CAUSALITY OF AIR POLLUTION PARAMETER AT INDUSTRIAL AREAS IN PENINSULAR MALAYSIA

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CAUSALITY OF AIR POLLUTION PARAMETER AT INDUSTRIAL AREAS IN PENINSULAR MALAYSIA

by

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APPROVAL AND DECLARATION SHEET

This project report titled Causality of Air Pollution Parameter at Industrial Area in Peninsular Malaysia was prepared and submitted by Nor Syahira Anisa binti Mohamad Azuhar (Matrix Number: 181130696) and has been found satisfactory in terms of scope, quality and presentation as partial fulfilment of the requirement for the Bachelor of Engineering (Honours) (Environmental Engineering) in Universiti Malaysia Perlis (UniMAP).

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KAUSALITI PARAMETER PENCEMARAN UDARA DI KAWASAN PERINDUSTRIAN DI SEMENANJUNG MALAYSIA

ABSTRAK

Kualiti udara di bandar terutamanya di negara yang membangun menjadi kebimbangan utama terhadap alam sekitar. Bahan pencemar udara seperti prekursor asap daripada industri, fotokimia dan hujan asid, telah menyumbang kepada penyakit utama sistem pernafasan manusia seperti asma dan kanser paru-paru selain menipiskan ozon stratosfera dan menyumbang kepada pemanasan global. Pencemaran udara adalah hasil sampingan yang wujud dalam ekonomi perindustrian moden yang tidak boleh dihapuskan sepenuhnya, walaupun ia boleh dikurangkan dengan peraturan yang ketat. Lima stesen pemantauan udara di kawasan industri seperti Seberang Perai, Tasek Ipoh, Klang, Pasir Gudang dan Paka telah dipilih untuk menilai hubungan antara parameter pencemaran udara yang menyebabkan peningkatan pencemaran dengan menggunakan kaedah statistik deskriptif untuk menganalisis sifat kepekatan pencemaran udara. Data diperolehi daripada Julai 2017 hingga Julai 2020. Pencemaran yang utama terdiri daripada bahan pencemar yang berbeza iaitu; PM_{10}, $PM_{2.5}$, SO_2, NO_2, dan O_3. Hasil kajian mendapati peningkatan pencemaran udara terutamanya PM_{10}, $PM_{2.5}$ yang mempunyai nilai kepekatan purata tertinggi iaitu 41.42 $\mu g/m^3$ (PM_{10}) dan 33.04 $\mu g/m^3$ ($PM_{2.5}$) yang terletak di stesen pemantauan Klang. Ujian Granger Kausalitic dijalankan untuk menganalisis semua kausalitas antara parameter secara konsisten dengan menggunakan perisian Eviews. Keputusan menunjukkan bahawa semua parameter adalah menjadi penyebab antara satu sama lain dengan nilai berbeza yang ketara di setiap stesen. Kajian ini membantu untuk menjadi rujukan kepada penyelidik lain untuk meramal kepekatan pencemaran udara.

CAUSALITY OF AIR POLLUTION PARAMETER AT INDUSTRIAL AREA IN PENINSULAR MALAYSIA

ABSTRACT

Air quality in cities, especially in developing countries, is a major concern for the environment. Air pollutants such as smoke precursors from industry, photochemical and acid rain, which contribute to major diseases of the human respiratory system such as asthma and lung cancer besides depleting stratospheric ozone, and contribute to global warming. Air pollution is a by-product inherent in the modern industrial economy that cannot be completely eliminated, although it can be reduced with strict measures. Five industrial area air monitoring stations, Seberang Perai, Tasek Ipoh, Klang, Pasir Gudang and Paka were selected to assess the relationship between the parameters that cause the increase in pollution by using descriptive statistical methods to analyse the nature of the air pollution concentration. Data were obtained from July 2017 to July 2020. The focus areas consist of different pollutants namely; PM_{10}, $PM_{2.5}$, SO_2, NO_2, and O_3. Results from research found an increase in air pollution, especially PM_{10}, $PM_{2.5}$ which are the highest mean value 41.42 $\mu g/m^3$ (PM_{10}) and 33.04 $\mu g/m^3$ ($PM_{2.5}$) located at Klang monitoring station. For more enhance look, Granger Causality test is conducted to analyse all the causalities among parameters in a consistent manner by using Eviews software. Result shows that all parameter is granger-cause towards each other with significantly different value in every station. This study helps to be a reference for other researchers to predict the air pollution.

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LIST OF SYMBOLS AND ABBREVIATIONS

ALC	Ambient Least Cost Model
ANOVA	One-way Analysis of Variance
API	Air Pollution Index
CO_2	Carbon Dioxide
CO	Carbon Monoxide
DOE	Department of Environment
GHG	Greenhouse Gas
LAP	Local Air Particulate Matter
MAA	Malaysia Automotive Association
MAAQAS	Malaysian Ambient Air Quality Standards
NOx	Nitrogen Oxides
NO_2	Nitrogen Dioxides
O_3	Ozone
PM_{10}	Particulate Matter diameter less than 10 μm
$PM_{2.5}$	Particulate Matter diameter less than 2.5 μm
SO_2	Sulphur Dioxide
TNB	Tenaga Nasional Berhad
TSP	Total Suspended Particles
USEPA	United States Environmental Protection Agency
VAR	Vector Autoregressive
VOCs	Volatile Organic Compounds
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Research Background

Air pollution is one of the most dangerous pollution to health, according to the World Health Organization (WHO), air pollution is one of the most hazardous pollutants to human health, killing an estimated seven million people globally each year. Air pollution contain contamination that involve in indoor and outdoor environment in various type of forms such as chemical, physical and biological. According to WHO data, virtually all of the world's population (99 %) breathes air that exceeds WHO standards for high levels of pollutants, with low- and middle-income countries bearing the brunt of the burden. Common air pollutants are including particulate matters (particularly PM_{10} and $PM_{2.5}$), carbon monoxide (CO), ozone (O_3), sulphur dioxide (SO_2) and nitrogen oxides (NOx), acid gases, heavy metals, volatile organic compounds (VOCs), solvents, pesticides, radiation and bio-aerosols (World Health Organization, 2021).

Advanced of technology, science and manufacturing has led to the growth of industry. It also strongly tied to the increasing of population that demand variety of necessities. Industry creates waste, whether it is solid, liquid, or gaseous, just as it produces goods. As examples wastewater from industry, stack emission, smoke from motor vehicles, and other factors that contribute to air pollution. Although not all harmful gases from factories emit into the atmosphere, as most factories already have air pollution control system that has been registered and certified by the Department of the Environment (DOE) however, small amount of emission may have the potential to release particular pollutants or exceed the precise concentrations of pollutants, which are controlled by the local government or DOE (Department of Environment, 2011).

In Malaysia, economic growth has resulted in pollution in many types of industries. In year 1996 to 2015, there were increased demand for motor vehicles and fast industrialization, particularly in the western corridor of the Malaysian Peninsular, resulted in increasing of air pollution emissions, which unavoidably and impacted the local and regional air quality (Sentian et al., 2019). For example, carbon monoxide is produced by a variety of industrial sources, including fuel-fired boilers, internal combustion gas boilers, and gas stoves (Weng et al., 2012). Some E-waste industries use pyro metallurgy processes that needs to use fuel burning to produce precious metal. If the company does not comply with the air emission limitation that has been standardized by DOE, emission of pollutant such as carbon monoxide, nitrogen oxide and sulphur can contribute to an increase in air pollution. Thus, this industrial activity may lead to a change of Air Pollution Index (API) pattern since the quality of air can be affected by the air pollution. Various approaches have already been taken by the DOE to address this issue, besides uncontrollable industrial activity may lead to large cause and effects on our air pollution.

1.2 Problem Statement

Due to rapid economic growth and seasonal trans-boundary pollution, air pollution has grown significantly as a severe potential threat to public health in the last decade (Sentian et al. 2019). In Malaysia, air pollution has been characterised by considerable seasonal changes over the years, this may have tracked back to transboundary contamination in a significant way. Malaysia is one of the countries most afflicted by air pollution which the contribution of pollutant in Malaysia are from power plants (85 %), motor vehicles (10 %), industrial activity (3 %) and other sources (2 %) (Sentian et al., 2019). Even though, industrial sector emits 3 % of pollutants to the atmosphere, the environment and surrounding of industrial areas also become one of the major contributions to the air pollution such as motor vehicles, business transportation, heavy traffic and more (Chik et al., 2013).

The emission of pollutants including particulate matter (particularly PM_{10} and $PM_{2.5}$), ozone (O_3), sulphur dioxide (SO_2) and nitrogen dioxides (NO_2). As air pollution is one of the most dangerous pollution, many cause and effects that might contribute in our daily life and environment. Over reliance on vehicles and lack of awareness in using public transportation especially in urban areas as well as heavy uses of fuels causing high number of pollutants such as nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) enter the atmosphere (Index Quality Air, 2020). Besides, the uncontrollable of emission from the factories and mixed with the existing pollutants by vehicles also worsen the environment. Increasing one of the parameters might cause other parameter increase and this will give an impact to our environment.

For human health, the pollutants can cause respiratory issues when harmful substances are absorbed directly into the lungs, as well as skin damage from the direct incidence of UV light rays on the skin owing to the ozone layer's depletion (United States Environmental Protection Agency, 2011). PM_{10} and SO_2 relationship had strong effects on asthma and other lower respiratory tract diseases and both of these pollutants usually emit from cement factory (Hajat el al., 1999). For environment and nature, air pollution can lead to acid rain, global warming, changing climate, haze and damage toward building and animal species. High concentration of NO_2 that emit from power plants and industrial sources may contribute in increasing of O_3 level in daylight. This pollutant possible to generate potential implications to human healths (WHO,2002)

Uncontrollable industrial activity and failure of industry to comply with the specification of air emission standards that have been set by Department of Environment can cause a big impact on air pollution at the same time affecting humans and nature. Internal industrial activity such as Seberang Perai emit large scale of O_3 and PM_{10} concentration and make it as one of the concerns among residents (DOE, 2012). Hence, the major aim of this research is to investigate the causality of air pollution parameters at industrial areas in Peninsular Malaysia.

1.3 Research Objective

The objectives of this research are:

i. To determine the characteristic of air pollution data at industrial area in Peninsular Malaysia.

ii. To investigate the relationship between air pollution parameters using Granger Causality Test and illustrate into graphical view of causality from July 2017 until July 2020.

1.4 Scope of Research

The primary goal of this study is to evaluate the causality of five (5) parameter which are particulate matter (PM_{10} and $PM_{2.5}$), nitrogen oxide (NO_2), sulphur oxide (SO_2), ozone (O_3) that commonly emitted from industrial area. The location of air monitoring station is representing the industrial area in Peninsular Malaysia which are in north region Seberang Perai (Pulau Pinang) and Tasek Ipoh (Perak), central region Klang (Selangor), east region Paka (Terengganu) and south region Pasir Gudang (Johor).

In order to obtain the characteristic of air pollution parameter, SPSS software is used to determine the features of data in this study. The data of five air pollutants concentration are acquired from the Department of Environment Malaysia from July 2017 to July 2020. The causal relationship between parameters are analysed through the Granger causality test by using Eviews student version software. The causality relationship between the parameters in the study will be illustrated by the graphical view of causality.

CHAPTER 2

LITERATURE REVIEW

2.1 Air Pollution

Air pollution is a mixture of solid particles, liquid particles and some gases that are suspended in the air. Air pollution can occur when the air is contaminated by natural and anthropogenic toxins coming from human activities including pollution residuals resulting from consumption and manufacturing activity (Zizi et al., 2018). The natural air pollution which includes in wind-blown dust, volcanic ash, and gases as well as smoke and trace gases from forest fires, and anthropogenic air, which included in combustion products such as nitrogen oxides (NOx), carbon monoxides (CO), and sulphur dioxide (SO_2) (Oyekanmi et al., 2010). Primary pollutants are pumped into the atmosphere and directly contaminate the air, whereas secondary pollutants are created in the air when primary pollutants react or interact by the chemical reactions (Agbaire, 2010).

Air pollution has been major negative impact on human health and the environment, it has been generally acknowledged as a concern in the previous 50 years (Gurjar et al., 2008). Air pollution can also occur when the air is polluted with natural and anthropogenic contaminants associated with human activities including pollution residuals from consumption and manufacturing activity (Sentian et al., 2019). Malaysia has recorded positive in economic growth recent years through the structural changes in industrialization, agriculture, tourism and export industries. This economic growth resulted in pollution in range of aspects, for instance there is increasing air pollution from the industrial activities as well as motor vehicles emissions (Chik et al., 2013). In findings, the researcher concludes that people that living near the major industrial areas are facing complex environment situations in many sectors such as chemicals combined with exposure to pollute air, dust, visual pollution stress and so forth possible associated with health risk (Marco, 2011). In addition, air pollution not only has a detrimental influence on human health, but it may also have a bad impact on habitats, structures, buildings, plants, and views.

Table 2.1: The Malaysian Ambient Air Quality Standards (Department of Environment Malaysia, 2016)

Pollutants	Average Time	Malaysian Standards	
		ppm	µg/m^3
Ozone (O_3)	1 Hour	0.10	200
	8 Hours	0.06	120
Carbon Monoxide (CO)	1 Hour	30.0	35 mg/m^3
	8 Hours	9.0	10 mg/m^3
Nitrogen Dioxide (NO_2)	1 Hour	0.17	320
	24 Hours	0.04	75
Sulphur Dioxide (SO_2)	1 Hour	0.13	350
	24 Hours	0.04	105
Particulate Matter (PM_{10})	24 Hours	-	150
	12 Months	-	50
Total Suspended Particulates (TSP)	24 Hours	-	260
	12 Months	-	90
Lead (Pb)	3 Months	-	1.5

2.2 Carbon Monoxides (CO)

In Malaysia, emission of carbon monoxides that largely occurs are mainly caused by the transportation activities (Department of Environment Malaysia., 2011). Economic growth has contributed in increasing the usage motor vehicle and traffic demand especially in urban area as well as increasing of air pollution especially from the industrial activity (Chik et al., 2013). From the data collected by the Malaysian

Department of Environment (2011), transportation activities contribute (97.1 %) among others factors; emissions from motor vehicles, both privately owned and commercially owned are among the surfaces. There are over 19 million registered and licensed by Department of Environment (DOE) with the total estimation of emission released of over 1.4 million metric tonnes in 2008 (DOE, 2010). From this we can actually expected a rise in transportation and motor vehicles in years to come, as well as an increase in CO_2 emissions into the environment. This is corroborated by Malaysia Automotive Association (MAA) data, which shows that consumer car sales climbed by 19.8 percent in the first half of 2010 and that overall vehicle sales have risen by an estimated 10-20 percent every year for the preceding five years (Malaysia Automotive Association, 2021).

Furthermore, industrial activities responsible for the emission of carbon monoxide that come from fuel-fired boilers, combustion in boilers and gas stove (Oland., 2002). Some scheduled waste factories, they apply pyro metallurgy process to melt the waste into precious metal by using the carbonators and boiler. Carbon dioxide is the critical measure of the quality combustion process. CO_2 emission from fuel combustion have an influence on the environment. Although the growth in population is considered as beneficial to the economy, it does add to the overall CO_2 emissions produced by Malaysian road cars and industry.

2.3 Nitrogen Oxides (NOx)

Nitrogen oxide (NOx) is a colloquial term for the nitric oxides (NO) and nitrogen dioxides (NO_2). Most combustion processes that use air as an oxidant produce nitrogen dioxide. Nitric oxide is formed when nitrogen interacts with oxygen at high temperatures. Nitric oxide is then oxidised in air to generate nitrogen dioxide, bringing the process to a close NO_2. Emission nitrous oxide in Malaysia was exceed up to 11,120 thousand metric tons of CO_2 equivalent. Emission of nitrous oxide in Malaysia climbed from 8,070 thousand metric tonnes of CO_2 equivalent in 1999 to 11,120 thousand metric tonnes of CO_2 equivalent in 2018, expanding at an annual rate of 1.85 % on average (World Data Atlas., 2018).

NOx is the dangerous chemical compound not just to human health but also to the nature. From the finding, researcher conclude that most of NO_2 emission released into the atmosphere are caused by motor vehicles and stack of factories that actual come from the fuel burning (Department of Environment, 2011) and power stations contributes 27 % of total NO_2 emissions with the total estimated NO_2 released at 111,858 metric tonnes not far behind the industrial sector contributed 21 % of total NO released (Department of Environment, 2008).

NO_2 is dispersed in the atmosphere, then it combines with other pollutants to generate secondary pollutants such as ground-level ozone and acid rain. Ground-level ozone is produced by chemical interactions between volatile organic compounds (VOCs) (hydrocarbon radicals) and NOx, which is found in the higher atmosphere. Smog might happen if the materials react with the presence of sunlight, and if the NOx reacts with the water vapour it forms as dilute acid which is acid rain.

2.4 Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is the chemical compound that produced by volcanoes and in various industrial processes. In Malaysia, SO_2 emissions are produced by power stations, coal and petroleum combustion from the vehicles since Malaysia has no volcanic activities. Malaysia has 41 power stations with various resources used as main combustors, Tenaga Nasional Berhad (TNB) is the main electricity utilities in Peninsular Malaysia. Resources used in these stations energy production include coal, oil, gas, steam, water (hydro) and biomass (Salahudin et al., 2013). Besides, other significant contributor to the emission of SO_2 to the atmosphere and the environment in Malaysia is industrial sectors, such as manufacturing and services.

From the researchers finding these industrial processes contributed 23 % or 36,938 metric tonnes of SO_2 released. Besides that, are the combustion engines found in motor vehicles since it contributed 8 % or 12,865 metric tonnes of SO_2 released. With the country's future energy consumption likely to rise in pace with expected economic expansion, Malaysia may anticipate additional SO_2 to be produced in the future, whether it be from current combustion power plants or from newly created ones.

Malaysia, like many other growing economies, is heavily reliant on the energy sector to move its economy ahead. Malaysia's energy consumption has increased in recent years and is likely to expand more in the future (Selamat & Abidin, 2010). As a result, more SO_2, will be discharged into the atmosphere in the future along with the growing market.

