announced on April 10th, 2020, the extension of the MCO for another two weeks, from April 15th to April 28th, 2020, with school sessions postponed until the crisis is resolved. The MCO was succeeded by the Conditional Movement Control Order (CMCO), a partial lockdown that began on May 1, 2020 and ended on June 9, 2020. Essential areas of the economy were allowed to reopen during this time, although social gatherings were still outlawed. From 10 June 2020 to 31 December 2020, the CMCO has announced Recovery Movement Controlling Order (RMCO). During this phase, most economic sectors were permitted to be opened including commercial events subject to stringent conformity with state standards (SOPs), and interstate travel was permitted (Tang, 2020).

2.3 Air Pollution

In Southeast Asia, Malaysia has been listed as the third-highest country for pollution emissions after Indonesia and Thailand (Sentian et al., 2019). In Malaysia, economic growth has caused pollution in many sectors, for instance, there is increasing air pollution from industrial activities and motor vehicles (Chik et al., 2013). Air pollution can be further classified into two categories which are primary and secondary pollutants. The primary pollution is emitted directly into the air while secondary pollutants are the by-products of chemical reactions that occur in the atmosphere between the pollutants and other tiny particles (Mohd Zizi et al., 2018). The main atmospheric pollutant parameters are sulphur dioxide, (SO_2), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and particulate matter (PM). In Malaysia, air pollution has mainly been caused by plants (85 %), motor vehicles (10 %), industrial activity (3 %) and other sources (2 %) for the past decades (Sentian et al., 2019). Furthermore, in an observation-based study by Ghahremanloo, Lops, Choi, and Mousavinezhad (2020), have shown that the rapid development of urbanization and industrialization where the continuous expansion of suburban areas close to industrial plants in some areas has led to increasing air pollution problems. The researcher also stated that air pollution not only adversely affects human health but can also negatively impact habitats, structures, buildings, plants and visions.

2.3.1 Particulate Matter (PM_{10} and $PM_{2.5}$)

Abulude (2016) discovered that particulate matter can be classed as either primary or secondary particles. Particulate matter can be classified as primary particles when it is emitted into the atmosphere by industrial processes, road dust, vehicle traffic, sea spray, and windblown soil. They also contain carbon and an organic complex, metals and metal oxides, and ions. Secondary particles are produced as a result of the chemical alteration of gaseous materials. Air pollution in India (Delhi) has been reported to cause 10,000 to 30,000 deaths per year, with acute and chronic difficulties caused by inhalation of PM_{10} and $PM_{2.5}$, as well as damage to respiratory organs. $PM_{2.5}$ has the greatest impact on health. Fine PM is especially dangerous to those with asthma, cardiovascular illness, and lung disease (both adults and children). These studies have found similar results where Hamanaka and Mutlu (2018) state that short-term exposure to PM levels is significantly associated with daily all-cause, cardiovascular, and pulmonary mortality, whereas long-term exposure to $PM_{2.5}$ is positively connected with lung cancer death.

2.3.2 Sulphur Dioxide (SO_2)

According to Pan (2019), although there are natural sources of sulphur dioxide (accounting about 35 – -65 % of global sulphur dioxide emissions), such as volcanoes, the majority of sulphur dioxide is created by burning sulphur-containing fuels or roasting metal sulphide ores. Thermal power stations that burn high-sulphur coal or heating oil, followed by industrial boilers and nonferrous metal smelters, are the primary sources of anthropogenic sulphur dioxide emissions globally. Reduced lung function, increased prevalence of respiratory symptoms and disorders, irritation of the eyes, nose, and throat, and early mortality have all been linked to exposure to sulphur dioxide in the ambient air. Children, the elderly, and those who already have respiratory problems, such as asthmatics, are especially vulnerable. Short exposures to ambient values above 1,000 g/m^3 appear to be particularly harmful to one's health (acute exposures measured over 10 minutes). Furthermore, in an observation-based study by Filonchyk, Hurynovich, Yan, Gusev, and Shpilevskaya (2020), the skin and mucous membranes of the eyes, nose, throat, and lungs are irritated by sulfur dioxide. High levels of SO_2 can irritate and inflame the respiratory system, especially during strenuous physical exercise. Coughing, throat irritation, and breathing difficulties are some of the symptoms that can occur as a result of this condition. In sensitive people, high levels of SO_2 can impair lung function, exacerbate asthma attacks, and exacerbate existing heart problems.

2.3.3 Nitrogen Dioxide (NO_2)

According to Cerbu, Codoceo, De, Kasal, and Kuppler (2019), nitrogen dioxide is one of a set of gaseous air pollutants produced by the combustion of fossil fuels and traffic. His study on NO_2 states that long-term exposure to NO_2 levels now reported in Europe has been shown in human studies to reduce lung function and increase the risk of respiratory symptoms such as acute bronchitis, cough, and phlegm, particularly in children. When nitrogen dioxide is released into the atmosphere, it can have a negative impact on the environment. Nitric acid is formed when nitrogen dioxide reacts with molecules created by sunlight, and it is a primary component of acid rain. In the air we breathe, nitrogen dioxide combines with sunlight, resulting in the development of ozone and smog. This researcher's research also discovered that NO_2 has a negative impact on human health. Lung illness can be caused by NO_2. NO_2 can also make human more susceptible to viruses.

2.3.4 Carbon Monoxide (CO)

According to Rajiah and Mathew (2011), Carbon monoxide (CO) is a by-product of incomplete combustion of organic matter with insufficient oxygen supply to allow complete oxidation to carbon dioxide (CO2). It is commonly produced in residential and industrial settings. The vulnerability of the brain and heart to CO poisoning is reflected in the immediate symptoms of CO poisoning. Patients may have headaches, dizziness, nausea, emotional instability, disorientation, decreased judgment, clumsiness, and syncope in the beginning. In new-borns, vomiting may be the only symptom, and gastroenteritis may be misdiagnosed. Patients who have been exposed to CO for an extended period of time may have coma or convulsions. This can be supported by Harper and Croft-Baker (2012), when carbon monoxide is inhaled, it displaces oxygen from the bloodstream, depriving the heart, brain, and other essential organs of oxygen. CO poisoning can happen quickly and without warning, causing you to lose suffocate and consciousness. In placing more emphasis, Adefeso, Sonibar, and Isa (2020) claimed that high CO concentrations can cause acute CO poisoning by mixing with haemoglobin to form carboxy-heamoglobin (COHB), which interrupts adequate oxygen transmission from the lungs to human organs. The elevated CO concentration impairs normal respiratory system function, which is a Covid-19 symptom.

2.3.5 Ozone (0_3)

Ozone (0_3) is colourless, similar to oxygen (0_2), but it has a highly unpleasant odour. When compared to oxygen, it is quite scarce. The globe is shielded from harmful ultraviolet rays by an ozone layer in the atmosphere. Agricultural, commercial, and industrial activity are all expanding and exacerbating ozone depletion at the same time. As a result, emissions of harmful chemicals such as CFCs, halons, and other pollutants from agriculture, fossil fuel combustion, and industrial activities are on the rise. As a consequence, the chemical composition of the earth's atmosphere has changed, resulting in the depletion of the stratospheric ozone layer (Safiuddin, 2016). The source of ozone pollution is power plants, industrial boilers, refineries, chemical plants, and some other sources. Furthermore, in an observation based study by Karthik, Sujith, Rizwan, and Sehgal (2017), ozone levels in an industrial area were found to be greater than in a non-industrial area, and population in an industrial area was directly linked to increased chronic respiratory symptoms such as dyspnea, cough and wheezing.

2.4 Effect of Pandemic on Air Pollution

Recently, satellite measurements of air pollutants during the pandemic by the European Space Agency showed a marked decrease in air pollution at the end of January and the beginning of February 2020 (Nadzir et al., 2020). According to Mahato, Pal, and Ghosh (2020), the level of pollution around the country has decreased dramatically in just a few days, making debates about lockdown an effective alternative method to control air pollution. In recent research, the increase in air quality during the lock-down period was attributed to the closure of the industry and the reduction in vehicle transit (Selvam et al., 2020). The levels of air pollutants are reduced when methods to minimize vehicular traffic or industrial emissions are implemented (Arregocés et al., 2020). It is supported by similar research done by Ghahremanloo et al. (2020), the impact of the mandatory shutdown of a large portion of the Chinese industry presented a rare opportunity to analyze atmospheric changes that correlate with decreases in emissions and pollutants. These research have found similar results where Arregocés et al. (2020) cited approximately 39 studies have been quoted in their article on the impact of lockdowns and their effects on the levels of various pollutants in the air across several places around the world.

2.5 Air Pollution Concentration Before and During the Pandemic

During the Covid-19 pandemic, nationwide lockdown was imposed in most countries to control an increase in the number of pandemic cases (Mahato et al., 2020). According to Selvam et al. (2020), the most populated cities with more industrial activities showed higher improvement in air quality. This claim also can be supported by similar research done by Mahato et al. (2020), in the transportation and industrial location air quality have improved close to 60 %. Many researchers from various articles found the reduction of air pollution concentration before and during a pandemic in certain countries as shown in Table 2.5.

Table 2.5: Summary of air pollution concentration before and during pandemic

Year	Area	Parameters	Finding	Reference
2015-2019	Southeast Asia region	Nitrogen oxides (NO_2)	• In March and April 2020, Aura-OMI satellite sensor readings revealed a decline in NO_2 mean concentrations over most of Southeast Asia (SEA) when compared to the years 2015-2019. • On April 17, No2 concentrations fell by -34 %, -27 %, and -30 % in Manila, Kuala Lumpur, and Singapore, respectively (15-day averages), compared to NO 2 baseline data (averaged over 2015-2019). This is linked to the lockdown, which caused businesses and industries to close. • However, the reduction in NO_2 was much lower due to continuous emissions from shipping for the international trade in Singapore.	Kanniah et al. (2020)
2020	Malaysia	NO_2, $PM_{2.5}$ and PM_{10}	• The comparison was made between the period 18 March to 30 April 2018, 2019 and 2020 respectively. • The comparison shows a substantial decrease in concentration of NO_2, $PM_{2.5}$ and PM_{10} at industrial and urban area during the MCO time. • PM_{10} levels are far lower than the 50 μg/m^3 limit and by 2020 are close to the 20 μg/m^3 recommended by the WHO. • The air quality conditions across the region are good with $PM_{2.5}$ levels below 25 μg/m^3. • Compared to 2019 and 2018, PM_{10} concentrations decreased by 28 % to 39 % at industrial sites and 26 % to 31 % in urban areas in 2020. • $PM_{2.5}$ concentrations decreased by (19 % - 42 %) at industrial and (23 % - 32 %) at the urban sites. • There were greater declines in NO_2 levels, which decreased by (33 % - 46 %) in industrial areas and (63 % - 64 %) in urban centres compared to 2018 and 2019.	Kanniah et al. (2020)

Continued

Table 2.5: Summary of air pollution concentration before and during pandemic (Continued)

Year	Area	Parameters	Finding	Reference
2020	Rajasthan, India	PM_{10}, $PM_{2.5}$, and SO_2	• The maximum reduction for PM_{10}, $PM_{2.5}$, and SO_2 concentration was observed, 58.2 %, 44.69 % and 69.90 % respectively, before and during the lockdown period. • The percentage reduction in $PM_{2.5}$ concentration levels during the lockdown period may also be credited to a reduction in NO_2 concentration.	Sharma et al. (2020)
2019 - 2020	Malaysia	$PM_{2.5}$, PM_{10} and CO	• During MCO, the concentrations decreased from (40 % - 50 %) for CO and (20 % - 60 %) for particulate matter at Petaling Jaya due to the reduction in vehicle numbers and industrial operations. • $PM_{2.5}$ and PM_{10} were increased in Kota Damansara during the MCO period because local burning activities and the highway construction nearby.	Nadzir et al. (2020)
2020	Malaysia	$PM_{2.5}$	• High reductions were found in Peninsular Malaysia at the North (6.5 % - 23.7 %), Central (8.8 % - 16.2 %), South (11.0 % - 15 %), and East (7.7 % - 11.3%) regions as well as the East Malaysia of Sabah (15.8 % - 23.1 %)	Abdullah et al. (2020)
2019 - 2020	Gujarat, India	NO_2 and O_3	• The reduction of NO_2 by about 30–84 % in during lockdown in western India. • Increasing of O_3 concentration (16–58 %) due to less NO_2 emission. • The Air Quality Index (AQI) have improved to 58 % compared to 2019. • Populated cities with more industrial activities showed higher improvement in air quality with Air Quality Index (AQI) value by about (60 % – 75 %).	Selvam et al. (2020)

Continued

Table 2.5: Summary of air pollution concentration before and during pandemic (Continued)

Year	Area	Parameters	Finding	Reference
2019 - 2020	East Asia	NO_2, CO and SO_2	• In Wuhan and BTH (Beijing, Tiajin and Hebei), the dramatic reductions in NO_2 concentrations declined nearly 54 % and 83 % respectively. • CO also decreased by about 8 % in BTH (Beijing, Tiajin and Hebei), 4 % in Wuhan, 6 % in the SMA (Soul Metropolitan Area), and 1 % in the TMA (Tokyo Metropolitan Area). • SO_2 decreased dramatically in Wuhan but remained relatively unchanged in BTH (Beijing, Tiajin and Hebei due to the larger number of power plants and industrial sections.	Ghahremanloo et al. (2021)
2020	Colombia	$PM_{2.5}$	• The weekly $PM_{2.5}$ concentration data values shows the reduction during the lockdown in the city of Bogotá (41 – 84 %), Funza (13 % – 66 %), Boyacá (17 % – 57 %), Valledupar (35 % – 86 %) and in the Risaralda region (31 % – 60 %) because of reductions in the mobility of public transport and the closure of some industries.	Arregocés et al. (2020)
2017-2020	Delhi, India	O_3, $PM_{2.5}$ and PM_{10}	• In Delhi, $PM_{2.5}$ and PM_{10} have witnessed maximum reduction followed byNO_2, CO and NH_3. • $PM_{2.5}$ and PM_{10} concentration has decreased by about −57 % and −33 % respectively in compare to the past three year. • However, there is a slight increase in O_3 concentration. • The air quality have improved close to 60 % in the transportation and industrial area. • About 40 % to 50 % improvement in air quality on the 2nd and 4th day of lockdown.	Mahato et al. (2020)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This research methodology is shown in Figure 3.1. This methodology can be divided into five paths, which are study area, data collection, descriptive analysis, data comparison, and data interpretation.

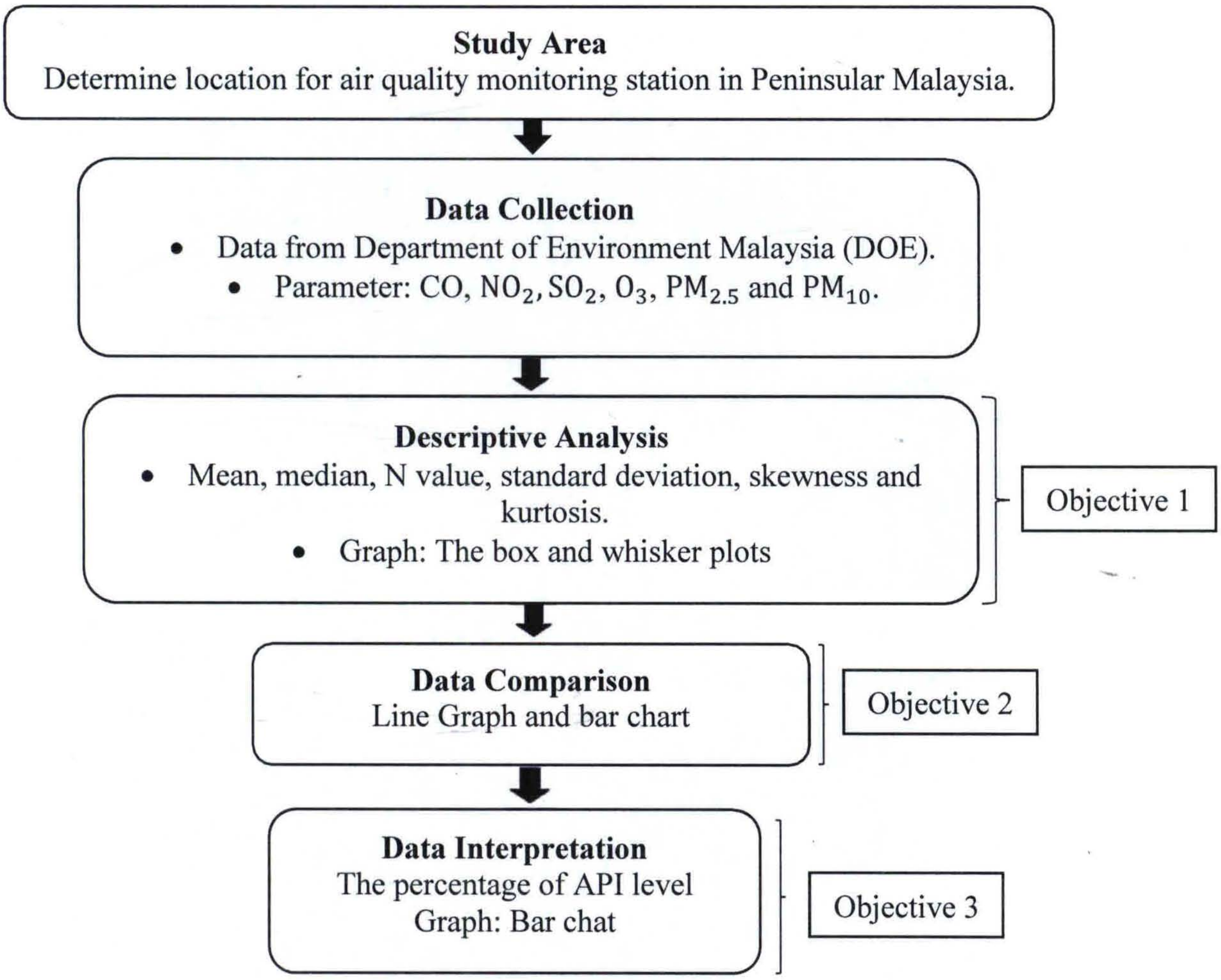


Figure 3.1: Research flowchart

3.2 Research Area

There were 68 stations air-monitoring throughout Malaysia that could have been divided into four categories such as industrial, rural, urban and sub-urban area. However, this studied only focus on the station that located at industrial areas in peninsular Malaysia that were responsible for monitoring the air quality status. Malaysia's peninsular region includes 11 of the country's 13 states as well as two of the country's three federal territories. It had a total area of 132,265 square kilometers. It could have been divided into four regions: north, east, central, and southern. Figure 3. 2 depicts maps of peninsular Malaysia.

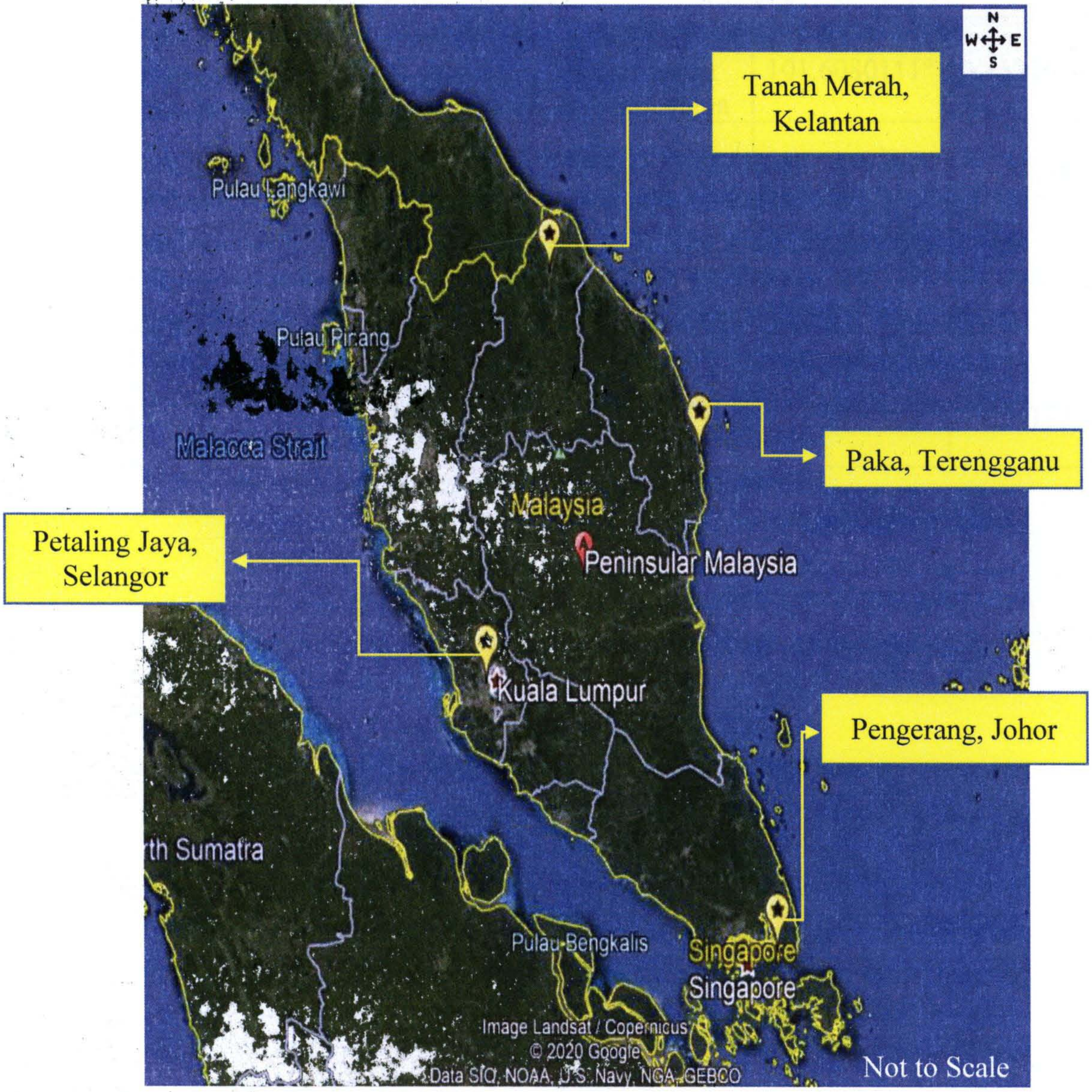


Figure 3.2: Air Quality Monitoring Station in Peninsular Malaysia

There were four monitoring stations out of six stations at industrial areas in peninsular Malaysia was selected in this study. Table 3. 1 below shows the data of station id, region, state, longitude, latitude and location of selected air monitoring station at industrial areas in peninsular Malaysia. Geographically, all the monitoring stations were strategically located in the rapid growth industrial areas resulting in a large amount of air pollution (Ahmat et al., 2015).

Table 3.1: Selected air monitoring station of industrial areas in Peninsular Malaysia

No.	Station ID	Region	State	Monitoring Station	Coordinate	
					Longitude	Latitude
1.	CA 19B	Central	Petaling Jaya, Selangor	Sekolah Kebangsaan Bandar Utama	101.6080111°	3.1331694°
2.	CA 35J	South	Pengerang, Johor	Sekolah Kebangsaan Lepau	104.1495861°	1.3894889°
3.	CA 43T	East	Paka, Terengganu	Kuarters TNB Paka	103.438194°	4.5980639°
4.	CA 46D		Tanah Merah, Kelantan	Sekolah Menengah Tanah Merah	102.1345000°	5.8111722°

3.3 Data Collection

The data collection for this research was obtained by using daily Air Pollution Index (API) and air pollutants concentrations data from Department of Environment Malaysia (DOE) to evaluate the lockdown effect due to pandemics to the air pollution status. The parameter of air pollution used in these research was carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), particulate matter with a diameter less than 2. 5 µm ($PM_{2.5}$) and particulate matter with a diameter less than 10 µm (PM_{10}). The average calculation for each parameter was obtained over a wide variety of time periods, as shown in Table 3.2 below, because they had various allowed exposure periods for people (Department of Environmental, 2020). The sub-indices for individual pollutants at a monitoring station were derived using an average period of 24 hours for particulate matter, one hour for sulphur dioxide and carbon monoxide, and one hour or eight hours for ozone. According to quality, (2019), the department of environment began calculating the air pollution index (API) using $PM_{2.5}$ in 2017. Thus, for selected stations, secondary data would be used from 1 March to 30 June (2018 – 2020). Finally, to complete data matrices, remove all missing values.

Table 3.2: The average concentration of each pollutant over a given period (Department of Environmental, 2020).

Pollutant Parameter	Averaging Period
Sulphur Dioxide (SO_2)	1 Hour
Particulate Matter (PM_{10})	24 Hours
Particulate Matter ($PM_{2.5}$)	24 Hours
Ozone (O_3)	8 Hours
	1 Hour
Nitrogen Dioxide (NO_2)	1 Hour
Carbon Monoxide (CO)	8 Hours

3.4 Descriptive Analysis

The descriptive analysis was conducted in ordered to determine the characteristics of air pollutant concentrations before and after the pandemic. The descriptive statistics would be carried out to determine the shape, dispersion and distributions of the data for the studied area (Mohd Zizi, Mohamed, Izzah, & Yususf 2018). The most important information needed to have been collected from a set of data was the measured of central tendency and the measures of variability (Mohd Zizi et al., 2018). The value of mean, median, standard deviation, skewness, kurtosis and coefficient of variation for every set data could have been analyzed by using SPSS software. The descriptive analysis data is shown by a box plot and whiskers graph.

3.5 Data Comparison

Then, the six pollutant parameters such as particulate matter of size less than 10 μm (PM_{10}), particulate matter of size less than 2. 5 μm ($PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) had been analyzed individually and compared with the result before and during the pandemic. The line graph was used to compare the air pollutants concentration at industrial areas in Peninsular Malaysia before and during the pandemic. The overall reduction (R) has been identified by comparing the mean of each pollutant concentration before and during the pandemic. Thus, the comparison of air quality status before and during the pandemic at industrial areas in Peninsular Malaysia by using daily Air Pollutant Index (API) and air pollutants concentration data could have been identified.

3.6 Data Interpretation

From the analysis, the percentage of Air Pollutant Index (API) level have been identified. The bar chart graph was plot to perform API level percentage value at all locations to determine the effects on air pollution status at industrial areas in Peninsular Malaysia before and during pandemic by using Air Pollutant Index (API). Instead of providing the actual concentration of air pollutants, this data interpretation by API percentage will be present to help clearly understood ranges of values as a way of reporting air quality before and during the pandemic. The Air Pollutant Index (API) is used to measure air quality and its impact on humans, as indicated in Table 3.3.

Table 3.3: Air Pollutant Index (API) Category (Department of Environmental, 2020)

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

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The Movement Control Order (MCO) in Malaysia was started on 18 March 2020 as a preventive measure of Covid-19 by the federal government of Malaysia. All economic activities are ordered to cease operations, except those considered important industries during a pandemic. This situation has had a huge impact on air quality, not only in Malaysia but in other countries as well. However, how does the MCO during a pandemic impact air quality in Malaysia's industrial areas? As a result, in this chapter of the thesis report, it will discuss the characteristics of air pollutants concentration data at industrial areas in Peninsular Malaysia from 1 March 2018 – 30 June 2018, 1 March 2019-June 2019 and 1 March 2020-June 2020. The comparison of the air quality status before and during the pandemic in industrial areas in Peninsular Malaysia was done by using daily Air Pollutant Index (API) and air pollutants concentration data to make it look clearer. Finally, the effects on air pollution status in industrial areas in Peninsular Malaysia before and during the pandemic by using Air Pollutant Index (API) data from the Department of Environment Malaysia (DOE) are concluded. The effects on air pollution status at industrial area in Peninsular Malaysia before and during the pandemic were simultaneously collected from four industrial areas such as Paka (Terengganu), Petaling Jaya (Selangor), Pengerang (Johor) and Tanah Merah (Kelantan). The descriptive analysis of daily Air Pollutant Index (API) and six pollutant parameters such as particulate matter of size less than 10 µm (PM_{10}), particulate matter of size less than 2.5 µm ($PM_{2.5}$), ozone (0_3), carbon monoxide (CO), nitrogen dioxide ($N0_2$) and sulfur dioxide ($S0_2$) from 1 March 2018 – 30 June 2018, 1 March 2019-June 2019 and 1 March 2020-June 2020 are analyzed and presented as shown below. The details on the time framed used for the research are summarized in Table 4.1.

4.2 Descriptive Analysis of Air Pollution

The secondary data acquired from the Department of Environment (DOE) for four monitoring stations in industrial areas in Peninsular Malaysia are presented in Table 4.2, 4.3, 4.4 and Table 4.5. The table descriptive statistics below analyze based on daily average value for six parameters of air pollutants concentrations. All the data for 0_3 and CO are not available at Paka (Terengganu) and Pengerang (Johor). This means ozone and carbon monoxide are not reach or exceed the averaging time of parameter as recommended by Malaysia Air Quality Guideline that contributes to air pollution in the API readings. Normally, the ozone and carbon monoxide concentration will be recorded high ozone concentrations due to production of energy in industrial activity such as burning fossil fuel. The overall average concentration parameters values of secondary data from CAQMS stations for each monitoring station are analyzed during the normal period (1 March 2018 – 30 June 2018), (1 March 2019 – 30 June 2019) and during pandemic period (1 March 2020 – 30 June 2020).

Table 4.1: Details on time frame used for the research

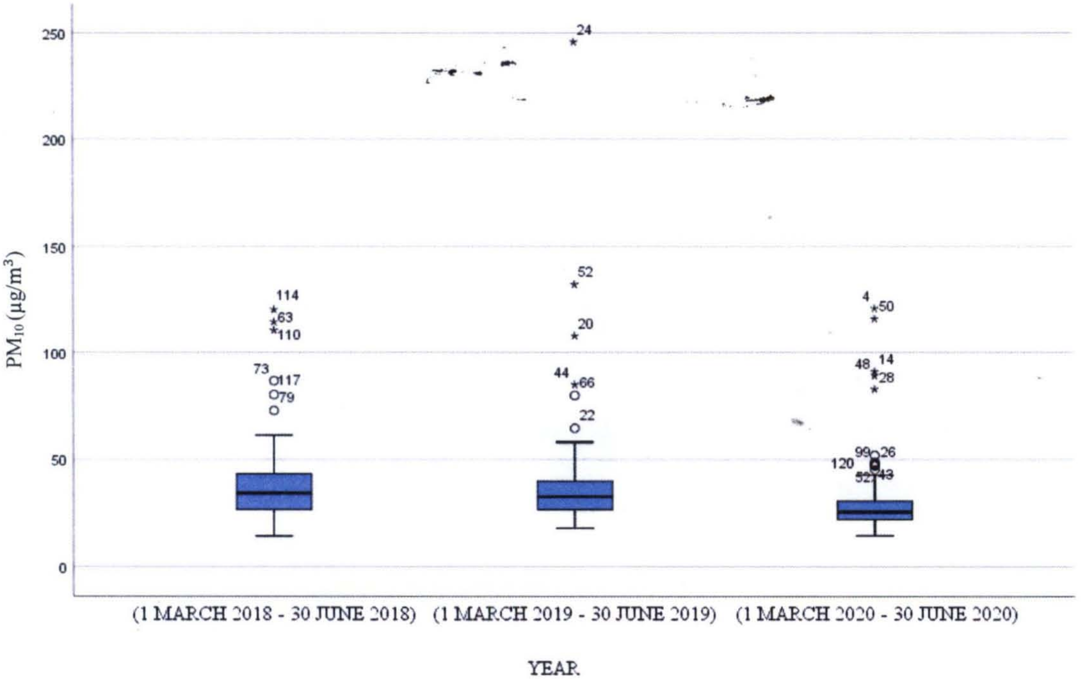
Year	Time	Date	Duration
2018	Before pandemic	1 March 2018 – 30 June 2018	122 days
2019	Before pandemic	1 March 2019 – 30 June 2019	122 days
2020	During pandemic	1 March 2020 – 17 March 2020	122 days
	During pandemic + Implementation of MCO	18 March 2020 – 30 June 2020	

4.2.1 Descriptive Statistics for Paka, Terengganu Monitoring Stations

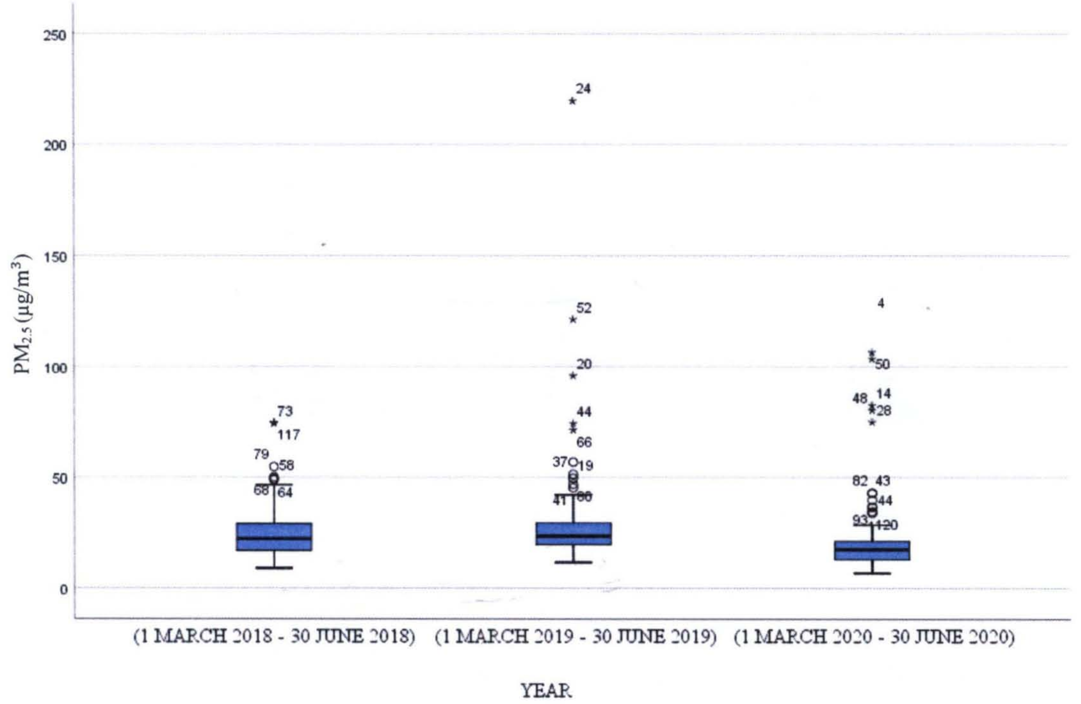
Paka, Terengganu is an industrial area for the oil and gas industry sector. According to Choy, Syahidah, Ahmad, and Jusoh (2013), the oil and gas industry in Paka is one of the country's development projects through the Kemaman-Dungun Corridor. This initiative has the potential to boost economic growth on the East Coast while also improving the well-being of the surrounding community. Various industries have been established to generate a development that delivers various benefits to the inhabitants of Terengganu, particularly in terms of raising living standards and, as a result, overall well-being. Electric power plants and the petrochemical industry, led by PETRONAS, are examples of industries in the Paka area. This industrial sector's growth has also had a negative impact on the environment.

Table 4.2: Descriptive statistics of daily average air pollutant concentration at Paka, Terengganu

Parameter	Year	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
PM_{10} ($\mu g/m^3$)	2018	122	14.215	120.205	37.4310	17.5584	2.473	8.36
	2019	122	17.868	245.739	37.2902	24.4148	6.007	45.905
	2020	122	14.43	120.732	29.6755	16.7666	3.536	14.503
$PM_{2.5}$ ($\mu g/m^3$)	2018	122	9.1	74.594	24.6833	11.2536	1.874	5.24
	2019	122	11.816	219.647	29.0239	22.7413	5.835	43.105
	2020	122	6.96	106.375	21.2424	16.0094	3.617	14.639
SO_2 (ppm)	2018	122	0.0007	0.0047	0.0014	0.0006	2.216	7.557
	2019	122	0.0007	0.0111	0.0024	0.0020	2.447	7.094
	2020	122	0.0006	0.0113	0.0017	0.0017	2.991	10.597
NO_2 (ppm)	2018	122	0.0007	0.0187	0.0055	0.0041	1.383	1.144
	2019	122	0.0018	0.0221	0.0071	0.0047	1.173	0.681
	2020	122	0.0012	0.0175	0.0046	0.0030	1.619	3.125



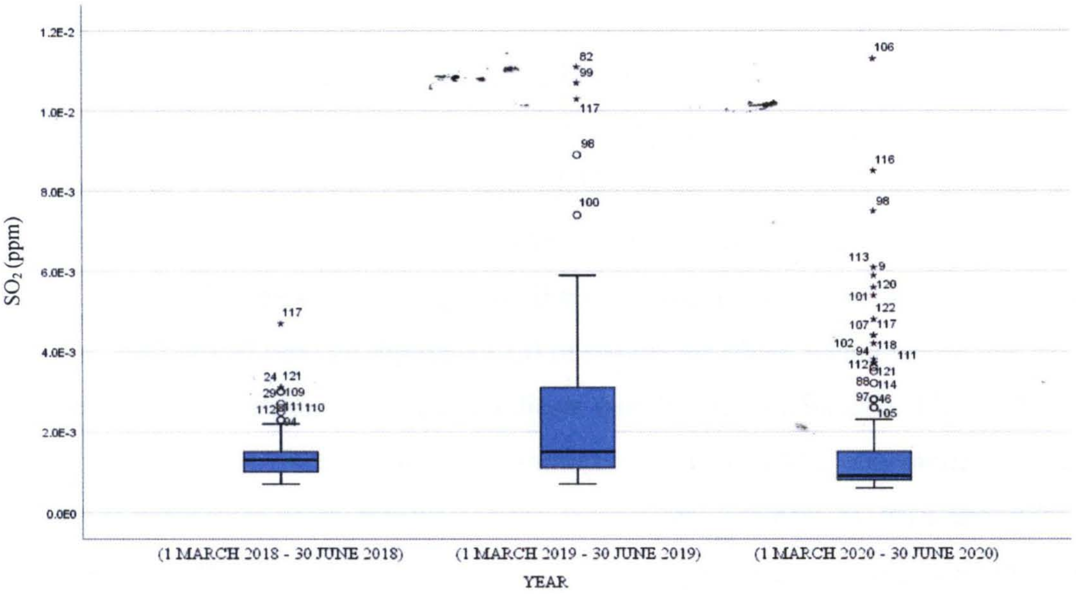
a) PM10 concentration at Paka, Terengganu



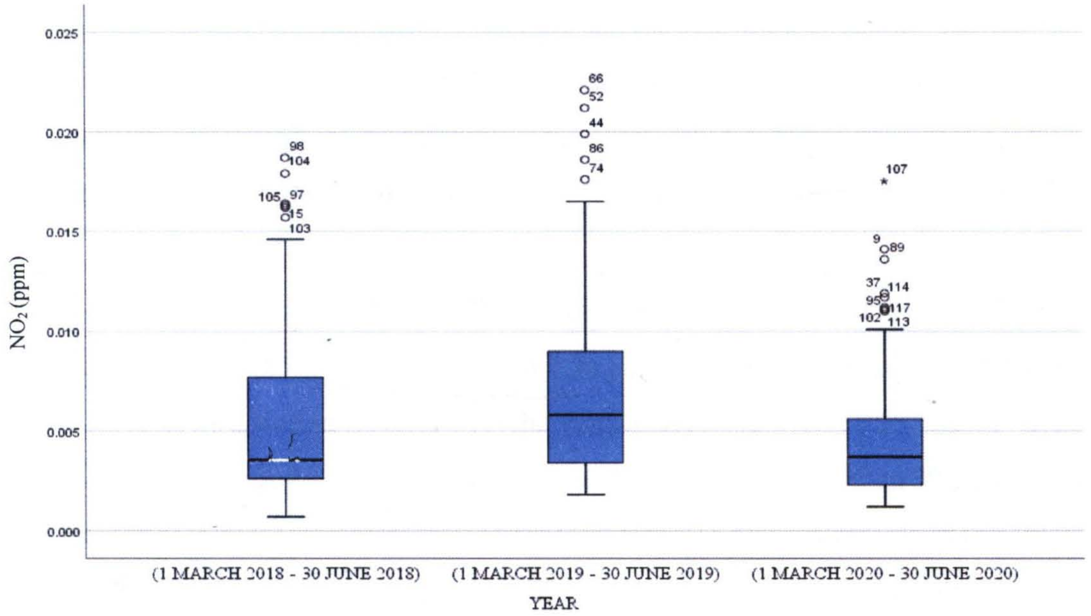
b) PM2.5 daily mean concentration at Paka, Terengganu

Continued

Figure 4.1: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations during 1 March- 30 June 2018, 2019 and 2020 at Paka, Terengganu



c) SO_2 daily mean concentration at Paka, Terengganu



d) NO_2 concentration at Paka, Terengganu

Figure 4.1: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations during 1 March- 30 June 2018, 2019 and 2020 at Paka, Terengganu (Continued)

Remarks: Symbols "*" represents the extreme out layer while symbols "o" represents the mile out layer that is based on interquartile range. The horizontal bar in each box represents the median.

Table 4.2 shows the overall data descriptive statistics of daily average air pollutant concentration while Figure 4.1 shows the box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations at Paka, Terengganu. The N value for each pollutant is 122 for three continuous years. The average daily minimum value for PM_{10} is 14.215 µg/m^3 (2018), 17.868 µg/m^3 (2019) and 14.430 µg/m^3 (2020). For the average daily maximum value of parameter PM_{10}, it showed a huge increase from 2018 to 2019, which is from 120.205 µg/m^3 to 245.739 µg/m^3 then it suddenly decreased to 120.732 µg/m^3 in 2020. This can be seen on Figure 4.1 (a) of parameter PM_{10}, which shows that severe values (q3 + 3s.d) at Paka, Terengganu indicate that the location has seen high particulate events as well as extreme events that promote increasing PM_{10} concentrations. Even though the maximum value for 2019 is the highest one compare to 2018 and 2020, it shows the reduction on average daily mean value of PM_{10} year by year which is from 37.431 µg/m^3 (2018) to 37.2902 µg/m^3 (2019) and 29.6755 µg/m^3 (2020). The drop in PM_{10} is primarily due to traffic restrictions and a slowdown in factory production (Selvam et al., 2020). The standard deviation, skewness and kurtosis for PM_{10} show positive values for all three continuous years. The box and whisker plots also demonstrate that the distribution is symmetric in 2018 due to the median being in the centre, whereas the distribution is skewed to the right due to the median being closer to the bottom of the box.