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

Particulate matter (PM) is referred as a mixture of solid particles and liquid droplets suspended in the air, containing organic and inorganic substances (United States Environmental Protection Agency, 2011). Steel manufacturing and chemical plant are a major source of pollution in the environment, since they emit a variety of pollutants such as particulate matter (PM), gas, and vapour (Yan et al., 2010). Minor elements such as lead, aluminium, zinc, manganese, chromium, cadmium, copper, nickel, titanium, vanadium, and other trace metals are found in most PM wastes from these sectors (Lima et al., 2009). PM emissions in Malaysia are mostly caused by the industrial sector, which accounts for 40 % (12,664 metric tonnes) of total PM emissions (Department of Environment, 2010). As chemical processes are used to manufacture and produce a variety of industrial goods.

2.6 Ground level Ozone (O_3)

Ground-level ozone (O_3) is one of the important photochemical compounds in the atmosphere. Increasing of industrial activity, motorized transportation and agricultural activities forefront to increasing of tropospheric ozone concentration (Awang et al., 2019). According to Screpanti et al (2009) found that dense ozone near ground level were adversely affects human health, ecological system, and also the heritage building. Industrial operations are expected to generate ozone precursors of such as nitrogen oxides (NOx) and volatile organic compounds (VOC_s) into the atmosphere (Mohd Napi et al., 2020). High ambient temperature, powerful photochemical interactions between NO_X and VOCs, and a thin boundary layer are all variables that encourage ground-level ozone concentrations. Furthermore, environmental factors such as sun brightness, relative humidity, and wind speed can have a significant impact on surface ozone concentration (Khiem et al., 2010).

2.7 Granger Causality

The concept of causality is inextricably linked to the concept of cause-and-effect relationships. On the other hand, Granger Causality is defined as when a past and present specific characteristic gives important information for forecasting the future in a time series. According to the study by Jiang et al (2018) the used of Granger Causality test is used to evaluate whether air pollution of a city is impacted by its surrounding and from the test the researcher can finally determining whether one-time series is useful for forecasting another time series. The objective is to investigate whether the present parameter can be described by its previous values weather adding lagged values of the parameter can enhance or are beneficial for forecasting another parameter (Stephanie, 2016).

2.8 Relationship of Nitric Oxide (NO) and Ground Level Ozone (O_3)

In urban areas, photochemical oxidants are one of the main problems caused by air pollution. In addition, ground level ozone (O_3) is formed photochemically from the photolysis of NO_2, and O_3 reacts rapidly with NO reactions to produce NO_2. As a result, NO, NO_2, and O_3 are in photo equilibrium, with no net formation or loss of O_3. Hence, typically, O_3 peaks do not occur until NO concentrations have fallen, as NO can titrate O_3.

O_3 is the major greenhouse gas, O_3 give a significant contribution to climate change (Monks et al., 2015). Climate change is anticipated to increase O_3 and NO_2 concentrations, as well as the increasing amount of ozone in urban and industrial areas across the world, thereby exacerbating the negative effects on respiratory health (Wilson et al., 2017). Local air pollution sources, climatic conditions, atmospheric boundary layer processes, and transport all play major roles in determining the O_3 and

NO_2 concentrations behave on the topography of the research areas (Beyram et al., 2001).

A significant number of data, according to Han et al., (2011), reveal that on clear days, the concentration of ozone grows with increasing intensity of solar radiation and temperature. They observed the average diurnal fluctuation of NO_2 and O_3 concentrations as a consequence of the research, and as a result, the ozone concentration steadily increases when the sun rises, reaching its maximum throughout the afternoon, and then gradually decreasing until the following morning. The NO_2 peak emerges 1–2 hours after the NO peak, while the O_3 peak appears around six (6) hours after the NO peak and five (5) hours after the NO_2 peak. In these cases, this prove that NO titrate the O_3.

2.9 Relationship of PM_{10} and Carbon Dioxide (CO_2)

The primary sources of PM_{10} emissions usually came from industrial applications such as cement factories, which have raw material such as storage piles, conveyor belts, crushers, furnaces, roadways within the plant, coal and mine excavation areas, iron and steel plants, and particles from vehicle exhausts, as well as dust from tyres and roads (Abu-Allaban & Abu-Qudais 2011; Lothongkum et al., 2008). Uncontrollable of industrial activity effects also leading to increased CO_2 emissions in manufacturing and energy intensity. The correlation between these two parameters is very strong since it goes by the same process. Particulate matter (PM) and CO_2 is the major compound that involves in combustion activities, the dirtier the object that combusts, the higher the levels of pollutants. These will lead to health problems which PM exposure can both cause and exacerbate, as PM_{10} is inhalable. Exposure to particulate matter pollution can damage both the heart and the lungs. The increasing of acid in sea water quality might harm the sea life due to the effluent that contain carbon oxide and particulate matter. Particulate pollution can also contribute in greenhouse effect, which prevents heat from leaving the planet, leading to the melting of the polar ice caps and sea level rise.

2.10 Effects of Industrial Activities on Air Pollution

Air quality in cities particularly in developed area of every country that increase along with the growth of industry has becoming a major environmental concern. However industrial activities emit large amount of pollution such as SO_2, NO_2, O_3, heavy metal and other particulate. Major emission of pollutants always come from industrial sector such as power plants, cement industry, manufacturer industry that include metallurgical, pyro and hydro process (Manisalidis et al., 2020). In addition, due to increasing of pollutants into the atmosphere, lots of method and experiment has been conduct to reduce and acknowledge this issue. Tons of researcher that came from every country have made studies in predicting and forecasting the air pollution parameter in their country, several methods have been used to determine significant result for their study in improving the air quality. Table 2.2 shows a summary of findings from researchers about air pollution impacts on industrial areas around the world. It also detailing about the method and air pollution parameters that they used in the findings.

Table 2.2: Summary of Air Pollution impacts on Industrial Areas

Year	Parameters	Areas	Findings	References
2006	NO, NO_2, NOx, O_3	China	• From September 8 to October 15, 2006, continuous measurements of nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NOx), and ozone (O_3) were taken in Tianjin. The data were utilised to explore the link between the O_3 distribution and its relationship with ambient NO, NO_2, and NOx concentrations (NO and NO_2). • Ground-level ozone concentrations exhibited a diurnal cycle with a mid-day peak and reduced midnight values. In addition, an inverse link was discovered between O_3, NO, NO_2, and NOx. A linear association between NO_2 and NOx, as well as NO and NOx, and a polynomial relationship between O_3 and NO_2, NO were also discovered.	Han et al., 2011

Table 2.2: Summary of Air Pollution impacts on Industrial Areas (Continued)

Year	Parameter	Areas	Findings	References
2016	$PM_{2.5}$, NO_2, Black carbon (Bc)	United States	• The research is about determining impact of local air pollution on mortality by using the causal modelling • The researchers used an approachable method to create a method for swings in local air pollution concentrations that are not even likely to be linked to other causes of death, and then compared it to daily fatalities in the Boston, Massachusetts, area. • The changes that were independent of year, month, and temperature were detected by combining the height of the planetary boundary layer and wind speed, both of which effect local emission concentrations. They also employed Granger causality to see whether there was any potential endogeneity. • They predicted that a 0.90 percent increase in daily fatalities was related with an interquartile range rise in the instrument for local $PM_{2.5}$ (95 percent CI: 0.25, 1.56). Other finding was reported for Bc, however a poor connection with NO_2 was discovered. For the instrument, the Granger test showed no evidence of omitted variable confounding. A further test indicated that the instrument was not linked to mortality in the absence of pollution. • Furthermore, when all days with $PM_{2.5}$ concentrations greater than 30 g/m^3 were omitted from the study, the connection maintained (0.84 percent increase in daily deaths; 95 percent CI: 0.19, 1.50).	Schwartz et al., 2016

Table 2.2: Summary of Air Pollution impacts on Industrial Areas (Continued)

Year	Parameters	Areas	Findings	References
2012-2014	O_3, VOCs, NOx	Malaysia	• Ozone (O_3) is one of the contaminants that might have long-term or short-term negative impacts on human health. Furthermore, it has the potential to disrupt the usual ecology and result in species extinction. The goal of this study is to look at the yearly patterns in ozone (O_3) levels as well as the diurnal trends in ozone in Kemaman, Terengganu. • Using one-way ANOVA, O_3 concentrations differed statistically substantially (p0.05) between 2012 and 2014. Meanwhile, the diurnal pattern indicated that the lowest average O_3 concentration values were found in the morning and the highest average O_3 concentration values were discovered in the afternoon, but that the concentrations steadily declined in the evening and night. Understanding the ozone trend on a monthly and hourly basis might help in resolving the problems created by air pollution.	Mohd Napi et al., 2020
2013	PM_{10}, CO_2	China	• This study evaluates the advantages of the Local Air Particulate Matter (LAP) reduction strategy and Greenhouse Gas (GHG) control plan in a coal-fired power industry in Tianjin, China. • The Ambient Least Cost Model (ALC) was used to determine PM_{10} and CO_2 emission reduction and budget, then developed a PM10 and CO_2 control technologies inventory was produced. • According to the findings, a rebuilt bag-house precipitator in 300 MW units is most cost-effective way of reducing PM_{10} emissions in a thermal power plant.	Zhang et al., 2013

Table 2.2: Summary of Air Pollution impacts on Industrial Areas (Continued)

Year	Parameters	Areas	Findings	References
2018	PM_{10}, $PM_{2.5}$, NO_X	China	• China has suffered from severe air pollution as a result of growing industrialisation and urbanisation. Beijing, in particular, is one of the world's most polluted cities. • As a result, Beijing is the research area's focal point. In the first step, they look at the geographical and temporal aspects of air pollution in the six cities, and in the second stage, they use the Granger causality test to see if a city's air pollution is influenced by its neighbours, and vice versa. • The AQI is highest in the winter and early spring, and lowest in the summer and fall. Baoding, the largest of the six cities, is the area's biggest source of air pollution. Furthermore, the findings of the Granger causality test reveal a unidirectional association from Baoding to Beijing and a bidirectional relationship between Beijing and Tianjin.	Jiang et al., 2018

CHAPTER 3

METHODOLOGY

3.1 Research Flowchart

In this chapter provides the flow of research work and details that were used to attain the objectives of this research. The first stage of the analysis was determined the parameters and selection of monitoring station. The data obtained from the Department of Environment Malaysia (DOE) from July 2017 to July 2020. The second stage was descriptive analysis to determine the minimum, maximum, mean, standard deviation, kurtosis and skewness of the data. This activity was being done to observe the trend of air pollution parameter in Malaysia especially at industrial areas. The descriptive analysis will obtain by IBM SPSS statistic software and will be used in the next stage in Granger Causality Test. The research flowchart is presented in Figure 3.1.

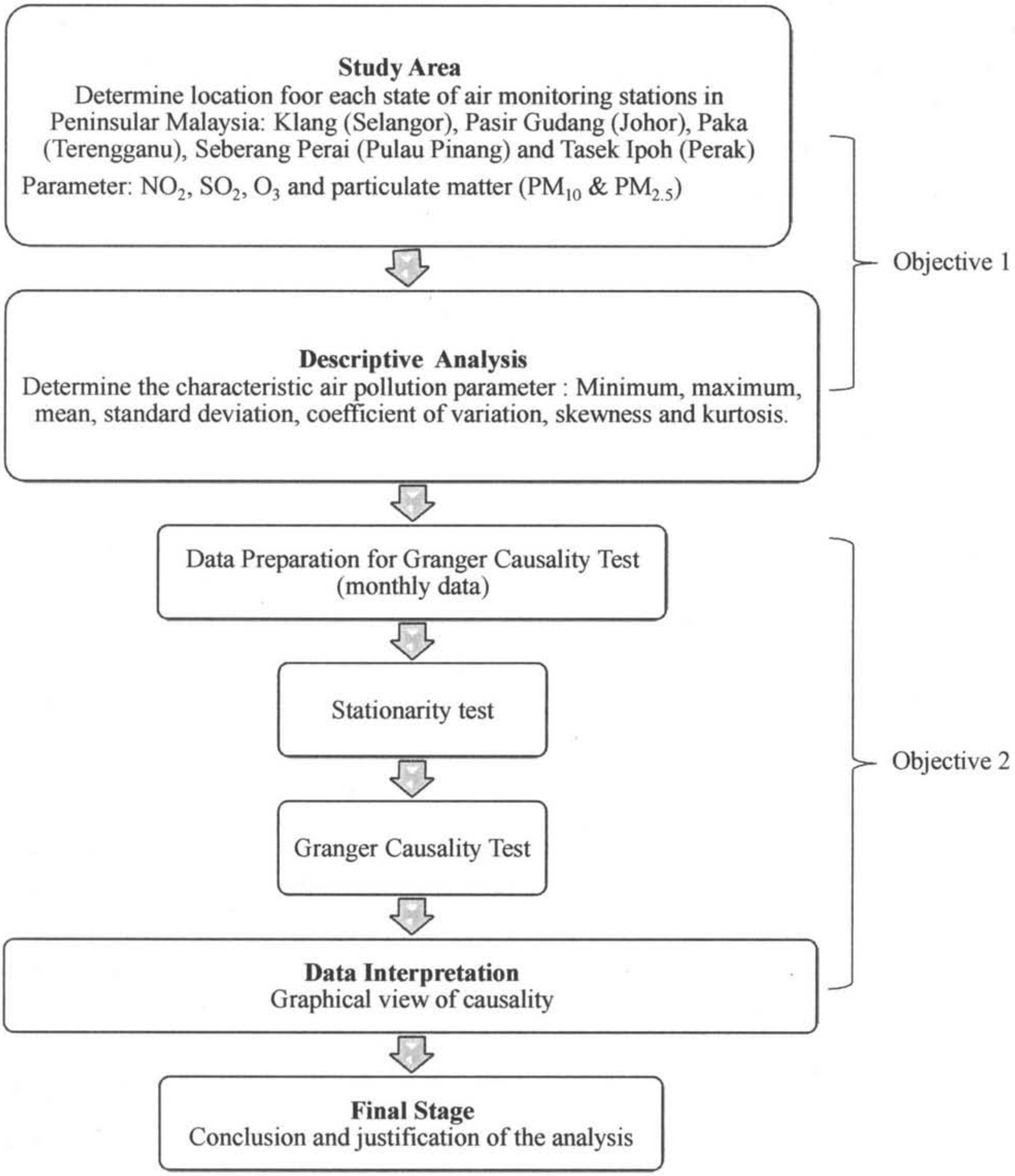


Figure 3.1: Research Flowchart

3.2 Research Area

There are 68 air-monitoring stations throughout the Malaysia. All 68 stations were classified into four categories which is industrial, urban, sub-urban and rural area. However, this research solely focuses on stations that responsible for monitoring air quality in industrial areas in peninsular Malaysia. The research area covered north east, central and southern region. The selected stations were located at Klang (Selangor), Pasir Gudang (Johor), Paka (Terengganu), Seberang Perai (Pulau Pinang) and Tasek Ipoh (Perak) as illustrated in Figure 3.2.

Figure 3.2: Location of research area Peninsular Malaysia

There are 11 air-monitoring stations that responsible in monitoring quality air status at industrial areas. However for this research only focus on five (5) monitoring station in Peninsular Malaysia. Table 3.1 shows the state, region, latitude and longitude of five selected air monitoring station in Peninsular Malaysia.

Table 3.1: Five air monitoring stations location (industrial area) in Peninsular Malaysia

No	State	Region	Monitoring Station	Cordinate (latitude, longitude)
1	Seberang Perai, Pulau Pinang	North	Sekolah Kebangsaan Cenderawasih, Tmn Inderawasih, Perai	5.3914794°, 100.3855716°
2	Tasek Ipoh, Perak	North	Sekolah Menengah Jalan Tasek, Ipoh, Perak	4.6313797°, 101.11792531°
3	Klang, Selangor	Central	Sekolah Menengah (Perempuan) Raja Zarina Port Klang, Selangor	3.0115213°, 101.4095797°
4	Pasir Gudang, Johor	South	Sekolah Menengah Pasir Gudang 2, Pasir Gudang Johor	1.4706139°, 103.8955537°
5	Paka, Terengganu	East	Tenaga Nasional Berhad Quarters, Paka-Kerteh, Terengganu	4.6056726°, 103.4329908°

Seberang Perai is located on the northwest cost of Peninsular Malaysia, it also known as capital of Penang. Seberang Perai is also well known for their high economic growth due to rapid and diverse industrial development with population of 1,740,405 in 2020 (Yusof et al., 2008), and the state government could not dispute that there were a number of environmental concerns, including traffic congestion, waste management, river pollution, and water supply problems that contribute in major air pollution emission (Mohtar et al., 2013). The selected monitoring station was located at Sekolah Kebangsaan Cenderawasih, Taman Inderawasih Perai. It was located close to various heavy industrial such as glove manufacturer, hardware industry and catalyst industry. Glove industry contribute SO_2, NO_2 and O_3 emission into the environment due to coal burning and fuel usage in producing glove products (Patrawoot et al., 2021).

Tasek Ipoh is an industrial area and monitoring station located at Sekolah Menengah Jalan Tasek, Ipoh Perak. Tasek Ipoh or Tasek is located on the north city of Ipoh. The monitoring station is situated near the Bercham and Tambun area which have various and heavy industry such as plastics, non-metal, rubber bases, food and wood manufacturer. Metal, textiles and furniture industrial are actively operated in Bercham. Besides that, IGB industrial is also located close to Tasek, The IGB International Industrial Park is a leased industrial complex with available factory unit for purchase or lease. The development is situated in Lebuh Perusahaan Keledang 5 in Ipoh, Perak. Every factory must include with their own transportation and transportation contributes in air toxics, which are known or suspected to cause cancer or other severe health and environmental impacts. Toxic air emissions from mobile sources include benzene, formaldehyde, and diesel particulate matter, among others (USEPA 2022).

Klang was located in west-central of Selangor, with latitude 3.0449°N and longitude 101.4456° E. Klang has total population of 287,500 and being the largest district in Selangor in 2017. Klang is the main economic development of various type of industrialisation, popular with their infrastructure and major trade centre in Malaysia. The air monitoring station are located in Sekolah Menengah (Perempuan) Raja Zarina Port Klang, Selangor about 2 kilometres from Port Klang. Port Klang was entitled as 12th busiest transhipment and cargo port activity in the world (World Shipping Council, 2020). The monitoring station are also located near the main roads, industrial activity and residential areas with high density of vehicle and can considerably increase the concentrations of air pollution.