Next, the minimum value for $PM_{2.5}$ indicates an increase from 9.1 µg/m^3 in 2018 to 11.816 µg/m^3 in 2019, but then drops to 6.96 µg/m^3 in 2020. The maximum value for $PM_{2.5}$ also follows a similar pattern, with the value increasing from 79.594 µg/m^3 in 2018 to 219.647 µg/m^3 in 2020, and the value decreasing to 106.375 µg/m^3 in 2021. The $PM_{2.5}$ parameter shows that the mean value increased from 24.683 µg/m^3 (2018) to 29.0239 µg/m^3 (2019) and declined to 21.2424 µg/m^3 (2020). However, according to a study by Abdullah et al. (2020), the $PM_{2.5}$ mean value increased from 8.7 µg/m^3 before the pandemic to 9.2 µg/m^3 during the pandemic since some industrial activity is still ongoing. As shown by Figure 4.1 (b), the highest outlier in 2019 is due to the extreme value standard deviation and kurtosis value, which are 22.7413 and 43.105, respectively. The box and whisker plots for 2018 and 2019 demonstrate that the distribution is skewed to the right because the median is closer to the bottom of the box, but the distribution is skewed to the left because the median is closer to the top of the box for 2020.

For SO_2, the minimum value remains the same in 2018 and 2019, at 0.0007 ppm, before decreasing slightly to 0.0006 ppm in 2020. The maximum value for SO_2 reveals that the value has continued to rise from 0.0047 ppm (2018), to 0.0111 ppm (2019), and to 0.0113 ppm (2020).The mean concentrations of SO_2 show increasing value from 0.0014 ppm (2018) to 0.0024 ppm (2019) and declined to 0.0017 ppm (2020). According to Nigam, Pandya, Luis, Sengupta, and Kotha (2021), the mean concentrations of SO_2 also shows the decreasing value 19.142 ppm before lockdown in 2019 to 9.434 ppm during lockdown 2020 at Vapi, India. The box and whisker plot for SO_2 in Figure 4.1 (c) has skew to the right for 2019 and 2020, with values of 2.447 and 2.991. According to the box and whisker plots, the extremely high outlier value is in 2020 when compared to the prior two years. This is because the kurtosis value in 2020 is 10.597, indicating that the data has a high number of extreme outliers or heavy tails.

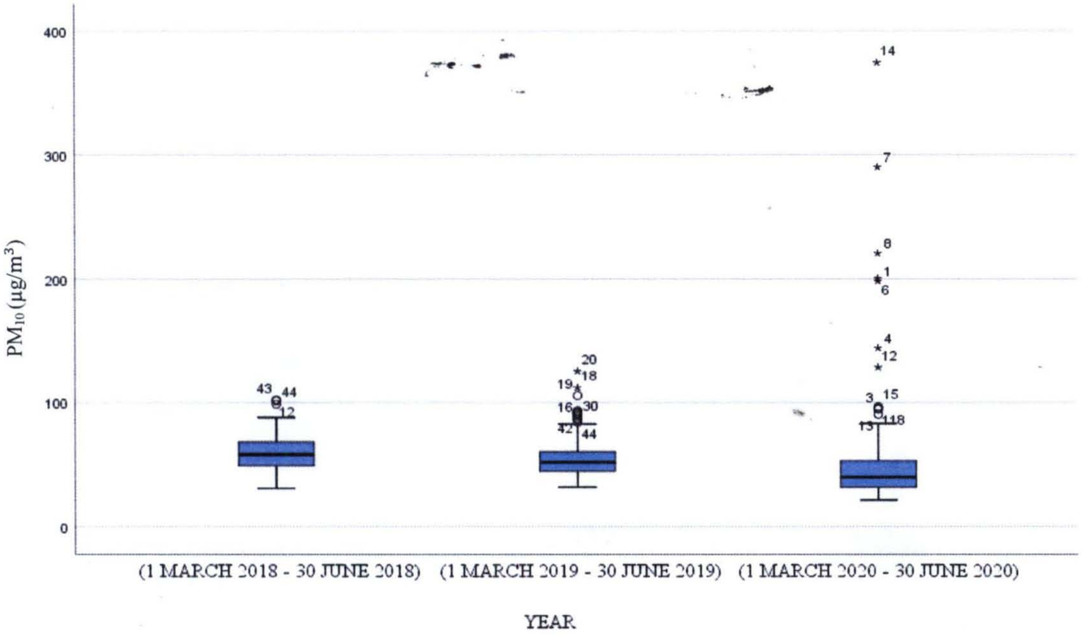
The mean concentration of NO_2 also shows that the value increased from 0.0055 ppm (2018) to 0.0071 ppm (2019) and decreased to 0.0046 ppm (2020). The maximum value of NO_2 for 2018, 2019 and 2020 are 0.0187 ppm, 0.0221 ppm and 0.0175 ppm. The Figure 4.1 (d) also shows that the NO_2 maximum value has decreased in 2020 and recorded the lowest maximum value compared to other years through the length of the line on the plot box. According to Nigam et al. (2021), there are some reduction of NO_2 from 18.015 (2019) ppm to 5.849 (2020) ppm at India. The root causes of rapid increases in air pollution are incomplete burning of fossil fuels by automobiles and industrial operations. The covid-19 pandemic, on the other hand, resulted in a nationwide lockdown to stop the spread of disease, providing an opportunity for the environment to cure itself from the ongoing exploitation by human activities. In Figure 4.1 (d), the box and whisker plot shape also represents that the mean values for NO_2 in three years are likewise higher than their respective medians, indicating that the pollutant distributions are positively skewed (also called right-skewed). For three consecutive years, all of the parameters show a positive value for skewness and kurtosis, indicating that the data are skewed right.

4.2.2 Descriptive Statistics for Petaling Jaya, Selangor Monitoring Stations

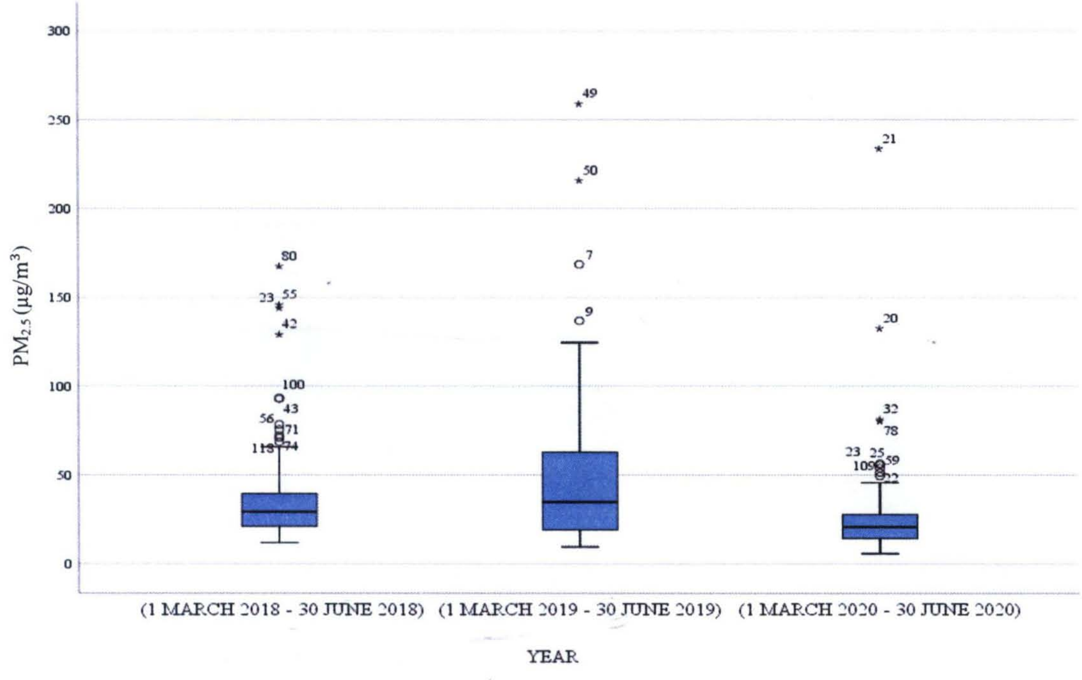
Petaling Jaya is a city in the Petaling District in the Malaysian state of Selangor. It was originally planned as a satellite township for Malaysia's capital, Kuala Lumpur, and is now part of the Greater Kuala Lumpur area. It is one of Peninsular Malaysia's industrial zones.

Table 4.3: Descriptive statistics of daily average air pollutant concentration at Petaling Jaya, Selangor

Parameter	Year	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
PM_{10} ($\mu g/m^3$)	2018	122	31.047	102.185	59.3673	14.1622	0.546	0.486
	2019	122	32.053	125.219	56.1524	17.0286	1.506	2.578
	2020	122	21.449	374.34	53.6795	48.5941	4.228	21.055
$PM_{2.5}$ ($\mu g/m^3$)	2018	122	20.021	85.814	45.4041	11.7241	0.774	1.188
	2019	122	22.51	107.308	43.0414	15.6591	1.679	3.148
	2020	122	16.706	113.108	35.4799	15.9260	2.195	6.279
SO_2 (ppm)	2018	122	0.0032	0.0262	0.0100	0.0049	1.068	0.834
	2019	122	0.0009	0.0144	0.0026	0.0020	3.956	20.452
	2020	122	0.0004	0.0193	0.0022	0.0022	4.907	32.35
NO_2 (ppm)	2018	122	0.0206	0.0708	0.0440	0.0103	0.022	-0.404
	2019	122	0.02	0.0592	0.0375	0.0088	0.288	-0.543
	2020	122	0.0056	0.0864	0.0302	0.0187	1.146	0.797
O_3 (ppm)	2018	122	0.0087	0.1091	0.0568	0.0192	-0.029	-0.46
	2019	122	0.0158	0.0941	0.0498	0.0173	0.366	-0.174
	2020	122	0.0071	0.0607	0.0343	0.0116	-0.074	-0.693
CO (ppm)	2018	122	1.076	3.565	2.3421	0.5180	-0.021	-0.412
	2019	122	1.232	3.213	2.1289	0.4722	0.153	-0.592
	2020	122	0.483	6.735	1.4734	0.7860	2.87	15.774



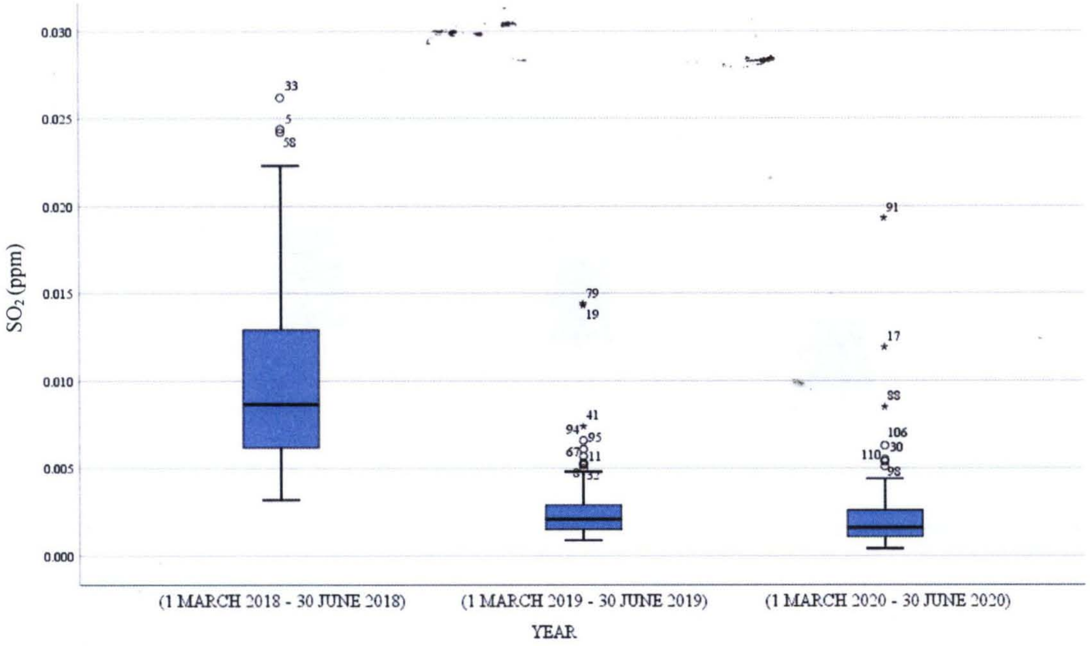
a) PM$_{10}$ daily mean concentration at Petaling Jaya, Selangor



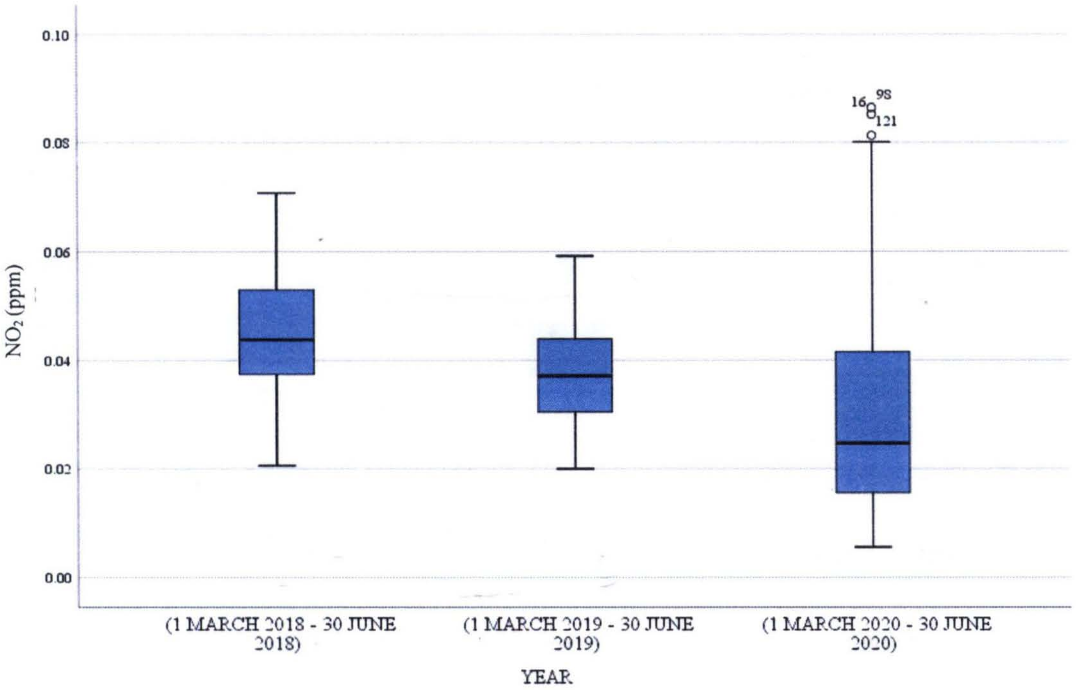
b) PM$_{2.5}$ daily mean concentration at Petaling Jaya, Selangor

Continued

Figure 4.2: The box and whisker plots of daily average PM$_{10}$, PM$_{2.5}$, SO$_2$ and NO$_2$, O$_3$ and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Petaling Jaya, Selangor



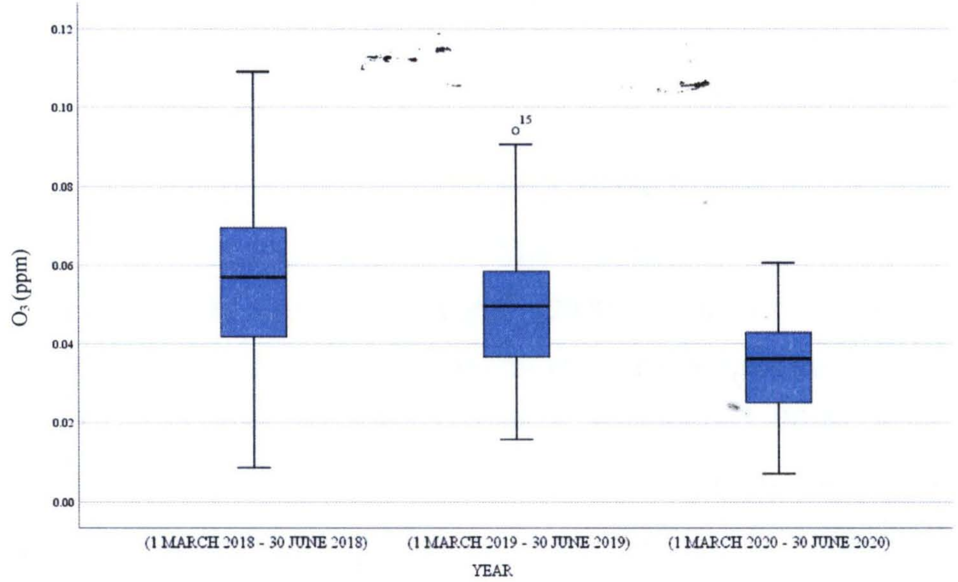
c) SO$_2$ daily mean concentration at Petaling Jaya, Selangor



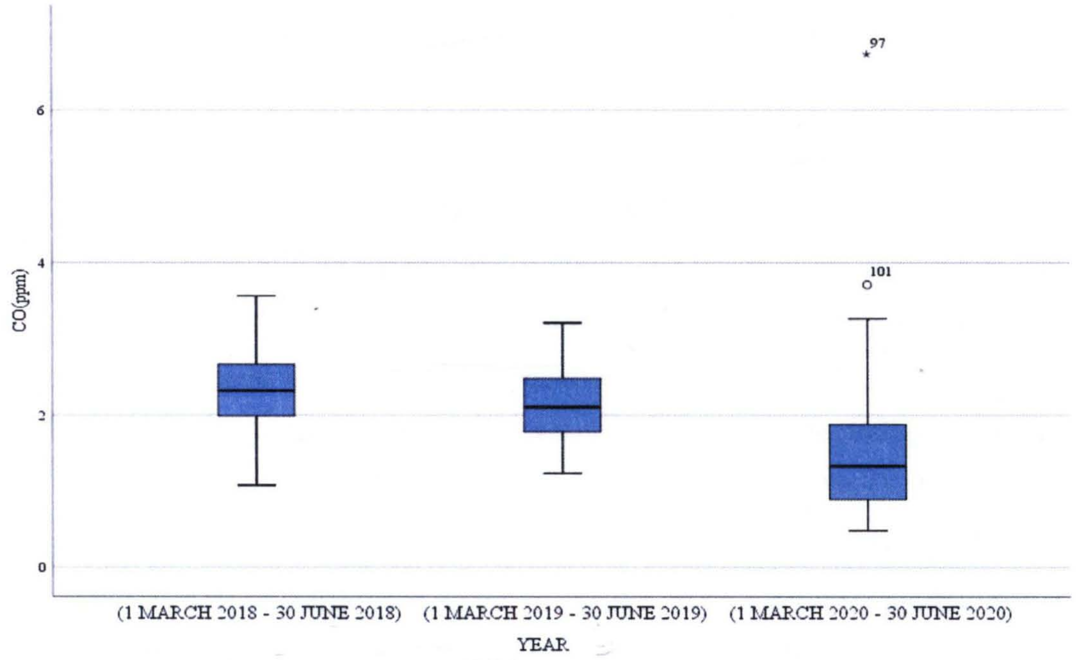
d) NO$_2$ daily mean concentration at Petaling Jaya, Selangor

Continued

Figure 4.2: The box and whisker plots of daily average PM$_{10}$, PM$_{2.5}$, SO$_2$ and NO$_2$, O$_3$ and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Petaling Jaya, Selangor (Continued)



e) O_3 daily mean concentration at Petaling Jaya, Selangor



f) CO daily mean concentration at Petaling Jaya, Selangor

Figure 4.2: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2, O_3 and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Petaling Jaya, Selangor (Continued)

Symbols "*" represents the extreme out layer while symbols "ᵒ" represents the mile out layer that based on interquartile range. The horizontal bar in each box represents the median.

The overall data Descriptive statistics of daily average air pollutant concentration for Petaling Jaya, Selangor are shown in Table 4.3. The descriptive statistic reveals that the data has N value of 122 for all parameters during a three-year period. The minimum value for PM_{10} exhibits an increasing pattern from 31.047 µg/m^3 (2018) to 32.053 µg/m^3 (2019), then unexpectedly drops to 21.449. µg/m^3 (2020) during pandemic. It shows that the average daily mean concentration of PM_{10} decreased by 59.3673 µg/m^3 (2018), 56.1524 µg/m^3 (2019), and 29.6755 µg/m^3 (2020). Reduced PM_{10} exposure level prevented 26 premature deaths among newborns under one year old and individuals aged 30 and above (Ghorani-Azam, Riahi-Zanjani, & Balali-Mood, 2016). However, the maximum value for PM_{10} was reported as the greatest in 2020 (374.34 µg/m^3) at Petaling Jaya, despite the fact that the average daily mean concentration is the lowest in 2020 when compared to other years. It can be shows on Figure 4.2 (a) of the box plot PM_{10} concentration at Petaling Jaya, Selangor that the high value of skewness during 2020 (4.228), number of outliers (q3 + 1.5s.d) and extreme values (q3 + 3s.d) indicated that Petaling Jaya experienced high particulates events as well as extreme events which promote increasing of PM_{10} concentrations.