Next is Pasir Gudang air monitoring station which represent the south region of Peninsular Malaysia. The monitoring station are located at Sekolah Menengah Pasir Gudang 2, Pasir Gudang Johor. Pasir Gudang is a city of industry situated in the Johor Bahru District, Johor, Malaysia. It is situated at the eastern edge of the metropolitan area of Johor Bahru. Shipbuilding, petrochemicals, and other heavy industries, such the storage and distribution of palm oil, also operate in that area, although transportation and logistics are the most prominent (Teh et al., 2014). Pasir Gudang is well known to be the area with high emission of toxic chemical pollution. Toxic industrial chemicals may damage the environment and threaten human health, particularly in vulnerable populations such as children, the elderly, and pregnant women.

Paka is situated on the shore of the South China Sea in the state of Terengganu with latitude 4.6266° N and longitude 103.4400° E. Paka is bustling city that thrives on oil and gas activity near Kerteh. Paka is well recognised as the location of the largest power plant in Malaysia which is operated by the national power corporation, Tenaga Nasional Berhad (TNB). Paka air monitoring station are located at Tenaga Nasional Berhad Quarters Paka-Kerteh Terengganu about three kilometres from the Paka Town. Kemaman Technology & Industrial Park Sdn Bhd and PETRONAS Chemicals Ethylene Polyethylene are also located near the air monitoring station.

3.3 Air Monitoring Data

For this research, data were acquired from Department of Environment Malaysia (DOE) from July 2017 until July 2020. The API is defined based on the concentrations of five (5) major pollutants in the air, which are particulate matter of less than 10 microns in size (PM_{10}) and particulate matter of less than 2.5 microns in size ($PM_{2.5}$). ground level ozone (O_3), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2) These major pollutants are the parameter selection that will conducted throughout the research for five monitoring stations. Fine dust (PM_{10}) has the greatest concentration compared to the other contaminants. This air quality station also recorded meteorological parameters such as ambient temperature (°C), wind speed (m/sec), and humidity (%).

3.4 Descriptive Statistics

The descriptive statistic conducted to analyze the shape, dispersion, characteristic of air pollutant concentration for three year (2017 to 2020) that were selected for the descriptive analysis. The descriptive is quick summary that helps to explain and comprehend the aspects of a specific data set regarding the sample and characteristics of the data, which might be a representation of the complete population or a sample of the population. The value of mean, median, standard deviation, skewness and kurtosis for every data set can be obtained from the statistical software. The selected parameters that obtained were compared to the Malaysian Ambient Air Quality Standard (MAAQS) by the Department of Environment Malaysia. The Malaysian Ambient Air Quality values are the bare maximums for outdoor air quality in order to preserve people's health and the environment. The total suspended particles (TSP) or lead (Pb) is not selected since these variables are consistently low throughout the year.

3.5 Granger Causality Test

The correlation between parameters are analyzed by the causality test. Granger causality test is approach to see how much of the current parameter can explained by its past values and to see whether adding lagged the values of the parameter can be improve by the explanation. Granger causality is an econometric test used to verify the usefulness of one variable to forecast another. Granger cause another variable if its is helpful for forecastig the other variable (Eric, 2021; Eviews, 2015). As example, if parameter of O_3 is found to be helpful for forecasting parameter NO_2, so this can be said as O_3 is granger-cause to NO_2. The Granger causality test for two time-series, O_3 and NO_2 and are modeling them in the following VAR model:

$$O_3 = \beta 1 + \sum_{i=1}^{n} \alpha_i \, O_{3,t-i} + \sum_{j=1}^{m} \lambda_j NO_2 \; + \varepsilon_{1t} \tag{3.1}$$

$$NO_2 = \beta 2 + \sum_{j=1}^{m} \partial_i NO_{2,t-j} + \sum_{j-1}^{n} \psi_j \, O_{3,t-j} + \; \varepsilon_{2t} \tag{3.2}$$

The hypothesis of this test is:

The null hypothesis, H_0: $\lambda_i \; and \; \psi_i = 0 \; for \; all \; i$ (There is no causality between the parameters)

An alternative hypothesis, H_1: $\lambda_i \; and \; \psi_i \neq 0 \; for \; all \; i$ (There is causality between the parameters).

To understand better of causal relationship, causal graphical models is necessary to describe the dynamics of causality. Modelling causality with graphs provides ideal framework in describing the causality as show on the Figure 3.3.

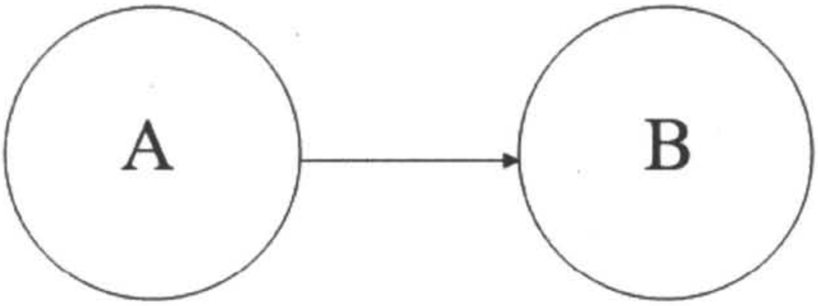


Figure 3.3: Example of graphical illustration of causality relationship

A is consider as the main event that cause by B so the direction of arrow will draw from A to B. This means that the model is considering a possible causal relation from A to B. A causal diagram also facilitates the visualisation of how various variables in a system are causally interconnected. The graphic is composed of a series of text and arrows. The narrative accompanying causal diagrams describes the causally closed scenario (Nick, 2022)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the outcome and analysis be described in detail. The analysis are performed by running the suitable software for each objective. First objective is to determine the characteristic of air pollution data in Peninsular Malaysia at industrial area from July 2017 until July 2020. The data are analysed by using IBM SPSS statistical software version 26 for descriptive statistics. The yearly mean result of air quality of PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 in each of selected air monitoring station specified at industrial area were compared to the Malaysian Ambient Air Quality Standard (MAAQS).

The second objective is to investigate the relationship between air pollution parameters using Granger Causality Test and illustrate the causality of air pollution parameters at industrial areas in Peninsular Malaysia by using graphical view of causality from July 2017 until July 2020. The causality between air pollution parameter is analysed by Eviews Software Version 12 for VAR Granger Causality Test. Then, the causal relationship between air pollution parameter at each selected station are illustrated into a graphical view.

4.2 Desriptive Statistics for Air Pollution

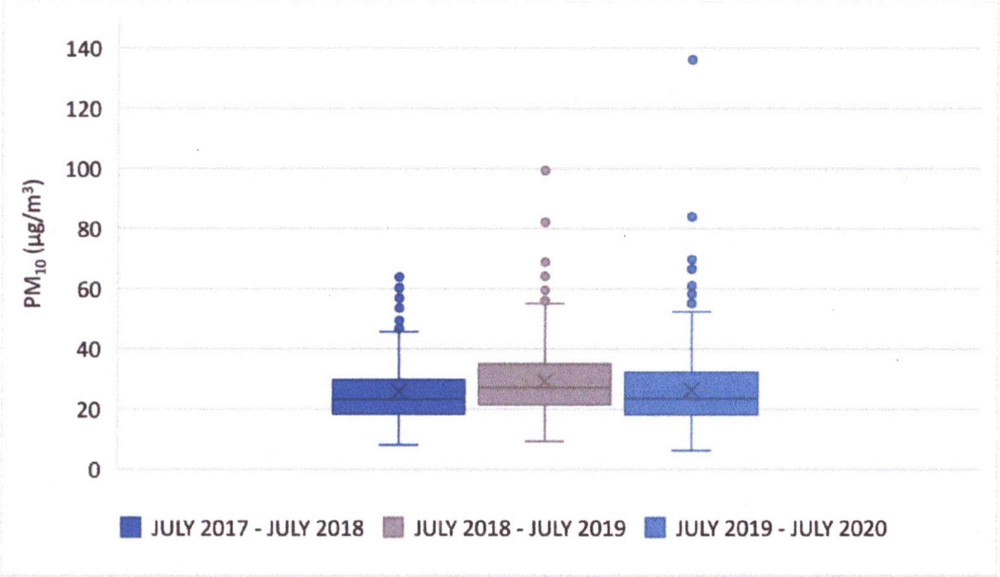
In this part, the descriptive data of air pollution parameter at five selected air monitoring station at Seberang Perai (Pulau Pinang), Tasek Ipoh (Perak), Klang (Selangor), Pasir Gudang (Johor), and Paka (Terengganu) are presented in Table 4.1, 4.2, 4.3, 4.4. and 4.5. The monthly data of air pollution parameter concentrations was subjected to descriptive analysis, and the results are useful in determining the pollution status and features of the PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentration at each monitoring station from July 2017 until July 2020. The result are also potrayed in box and whiskers plot in Figure 4.1, 4.2, 4.3, 4.4 and 4.5.

4.2.1 Descriptive Analysis for Seberang Perai, Pulau Pinang Monitoring Station

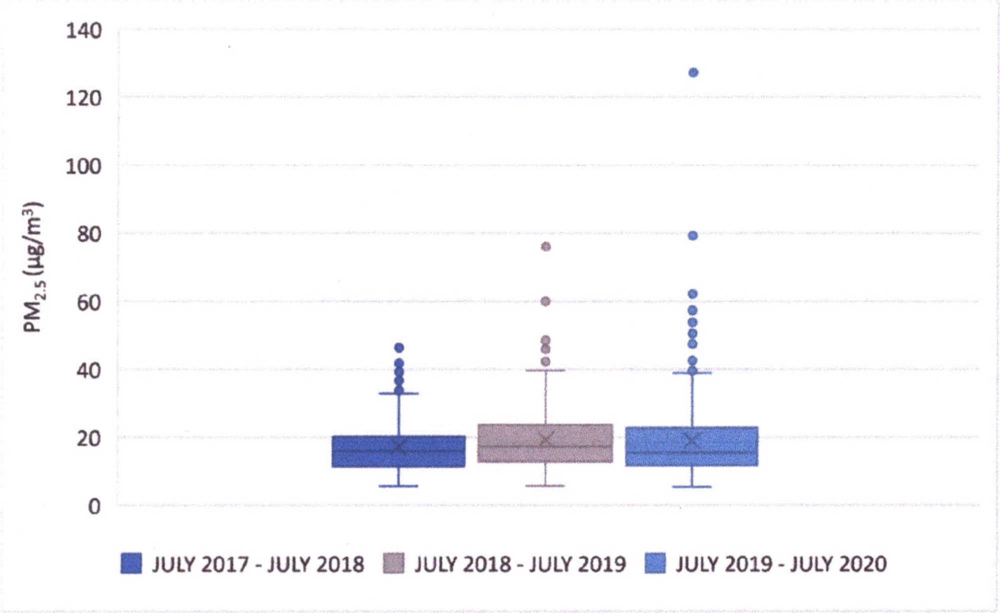
Pulau Pinang is one of Malaysia's most quickly developing states, with a high population density, industrial activity, motor vehicle density, and development projects. Penang's island area encompasses around 285 km^2 and is densely populated, with 1,490 persons per square kilometre and a total population of 1,596,900 in 2010. Seberang Perai is a large Malaysian city located in the northern region of Peninsular Malaysia. (Ul-Saufie et al., 2012).

Table 4.1: The Descriptive Analysis at Seberang Perai, Pulau Pinang

Parameter	Year	N	Minimum	Maximum	Mean	St. Deviation	Skewness	Kurtosis
PM_{10} ($\mu g/m^3$)	2017	181	**9.634**	63.952	27.353	11.445	1.100	0.850
	2018	365	8.164	99.381	27.453	12.130	1.580	4.190
	2019	365	6.302	**136.082**	**27.818**	**12.919**	**2.450**	**14.150**
	2020	188	10.172	51.968	25.254	8.209	0.500	-0.360
$PM_{2.5}$ ($\mu g/m^3$)	2017	181	5.629	41.870	17.020	8.380	1.070	0.540
	2018	365	**6.192**	76.000	18.740	9.200	1.780	5.070
	2019	365	5.453	**127.260**	**20.040**	**12.270**	**3.060**	**17.890**
	2020	188	5.473	36.340	16.549	6.348	0.540	-0.270
SO_2 (ppm)	2017	181	0.000	**0.004**	0.001	0.000	**1.592**	**9.429**
	2018	365	0.000	0.003	0.001	0.000	0.817	1.724
	2019	363	0.000	0.002	0.001	0.000	0.893	1.140
	2020	188	0.000	0.001	0.001	0.000	0.210	-0.380
NO_2 (ppm)	2017	181	0.000	0.022	0.009	0.004	-0.399	**0.838**
	2018	365	0.003	0.020	**0.010**	0.003	0.398	0.231
	2019	363	0.003	0.018	0.009	0.002	0.316	0.387
	2020	188	0.002	0.015	0.007	0.002	**0.610**	0.160
O_3 (ppm)	2017	181	0.000	**0.060**	0.019	0.010	0.210	**0.942**
	2018	365	0.003	0.047	**0.021**	0.008	**0.317**	-0.350
	2019	365	0.004	0.040	0.020	0.010	0.250	-0.180
	2020	188	**0.005**	0.040	0.017	0.006	0.310	-0.290



a) PM_{10} daily mean concentration at Perai, Pulau Pinang



b) $PM_{2.5}$ daily mean concentration at Perai, Pulau Pinang

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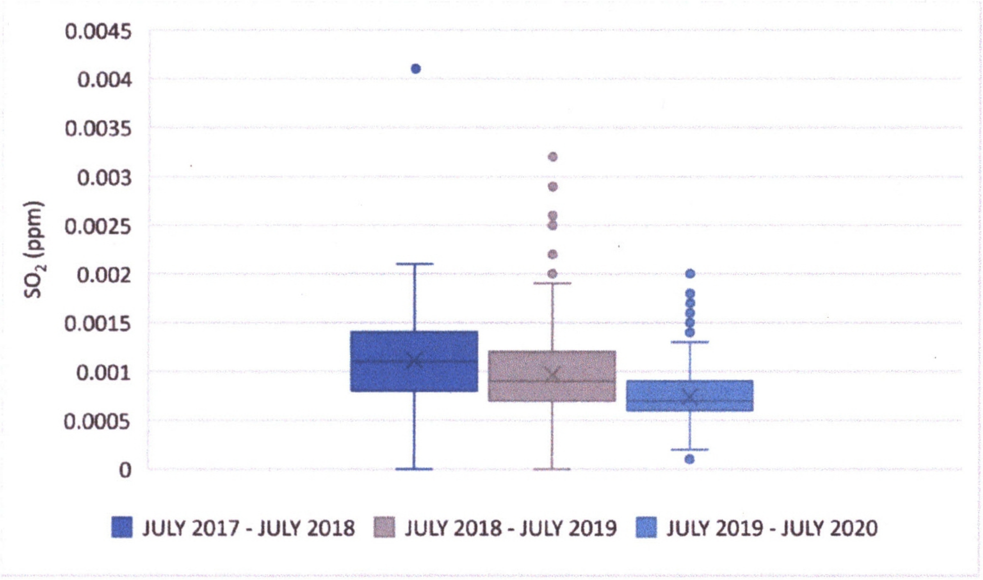
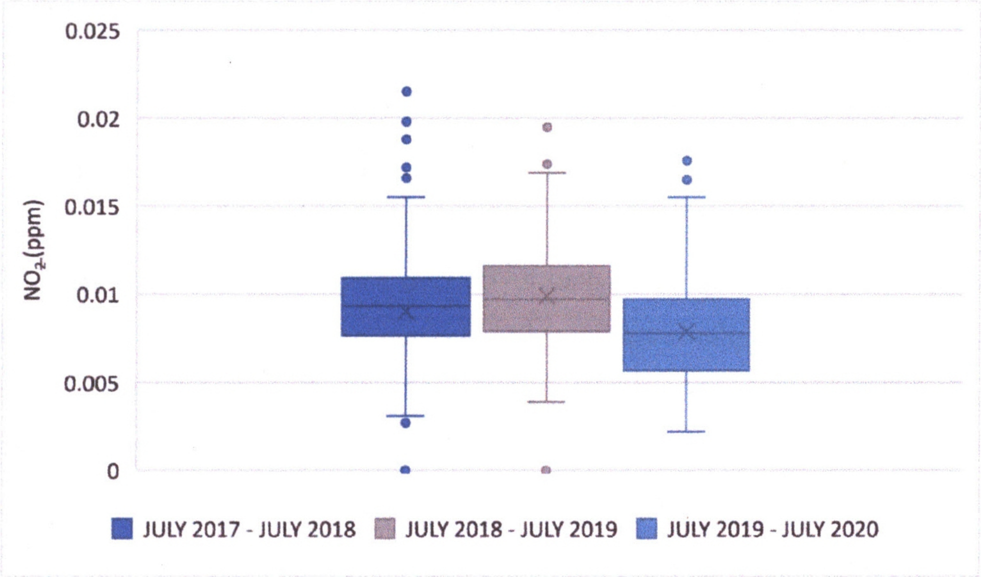
Figure 4.1: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Perai, Pulau Pinang



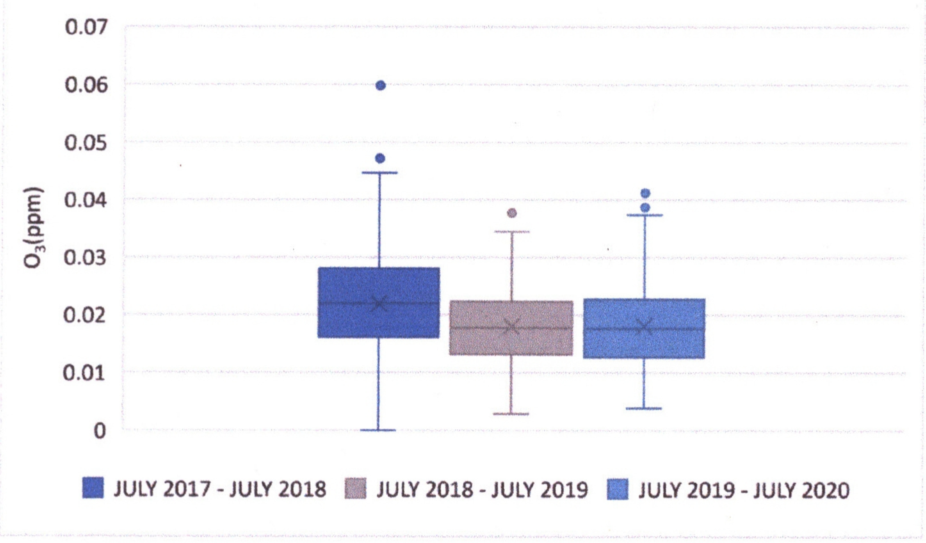
c) SO_2 daily mean concentration at Perai, Pulau Pinang



d) NO_2 daily mean concentration at Perai, Pulau Pinang

Continued

Figure 4.1: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017 – July 2020 at Seberang Perai, Pulau Pinang (Continued)



e) O_3 daily mean concentration at Perai, Pulau Pinang

Figure 4.1: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017 – July 2020 at Seberang Perai, Pulau Pinang (Continued)

Seberang Perai monitoring station located near the industrial area such as manufacturing factory, residential and commercial area with high load traffic. From Table 4.1 shown the overall data of decriptive analysis of daily average air pollutant concentration for Perai monitoring station. The minimum value for PM_{10} shows that there was a gradual decrease from 9.634 µg/m^3 (2017) to 6.302 µg/m^3 (2019) then slight rise to 10.172 µg/m^3 (2020). The maximum value for PM_{10} shown modest annual growth from 63.952 µg/m^3 (2017) to 136.082 µg/m^3 (2019) and unexpectedly the value fell dramatically to 51.968 µg/m^3 (2020). The highest maximum value was reported in 2019 (136.082 µg/m^3) along with the mean value 27.818 µg/m^3. However, the mean trend shows there is steady trend from 2017 (27.353 µg/m^3) to 2019 (27.818 µg/m^3). It also recorded in Department of Statistic Malaysia there were an increasing of manufacturing in Seberang Perai such as electrics and electronics industry, machinery manufacturing and more (Yusof et al., 2008). These scenarios exacerbated the area's air pollution problem, exposing residents of Seberang Perai to the effects of air pollution. These also support by the PM_{10} concentrations the value of skewness during 2019 (2.450) The value of kurtosis shows that the peaked-ness of the PM_{10} distribution in Perai is higher than the normal distribution which indicates extreme event occurrence in

PM_{10} concentrations primarily because of increasing number of industrial, usage motor vehicles and the haze that occur during the months from June to August.