The highest minimum concentration value of $PM_{2.5}$ was recorded as 11.816 µg/m^3 (2019) and declined to 6.96 µg/m^3 (2020) during the phase of pandemic. The highest maximum concentration value of $PM_{2.5}$ was recorded as 113.108 µg/m^3 in 2020. However, the average daily mean concentration of $PM_{2.5}$ recorded the lowest value 35.4799 µg/m^3 in 2020 compared to other years. According to the findings by Abdullah et al. (2020), Petaling Jaya recorded the mean value before the MCO (14 – 17 March 2020) of 22.1 µg/m^3 and the reduced value during the MCO (18 – 31 March 2020) of 16.7 µg/m^3. For three consecutive years, the skewness also shows a positive value for $PM_{2.5}$ with a skew to the right, as illustrated in Figure 4.2 (b). The highest kurtosis values were also reported in 2020, which is 6.279, indicating large outliers.

Petaling Jaya shows that the average daily mean concentration of SO_2 (0.0100, 0.0026, and 0.0022 ppm) and NO_2 (0.0440, 0.375, and 0.032 ppm) has declined from 2018 to 2020. These two parameters, nitrogen dioxide (NO_2) and sulfur dioxide (SO_2), are abundant, with nitrogen dioxide being the most contributing factor to vehicular emissions (Petaling Jaya Air Quality Index (AQI) & Malaysia Air Pollution | AirVisual, 2021). The box and whisker plots for SO_2 in Figure 4.2 (c) show that the distribution is skewed to the right for all years because all of the whiskers are shorter on the lower end of the box and the highest outliers are recorded on 2018, indicating that it has an extreme outlier's value when compared to other years. The box and whisker plot in Figure 4.2 (d) for NO_2 demonstrates that it has a symmetric distribution because the whiskers are almost the same on both sides of the box, whereas the distributions for 2018 and 2020 are positively skewed.

The minimum value for O_3 shows that the value is increasing from 0.0087 ppm (2018) to 0.0158 (2019) and then declining to 0.0071 ppm on pandemic 2020. However, the maximum value shows a continuous reduction year by year, which is 0.1091 ppm, 0.0941 ppm, and 0.0607 ppm. The O_3 parameters show negative values for kurtosis and skewness, indicating that the data is skewed to the left for 2018 and 2020 and it can be seen in Figure 4.2 (e). The average daily mean concentration for O_3 are 0.0568 ppm (2018), 0.0498 ppm (2019), 0.0343 ppm (2020), respectively. Due to the rising sources of ozone precursors such as natural sources (e.g., vegetation), mobile sources (e.g., motor vehicles), and stationary sources (e.g., power plants), ground level ozone (O_3) has become one of the most serious air pollutants in Malaysia (power plants, industrial facilities, residential and commercial establishments) (Mohamad Hashim, Mohamed Noor, & Yusuf, 2018).

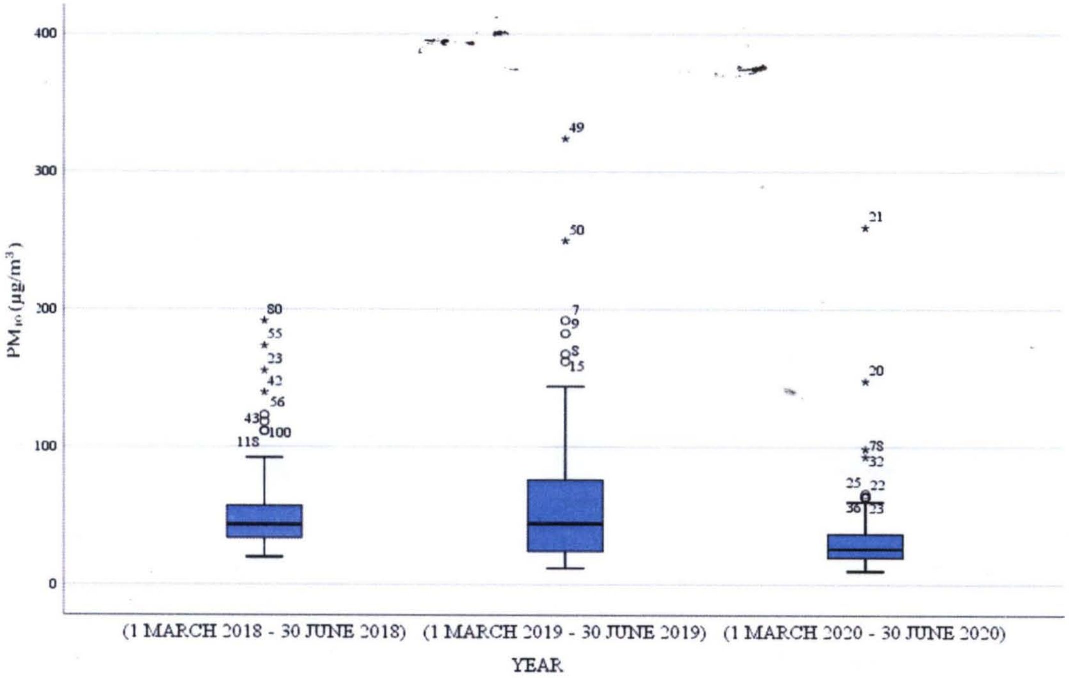
The CO parameter reveals that the minimum value is lowest in pandemic 2020 (0.483 ppm) and highest in 2018 (1.232), while the maximum value is highest in pandemic 2020 (6.735 ppm) and lowest in 2019 (3.213 ppm). The highest maximum value of CO during pandemic 2020 may be attributable to industrial processes involving the combustion of fossil fuels being at its peak during that time (Abdullah et al., 2020). The average daily mean CO concentration has dropped every year, with values of 2.3421 ppm (2018), 2.1289 ppm (2019), and 1.4734 ppm (2020). Figure 4.2 (f) illustrates that the box and whisker plots for 2018 and 2019 are normal distributions since the median is in the centre of the box, whereas the distribution for 2020 is skewed to the right. The kurtosis value also indicates the extreme high value for 2020, which is 15.774 when compared to two other years where the kurtosis value is negative, indicating that the distribution is flat with thin tails.

4.2.3 Descriptive Statistics for Pengerang, Johor Monitoring Stations

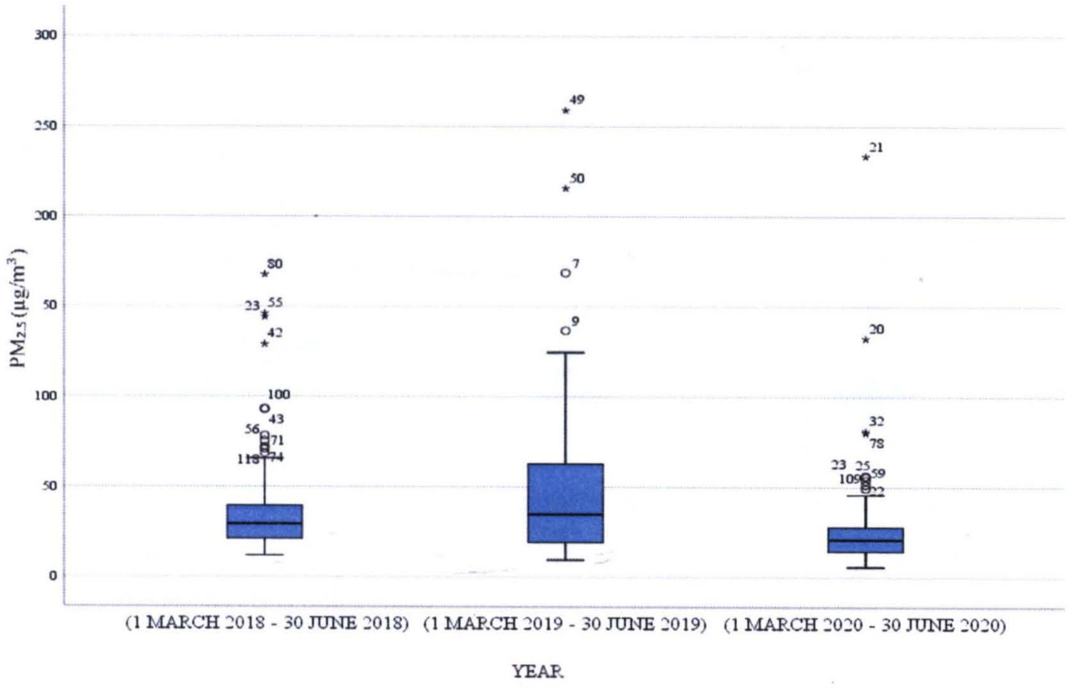
According to Rezayee, Ling, Ibrahimy, and Sadat (2020), Pengerang is the location with the most intense oil and gas activities in Malaysia. Pengerang Integrated Petroleum Complex (PIPC), which began in 2011 as the Refinery and Petrochemical Integrated Development (RAPID), in particular, offers enormous potential for industrial development in the region. The Pengerang Maritime Industrial Park (PMIP), Independent Deepwater Petroleum Terminal (PIDPT), Pengerang Integrated Complex (PIC), Refinery and Petrochemical Integrated Development (RAPID) project and other auxiliary facilities are all part of PIPC. The Pengerang Maritime Industrial Park (PMIP), Independent Deepwater Petroleum Terminal (PIDPT), Pengerang Integrated Complex (PIC), Refinery and Petrochemical Integrated Development (RAPID) project and other auxiliary facilities are all part of PIPC.

Table 4.4: Descriptive statistics of daily average air pollutant concentration at Pengerang, Johor

Parameter	Year	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
PM_{10} ($\mu g/m^3$)	2018	122	20.367	191.544	52.13374	29.4152504	2.381	6.909
	2019	122	12.077	324.084	59.98576	50.09488	2.217	7.036
	2020	122	10.07	259.621	32.50495	27.5953415	5.522	40.035
$PM_{2.5}$ ($\mu g/m^3$)	2018	122	11.897	167.514	36.08948	26.1290802	2.879	9.802
	2019	122	9.544	258.835	48.257	40.3506245	2.284	7.541
	2020	122	5.898	233.371	26.25855	24.9832423	5.621	41.28
SO_2 (ppm)	2018	122	0.0006	0.0061	0.001908	0.0010043	1.759	3.535
	2019	122	0.0007	0.0106	0.002316	0.0017347	2.586	7.717
	2020	118	0.0011	0.0136	0.001835	0.001399	6.594	48.309
NO_2 (ppm)	2018	122	0.0034	0.0509	0.012907	0.0067883	2.202	8.744
	2019	122	0.0037	0.0361	0.011897	0.006739	1.727	2.835
	2020	122	0.0027	0.0301	0.008701	0.0047619	1.924	4.611



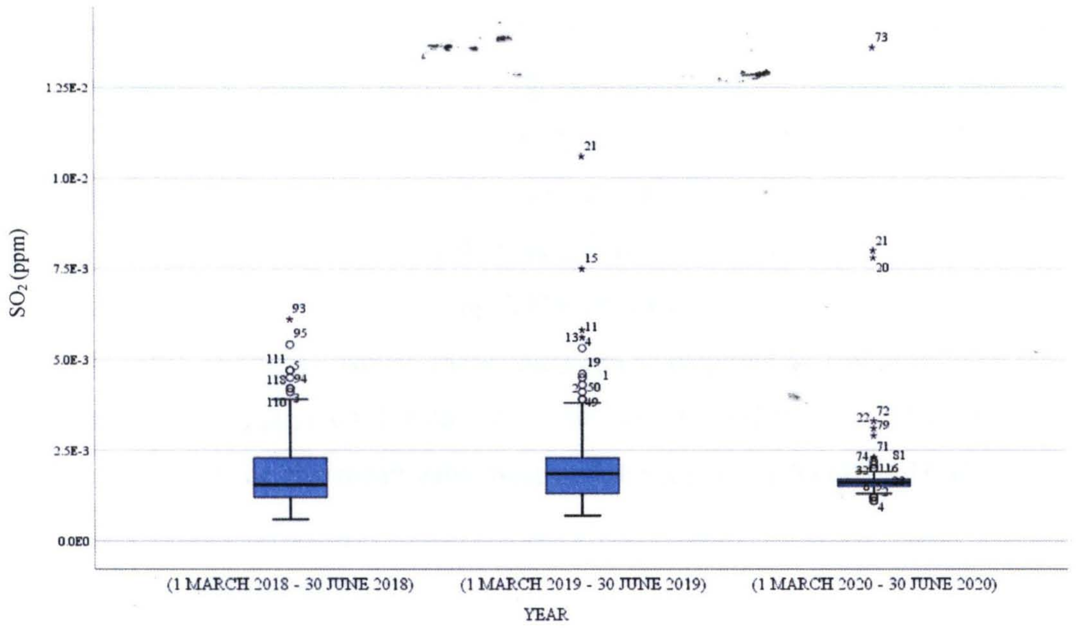
a) PM_{10} daily mean concentration at Pengerang, Johor



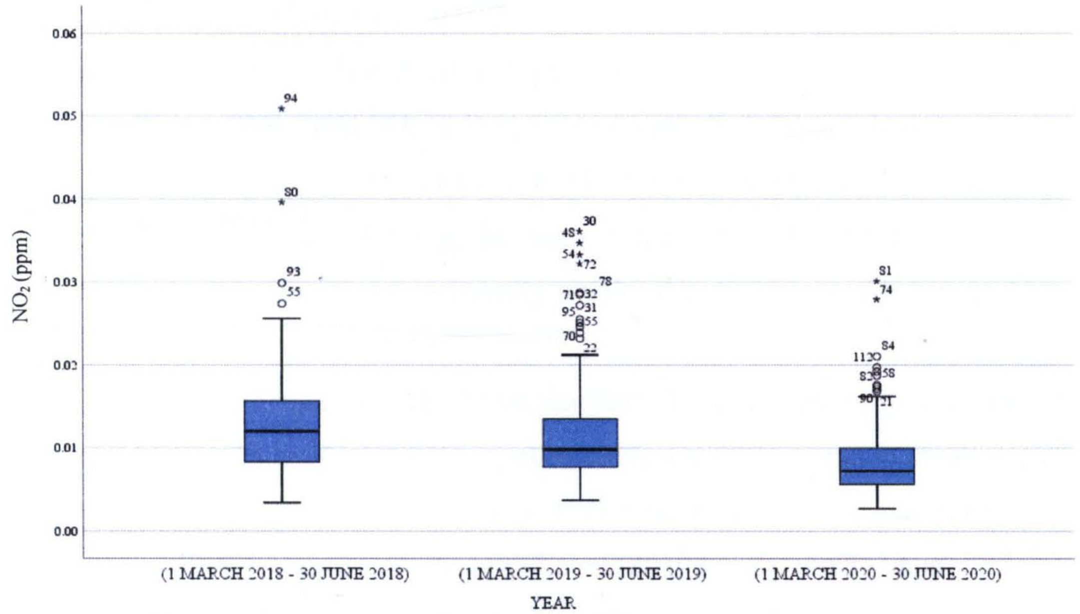
b) $PM_{2.5}$ daily mean concentration at Pengerang, Johor

Continued

Figure 4.3: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations during 1 March- 30 June 2018, 2019 and 2020 at Pengerang, Johor



c) SO_2 daily mean concentration at Pengerang, Johor



d) NO_2 daily mean concentration at Pengerang, Johor

Figure 4.3: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations during 1 March- 30 June 2018, 2019 and 2020 at Pengerang, Johor (Continued)

Symbols "*" represents the extreme out layer while symbols "o" represents the mile out layer that is based on interquartile range. The horizontal bar in each box represents the median.

Table 4.4 displays descriptive statistics for daily average air pollutant concentrations in Pengerang, Johor. The N value in Pengerang is 122 for all parameters and years except SO_2 in 2020, which is 118. Pengerang had the highest maximum value of PM_{10} concentration in 2019 at 324.084 µg/m^3, as well as the highest average daily mean for PM_{10} readings in 2019 at 50.09488 µg/m^3. However, it shows the reduction mean value on PM_{10} which is 32.50495 µg/m^3 in 2020. $PM_{2.5}$ shows that the highest reduction of mean value occurs during 2020 which are from 48.257 µg/m^3 (2019) to 26.25855 µg/m^3 (2020). However, these claim can be disputed by Abdullah et al. (2020), who state that Pengerang recorded the mean value before the MCO (14 – 17 March 2020) was 8.0 µg/m^3 and the rise mean value occurred during the MCO (18 – 31 March 2020) was 14.5 µg/m^3.

In 2020, for three consecutive years, the value of kurtosis and skewness at Pengerang has been positive for all parameters. However, the greatest kurtosis values of PM_{10}, $PM_{2.5}$ and SO_2 in 2020 are 40.035, 41.28, and 48.309, respectively, resulting in a large value of outliers, as illustrated in Figures 4.3 (a), (b), and (c) . The box plot for parameters PM_{10}, $PM_{2.5}$ and SO_2 at Pengerang reveals that the box lengths are shorter than in previous years, implying that the shorter the box length, the less dispersed the data. As shown by Figure 4.3 (c), the size of the box and whisker plots for SO_2 concentration in 2020 was also significantly smaller than the previous two years.

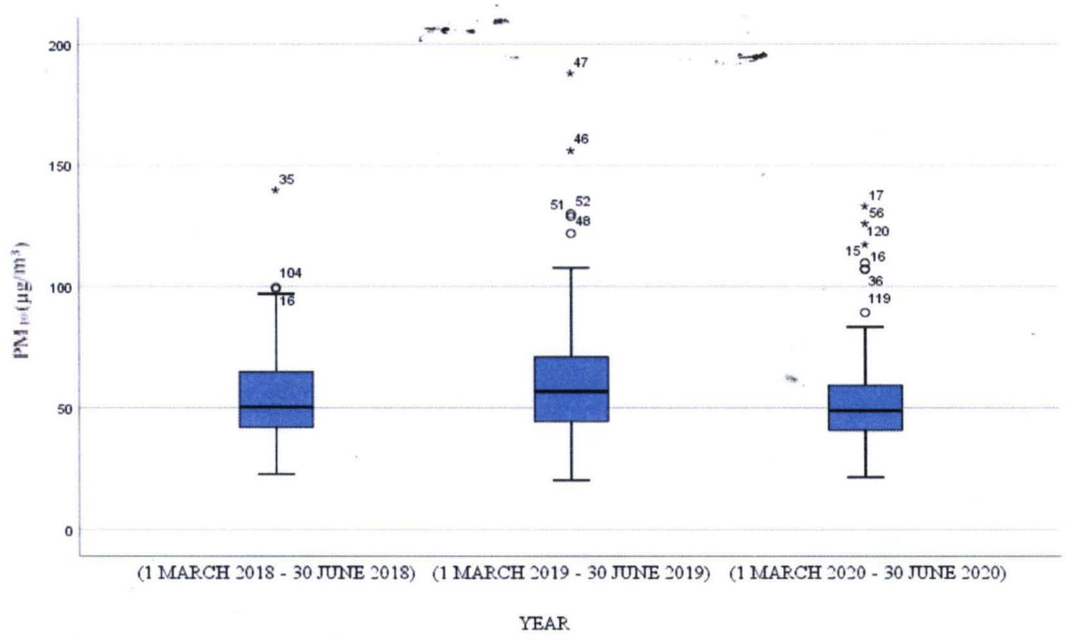
The maximum value of NO2 shows that the value is decreasing year by year, with values of 0.0509 ppm in 2018, 0.0361 ppm in 2019, and 0.0301 ppm in pandemic 2020. Parameter NO_2 shows a significant drop from year to year for mean daily average readings of 0.012907 ppm (2018), 0.011897 ppm (2019), and 0.008701 ppm (2020). The implementation of MCO during an outbreak of pandemic has been one of the reasons for the decrease in NO_2 readings. This is because the reading NO_2 is affected by the industrial activities in the area. This claim can be supported by similar research done by Skirienė and Stasiškienė, (2021), the intensity of industrial facilities, vehicles, and power plants influences NO_2 concentrations. It has the potential to have a considerable influence on human health, worsening respiratory disorders. Figure 4.3 (d) shows that the box and whisker plots for 2019 and 2020 are positively skewed, but the distribution is symmetric in 2018 with the highest outlier's values of 8.744.

4.2.4 Descriptive Statistics for Tanah Merah, Kelantan Monitoring Stations

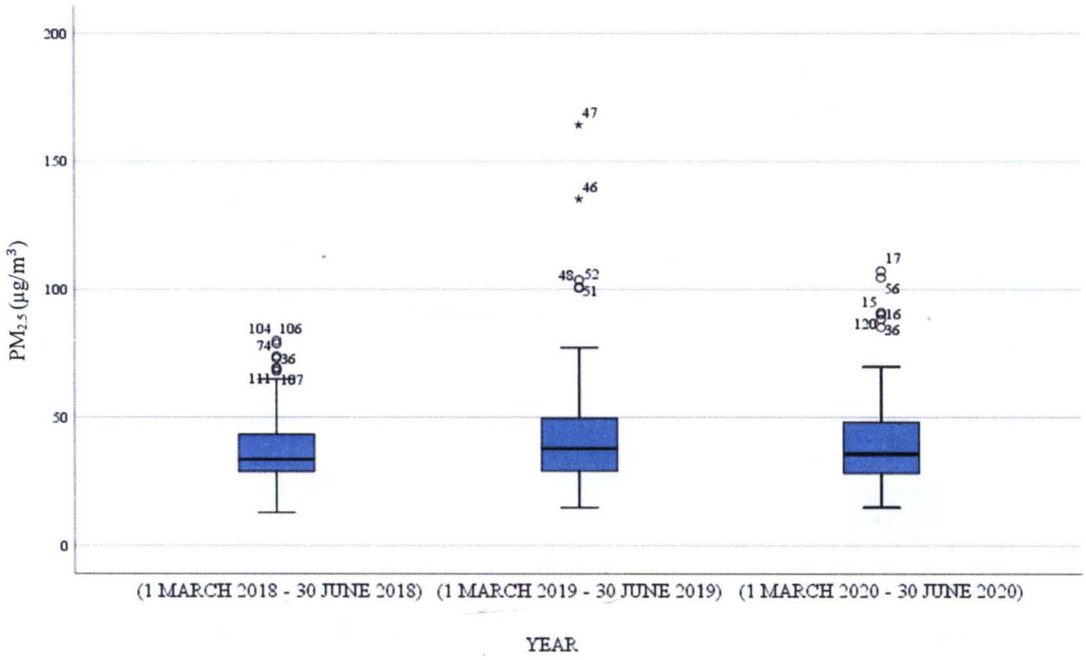
Tanah Merah, Kelantan's economic activities are centered on manufacturing, agriculture, and the agro industrial sector. Wood-processing is one of the largest manufacturing industries. According to Jemali, Muhammad, and Yahya (2020), Tanah Merah districts have the highest proportions of wood-based industries and factories, with 17.6 % respectively.

Table 4.5: Descriptive statistics of daily average air pollutant concentration at Tanah Merah, Kelantan.

Parameter	Year	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
PM_{10} (μg/m^3)	2018	122	22.905	139.742	54.72094	18.26679	1.38	3.312
	2019	122	20.331	187.886	60.96846	26.15038	1.749	5.104
	2020	122	21.581	133.072	52.29811	20.06678	1.675	3.949
$PM_{2.5}$ (μg/m^3)	2018	122	12.817	79.956	37.45899	14.15249	1.04	0.797
	2019	122	14.705	164.357	43.2386	22.65549	2.279	8.113
	2020	122	14.967	107.307	39.53835	17.76867	1.507	3.017
SO_2 (ppm)	2018	122	0.0003	0.0116	0.001998	0.002191	2.136	3.985
	2019	122	0.0004	0.02	0.001885	0.00253	5.361	33.575
	2020	122	0.0005	0.0018	0.00102	0.000207	0.637	1.634
NO_2 (ppm)	2018	122	0.0053	0.0191	0.010944	0.002687	0.6	0.268
	2019	122	0.0059	0.0493	0.013084	0.005492	4.225	24.445
	2020	122	0.0029	0.017	0.008724	0.003162	0.323	-0.614
O_3 (ppm)	2018	122	0.0135	0.0424	0.025187	0.005551	0.386	0.139
	2019	122	0.0156	0.0429	0.028345	0.005981	0.201	-0.309
	2020	122	0.012	0.0421	0.022557	0.005816	1.227	1.421
CO (ppm)	2018	122	0.677	2.252	1.057279	0.209264	1.772	7.789
	2019	122	0.627	2.707	1.258852	0.30818	1.144	3.53
	2020	122	0.523	1.973	0.977443	0.239723	0.822	1.719



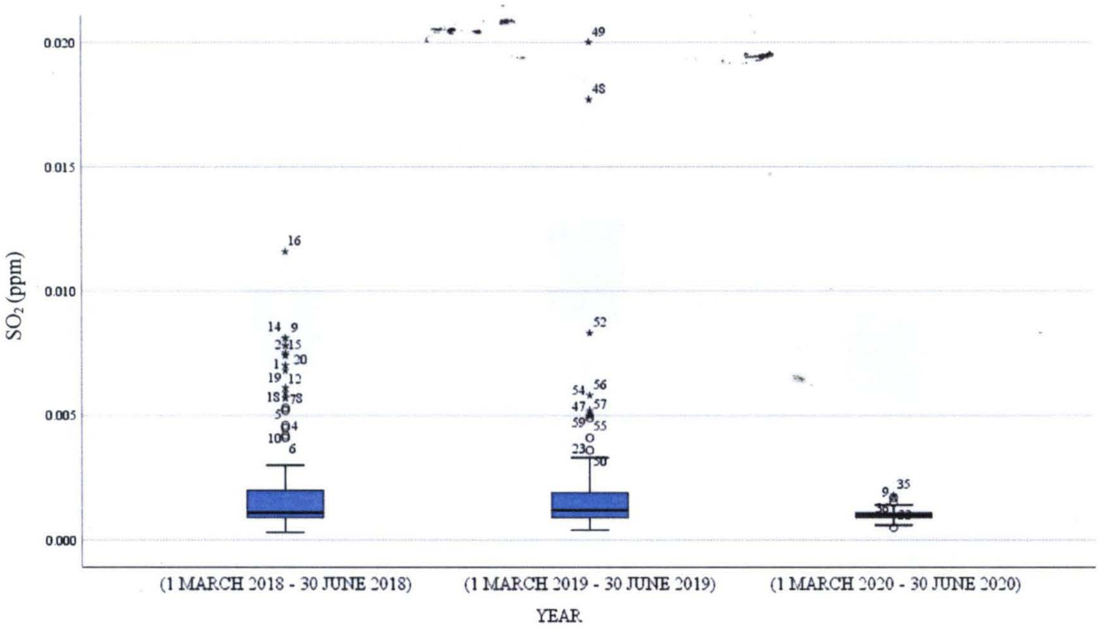
a) PM_{10} daily mean concentration at Tanah Merah, Kelantan



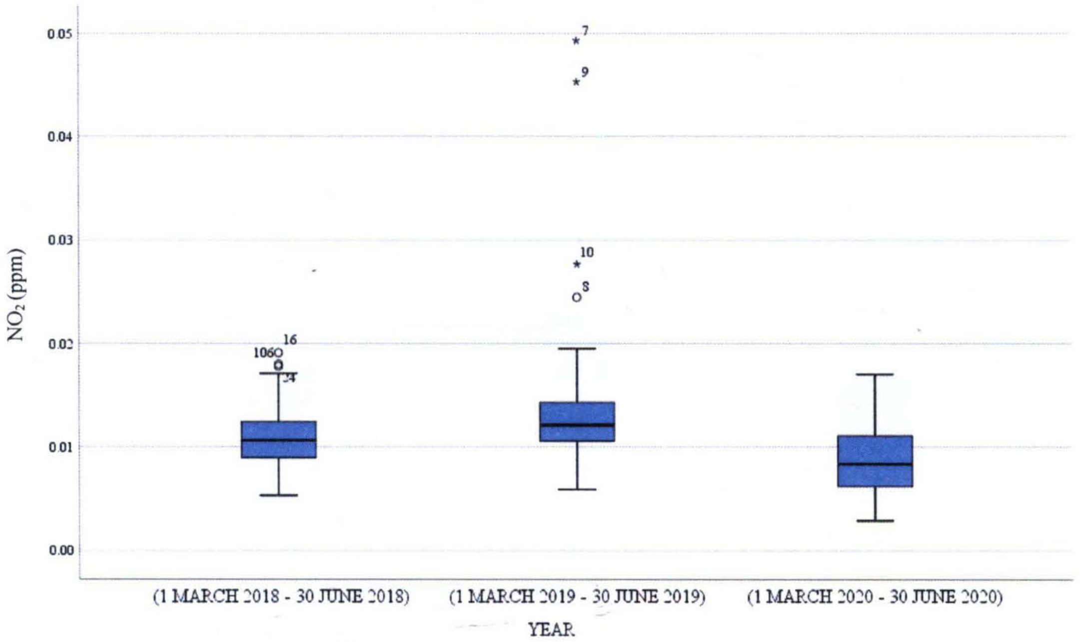
b) $PM_{2.5}$ daily mean concentration at Tanah Merah, Kelantan

Continued

Figure 4.4: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Tanah Merah, Kelantan



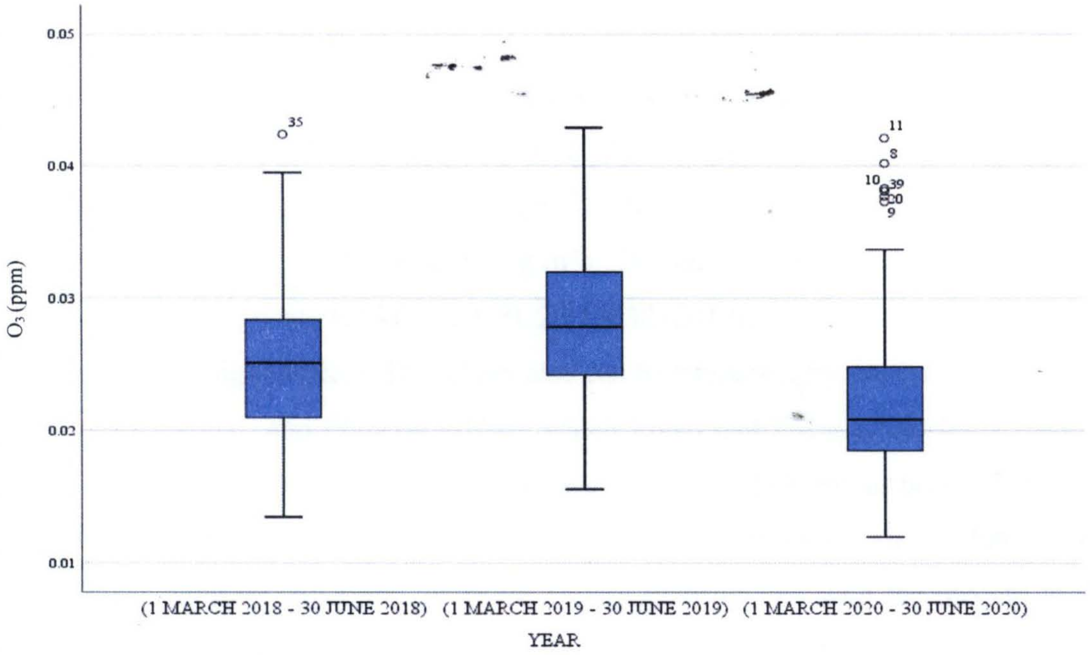
c) SO_2 daily mean concentration at Tanah Merah, Kelantan



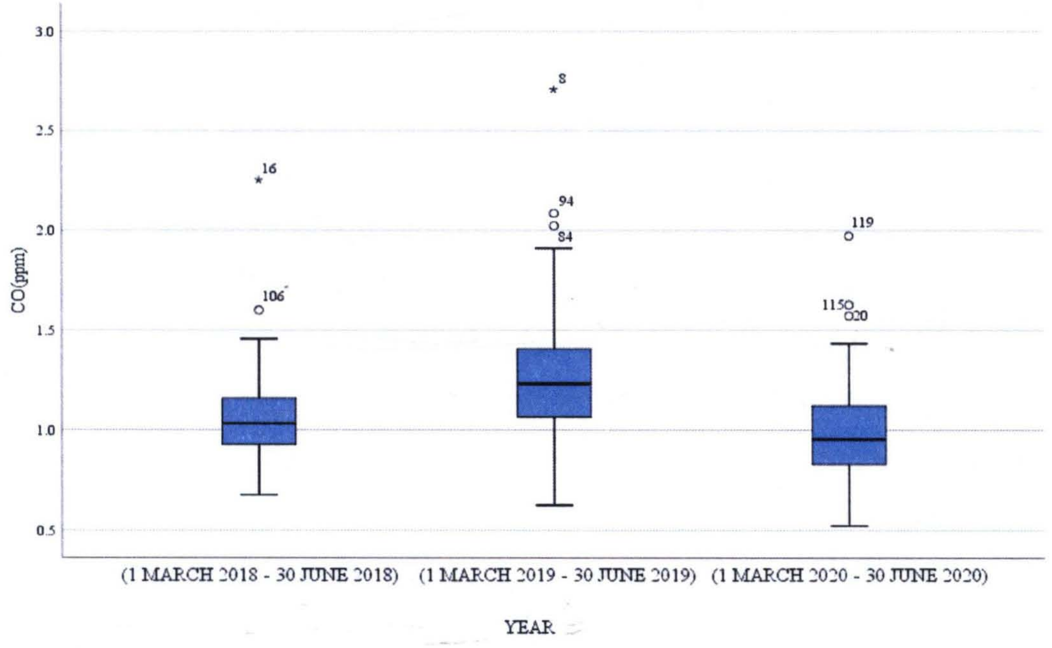
d) NO_2 daily mean concentration at Tanah Merah, Kelantan

Continued

Figure 4.4: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Tanah Merah, Kelantan (Continued)



e) O_3 daily mean concentration at Tanah Merah, Kelantan



f) CO daily mean concentration at Tanah Merah, Kelantan

Figure 4.4: The box and whisker plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO concentrations during 1 March- 30 June 2018, 2019 and 2020 at Tanah Merah, Kelantan (Continued)

Symbols "*" represents the extreme out layer while symbols "o" represents the mile out layer that is based on interquartile range. The horizontal bar in each box represents the median.

The descriptive statistic data of daily average air pollutant concentrations at Tanah Merah, Kelantan, are shown in Table 4.5. The N value for all parameters is 122 for all three years. Throughout the three-year period, the maximum value for PM_{10} was recorded as the lowest value in 2020 (133,072 µg/m^3). The decline in mean PM_{10} concentration also can be noticed in 2020 (52.29811 µg/m^3) when compared to same period in 2018 (54.72094 µg/m^3) and 2019 (60.96486 µg/m^3). The standard deviation values for PM_{10} are exceptionally high, at 18.26679 (2018), 26.15038 (2019), and 20.06678 (2020), owing to the extremely high outliers. This claim also can be supported by similar research done by Navinya, Patidar, and Phuleria (2020), which found that PM_{10} across India shows a drop in mean during the pre-lockdown 2020 when compared to similar period 2019 with standard deviations that are substantially overlapped. Figure 4.4 (a) shows that the box and whisker plots for 2019 and 2020 are normal distributions with the median in the middle of the box, but the distribution is positive skewed for 2018.

In perspective of the $PM_{2.5}$ parameter, the minimum value was the lowest in 2018 (12.817 µg/m^3), grew in 2019 (14.705 µg/m^3), and continued to increase slightly in 2020 (14.967 µg/m^3). For maximum value, the highest value was recorded during 2019, which is 164.357 µg/m^3, while the lowest value was recorded during pandemic 2020, which is 107.307 µg/m^3. The average daily mean concentration of $PM_{2.5}$ show the reduction from 2019 (43.2386 µg/m^3) to 2020 (39.53835 µg/m^3). According to the findings of an observation-based study conducted by Abdullah et al. (2020), Tanah Merah recorded the mean value before the MCO (14 – 17 March 2020) of 22.9 µg/m^3 and the reduction value during the MCO (18 – 31 March 2020) of 22.38 µg/m^3. Figure 4.4 (b) illustrates that the box and whisker plots for $PM_{2.5}$ in three consecutive years are positively skewed, with the median near the bottom of the box. The tails of the box and whiskers for $PM_{2.5}$ similarly reveal that it is right skewed, with values of 1.04 (2018), 2.279 (2019), and 1.507 (2020).

The minimum value for SO_2 reveals that the value has been growing year after year, and was 0.0003 ppm (2018), 0.0004 ppm (2019), and 0.0005 ppm (2020). The maximum value, on the other hand, represents the reduction value from 2019 to 2020, which values from 0.02 ppm to 0.0018 ppm. Based on Figure 4.4 (c), the size of the box and whisker plots for SO_2 concentration in 2020 was likewise significantly smaller than the previous year. This is related to the lowest values of standard deviation, skewness, and kurtosis, which are 0.000207, 0.637, and 1.634, respectively. The average daily mean concentration of SO_2 show the reduction through year from 2018 (0.001998 ppm), 2019 (0.001885 ppm) and 2020 (0.00102 ppm). Furthermore, in an observation based study by Navinya et al., (2020), a significant drop in SO_2 mean air pollutant concentrations can be seen beginning on March 22, 2020 ahead to the start of national lockdown across India.

The highest minimum and maximum values of NO_2 were reported in 2019, at 0.0059 ppm and 0.0493 ppm, respectively, while the lowest minimum and maximum values of NO_2 were recorded during pandemic 2020, at 0.0029 ppm and 0.017 ppm. In 2020, the average daily mean concentration of NO_2 recorded the lowest value of 0.008724 ppm, compared to period 2018 (0.010944 ppm) and 2019 (0.013084 ppm). However, according to Oo et al. (2021), the northern part of Thailand had experienced the greatest increase in NO_2 mean levels during the COVID-19 pandemic, owing to biomass burning. This Figure 4.4 (d) shows the box and whisker plots for NO_2 in 2020 may be lower than the equivalent plot for previous year which is in 2018 and 2019. All of the skewness values are positive, specifically 0.6, 0.201, and 1.227, indicating that the distribution is skewed to the right. Except for 2020, the kurtosis value for NO_2 is negative, -0.614, indicating that the distribution has thin tails.

The maximum value for parameters O_3 and CO shows that the highest value is in 2019, with 0.429 ppm and 2.707 ppm, respectively, while the lowest value is in 2020, with 0.421 ppm and 1.973 ppm. Scientists discovered that the average surface ozone concentration increased by a factor of 1.5–2 since all man-made emissions were limited owing to the COVID-19 lockdown Navinya et al., (2020). The minimum value for CO also reveals that it has been decreasing over year, with values of 0.667 ppm (2018), 0.627 ppm (2019), and 0.523 ppm (2020). Figure 4.4 (e) and 4.4 (f) show the size of box plots of O_3 and CO are the highest one in 2019 compared to other years. This is because the highest average daily mean concentration in 2019 of O_3 and CO are 0.429 ppm and 2.707 ppm. All of the standard distribution and skewness values for O_3 and CO imply that the distribution is skewed to the right.

4.3 Comparison of Air Quality Status Before and During the Pandemic

The comparison of air quality status before and during the pandemic by using daily air pollutant index (API) and air pollution concentration data is the second objective of this thesis report. In this section, the objective two of this thesis will be represented by two graphs: a line graph and a bar graph.

Firstly, a line graph was used to compare the trend of each pollutant before and during the pandemic at industrial areas in Peninsular Malaysia, specifically Paka (Terengganu), Pengerang (Johor), Petaling Jaya (Selangor), and Tanah Merah (Kelantan). The line graph below depicts the trend of average daily maximum concentrations of PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO at various industrial air monitoring stations. The period of daily average trend of Air Pollutant Index (API) and air pollutants concentration data from 1 March to 30 June 2018, 2019, and 2020 at four industrial monitoring station areas. For each air pollutant concentration, the dashed red line represents the value level of the Malaysian Ambient Air Quality Guidelines (MAAQG).

Second, the variation of daily air pollutants concentrations and the Air Pollutant Index (API) at four industrial monitoring stations in Peninsular Malaysia is shown using a bar chart to compare the rise and reduction values for each pollutant before and during the pandemic. The variation range is divided into two parts: 1 March to 30 June (2018-2019) and 1 March to 30 June (2019-2020).