$PM_{2.5}$ concentration has the highest mean value in 2019 which is 20.040 µg/m^3 and were also declined significantly to 16.549 µg/m^3 in 2020. The highest maximum value of $PM_{2.5}$ concentration was also recorded in year 2019 (127.260 µg/m^3). However, the minimum value of average daily mean concentration of $PM_{2.5}$, was in 2020 which is 15.93 µg/m^3 among the three years and we can clearly see that in 2020 the concentration among parameter was decreased significantly as it influenced by the Movement Control Order (MCO) that has been implement by the country. According to the researcher Abdullah et al. (2020) that the MCO has been found to reduce $PM_{2.5}$ concentrations. Seberang Perai recorded the mean value before the MCO was 19.2 µg/m^3 and after MCO was 17.4 µg/m^3. Figure 4.1 (b) also show the illustration of box plot for $PM_{2.5}$ concentration and the result shows that there was positive skewness of $PM_{2.5}$ for the three consecutive years.

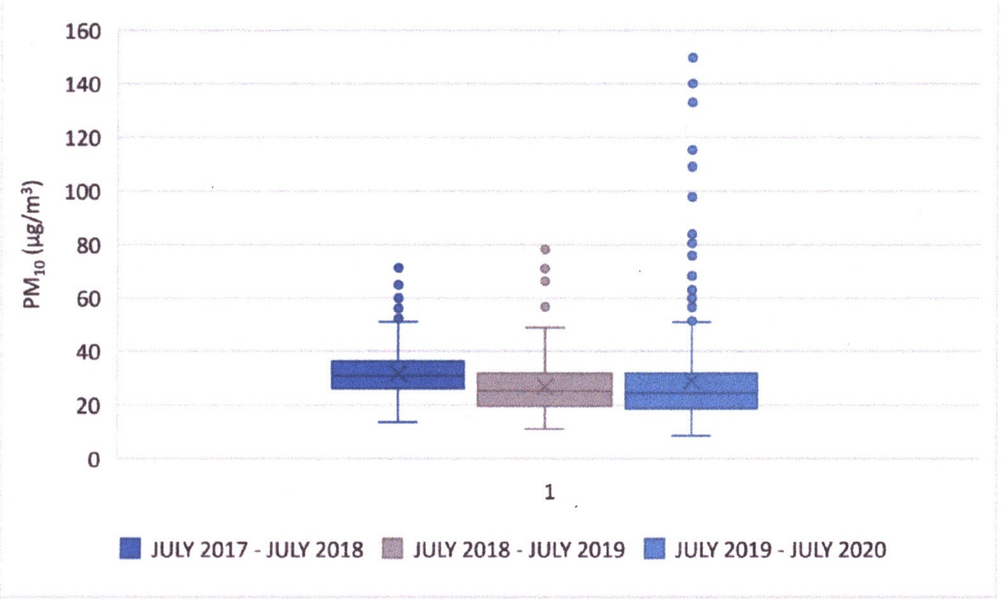
The SO_2 concentration have less emission due to Perai monitoring station is far from any power plant that may pollute the atmosphere. However, it is still recorded since the two of parameter which is SO_2 and NO_2 were widespread. NO_2 was also being the most significant contributor in vehicular emission that usually comes from the burning of fossil fuels mostly in type of gasoline. From Figure 4.1(c) there is normal distribution of box and whiskers plot in year 2017-2018 since the median is in the centre of box for SO_2 concentration, despite the fact that on 2017 there is high value of kurtosis 9.429, indicating it has extreme outliers compared to other years. As for NO_2, Figure 4.1 (d) illustrated that it has a symmetric distribution since the whiskers between the box were nearly same.

4.2.2 Descriptive Analysis for Tasek Ipoh, Perak Monitoring Station

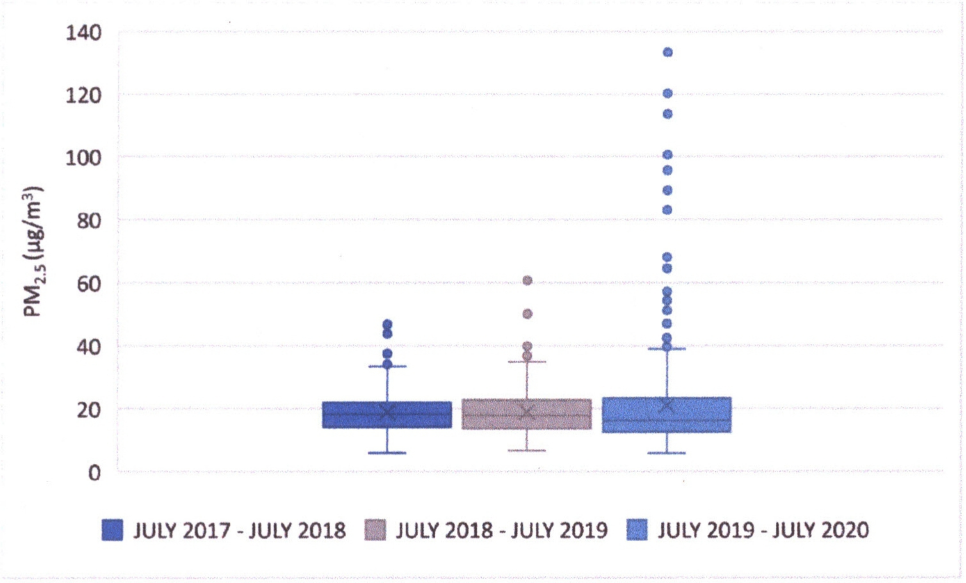
There are several heavy industries in the Tasek Ipoh region, especially near Bercham. Tasek Industrial area is home to a variety of industries including plastics, non-metal, rubber bases, food, printing, and wood bases. Many textiles, metal, and wood businesses may be found in Bercham and the IGB Industrial area. Two landfill disposal quarries are also located within three kilometres from the air monitoring station (Azman et al., 2017).

Table 4.2: The Descriptive Analysis at Tasek Ipoh, Perak

Parameter	Year	N	Minimum	Maximum	Mean	St. Deviation	Skewness	Kurtosis
PM_{10} ($\mu g/m^3$)	2017	181	**13.640**	71.300	30.040	10.930	1.070	1.270
	2018	365	11.270	78.190	28.760	9.970	0.860	2.020
	2019	365	11.110	**149.740**	**31.140**	**17.650**	**3.470**	**15.840**
	2020	188	8.550	43.810	22.480	7.840	-0.380	0.0
$PM_{2.5}$ ($\mu g/m^3$).	2017	181	5.900	46.700	18.810	7.600	1.020	1.100
	2018	365	6.700	60.630	18.750	6.950	1.570	5.200
	2019	365	6.610	**133.330**	**22.840**	**16.030**	**3.470**	**15.840**
	2020	188	5.790	38.240	15.930	5.980	0.640	0.250
SO_2 (ppm)	2017	181	-	-	-	-	-	-
	2018	365	-	-	0.0013	-	0.420	-0.150
	2019	365	0.000	0.000	0.0013	0.000	0.782	4.187
	2020	188	-	-	0.0009	-	0.620	1.120
NO_2 (ppm)	2017	181	-	-	-	-	-	-
	2018	365	-	0.020	0.0107	-	0.090	-0.060
	2019	365	0.000	0.020	0.0106	0.003	0.326	0.373
	2020	188	-	0.010	0.0073	-	0.020	-0.910
O_3(ppm)	2017	181	-	-	-	-	-	-
	2018	365	-	0.040	0.0182	0.010	0.280	0.860
	2019	365	0.010	0.040	0.0207	0.010	0.550	0.030
	2020	188	0.010	0.040	**0.0216**	0.010	0.240	-0.410



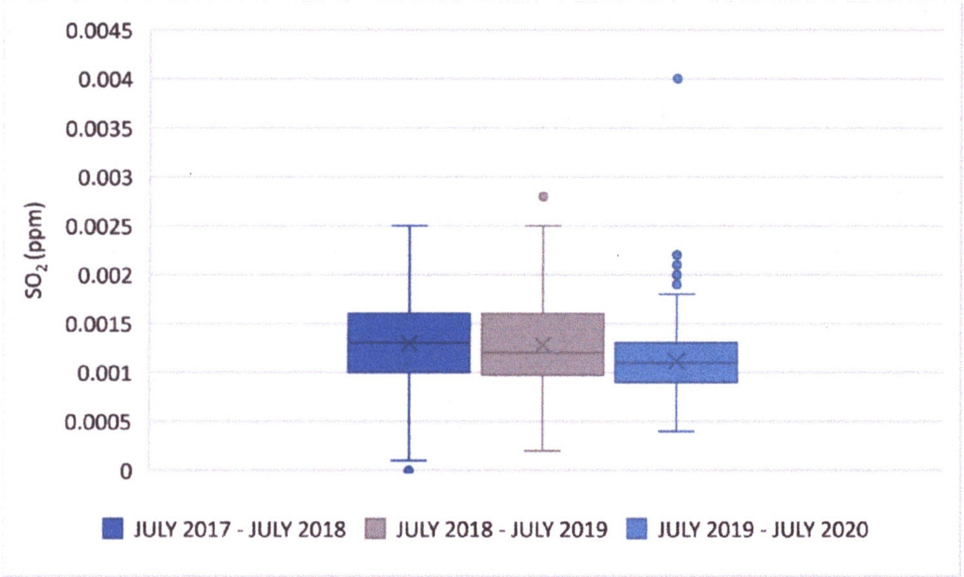
a) PM_{10} daily mean concentration at Tasek Ipoh, Perak



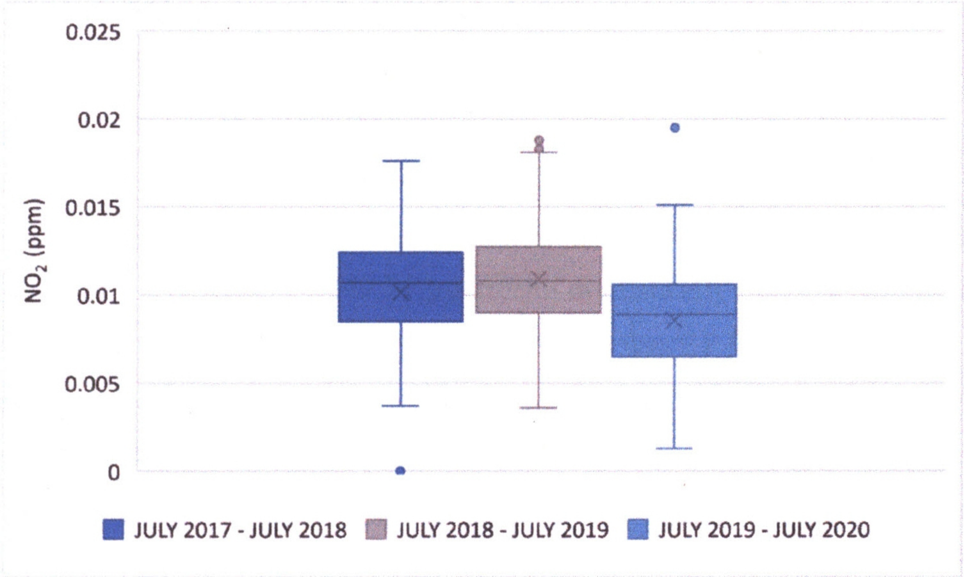
b) $PM_{2.5}$ daily mean concentration at Tasek Ipoh , Perak

Continued

Figure 4.2: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Tasek Ipoh, Perak.



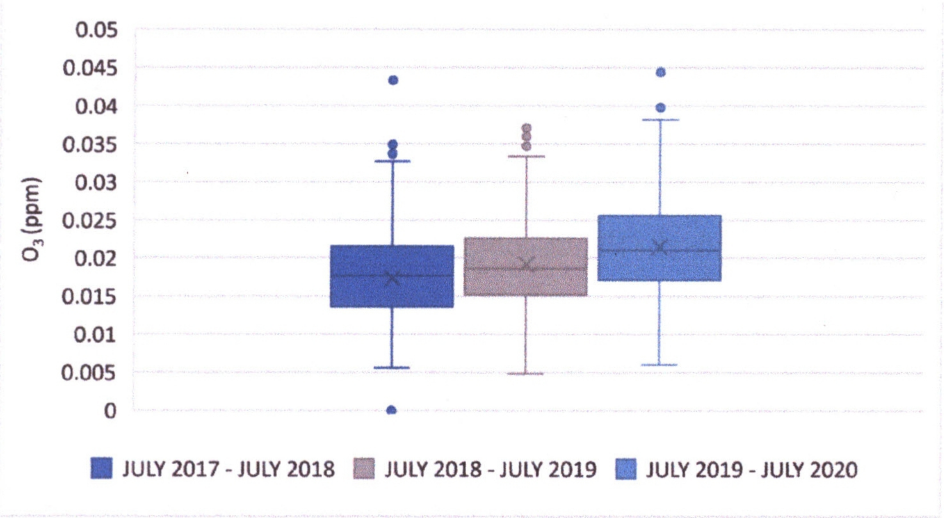
c) SO_2 daily mean concentration at Tasek Ipoh, Perak



d) NO_2 daily mean concentration at Tasek Ipoh, Perak

Continued

Figure 4.2: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Tasek Ipoh, Perak (Continued).



e) O_3 daily mean concentration at Tasek Ipoh, Perak

Figure 4.2: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Tasek Ipoh, Perak (Continued).

From Table 4.2, the analysis shows the overall data of descriptive statistics of daily average of air pollutant concentration in Tasek Ipoh, Perak. The analysis shows the minimum value of PM_{10} concentration were reduce significantly from 13.64 µg/m^3 to 8.55 µg/m^3. However, the highest maximum value for PM_{10} concentration was in 2019 (149.74 µg/m^3). The maximum value exhibits a fluctuant trend where it slightly increases from 71.30 µg/m^3 to 149.74 µg/m^3 and dramatically decrease on 2020 43.81 µg/m^3. The highest mean average value for PM_{10} was 31.14 µg/m^3 (2019) and if compared to the Malaysian Ambient Air Quality Standard the value still not exceed the limit which it under 100 µg/m^3. The box and whiskers plot in Figure 4.2 (a) also demonstrated that on year July 2019 to July 2020 there were high value in skewness and kurtosis which 3.47 and 15.84, indicating large outliers and the existence of extreme events during the year.

Table 4.2 shown there were increasing trends in maximum values of $PM_{2.5}$ concentration from 46.70 µg/m^3 in 2017 to 133.33 µg/m^3 in 2019 and was reported as the greatest in 2019. According to the study by Ismail et al. (2017), Tasek Ipoh is an area with variety of industries including plastics, non-metal, rubber bases, food, printing, and wood bases. Many textiles, metal, and wood businesses may be found in Bercham and the IGB Industrial Area. Two landfill disposal quarries are located three kilometres from the air monitoring station.

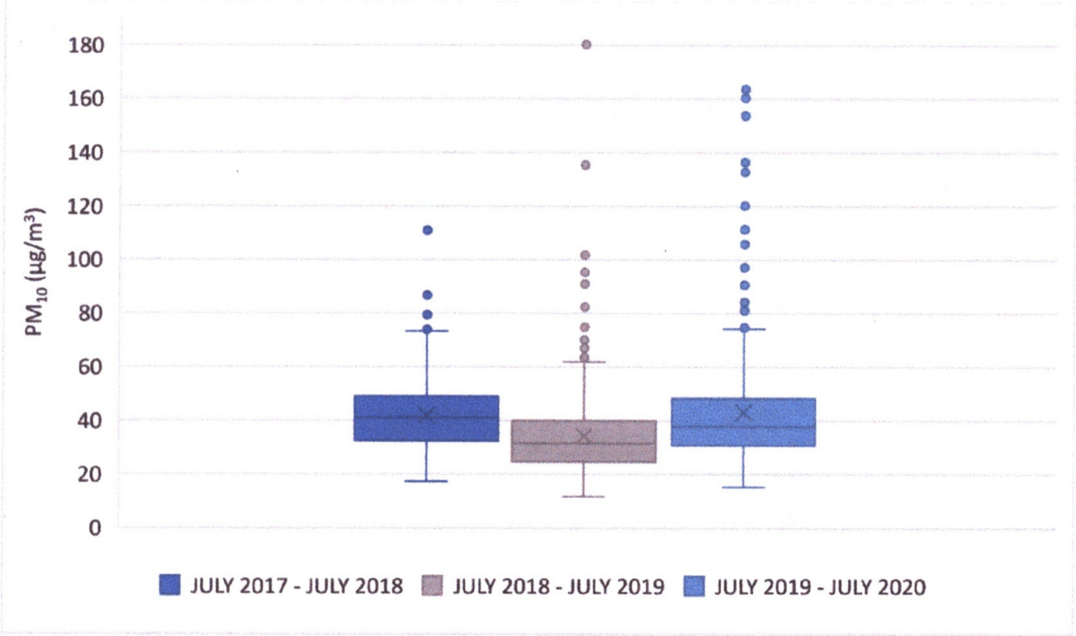
From Figure 4.2 (d) demonstrate the distribution of box and whiskers plot for NO_2 concentration which show on July 2017 to July 2018 and July 2019 to July 2020 the box skewed to the left which also indicates in negative skewness as shown on Table 4.2 that the kurtosis value for NO_2 concentration in 2018 is -0.06 and in 2020 is –0.91. The O_3 concentration has almost the same value for all the statistics. The mean value for O_3 concentration was significantly stable through the three consecutive years.

4.2.3 Descriptive Analysis for Klang, Selangor Monitoring Station

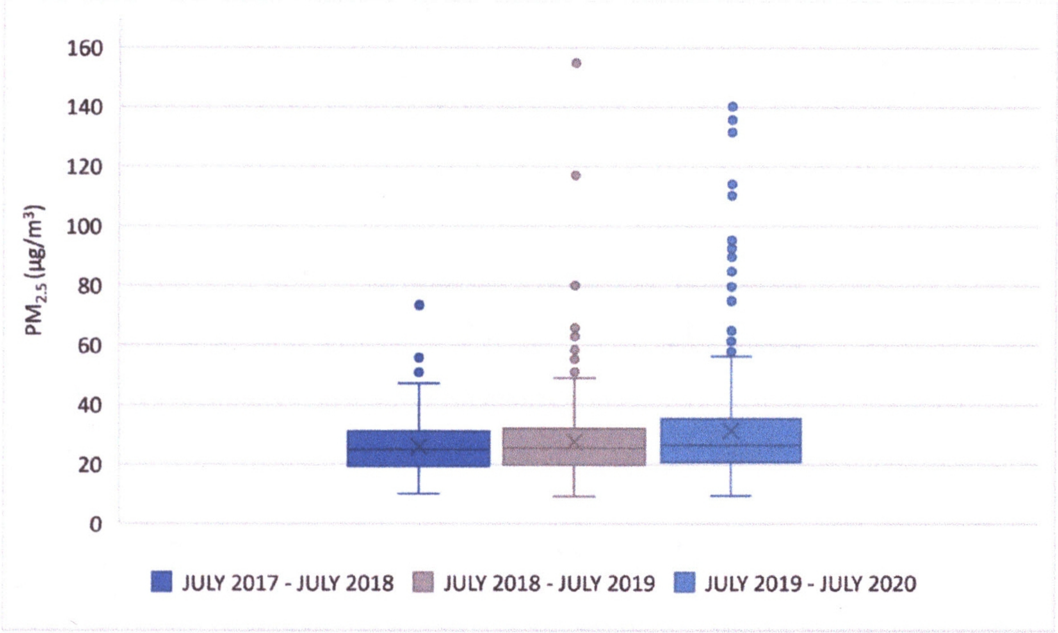
Klang is Malaysia's primary economic area, with considerable physical infrastructure development, industrialization, and urbanisation (Department of Statistics Malaysia, 2011). The monitoring station located at SMK (P) Raja Zarina at Port Klang. Port Klang is located in the southwestern part of the Malaysian Peninsular, flanked to the east by mountains surpassing 1,500 m in elevation and to the west by the Straits of Malacca (Abas and Simoneit 1996; Omar et al. 2002).

Table 4.3: The Descriptive Analysis at Klang, Selangor

Parameter	Year	N	Minimum	Maximum	Mean	St. Deviation	Skewness	Kurtosis
PM_{10}($\mu g/m^3$)	2017	181	**17.21**	110.99	39.01	12.51	1.4	5.22
	2018	365	13.59	**180.23**	41.3	17.33	2.35	13.14
	2019	365	11.69	163.54	**41.42**	**22.58**	**2.6**	9.42
	2020	188	15.2	61.55	34.34	9.77	0.49	-0.28
$PM_{2.5}$($\mu g/m^3$).	2017	181	**10.05**	73.55	23.93	8.61	1.66	5.9
	2018	365	9.21	**154.85**	28.14	13.05	**3.99**	**30.22**
	2019	365	9.76	140.32	**33.04**	**18.52**	2.93	11.75
	2020	188	9.45	45.85	23.61	7.1	0.62	0.02
SO_2 (ppm)	2017	181	-	0.01	**0.0022**	-	2.47	8.99
	2018	365	-	0.01	0.0019	-	1.07	1.85
	2019	365	-	0.01	0.0013	-	3.29	11.97
	2020	188	-	-	0.0010	-	0.76	0.68
NO_2(ppm)	2017	160	0.01	0.03	0.0171	-	0.21	-0.09
	2018	365	0.01	0.04	0.0203	0.01	0.52	0.24
	2019	365	0.01	0.03	**0.0178**	-	0.21	-0.16
	2020	188	-	0.03	0.0141	0.01	0.21	-0.36
O_3(ppm)	2017	160	-	0.03	0.0130	0.01	0.76	1.42
	2018	365	-	0.04	**0.0177**	0.01	0.35	0.4
	2019	365	-	0.03	0.0137	0.01	0.77	0.7
	2020	188	-	0.04	0.0176	0.01	0.62	0.18



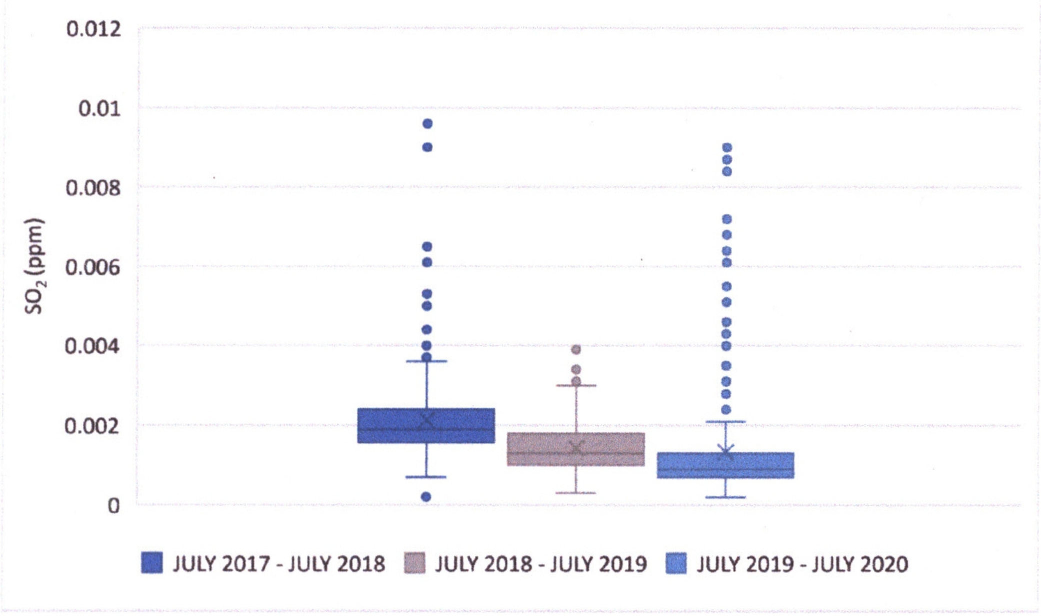
a) PM_{10} daily mean concentration at Klang, Selangor



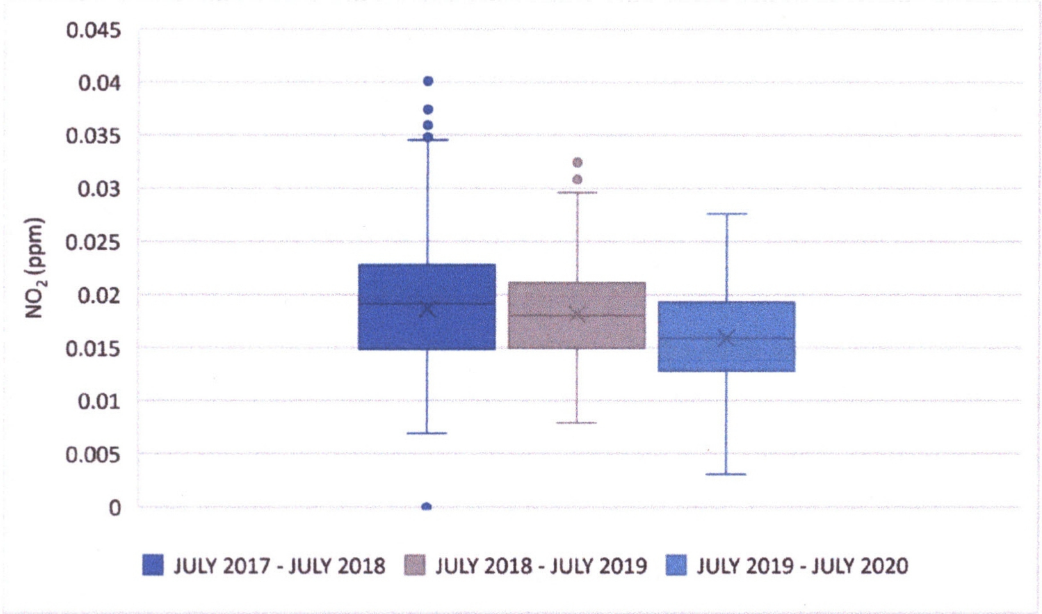
b) $PM_{2.5}$ daily mean concentration at Klang, Selangor

Continued

Figure 4.3: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2018, 2019 nd 2020 at Klang, Selangor.



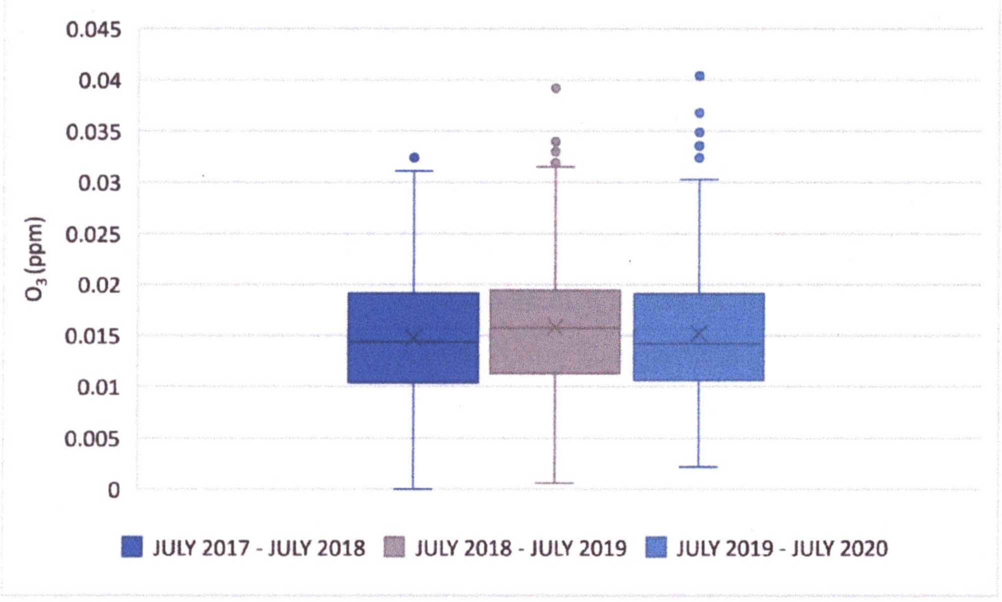
c) SO_2 daily mean concentration at Klang, Selangor



d) NO_2 daily mean concentration at Klang, Selangor

Continued

Figure 4.3: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Klang, Selangor (Continued).



e) O_3 daily mean concentration at Klang, Selangor

Figure 4.3: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Klang, Selangor (Continued).

Table 4.3 shown the overall data of daily average air pollution concentration for Klang air monitoring station. The data analysis has N value of 181 for 2017, 365 for 2018, 365 for 2019 and 188 for 2020. The maximum value for PM_{10} concentration were recorded as the greatest in 2018 with 180.23 µg/m^3 and the value drop dramatically to 61.55 µg/m^3 (2020). The reduction of PM_{10} can prevented infants' deaths as well as early death among adult with heart or respiratory illness such as cardiac dysrhythmias, nonfatal heart attacks, exacerbated asthma, and diminished the lung functions (Ghorni-Azam, Riahi-Zanjani, & Balali-Mood, 2016). Despite the fact that the pollutant level did not exceed the threshold, the greatest concentration of PM_{10} was observed in Klang, the state capital and the centre of numerous industrial operations and enterprises. It is also home to Malaysia's busiest and largest port, Port Klang, which may add to the significant traffic congestion caused by the Port (Shah et al., 2010). Figure 4.3 (a) illustrate the box and whiskers plot for PM_{10} concentration for the three consecutive years, the skewness shows a positive value as it skews to the right. The greatest kurtosis readings (13.14) were also found in 2018, indicating the most outliers across the three years that influenced by haze and open burning activities during hot weather seasons (DOE, 2018)

In 2018, the maximum value for $PM_{2.5}$ concentration were the highest compared the other years which is 154.85 μg/m^3. There is a fluctuant trend for mean value, $PM_{2.5}$ concentration shows a gradually increase from 23.93 μg/m^3 (2017) to 33.04 μg/m^3 (2019) and unexpectedly drop to 23.61 μg/m^3 (2020). However, the highest kurtosis value for $PM_{2.5}$ were reported on 2018 which is 30.22 indicating the largest outliers with the distribution were skewed to the right which also indicates the extreme high value for 2018. During 2018, haze was happened during that particular period and Klang has registered the reading to 227 and extremely exceed the Air Pollution Index reading which shown as unhealthy air. It is likely that the distribution of pollutants was influenced by these monsoons (DOE, 2018). Meanwhile, Klang station was located near main roads and industrial and residential areas and thus experienced a high density of vehicles which significantly contributed to high concentrations of air pollutants (Azid et al., 2015).

In 2018 mean value for NO_2 and O_3 were within range of 0.0203 ppm and 0.0177 ppm. Which these values were highest among three years. NO_2 that emit into the atmosphere from the chemical reaction from industry also produce O_3, this support by the finding from DOE, 2018 which there is several unhealthy days recorded in Klang which were stated for 10 days with API reading between 101-200 that due to O_3 level especially on sunny day. Meanwhile, Klang station was located near main roads and industrial and residential areas and thus experienced a high density of vehicles which significantly contributed to high concentrations of air pollutants (Azid et al., 2015).

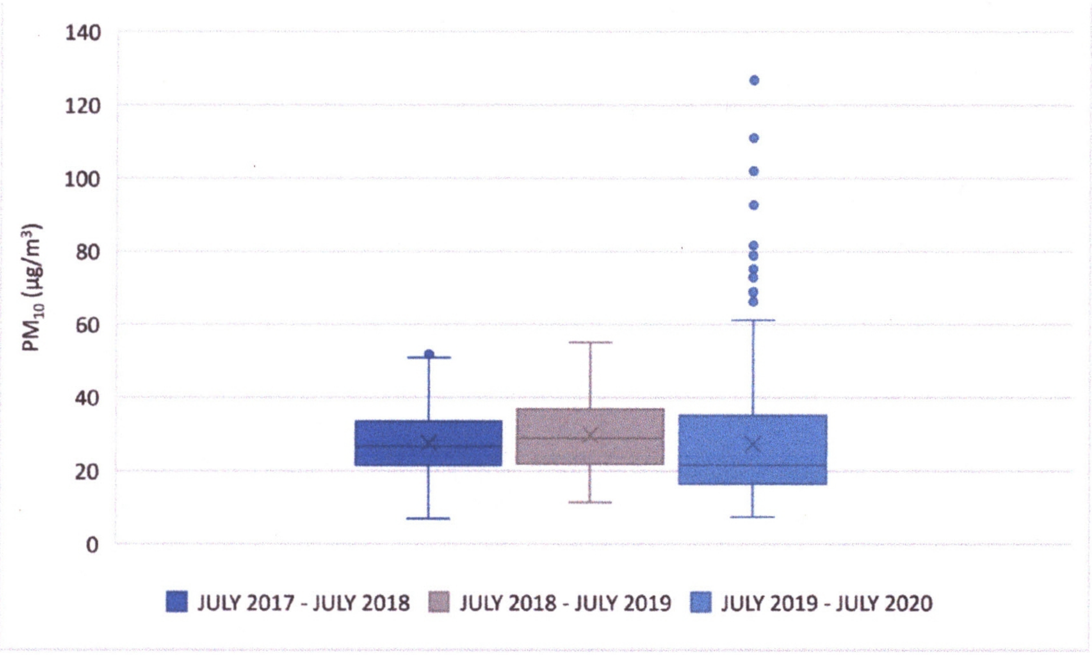
4.2.4 Descriptive Analysis for Pasir Gudang, Johor Monitoring Station

Pasir Gudang is an important Malaysian industrial and coastal city (Abdullah et al.,2012). Pasir Gudang is an economic hub with 2,005 enterprises, including 250 chemical plants.