4.3.1 Trend of PM_{10}

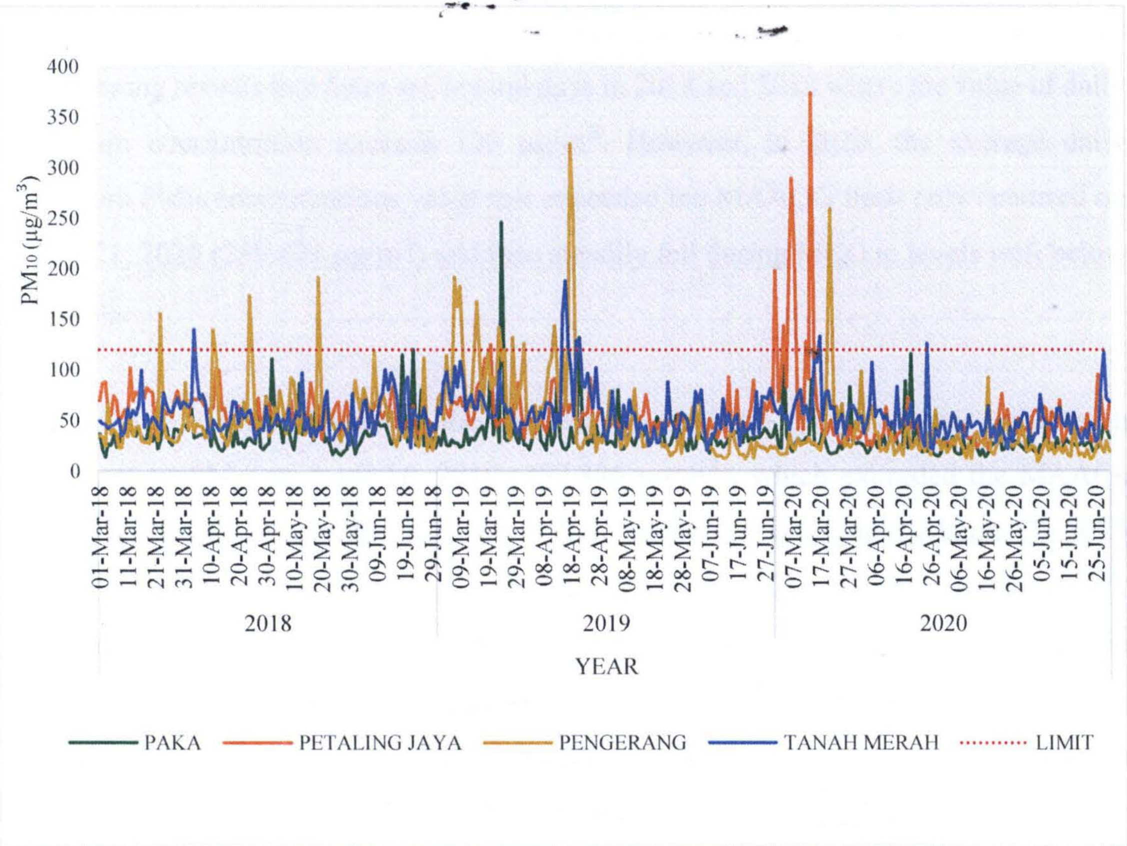


Figure 4.5: Trend of Average Daily Maximum PM_{10} concentration (Department of Environment Malaysia, 2020)

Figure 4.5 shows the trend of average daily maximum PM_{10} concentrations. During 2018 and 2019, Petaling Jaya achieved average daily maximum PM_{10} concentrations well below 120 µg/m^3 every day. However, Petaling Jaya recorded the highest maximum concentration of PM_{10} that exceeded 120 µg/m^3 on 14 March 2020 (374.34 µg/m^3), during the pandemic but before the implementation of MCO. Then, from 15 March 2020 to 30 June 2020, the average daily maximum PM_{10} concentrations at Petaling demonstrate a continuous reduction much below 120 µg/m^3, meeting the Malaysian Ambient Air Quality Guidelines for 24-hour PM_{10} (MAAQG). The changes in PM_{10} concentrations can be attributed to an increase in forest and biomass burnings, which are the primary causes of high particulate events (HPE) in Malaysia, as well as an unusually high number of automobiles and industrial emissions in urban areas (Awang, Ramli, Shith, Zainordin, & Monogaran, 2018).

The second highest reading of daily average maximum concentration PM_{10} is located at Pengerang, Johor which is 324.084 µg/m^3 (18 April 2019) which is exceed the MAAQG limit (120 µg/m^3). The trend of average daily maximum PM_{10} concentrations in Pengerang reveals that there are several days in 2018 and 2019 where the value of daily maximum concentration exceeds 120 µg/m^3. However, in 2020, the average daily maximum PM_{10} concentrations value that exceeded the MAAQG limit only occurred on March 21, 2020 (259.621 µg/m^3) and then steadily fell during MCO to levels well below the limits.

Tanah Merah reported the highest reading of daily average maximum concentration PM_{10} on April 16, 2019 (187.886 µg/m^3), which exceeded the MAAQs limit, and then showed a declining trend well below the limits until March 17, 2020 (133.072 µg/m^3), when the value reported to exceed the MAAQG limit was recorded. The trend then declined during the implementation of MCO, which was well below the MAAQG limit, but only on April 25, 2020 (125.966 µg/m^3) did the value exceed the limitations. Paka only shows the highest reading of daily average maximum concentration PM_{10} that exceeds the MAAQG limit once in three years, on March 24, 2019, with a value of 245.739 µg/m^3, and the values for the remaining days are significantly below the limits.

According to Chooi and Yong (2016), the high concentration of PM_{10} is attributable to the high concentration of industrial sectors in the surrounding area. High levels of PM_{10} were also linked to the Southeast Asian haze incident, which was caused by uncontrolled forest fires in Indonesia. During the Covid-19 lockdown in 2020, these activities substantially decreased, resulting in a drastic drop and degradation in PM_{10}, particularly in places that are highly contaminated associated with transportation, production, and industrial activities (Hasnain et al., 2021). Exposures to fine particulate matter causes early death in people with heart or lung illness, including nonfatal heart attacks, asthma, and reduced lung functioning (Ghorani-Azam et al., 2016).

As a result, the reduction in certain activity, particularly in industrial regions, has resulted in a reduction in PM_{10} during MCO. Following the implementation of MCO on 18 March 2020 in Malaysia, the concentration trend of PM_{10} for all locations has declined and the reading is well below 120 μg/m^3 every day until 30 June 2020, which is considerably meet the 24-hour PM$_{10}$ the Malaysian Ambient Air Quality Guidelines (MAAQG) because it does not exceed more than 120 μg/m^3.

4.3.2 Trend of PM$_{2.5}$

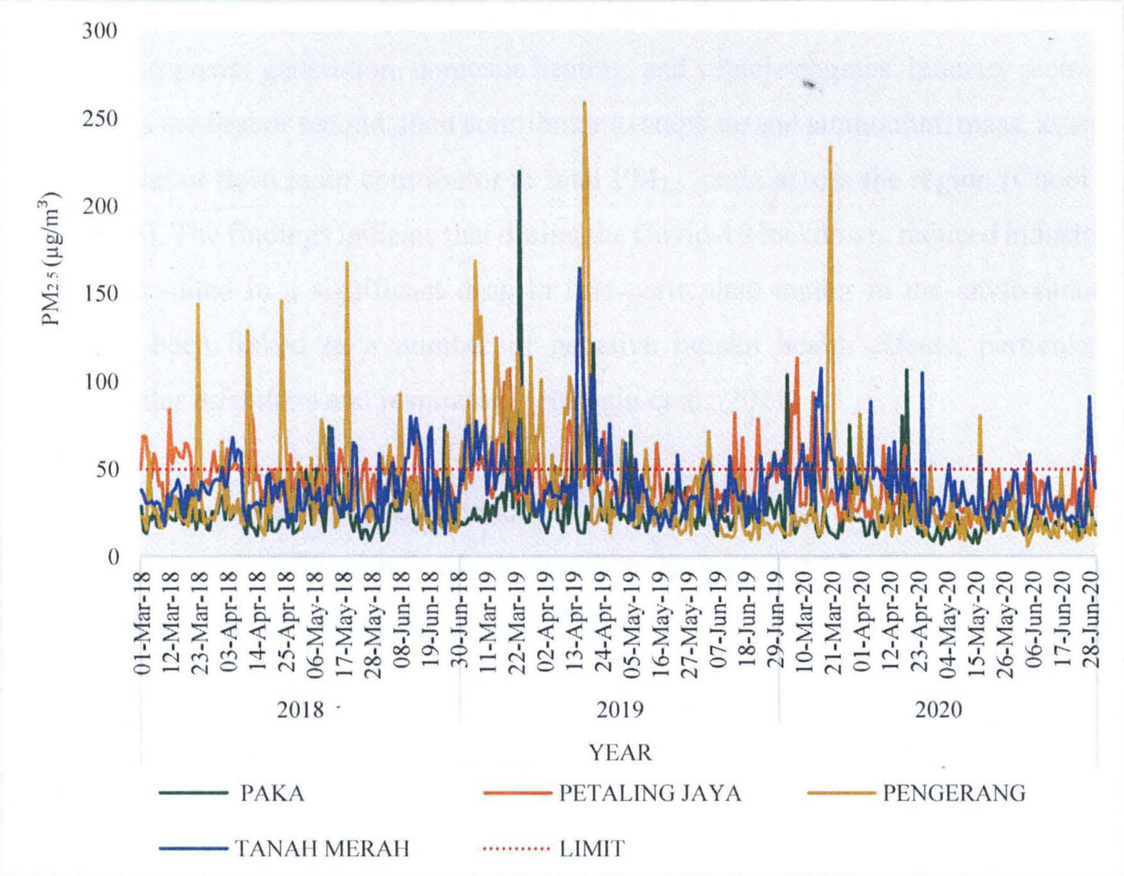


Figure 4.6: Trend of Average Daily Maximum PM$_{2.5}$ concentration (Department of Environment Malaysia, 2020)

PM$_{2.5}$ pollution can arise from a wide range of sources, making it a very complicated sort of pollution. The particles are directly emitted from some PM$_{2.5}$ sources. Some power plants and industrial processes are examples of "primary sources." Secondary PM$_{2.5}$ particles, on the other hand, are created when various substances react in the air. Chemicals from coal power plants or automotive exhaust can mix with atmospheric water vapor and sunlight to generate new particles or compounds, which can be as small as 2.5 microns. PM$_{2.5}$ is a major public health problem and it has been connected to a variety of illnesses.

The parameter $PM_{2.5}$ in Figure 4.6 shows the similar trend with no clear decreasing concentrations after the implementation of MCO. However, it can be seen that the highest maximum value of $PM_{2.5}$ is located at Pengerang which is 258.853 µg/m^3 on April 18, 2019. During the MCO, the parameter $PM_{2.5}$ also recorded the highest average reading at Pengerang, which was 233.371 µg/m^3 on March 21, 2020, but the reading dramatically declined after that.

The highest reading of $PM_{2.5}$ because of the industrial sector during combustion fuels, such as power generation, domestic heating, and vehicle engines. Industry sector is identified as the first or second main contributor to sulphate and ammonium mass, as well as the second or third main contributor to total $PM_{2.5}$ mass across the region (Chooi & Yong, 2016). The findings indicate that during the Covid-19 lockdown, reduced industrial processes resulted in a significant drop in fine particulate matter in the environment, which has been linked to a number of negative human health effects, particularly cardiovascular infections and respiratory (Hasnain et al., 2021).

Overall, during the MCO period, most of the average concentrations for all locations are less than 50 µg/m^3, which significantly meets the Malaysian Ambient Air Quality Guidelines (MAAQG) for 24-hour $PM_{2.5}$.

4.3.3 Trend of SO_2

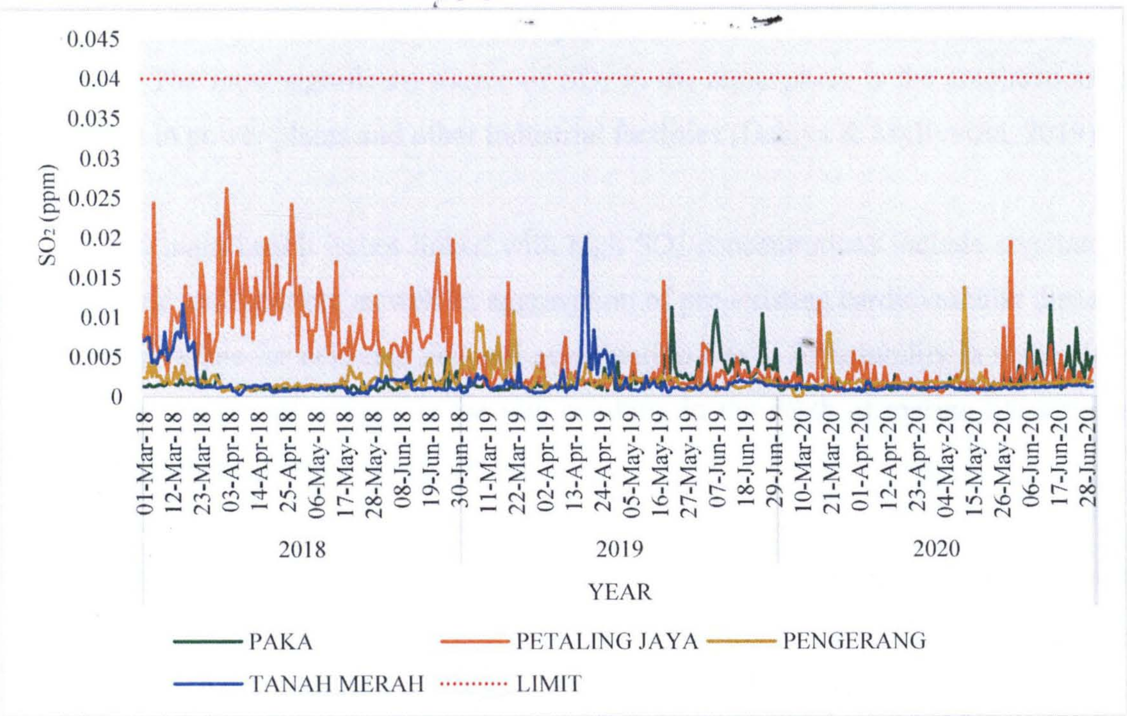


Figure 4.7: Trend of average daily maximum SO_2 concentration (Department of Environment Malaysia, 2020)

In research from Filonchyk et al. (2020), sulphur dioxide sometimes known as SO_2, is a chemical compound. It is a poisonous gas that causes the odour of burnt matches. It is produced naturally as a by-product of the combustion of sulphur-contaminated fossil fuels.

In 2018, the trend graph in Figure 4.7 of the SO_2 maximum value near Petaling Jaya showed a high reading compared to other years. The rise in industrial, motorized traffic, and agricultural activities will result in an incremental increase in numerous air pollutants, such as sulphur dioxide (SO_2) (Awang et al., 2018).

The maximum value trend of SO_2 concentration dropped in 2019 and continued to decline during the pandemic 2020. The highest maximum value of SO_2 in Tanah Merah was 0.02 ppm (2019), and it continues to exhibit a decent dropping reading and remains consistent in 2020, which is during the pandemic.

However, there are still days when the maximum SO_2 level is significantly higher than usual for every monitoring location, which could be linked due to industry activity nearby. This is due to the fact that the power plants were still running during the lockdown. The most significant source of SO_2 in the atmosphere is the combustion of fossil fuels in power plants and other industrial facilities (Dahiya & Myllyvirta, 2019).

The main health issues linked with high SO_2 concentrations include respiratory irritation and malfunction, as well as aggravation of pre-existing cardiovascular disease. SO_2 is responsible for acid rain and soil acidification due to its solubility in water. SO_2 reduces the amount of oxygen in the sea, resulting in the death of marine life such as plants and animals (Hasnain et al., 2021).

Overall, the trend of SO_2 for all locations reveals that the average maximum value has been below 0.04 ppm for three years, according to Malaysian Ambient Air Quality Guidelines (MAAQG). Moreover, when compared to the other three locations, Paka has the best reading value for three consecutive years.

4.3.4 Trend of NO_2

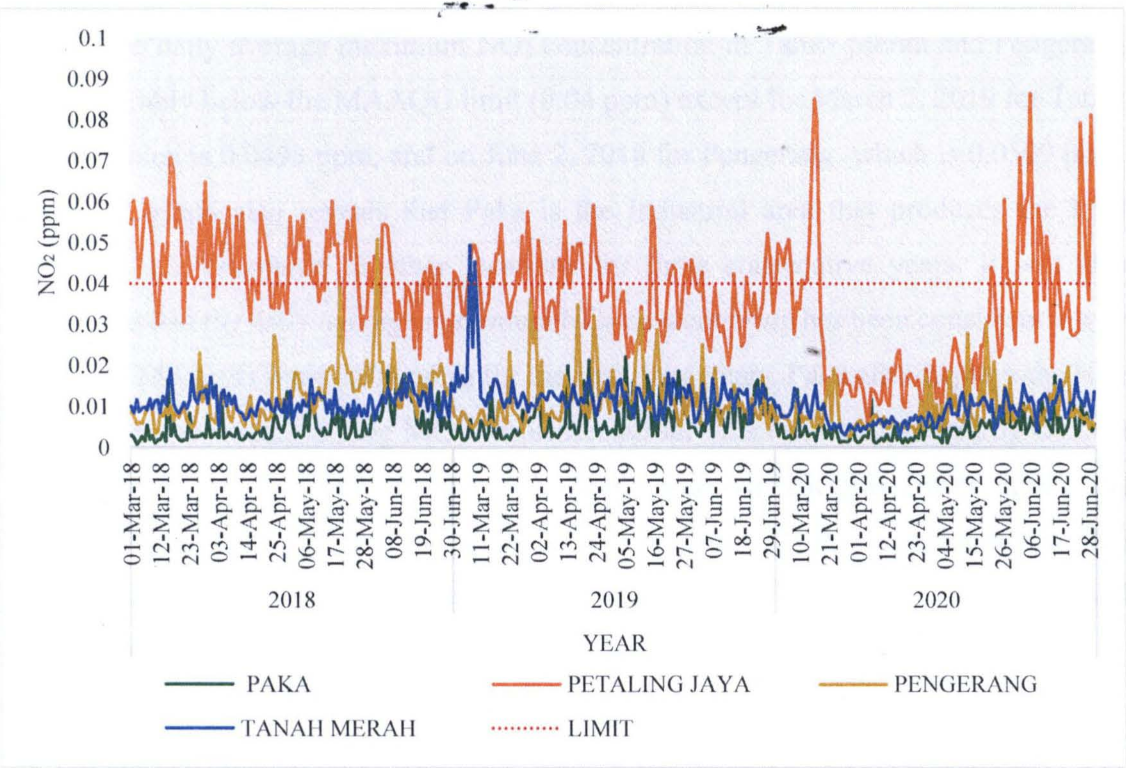


Figure 4.8: Trend of average daily maximum NO_2 concentration (Department of Environment Malaysia, 2020)

For three consecutive years, the graph pattern in Figure 4.8 reveals that Petaling Jaya is the industrial location that provides the most NO_2 pollution compared to other air industrial monitoring stations. The maximum value of NO_2 at Petaling Jaya was recorded 0.0852 ppm (16 March 2020) during the pandemic but before the implementation of MCO. The reading was drastically declined to 0.0303 ppm (18 March 2020) during the implementation of MCO. According to Ghosh and Ghosh (2020), the decrease in NO_2 level may be attributable to a reduction in fuel combustion during the lock-down. Nitrogen oxides are emitted into the air by motor vehicle exhaust, coal, oil, and natural gas combustion. However, on June 6, 2020, the NO_2 value increased drastically to 0.0864 ppm, which is the highest reading for the maximum value for parameter NO_2. According to Hasnain et al. (2021), the Tlymphocytes, particularly CD8+ cells and natural killer cells, have been demonstrated to be affected by 2.0–5.0 ppm NO_2 exposures, which play a crucial role in host defenses against viruses. Despite the fact that these levels are high, epidemiologic studies show that NO_2 has an influence on respiratory illness rates in children. Nitrogen oxide (NO_2) emissions have the strongest link to human use of fossil energy of all the air pollutants (Wang et al., 2020).

The daily average maximum NO_2 concentration in Tanah Merah and Pengerang is considerably below the MAAQG limit (0.04 ppm) except for March 7, 2019 for Tanah Merah, which is 0.0493 ppm, and on June 2, 2018 for Pengerang, which is 0.0509 ppm. The trend graph also reveals that Paka is the industrial area that produces the least pollution NO_2 compared to other locations for three consecutive years. It was also discovered that the daily average maximum NO_2 concentration has been consistently well below the MAAQG limit (0.04 ppm) for the past three years. Paka also displays the NO_2 reduction trend reading during MCO implementation. This can be supported by Olusola et al. (2021), the data indicate that NO_2 levels were significantly lower during the lockdown period compared to the pre-lockdown period in 2019. The reduction in NO_2 concentration levels during lockdown is most likely due to less traffic, socializing, and limits on business and human activities.

4.3.5 Trend of O_3

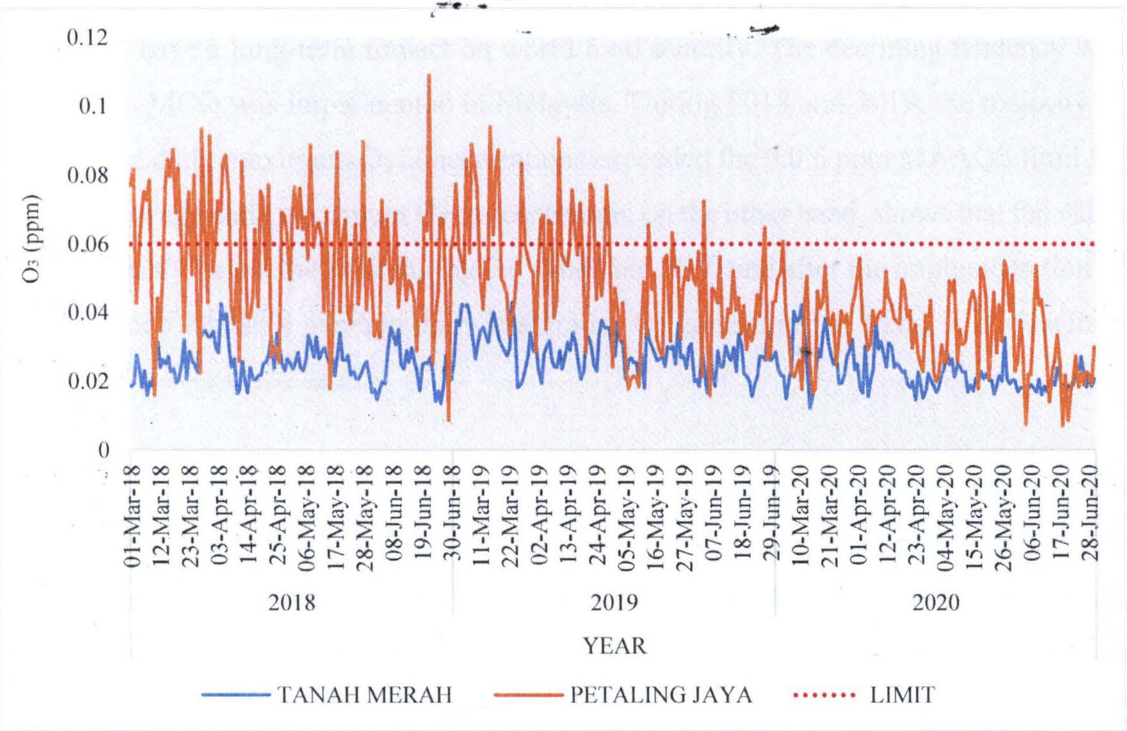


Figure 4.9: Trend of average daily maximum O_3 concentration (Department of Environment Malaysia, 2020)

Ozone is a gas that exists in both the upper and lower atmospheres which is on ground level of the Earth. Depending on where it is in the atmosphere, ozone can be either "good" or "bad" for nature and environment. The protective ozone layer exists naturally in the upper atmosphere (the stratosphere), 6 to 30 miles above the Earth's surface, shielding the Earth from the sun's ultraviolet rays. Ground-level ozone, which is found in the Earth's lower atmosphere, is a significant photochemical pollutant. When pollutants such as volatile organic compounds (VOCs) and nitrogen oxides chemically react in the presence of sunlight, surface ozone (O_3) is generated. As a result, the highest amounts of ozone pollution occur when the weather is sunny (Karthik et al., 2017). These pollutants are produced by automobiles, power plants, industrial boilers, refineries, chemical facilities, and other sources.