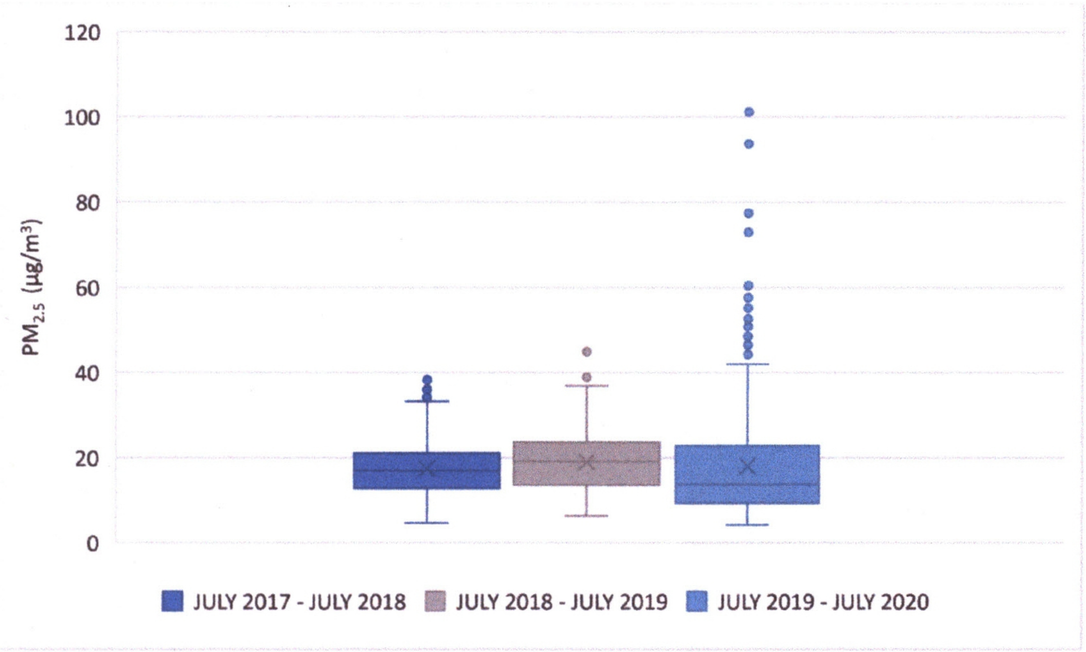
Table 4.4: Descriptive Analysis Pasir Gudang, Johor

Parameter	Year	N	Minimum	Maximum	Mean	St. Deviation	Skewness	Kurtosis
PM_{10}($\mu g/m^3$)	2017	181	**12.15**	51.76	29.25	8.28	0.23	-0.19
	2018	365	6.90	52.58	**29.51**	9.93	0.31	-0.71
	2019	365	7.44	**126.94**	31.46	**15.36**	**2.02**	**7.31**
	2020	188	7.64	37.35	18.73	5.24	0.93	1.25
$PM_{2.5}$($\mu g/m^3$)	2017	181	6.65	36.26	18.47	5.93	0.47	0.24
	2018	365	4.68	39.92	18.61	6.56	0.40	-0.21
	2019	365	4.51	**101.21**	**21.07**	**12.48**	**2.36**	**9.20**
	2020	188	4.21	29.59	11.43	4.34	1.27	2.32
SO_2(ppm)	2017	181	-	0.01	-	-	1.12	2.43
	2018	365	-	0.01	-	-	2.23	9.75
	2019	365	-	-	-	-	0.43	0.13
	2020	188	-	-	-	-	2.26	10.47
NO_2(ppm)	2017	156	-	0.03	0.01	-	0.05	-0.32
	2018	365	-	0.03	0.01	0.01	0.51	0.08
	2019	365	-	0.03	0.01	0.01	0.61	0.13
	2020	188	-	0.02	0.01	-	0.86	-0.24
O_3(ppm)	2017	156	-	0.04	0.01	0.01	0.93	0.62
	2018	365	-	0.04	0.01	0.01	0.88	1.34
	2019	365	-	0.04	0.02	0.01	0.43	-0.02
	2020	188	-	0.03	0.02	0.01	-0.04	-0.37

Table 4.4 displays the descriptive statitsics for daily average of air pollutant concentrations in Pasir Gudang, Johor which is one of heavy industrial activity in Peninsular Malaysia. Pasir Gudang had the highest maximum value of PM_{10} concentration during 2019 which is 126.94 $\mu g/m^3$, as well as the highest value of average mean daily for PM_{10} value in 2019 which is 31.46 $\mu g/m^3$. However, the highest minimum value was in 2017 at 12.15 $\mu g/m^3$. The reduction of mean and maximum value of PM_{10} concentrations occurs on 2020 which are 18.73 $\mu g/m^3$ and 37.35 $\mu g/m^3$ respectively.



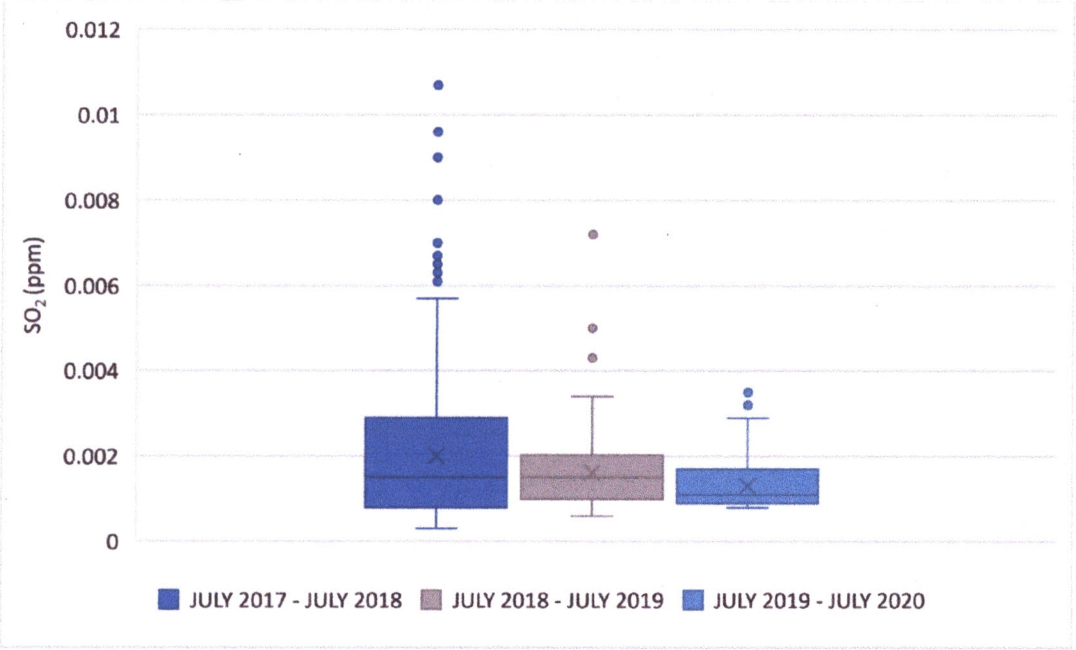
a) PM_{10} daily mean concentration at Pasir Gudang, Johor



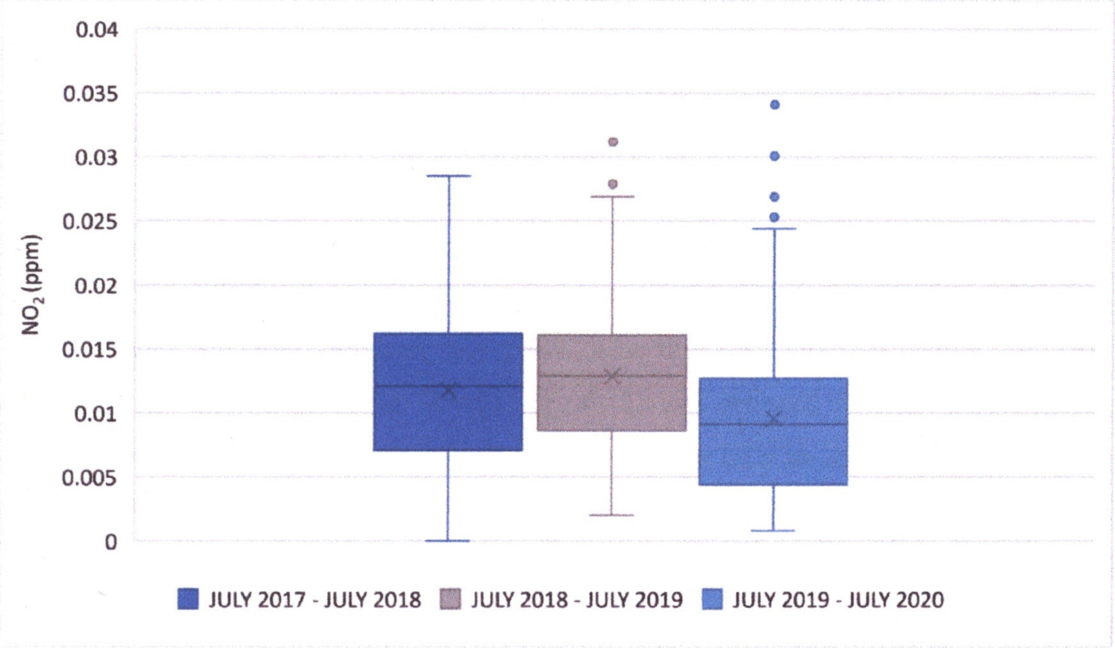
b) $PM_{2.5}$ daily mean concentration at Pasir Gudang, Johor

Continued

Figure 4.4: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Pasir Gudang, Johor.



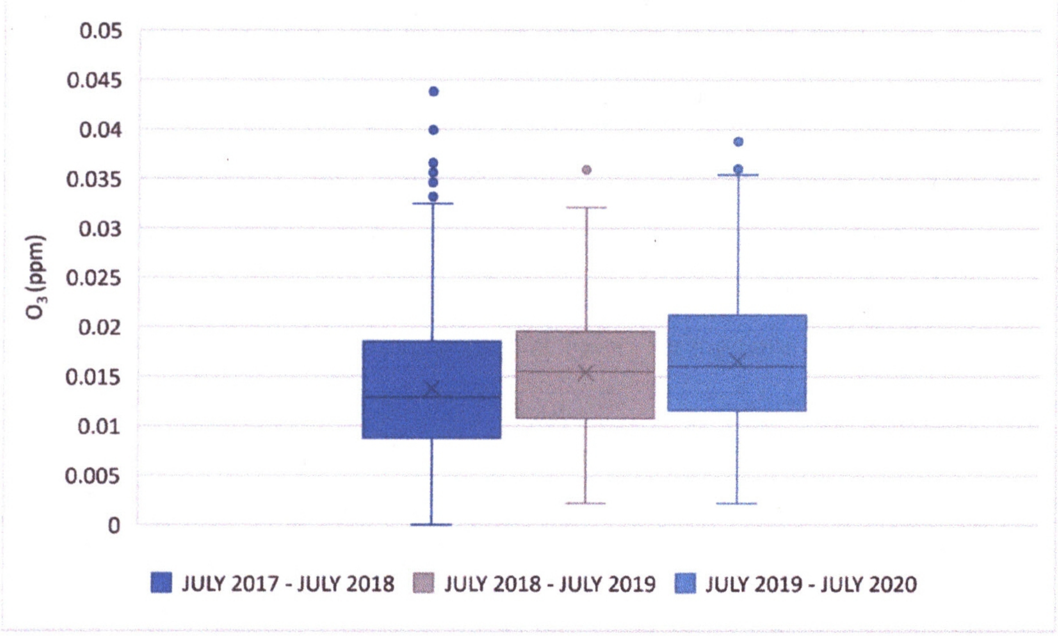
c) SO_2 daily mean concentration at Pasir Gudang, Johor



d) NO_2 daily mean concentration at Pasir Gudang, Johor

Continued

Figure 4.4: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Pasir Gudang, Johor (Continued).



e) O_3 daily mean concentration at Pasir Gudang, Johor

Figure 4.4: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Pasir Gudang, Johor (Continued).

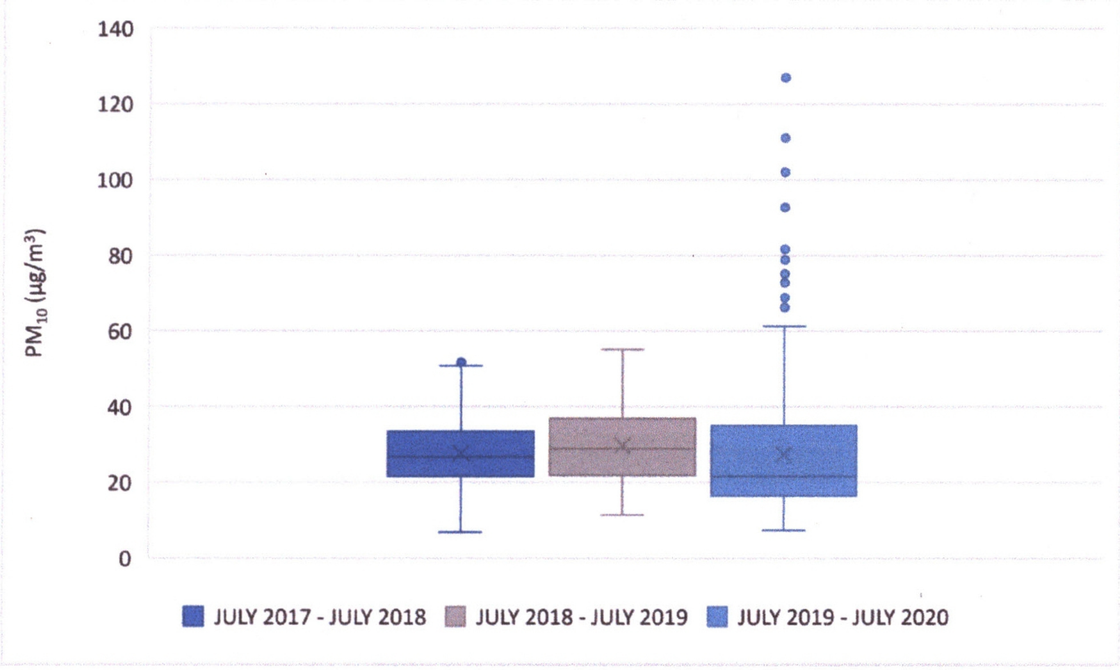
The PM_{10} distribution during July 2019 until July 2020 were skewed to the right with the skewness value of 2.02 that shows occurrence high concentrations event as illustrated in Figure 4.4 (a). From the result obtained, for $PM_{2.5}$ concentration, the minimum value for this parameter has slightly decrease from 6.65 37.35 µg/m^3 in 2017 to 4.21 µg/m^3 in 2020. However, the minimum value for $PM_{2.5}$ from 2018 to 2020 it has no significant different between the years. The highest maximum value for $PM_{2.5}$ concentration was on 2019 at 101.21 µg/m^3. It can be said that it has significant increased from year 2017 which the maximum value is only at 36. 26 µg/m^3 until year 2019, and sudden drop on 2020 at 29.59 µg/m^3. The trends are same for average daily mean concentration of $PM_{2.5}$ which is the highest value was on 2019 at 21.07 µg/m^3 and sudden drop in 2020 at 11.43 µg/m^3 that cause by the MCO. Unexpectedly, the result is different from the finding of Abdullah et al. (2020) it show that Pasir Gudang before MCO 9.3 µg/m^3 (14-17 March 2020) and the value increased to 10.9 µg/m^3 (18-31 March 2020). Proceed with the box and whiskers plot for $PM_{2.5}$ concentration as illustrated in Figure 4.4 (b) the tail of the box skewed to the left, for year (2018 -2019 with -0.21(2018-2019). The box for year 2019 -2020 skewed to the right with the larger outliers at 9.20.

4.2.5 Descriptive Analysis for Paka, Terengganu Monitoring Station

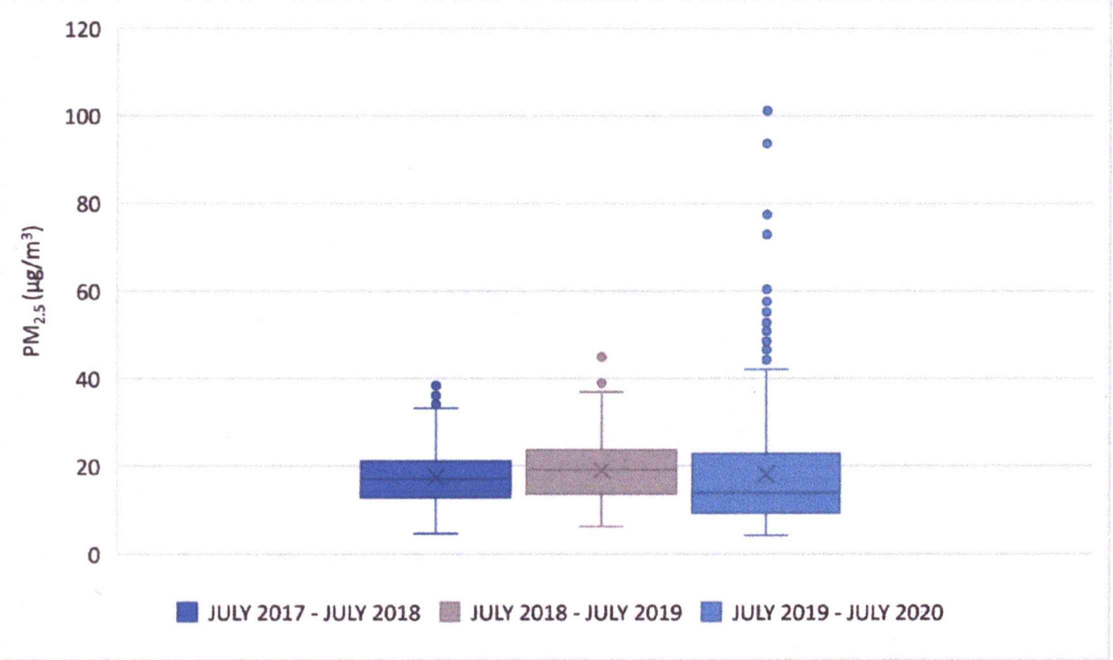
Paka Terengganu well known with their power plants and potroleum activities near Kerteh Terengganu. this industrial activity contribute large of pollutant into the atmosphere. Table 4.5 shows the descriotive analysis at Paka, Terengganu and figure 4.5 shows box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Paka, Terengganu.

Table 4.5: The Descriptive Analysis Paka, Terengganu

Parameter	Year	N	Minimum	Maximum	Mean	St. Deviation	Skewness	Kurtosis
PM_{10} (μg/m^3)	2017	181	5.35	37.99	18.88	6.18	0.38	-0.09
	2018	181	**12.15**	51.76	**29.25**	8.28	0.23	-0.19
	2019	365	8.64	**114.00**	24.33	**14.63**	**2.87**	**10.79**
	2020	188	8.50	36.20	17.82	5.66	0.98	0.66
$PM_{2.5}$ (μg/m^3)	2017	181	2.57	25.60	10.13	4.55	0.82	0.45
	2018	181	6.65	**36.26**	**18.47**	5.93	0.47	0.24
	2019	365	2.93	97.87	15.38	**12.92**	**3.18**	**12.74**
	2020	188	3.47	23.52	8.95	2.84	1.03	3.36
SO_2 (ppm)	2017	180	-	0.01	-	-	2.24	7.42
	2018	181	-	0.01	-	-	1.12	2.43
	2019	365	-	0.01	-	-	2.54	10.82
	2020	188	-	-	-	-	1.59	2.61
NO_2 (ppm)	2017	160	-	0.01	-	-	1.86	5.61
	2018	156	-	0.03	0.01	-	0.05	-0.32
	2019	365	-	0.01	-	-	0.91	0.74
	2020	188	-	-	-	-	0.69	-0.30
O_3 (ppm)	2017	-	-	-	-	-	-	-
	2018	156	-	0.04	0.01	0.01	0.93	0.62
	2019	-	-	-	-	-	-	-
	2020	-	-	-	-	-	-	-



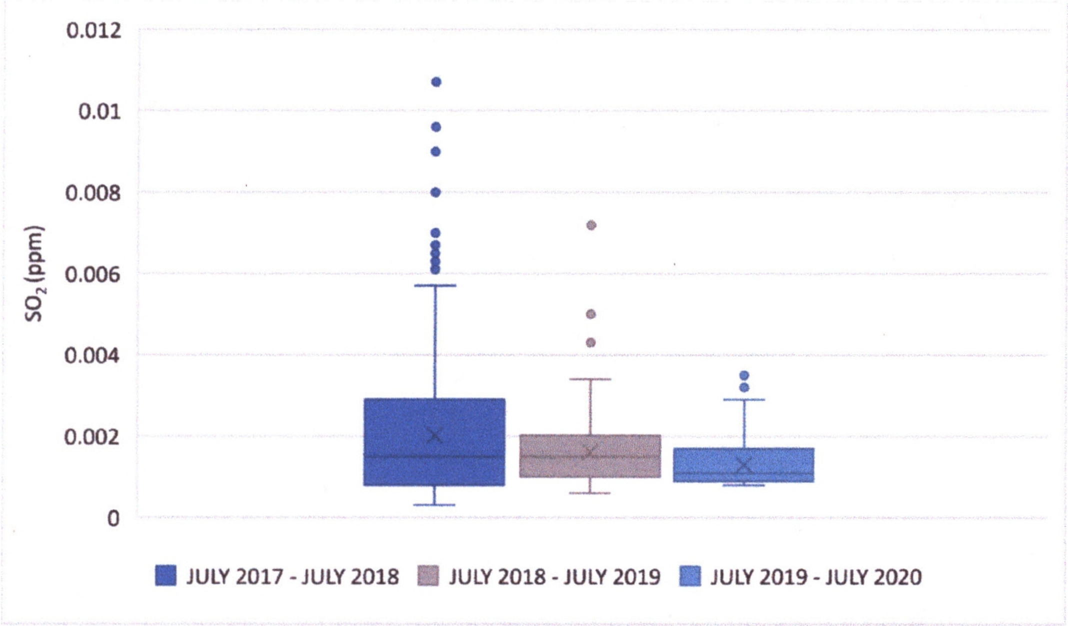
a) PM_{10} daily mean concentration at Paka, Terengganu



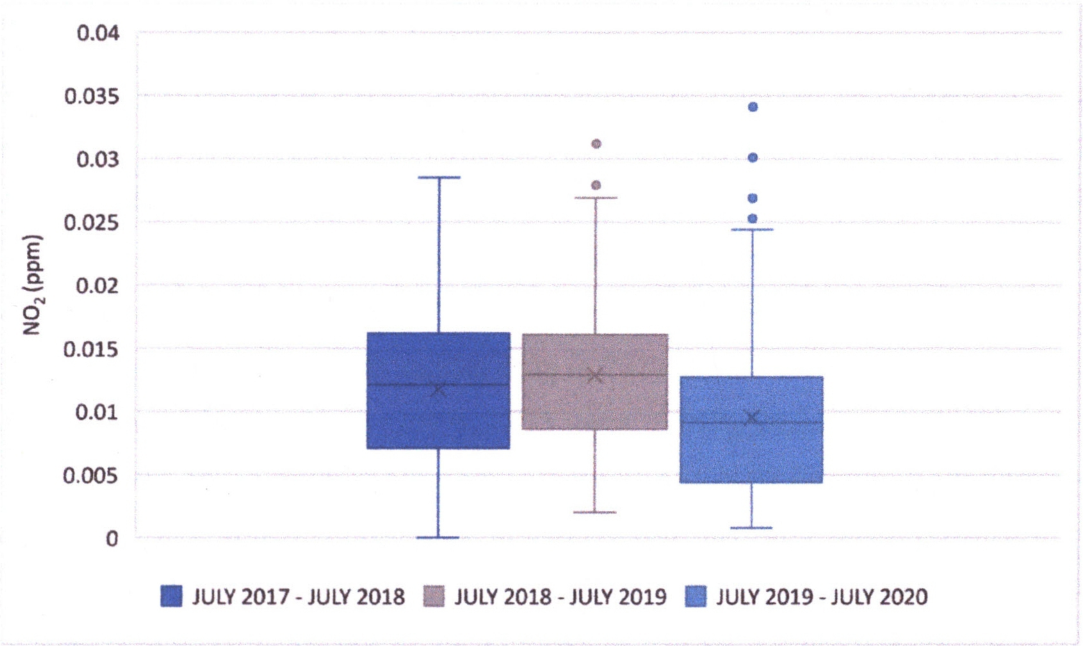
b) $PM_{2.5}$ daily mean concentration at Paka, Terengganu

Continued

Figure 4.5: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Paka, Terengganu.



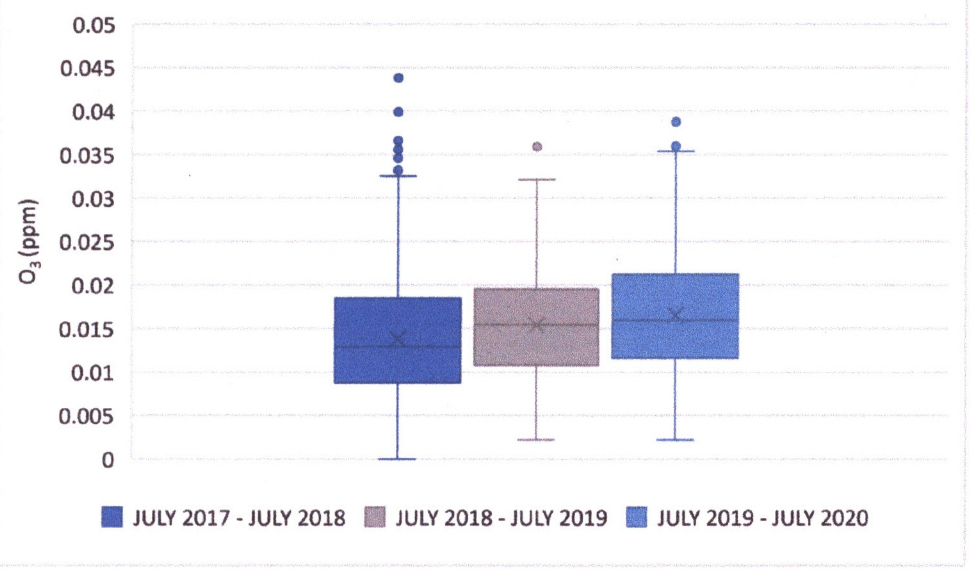
c) SO_2 daily mean concentration at Paka, Terengganu



d) NO_2 daily mean concentration at Paka, Terengganu

Continued

Figure 4.5: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Paka, Terengganu (Continued).



e) O_3 daily mean concentration at Paka, Terengganu

Figure 4.5: The box and whiskers plots of daily average PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 concentrations during July 2017- July 2020 at Paka, Terengganu (Continued).

Table 4.5 presented the overall data descriptive statistics of daily average air pollution concentration for Paka, Terengganu monitoring station. The N value for Paka for pollutant in each year are not same as 2017 has 181, 2018 has 181, 2019 has 365 and 2020 has 188. The highest minimum value for PM_{10} was on 2018 which is 12.15 $\mu g/m^3$. The highest maximum value was on 2019 which at 114 $\mu g/m^3$, even though there is increasing trends from 37.99 $\mu g/m^3$ (2017) followed with 51.76 $\mu g/m^3$ (2018) and 114 $\mu g/m^3$ (2019), however, there is sudden drop in 2020 at 36.20. The average daily mean concentration of PM_{10} is 18.88 (2017), 29.25 $\mu g/m^3$ (2018), 24.33 $\mu g/m^3$ (2019) and 17. 82 $\mu g/m^3$. Paka an industrial zone that houses the PETRONAS Petrochemical Integrated Complex (PPIC), which connects the whole oil and gas value chain (Hamza et al., 2014). Figure 4.5 (a) portrays the box and whiskers plot for PM_{10} concentration shown that there is symmetric distribution for July 2017 – July 2018 and July 2018 – July 2019 since the median line is on the near the same position. For July 2019 – July 2020 show that the distribution is skewed to the right with larger outliers. This pattern support by the maximum value of kurtosis in 2019 at 10.79 and this also indicates that during the period there is existence of extreme event.

For $PM_{2.5}$ the minimum value has slightly decreased and stable pattern from 10.05 $\mu g/m^3$ (2017) followed with 9.21 $\mu g/m^3$ (2018) then 9.76 $\mu g/m^3$ (2019) and finally 9.45 $\mu g/m^3$ (2020). The highest maximum value for $PM_{2.5}$ concentration was in

2018 at 154.85 μg/m^3, while the highest average daily mean concentration was in 2019 in 33.04 μg/m^3. Fortunately, the mean value is not exceeding the MAAQS and still under the limit of 35 μg/m^3. The skewness and kurtosis value in 2019 are 3.18 and 12.74. The median line is not equidistant from the hinges and the box is also moved slightly to the bottom side which indicates that the PM_{10} data is positively skewed.

4.3 Granger Causality

Granger Causality is defined as when a past and present specific characteristic gives important information for forecasting the future in a time series. Granger causality test has been conducting to identify the causal relationship between the parameter PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3. The result of granger causality test for each station are represented in table 4.6, 4.7, 4.8, 4.9 and 4.10. Hence, the graphical view of causality relationship between parameter are illustrated in figure 4.6, 4.7, 4.8, 4.9 and 4.10.

In this part, three causal relationship such as unidirectional, bidirectional and no relationship will be used to defined causality between the parameter. The unidirectional indicates a one-way relationship, the bidirectional indicates a two-way interaction, and the no relationship indicates that there is no link between the parameters. The graphical view is represented based on the significant levels of 5 %, 10 %, and 15 %, respectively.

4.3.1 Granger Causality for Seberang Perai, Pulau Pinang Monitoring Station

In Table 4.6, shown data granger causality for Seberang Perai monitoring station and Figure 4.6 is the illustration of causality between parameter in Seberang Perai monitoring station.

Table 4.6: Granger causality for Seberang Perai monitoring station

Station Seberang Perai		
Dependent parameter: PM_{10}		
Independent Parameter	Chi-Sq	p-value
$PM_{2.5}$	10.593	0.005*
SO_2	9.966	0.007*
O_3	41.54	0.000*
NO_2	9.448	0.009*
Dependent parameter: $PM_{2.5}$		
PM_{10}	4.851	0.088**
SO_2	3.606	0.165
O_3	51.257	0.000*
NO_2	2.277	0.320
Dependent Variable: SO_2		
PM_{10}	3.925	0.141***
$PM_{2.5}$	1.393	0.498
O_3	0.724	0.696
NO_2	2.892	0.236
Dependent Variable: O_3		
PM_{10}	2.007	0.367
$PM_{2.5}$	4.382	0.112***
SO_2	5.767	0.056**
NO_2	6.925	0.031**
Dependent Variable: NO_2		
PM_{10}	0.37	0.831
$PM_{2.5}$	0.061	0.97
O_3	36.855	0.000*
SO_2	10.278	0.006*
* Indicates significant at 5 % level, ** indicates significant at 10 % level, *** indicates significant at 15 % level		

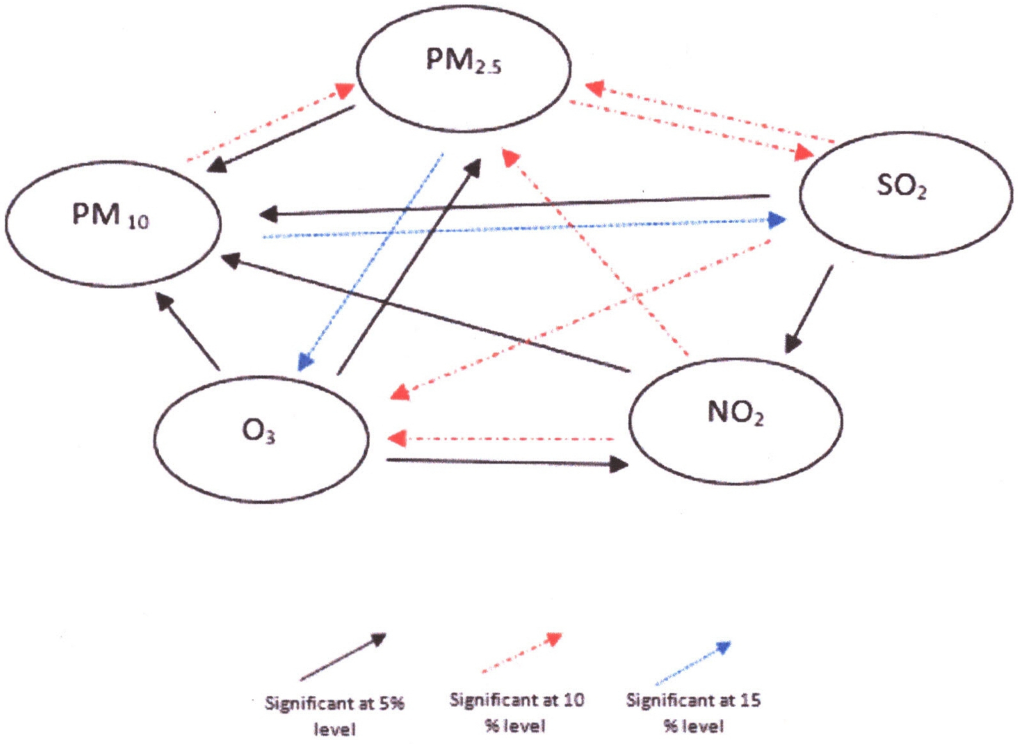


Figure 4.6: Graphical view of causality for Seberang Perai, Pulau Pinang Monitoring Station

From the result, it shows that all parameter is tend to granger cause to PM_{10} as all parameter are unidirectional causal relationship at 5 % significant level at Seberang Perai monitoring station. The PM_{10} data contains numerous outliers compared to other contaminants at that region. This indicates that the concentration of PM_{10} was high on numerous days compared to other pollutants. Seberang Perai monitoring station usually has the highest concentration of PM_{10} that influenced by other parameter as the location of the monitoring sites, were located near a busy road and business districts. According to DOE 2012, The major pollution in Seberang Perai areas from wood industries (2.75 %), electronics (27.52 %), metals (39.45 %), chemical industries (24.77 %) and rubber industries (5.50 %). Wood industries activity such as coatings and staining can release some toxic air pollutants and volatile organic compounds (VOC). These compounds chemicals can react in the air to produce ground-level ozone (smog) (USEPA, 2016).

As portrayed in Figure 4.6, there is also a bidirectional causal relationship between $PM_{2.5}$ and SO_2 at 10 % significant level. According to research made by Ku et al., (2016) $PM_{2.5}$ and sulphur dioxide (SO_2) are the major anthropogenic contributors to air pollution from burning of coal as industrial in Seberang Perai mostly have burning activities that may contribute in occurrence of PM_{10} and SO_2. The gas-to-particle transformations of SO_2, NO_2, and VOCs also substantially contribute to the formation of $PM_{2.5}$ pollution (Wang et al., 2015).

4.3.2 Granger Causality for Tasek Ipoh, Perak Monitoring Station

Table 4.7 shows result of granger causality test for Tasek Ipoh monitoring station, and figure 4.7 shows graphical view of causality for Tasek Ipoh monitoring station.