The trend graph in Figure 4.9 clearly shows the decrease in air pollution of O_3 parameters in Petaling Jaya. On June 20, 2018, the highest value of average daily maximum O_3 concentration was recorded, which was 0.0638 ppm, which exceeded the MAAQG limit. According to Hasnain et al. (2021), the ground-level ozone (GLO) is thought to be associated with a greater risk of respiratory disorders, including asthma. In terms of the environment, O_3 can inhibit carbon uptake in trees, resulting in deforestation, which can have a long-term impact on world food security. The declining tendency was clear when MCO was implemented in Malaysia. During 2018 and 2019, the majority of the average daily maximum O_3 concentrations exceeded the 0.0.6 ppm MAAQS limit for O_3. The average daily maximum O_3 concentration, on the other hand, shows that the value is significantly below the limit during the pandemic 2020 and after the implementation of MCO. Tanah Marah's average daily maximum O_3 concentration trend is consistently substantially below the limit.

The graph also reveals that Petaling Jaya is the industrial area that contributes to the highest O_3 pollution compared to Tanah Merah. According to Karthik et al. (2017), ozone levels were shown to be greater in an industrial town than in a non-industrial town that increased chronic respiratory problems. The O_3 concentrations exhibit similar trends as those found by Awang et al., (2018) that relatively higher O_3 concentrations during high particulate events (HPE) were recorded in Shah Alam, Petaling Jaya and Bandaraya Melaka. The researcher also stated that high O_3 concentrations correspond to high solar radiation intensity during the day, which is a suitable condition for initiating photochemical reactions.

4.3.6 Trend of CO

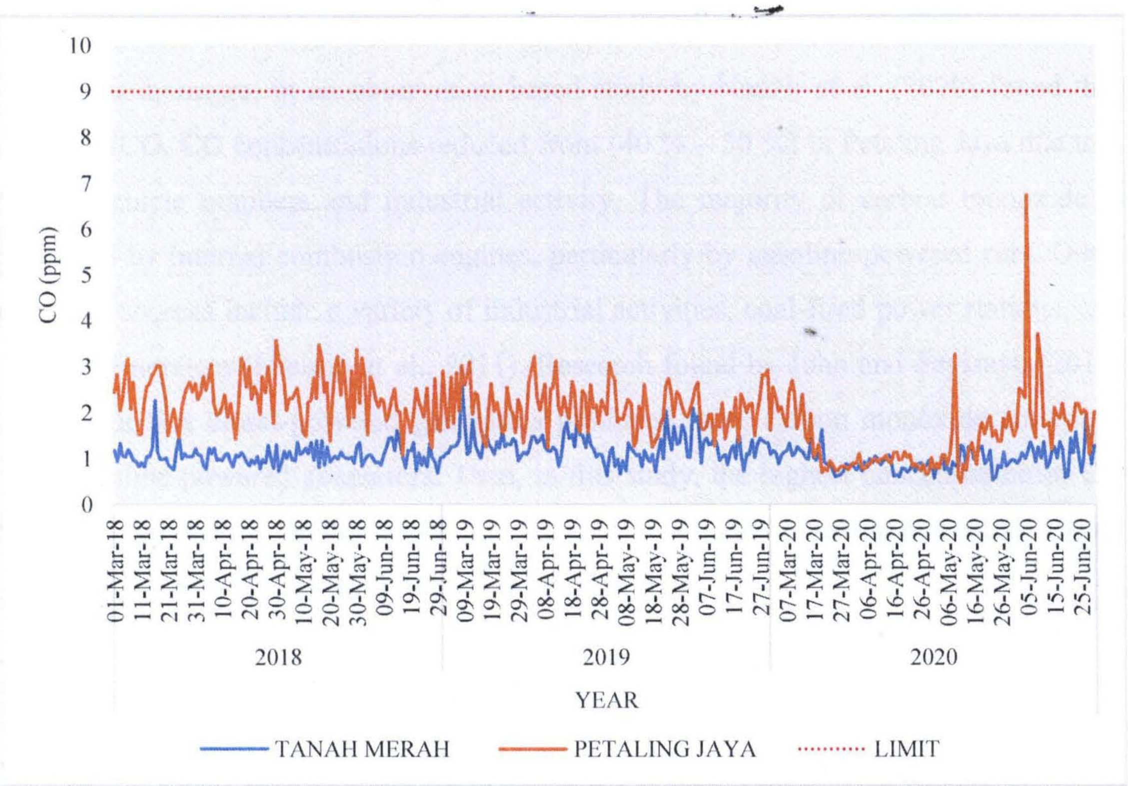


Figure 4.10: Trend of average daily maximum CO concentration (Department of Environment Malaysia, 2020)

Carbon monoxide (CO) is a typical industrial hazard that occurs when carbon-containing materials such as natural gas, gasoline, kerosene, oil, propane, coal, or wood are burned incompletely. CO produced by internal combustion engines is one of the most common causes of exposure in the workplace (Harper & Croft-Baker, 2012). Manufacturing industries emit a significant amount of carbon monoxide into the atmosphere, lowering air quality. Many manufacturing sectors can be located in Petaling Jaya and Tanah Merah, which have impacted the air quality.

Based on Figure 4.10, the average daily carbon monoxide concentration at all study locations for three consecutive years was below the MAAQG standard. The decrease in air pollution for CO parameters clearly occurred at Petaling Jaya and Tanah Merah when the MCO in Malaysia was conducted. The trend graph in Figure 4.10 also shows that Petaling Jaya is an industrial area that contributes to air pollution with the highest CO parameter compared to Tanah Merah for three consecutive years. During the implementation of the MCO, it can be seen that the carbon monoxide reading recorded a better reading than on other days at Petaling Jaya starting on 20 March 2020 until 7 May 2020 and after that it showed a slight increase in readings as usual on the following days.

Furthermore, in an observation-based study by Nadzir et al. (2020) found that during MCO, CO concentrations reduced from (40 % – 50 %) in Petaling Jaya due to a fall in vehicle numbers and industrial activity. The majority of carbon monoxide is produced by internal combustion engines, particularly by gasoline-powered cars. Other common sources include a variety of industrial activities, coal-fired power stations, and waste incinerators (Nielsen et al., 2011). Research found by John and Feyisayo (2013) stated that that diesel-powered generators produced more carbon monoxide emissions than gasoline-powered generators. Thus, in this study, the highest concentration of CO was reported in Petaling Jaya, which is the center of many industrial activities, despite the fact that the pollutant level did not exceed the standard.

4.3.7 Trend of Air Pollutant Index (API)

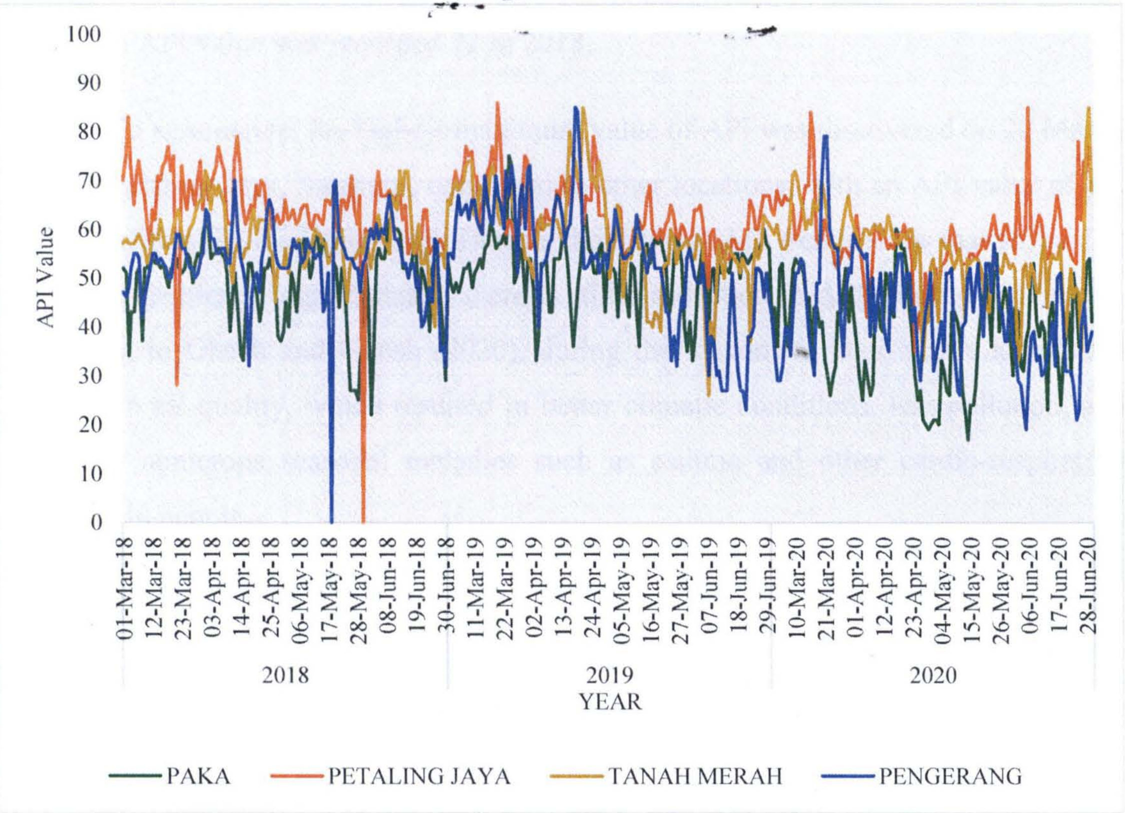


Figure 4.11: Trend of average daily maximum concentration of Air Pollutant Index (API) (Department of Environment Malaysia, 2020)

The Figure 4.11 shows that there is some improvements in the trend of the Air Pollutant Index (API) at four industrial monitoring stations. On average, the reading of highest maximum API value at Petaling Jaya is increased for the period of 2018 (1 March to 30 June), and 2019 (1 March to 30 June), which is 83 (2018) and 86 (2019). However, it shows the reduction value in 2020, which is 85 during the pandemic.

In this research, it shows that the highest minimum value of air pollutant index (API) at Paka Terengganu has been raised from 22 (2018) to 33 (2019) but shows a huge reduction of 17 (2020) due to the pandemic. The highest maximum value also shows the reduction of 60 (2020), which is the lowest reading compared to 62 (2018) and 75 (2019). This is due to Malaysia's energy demands in the industrial sector rising by the day (Tronoh , Perak, 2014).

At Pengerang, the highest maximum API reading has increased marginally from 70 (2018) to 85 (2019). The highest maximum API reading, on the other hand, shows a reduction of 79 in 2020 during the pandemic. The status of highest maximum API reading at Tanah Merah, Kelantan was at moderate level for all three years, however the lowest maximum API value was recorded 72 in 2018.

To summarize, the highest maximum value of API was discovered on 20 March 2019 in Petaling Jaya, Selangor, compared to other locations, with an API value of 86, which is within the moderate level. Despite the fact that API trends show that air quality during pandemics is unpredictable, there is still a reduction in APIs during pandemics. According to Ghosh and Ghosh (2020), during the lockdown, there was a significant increase in air quality, which resulted in better climatic conditions, less pollution, and improved numerous seasonal maladies such as asthma and other cardio-respiratory disorders in people.

4.3.8 Reduction of Air Pollution Status Before and During Pandemic

Table 4.6 below shows the variation of daily air pollutants concentration and Air Pollutant Index (API) at four industrial monitoring stations in Peninsular Malaysia. The rise and reduction of average daily mean concentration for each pollutant have been recorded in Table 4.6 and the trend has been present on Figure 4.12.

Table 4.6: Variation of daily air pollutants concentrations (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO) and Air Pollutant Index (API) before and during pandemic.

Parameter	Monitoring Station	Variation (%) (2018-2019)	Variation (%) (2019-2020)
API	Paka, Terengganu	5.41	-24.66
	Petaling Jaya, Selangor	-2.19	-8.06
	Pengerang, Johor	0.22	-20.57
	Tanah Merah, Kelantan	2.17	-6.13
PM_{10}	Paka, Terengganu	-0.37	-20.41
	Petaling Jaya, Selangor	-5.42	-4.4
	Pengerang, Johor	15.08	-45.81
	Tanah Merah, Kelantan	11.42	-14.22
$PM_{2.5}$	Paka, Terengganu	17.59	-26.19
	Petaling Jaya, Selangor	-5.2	-17.42
	Pengerang, Johor	33.72	-45.59
	Tanah Merah, Kelantan	15.43	-8.56
SO_2	Paka, Terengganu	71.43	-29.17
	Petaling Jaya, Selangor	-74	-19.23
	Pengerang, Johor	21.05	-21.74
	Tanah Merah, Kelantan	-5	-47.37
NO_2	Paka, Terengganu	29.09	-35.21
	Petaling Jaya, Selangor	-14.77	-19.47
	Pengerang, Johor	7.75	26.89
	Tanah Merah, Kelantan	20.18	33.59
O_3	Petaling Jaya, Selangor	-12.32	-31.12
	Tanah Merah, Kelantan	12.3	-20.14
CO	Petaling Jaya, Selangor	-9.1	-30.79
	Tanah Merah, Kelantan	19.07	-22.36

*2018 (before pandemic), 2019 (before pandemic) and 2020 (during pandemic).

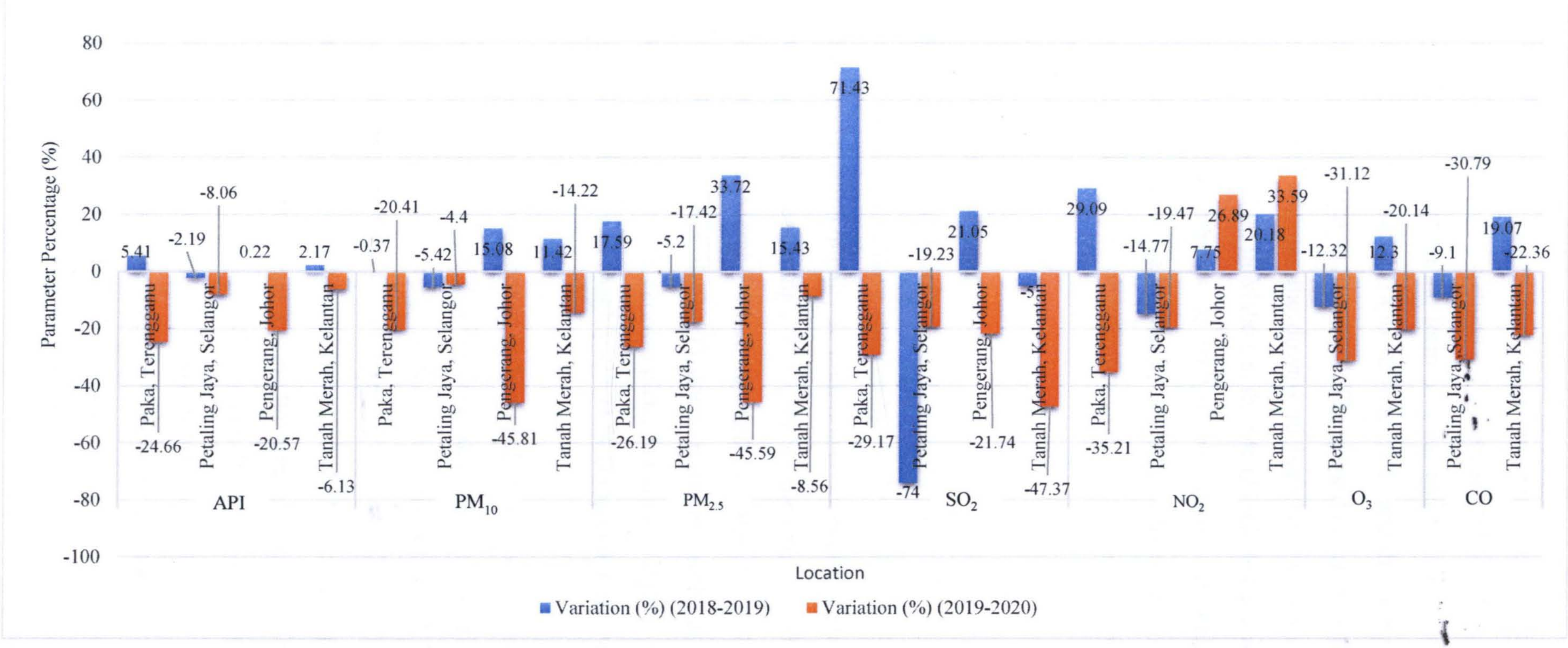


Figure 4.12: Percentage of reduction and rise average based on different industrial air monitoring stations.

Remarks: (+ve) = rise value and (-ve) = reduction value.

Figure 4.12 shows the average percentage reduction and rise value from several industrial air monitoring stations in Peninsular Malaysia before and during the pandemic. The data is displayed in the form of a bar chart graph, with the blue bar representing variance from 1 March 2018 to 30 June 2019, and the orange bar representing variation from 1 March 2019 to 30 June 2020. The upward bar chart with a positive value represents a rise in value, whereas the downward bar chart with a negative value represents a reduction in the value. In Malaysia, the MCO included a number of restrictions on mass movement and gatherings, as well as restrictions on Malaysians traveling overseas, tourists and visitors' admittance, and the shutdown of educational institutions, government and private organizations (except for necessary services) (Abdullah et al., 2020).

First, the variation of daily air pollutants concentrations for PM_{10} shows that Pengerang and Tanah Merah have risen by 15.08 % and 11.42 %, respectively, whereas Paka and Petaling Jaya have reduced by -0.37 % and -5.42 % throughout the 2018-2019 period. The variation of daily air pollution concentrations for PM_{10} over the period 2019-2020 reveals that Pengerang (-45.59 %) has the greatest reduction, followed by Paka (-20.41 %), Tanah Merah (-14.22 %), and Petaling Jaya (-4.4 %). For instance, it was reported by Hasnain et al. (2021), due to restricted traffic and industry shutdown during the Covid-19 pandemic lockdown phase in China, Nanjing, it shows a major decrease in PM_{10} and a reduction of roughly -27.71 % compared to the pre-lockdown period.

Second, the variance of daily air pollutants concentrations for $PM_{2.5}$ demonstrates that, with the exception of Petaling Jaya, all locations show rise value percentage over the 2018-2019 period. Pengerang has the highest rise value (33.72 %) during the 2018-2019 period, followed by Paka (17.59 %) and Tanah Merah (15.43 %), while Petaling Jaya has the reduction value (-5.2 %). The reduction of $PM_{2.5}$ occurred during the pandemic (2019-2020), with Pengerang experiencing the greatest reduction (45.81 %), followed by Paka (26.19 %), Petaling Jaya (17.42 %), and Paka (8.56 %). According to the findings of Abdullah et al. (2020), the MCO was beneficial in lowering pollutant emissions, notably $PM_{2.5}$ mean concentrations, because there were less motor vehicles and industrial activity during the MCO. This researcher also discovered that there is a reduction in $PM_{2.5}$ levels before and during MCO I in Petaling Jaya (22.0 %) and Paka (3.7 %).

CO and O3 parameters likewise reveal a reduction for both locations, Petaling Jaya and Tanah Merah, with values of (-30.79 %, -31.12 %) and (-22.36 %, -20.14 %), respectively, over the period (2019-2020).

However, the rise of NO_2 mean concentration occurred at Tanah Merah and Pengerang during the pandemic (2019-2020) which are 26.89 % and 33.59 %. Even though most Malaysians are obliged to stay at home and avoid outside activities, there could be an increase in air pollution at parameter NO_2 when MCO due to power plants industry. According to Wang et al., (2016), NO_2 gas is produced when high-temperature fuel is burned, typically from the exhaust of motor vehicles and power plants. The highest reductions in NO_2 mean concentration occurred at Paka (35.21 %), followed by Petaling Jaya (19.47 %). Furthermore, in an observation based study by Kandari and Kumar (2021), the mean of NO_2 concentration has clearly dropped (by 30 % – 60 %) over the largest territory of South Asia. The principal source of environmental NO_2 from their study is due to fuel combustion. The negative effects of breathing air with a high NO_2 mean concentration are irritation in the human respiratory structure. According to Kanniah et al. (2020), on 17 April, the decline of NO_2 reached -34 %,-27 %, and -30 % over Manila, Kuala Lumpur, and Singapore (15-day averages), respectively, compared to NO_2 baseline data (averaged over 2015-2019), which is attributable to company and factory lockdowns.

The highest reduction for SO_2 mean concentration occurs at Tanah Merah, Kelantan (-47.37 %) followed by Paka (-29.17 %), Pengerang (-21.74 %) and Petaling Jaya (19.23 %). The research shows that the reduction of Air Pollutant Index (API) occurred during the pandemic (2019 - 2020) and the highest reduction is 14.66 % at Paka, Terengganu. These studies have found similar results where cities with a larger concentration of industrial activity in Gujarat, India, exhibited a greater improvement in air quality, with an increase in the Air Quality Index (AQI) value of around (60 – 75 %) during the lockdowns by Selvam et al. (2020).

Furthermore, the variance of air pollutant index (API) shows that during the period 2019-2020, the bar chart shows the reduction value for all locations, with Paka (-24.66 %) recording the highest reduction, followed by Penegerang (-20.57 %), Petaling Jaya (-8.06 %), and Tanah Merah (-6.13 %). It also shows that there was a -2.19 %

reduction in Petaling Jaya during the period 2018-2019, while other locations recorded a rising value, with Paka (5.41 %), Tanah Merah (2.17 %), and Pengerang recording the most (0.22 %).

Based on the results, the MCO had successfully reduced pollutants emission, PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO mean concentrations as well as air pollutant index (API), as there were less industry activities and motor vehicles during the MCO. Except for NO_2 mean concentrations in Pengerang and Tanah Merah, all pollutants show a reduction in 2020 during the pandemic.

4.4 Air Pollutant Index (API) Status Before and During Pandemic

Figure 4.7 displays objective 3 of this research, which is displayed on a bar chart of API trend from 1 March to 30 June 2018, 2019, and 2020 in Paka (Terengganu), Petaling Jaya (Selangor), Tanah Merah (Kelantan), and Pengerang (Johor) before and during the pandemic. The blue bar chart represents data from 1 March 2018 to 30 June 2018, the orange bar chart represents data from 1 March 2019 to 30 June 2019, and the red bar chart represents data from 1 March 2020 to 30 June 2020.

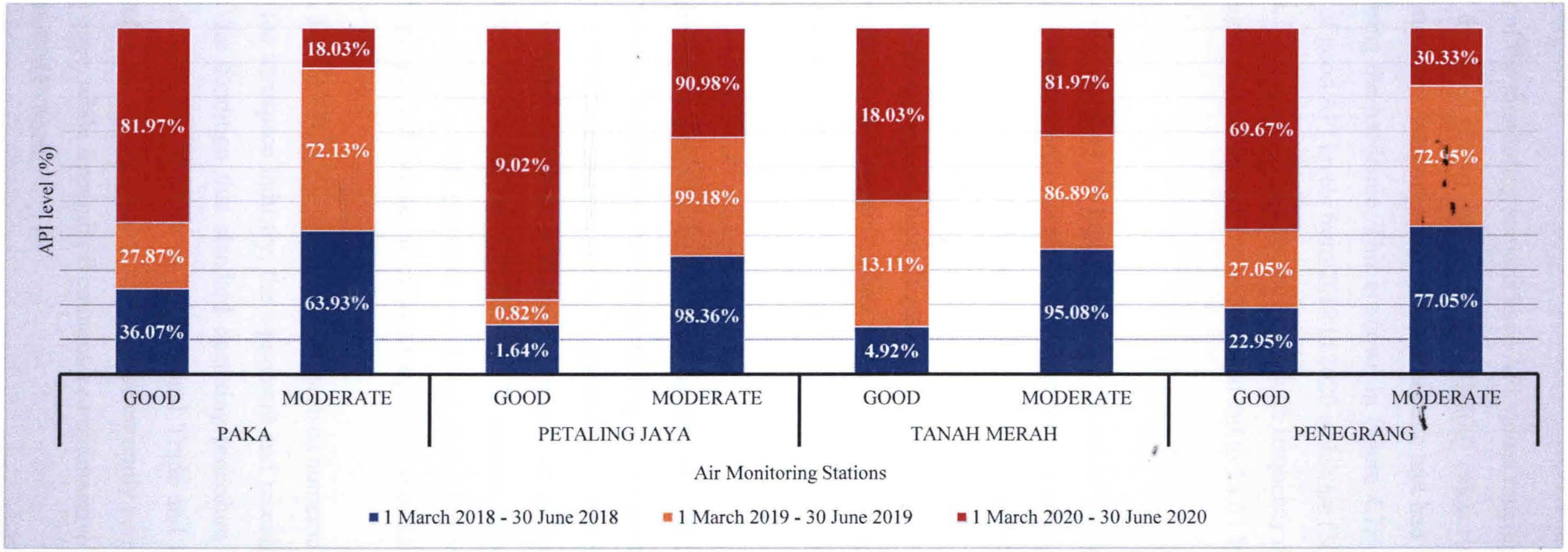


Figure 4.13: Air pollution level before and during pandemic

The majority of the monitoring stations have API values ranging from 0 to 100, which falls between the good (0-50) and moderate (51-100) categories. Most of the locations fall within moderate categories before the pandemic and had API readings in the good category during the pandemic. This is shown in Figure 4.7, which shows an increasing frequency of good API levels from 2018 to 2020 which are (36.07 %, 27.87 % and 81.97 %) at Paka, Terengganu. The data shows the high frequency of moderate API levels at Paka, Terengganu which is 72.13 % in 2019 and fall to 18.03 % in 2020 due to the pandemic.

In Petaling Jaya (Selangor), the high frequency of good API levels was recorded in 2020 (9.02 %) during the pandemic compared to before the pandemic, which was 0.82 % (2019) and 1.64 % (2018). Tanah Merah also shows the increasing frequency of good API levels from 2018 to 2020, which are 4.92 %, 13.11 % and 18.03 %, though that monitoring station area has recorded a high frequency of moderate API levels in three years. In 2020, Pengerang (Johor) had the highest frequency of good API levels (69.67 %) and the lowest frequency of moderate API levels (30.33 %) when compared to 2018 and 2019.

From the analysis, especially for 1 March to 30 June 2020, all industrial monitoring stations recorded the highest API category of good frequency levels due to MCO during the pandemic. This claim can also be supported by similar research done by Mahato et al. (2020), which found that air quality had improved by about 60 % in the industrial and transportation areas of Delhi, India. This is because, except for essential servicess, all government and private premises are closed during the MCO in order to limit the movement of people and reduce infection through human contact.

During Phase 3 of the MCO, the government authorized numerous new economic sectors, including as the aerospace industry, the equipment and machinery industry to restart operations on the condition that standard operating procedure (SOP) rules be followed. Appendix A from the Ministry of International Trade and Industry (MITI) contains a comprehensive list of additional sectors that are currently permitted to operate under the MCO phase three, while Appendix B contains a comprehensive list of "essential services" that are permitted to open.

As a result, it can be concluded that all locations have air quality with API values less than 100 throughout a three-year period, and the majority of locations have air quality with API values less than 50 during pandemic 2020, which is unlikely to cause health consequences on human. This is due to multiple studies that have discovered a direct correlation between poor air quality and an increase in incidence and death, particularly from cardiovascular and respiratory illnesses. Asthma, lung cancer, psychological issues, autism, vision problem and premature birth are all considered important environmental risk factors in the occurrence and progression of these diseases (Ghorani-Azam et al., 2016).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This research project was carried out with three main objectives in mind. The primary objective of this study is to use SPSS software to determine the characteristics of air pollutants concentration data at industrial areas in Peninsular Malaysia from 1 March 2018 to 30 June 2018, 1 March 2019 to June 2019, and 1 March 2020 to June 2020. Second, to compare the air quality status before and during the pandemic at industrial areas in Peninsular Malaysia by displaying a trend graph and variation. Finally, using the Air Pollutant Index (API) to assess the effects on air pollution status at industrial areas in Peninsular Malaysia before and during the pandemic.

The first objective of this research was met by displaying descriptive statistics to analyse air pollution characteristics based on daily average air pollution concentrations in Paka, Petaling Jaya, Pengerang, and Tanah Merah using SPSS software. In this study, box and whisker plots were used to show changes in the form, dispersion, and distribution of the data. As a result, most of the minimum, maximum, mean, standard deviation, skewness, and kurtosis values for pandemic 2020 have been drastically reduced when compared to 2018 and 2019 that produce a varied shape of box and whisker plots for each location during a three-year period comparison.

Furthermore, the second objective was met by showing that during the pandemic, it has a significant impact on improving PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3 and CO trend concentrations, as well as increasing the reduction percentage value. All parameters except NO_2 at Pengerang and Tanah Merah exhibit a reduction percentage value during the comparison period of 2019 and pandemic 2020. This is due to the implementation of MCO during the pandemic to control the spread of the virus. Over the comparative period between 2018 and 2019 which is before pandemic, it also show that PM_{10}, $PM_{2.5}$, SO_2,

NO_2, O_3 and CO concentrations in specific places have decreased slightly. This could be because the Malaysian government has played a significant role in resolving air pollution issues in industrial areas. Based study-observed by Giz, (2021), Malaysian Department of Environment together with the partner authority in formulating and implementing modern air pollution control policies such as exhaust emission ceilings for industry at the national level.

Based on this research, it is possible to conclude that the lockdown greatly improved air quality in industrial areas in Peninsular Malaysia merely to MCO. However, from the last objective, it can be conclude that all of the locations recorded highest frequency within moderate categories before the pandemic but recorded highest frequency within good category during the pandemic due to implementation of MCO. Since the API level is less than 100, this air quality category is thought to be safe for the human being. Just like a coin has two sides, healing of the earth had happened amongst all of Covid-19's negative impact on health. The improvement in air quality has resulted in improved climatic conditions and, as a result, improved health.

5.2 Recommendations for Future Research

The recommendations for future research is to explore the relationship between air pollution and meteorological conditions because the meteorological conditions have an important effect on the amount of pollution in the atmosphere. Other factors, such as weather conditions, traffic density, industrial activities, and biomass burning also should be considered for further investigations. As the MCO has been extended to 2021, the air quality comparison period also needs to be extended to see the changes in air quality before and after the pandemic more clearly.

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APPENDICES

Appendix A

LIST OF ADDITIONAL SECTORS ALLOWED TO OPERATE UNDER THE MOVEMENT CONTROL ORDER (MCO) or ENHANCED MCO?

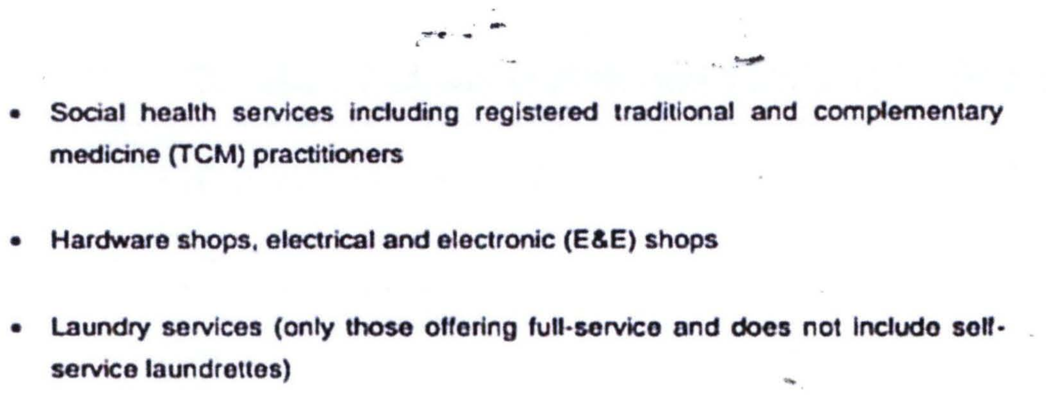
- Automotive industry (limited to exports of CBU, parts and components, as well as after-sale services, e.g., repair and maintenance)

- Machinery and equipment industry

- Aerospace industry

- Construction projects and services related to construction works:
  - ✓ Projects whereby the main contractors are G1–G2
  - ✓ Projects that have achieved physical progress of 90% and above
  - ✓ Tunneling works
  - ✓ Maintenance works
  - ✓ Sloping works
  - ✓ Emergency works that are consequent to contractual obligations
  - ✓ Maintenance, cleaning and drying of stagnant water, spraying of pesticides at construction sites which prevent the breeding of Aedes mosquitoes and other pests
  - ✓ Other works that if left incomplete may result in danger
  - ✓ Building projects with 70 IBS score and above
  - ✓ Construction projects with accommodation facilities for workers, such as centralised quarters for workers or workers' camp
  - ✓ Professional services related to the construction industry including architects, engineers, town-planners, land surveyors, quantity surveyors, project managers, facility managers as well as other relevant services

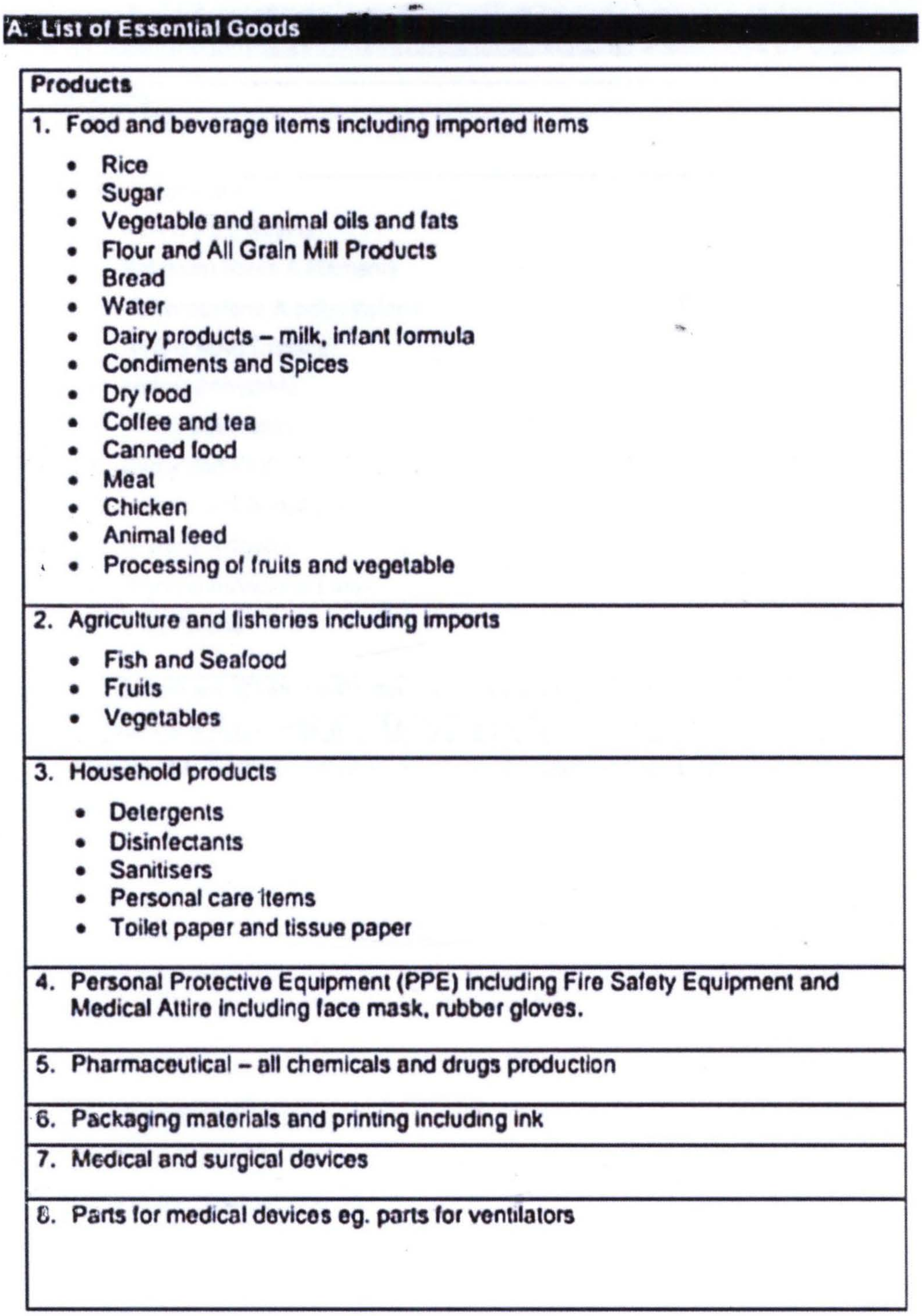
- Science, professional and technical services, including R&D (limited to legal services, services incidental to oil and gas, R&D activities related to COVID-19, and testing labs for the sectors allowed to operate)



- Social health services including registered traditional and complementary medicine (TCM) practitioners
- Hardware shops, electrical and electronic (E&E) shops
- Laundry services (only those offering full-service and does not include self-service laundrettes)

Figure A1: List of additional sectors allowed to be operate under the Movement Control Order (MCO)

Appendix B

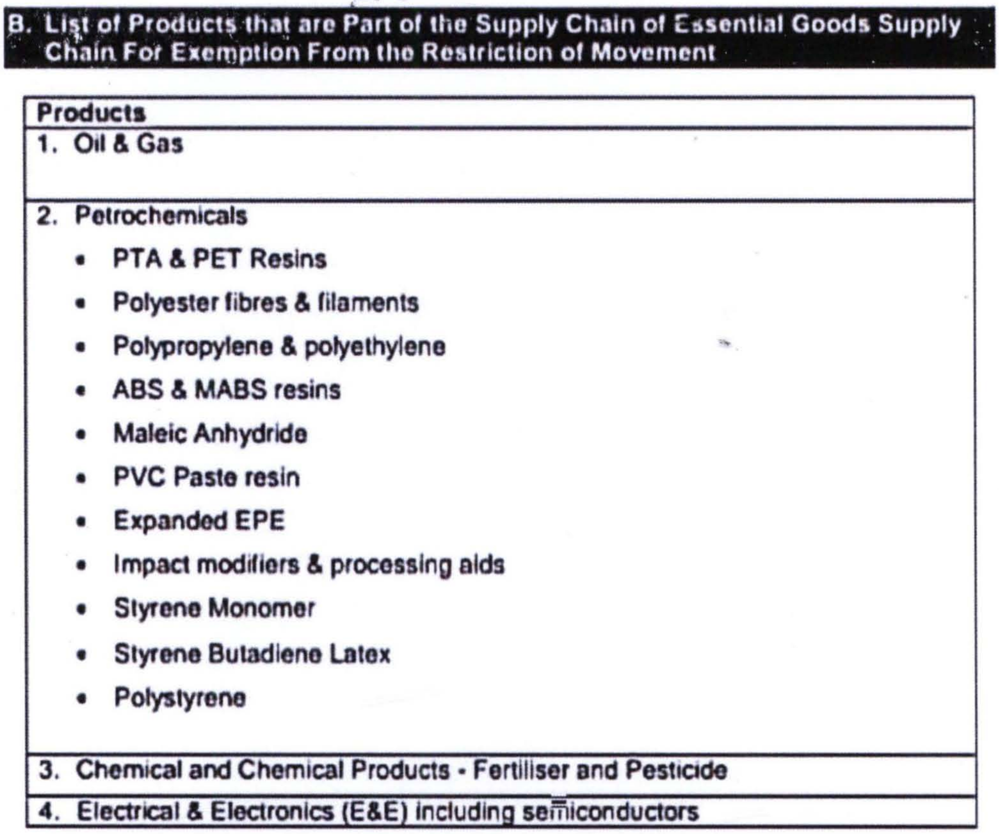


A. List of Essential Goods

Products

1. Food and beverage items including imported items
    - Rice
    - Sugar
    - Vegetable and animal oils and fats
    - Flour and All Grain Mill Products
    - Bread
    - Water
    - Dairy products – milk, infant formula
    - Condiments and Spices
    - Dry food
    - Coffee and tea
    - Canned food
    - Meat
    - Chicken
    - Animal feed
    - Processing of fruits and vegetable
2. Agriculture and fisheries including imports
    - Fish and Seafood
    - Fruits
    - Vegetables
3. Household products
    - Detergents
    - Disinfectants
    - Sanitisers
    - Personal care items
    - Toilet paper and tissue paper
4. Personal Protective Equipment (PPE) including Fire Safety Equipment and Medical Attire including face mask, rubber gloves.
5. Pharmaceutical – all chemicals and drugs production
6. Packaging materials and printing including ink
7. Medical and surgical devices
8. Parts for medical devices eg. parts for ventilators

Figure B1: List of essential goods



B. List of Products that are Part of the Supply Chain of Essential Goods Supply Chain For Exemption From the Restriction of Movement

Products
1. Oil & Gas
2. Petrochemicals • PTA & PET Resins • Polyester fibres & filaments • Polypropylene & polyethylene • ABS & MABS resins • Maleic Anhydride • PVC Paste resin • Expanded EPE • Impact modifiers & processing aids • Styrene Monomer • Styrene Butadiene Latex • Polystyrene
3. Chemical and Chemical Products - Fertiliser and Pesticide
4. Electrical & Electronics (E&E) including semiconductors

Figure B2: List of essential goods that a part of the supply food chain