Table 4.7: Granger Causality for Tasek Ipoh monitoring station

Station Tasek Ipoh		
Dependent parameter: PM_{10}		
Independent parameters	Chi-Sq	p-value
$PM_{2.5}$	6.857	0.032**
SO_2	0.331	0.895
NO_2	1.97	0.373
O_3	47.51	0.000*
Dependent parameter: $PM_{2.5}$		
PM_{10}	0.61	0.737
SO_2	0.006	0.997
NO_2	0.974	0.615
O_3	51.018	0.000*
Dependent Variable: SO_2		
PM_{10}	0.385	0.825
$PM_{2.5}$	0.836	0.658
NO_2	0.082	0.960
O_3	2.667	0.264
Dependent Variable: O_3		
PM_{10}	2.007	0.367
$PM_{2.5}$	4.382	0.112**
SO_2	5.767	0.056**
NO_2	6.925	0.031**
Dependent Variable: NO_2		
PM_{10}	2.788	0.248
$PM_{2.5}$	3.905	0.142***
SO_2	4.379	1.112
O_3	1.862	0.000*
* Indicates significant at 5 % level, ** indicates significant at 10 % level, *** indicates significant at 15 % level		

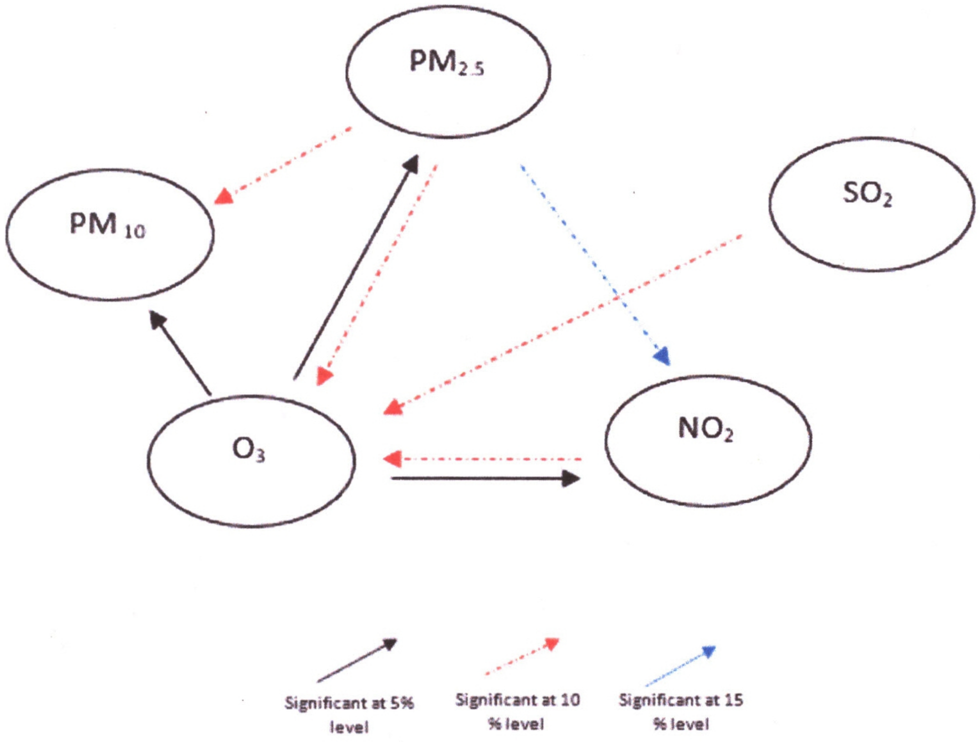


Figure 4.7: Graphical view of causality for Tasek Ipoh, Perak Monitoring Station

At Tasek Ipoh monitoring station as displayed in Table 4.7, O_3 is independent at 5 % significant level while $PM_{2.5}$ is independent at 10 % significant level towards PM_{10} parameter. O_3 is independent parameter towards $PM_{2.5}$ at significant 5 % level. Meanwhile there is larger significant level for dependent parameter of SO_2, indicates that there is no relationship in causality between PM_{10}, $PM_{2.5}$, NO_2 and O_3 with the parameter SO_2 as illustrated in figure 4.7. However, there is unidirectional occurred between O_3 to PM_{10} concentration and O_3 to NO_2 which is significant to 5 % level. O_3 and NO_2 are the major pollutants contributing to degradation of air quality in the Northern region due to the combustion process from vehicles and industries this also influenced the high concentration of PM_{10} (Azman et al., 2017). There is also unidirectional causal relationship between $PM_{2.5}$ to NO_2 that significant at 15 % level which is does not gives any big impact towards each other.

4.3.3 Granger Causality for Klang, Selangor Monitoring Station

Table 4.8 presents the result of granger causality test for Klang monitoring station for each parameter PM_{10}, $PM_{2.5}$, SO_2, NO_2 and O_3 as independent and dependent parameter.

Table 4.8: Granger Causality or Klang monitoring station

Station Klang		
Dependent parameter: PM_{10}		
Independent parameters	Chi-Sq	p-value
$PM_{2.5}$	16.76	0.000*
SO_2	2.117	0.347
NO_2	13.236	0.001*
O_3	1.875	0.392
Dependent parameter: $PM_{2.5}$		
PM_{10}	2.35	0.309
$PM_{2.5}$	1.484	0.476
NO_2	13.466	0.001*
O_3	2.541	0.290
Dependent Variable: SO_2		
PM_{10}	10.664	0.005*
$PM_{2.5}$	12.614	0.002*
NO_2	3.489	0.175
O_3	5.824	0.054**
Dependent Variable: O_3		
PM_{10}	1.09	0.580
$PM_{2.5}$	1.37	0.504
SO_2	0.551	0.759
NO_2	11.027	0.004*
Dependent Variable: NO_2		
PM_{10}	8.228	0.016**
$PM_{2.5}$	9.889	0.007*
SO_2	4.737	0.094**
O_3	20.133	0.000*

* Indicates significant at 5 % level, ** indicates significant at 10 % level, *** indicates significant at 15 % level

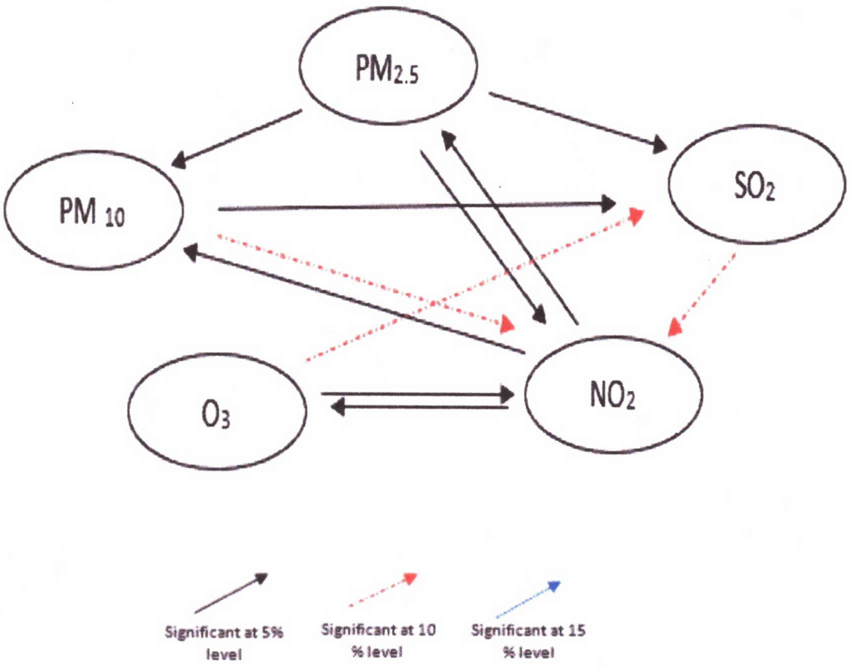


Figure 4.8: Graphical view of causality of Klang monitoring station

Table 4.8 shown the overall data for granger causality for Klang monitoring station. $PM_{2.5}$ and NO_2 has 5 % significant levels toward PM_{10} since PM_{10} is the dependent parameter. As for $PM_{2.5}$ the independent parameter NO_2. SO_2 has independent parameter that has significant to 10 % level which is O_3, and the rest except NO_2 is significant to 5% level. Figure 4.8 portrays the graphical view of causality between parameter in Klang monitoring station. The unidirectional causal relationship was significant between PM_{10} and $PM_{2.5}$ and NO_2 at 5 % level. The bidirectional causal relationship was significant between NO_2 and CO_3 at 5 % level. According to the research by Siti Rahmah et al., (2015) The formation of O_3 in the study has a significant negative low relationship with its main precursor pollutant, NO_2 ($r = -0.373$, $p < 0.01$). This shown there is high correlation between these two parameters as NO_2 plays a major role in producing O_3 in the environment (Chelani, 2013). Although all combustion in air might produce this chemical compound, it does rely on the composition of the nitrogen in the combustion emissions (USEPA, 2010). The bidirectional causal relationship also occurs between $PM_{2.5}$ and NO_2 at 5 % significant level. Increasing of primary pollutants concentrations can lead to the growth of secondary pollutants and raise the particulate matters.

4.3.4 Granger Causality for Pasir Gudang, Johor Monitoring Station

Table 4.9 shows the dependent parameter, independent parameter, chi-square and p-value for each parameter at Pasir Gudang monitoring station.

Table 4.9: Granger Causality for Pasir Gudang monitoring station

Station Pasir Gudang		
Dependent parameter: PM_{10}		
Independent parameters	Chi-Sq	p-value
$PM_{2.5}$	11.483	0.003*
SO_2	18.87	0.000*
NO_2	3.875	0.144***
O_3	5.395	0.067**
Dependent parameter: $PM_{2.5}$		
PM_{10}	6.742	0.034**
SO_2	13.15	0.001*
NO_2	13.491	0.001*
O_3	9.961	0.007*
Dependent Variable: SO_2		
PM_{10}	19.751	0.000*
$PM_{2.5}$	7.432	0.024**
NO_2	1.714	0.424
O_3	22.572	0.000*
Dependent Variable: O_3		
PM_{10}	13.898	0.001*
$PM_{2.5}$	11.584	0.003*
SO_2	7.555	0.023**
NO_2	3.74	0.154***
Dependent Variable: NO_2		
PM_{10}	1.889	0.389
$PM_{2.5}$	0.36	0.835
SO_2	1.294	0.524
O_3	0.755	0.686
* Indicates significant at 5 % level, ** indicates significant at 10 % level, *** indicates significant at 15 % level		

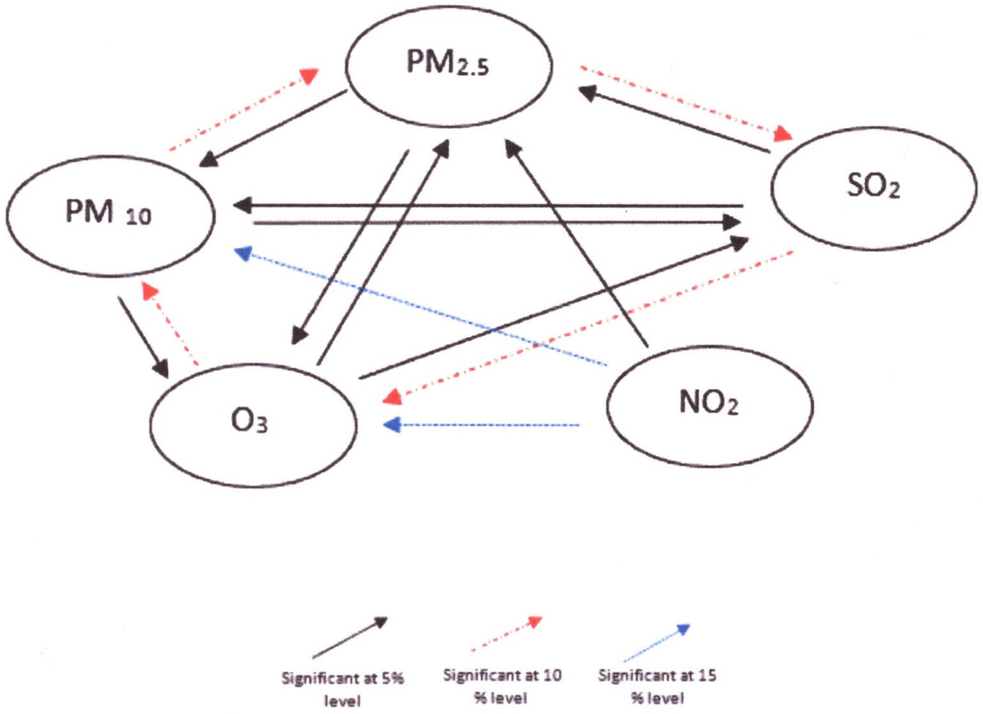


Figure 4.9: Graphical view of causality of Pasir Gudang, Johor monitoring station

As shown in Table 4.9, there is a lot of 5 % significant level between the parameter. From the study, for dependent parameter PM_{10}, all parameter contributes in causal relationship between parameters, despite having significantly different value. $PM_{2.5}$ and SO_2 are significant at 5 % level towards PM_{10}, O_3 is significant at 10 % level toward PM_{10} and NO_2 is significant at 15 % level towards PM_{10} which indicates there is small correlation between parameters. From Figure 4.9 we can clearly see that there is bidirectional causal relationship between PM_{10} and SO_2 at 5 % significant that indicates of two-way relationship. As reported in news on 2018 the seasonal monsoons such as haze has contributed in high concentration of PM_{10}, and this parameter also may be either directly emitted from sources (primary particles) or formed in the atmosphere through chemical reactions of gases (secondary particles) such as sulphur dioxide, SO_2. According to Saygin et al., (2017) high tolerance of PM_{10} and SO_2 in atmosphere can caused to major respiratory problem such as asthma.

For $PM_{2.5}$ all parameter is significant at 5 % level except for PM_{10}. This indicates that there is high occurrence in pollutant in that area that contribute to high concentration of $PM_{2.5}$. From the Table 4.9, $PM_{2.5}$ are at 5 % significant level towards

O_3, O_3 are at 5 % significant level towards $PM_{2.5}$ which make it a bidirectional causal relationship with each other. A study made by Jia et al., (2017) high concentrations of O_3 in the presence of severe atmospheric oxidation may enhance secondary particle production, hence increasing ambient $PM_{2.5}$ levels. From the Figure 4.9 above it also can be said that all parameter is granger-cause towards each other even though there is small different in significant level.

4.3.5 Granger Causality for Paka, Terengganu Monitoring Station

As shown on the table 4.10 is the granger causality test data at Paka Terengganu monitoring station which located at TNB Quarters, Paka- Kerteh Terengganu.

Table 4.10: Granger Causality for Paka, Terengganu monitoring station

Station Paka		
Dependent parameter: PM_{10}		
Independent Parameter	Chi-Sq	p-value
$PM_{2.5}$	8.621	0.013**
SO_2	4.814	0.090**
NO_2	0.147	0.929
Dependent parameter: $PM_{2.5}$		
PM10	4.851	0.088**
SO2	3.606	0.165
NO2	2.277	0.32
Dependent Variable: SO_2		
PM_{10}	0.909	0.635
$PM_{2.5}$	2.457	0.293
NO_2	1.805	0.406
Dependent Variable: NO_2		
PM_{10}	4.956	0.084**
$PM_{2.5}$	9.075	0.011**
SO_2	3.912	0.141***
* Indicates significant at 5 % level, ** indicates significant at 10 % level, *** indicates significant at 15 % level		

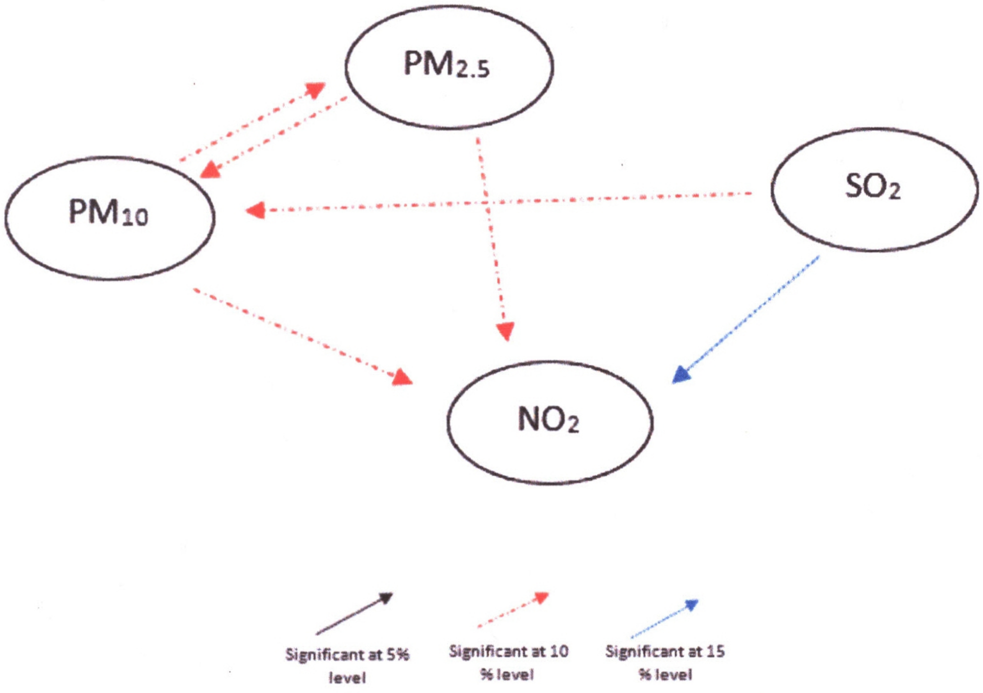


Figure 4.10: Graphical view of Causality for Paka, Terengganu monitoring station

Table 4.10 shows the overall data of granger causality test result for Paka, Terengganu monitoring station. As displayed in the table there is no correlation between O_3 parameter as dependents due to no reading for O_3 at the station. $PM_{2.5}$ and SO_2 are significant at 10 % level to PM_{10}. Paka is industrial area that more focused on the power plant, contribution in SO_2 to PM_{10} is clearly proved as burning activity contribute in abundant of PM_{10} pollutant. Figure 4.10 shows there is unidirectional between PM_{10} to NO_2 and $PM_{2.5}$ to NO_2 at 10 % significant level, and there is also bidirectional causal relationship between PM_{10} and $PM_{2.5}$. According to one of findings by Wu et al. (2016) Coal combustion is a major source of $PM_{2.5}$, biomass burning is an important source of $PM_{2.5}$ during the post-harvest seasons from May to June and from October to November. Lastly, all directional are tend to granger cause NO_2, this scenario prove that all parameters giving an impact toward the contribution of NO_2 despite the fact that NO_2 emitted in atmosphere that usually cause by the any burning activity such as fuels, power plant and vehicular (USEPA, 2010).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research was conducted to determine the causality of air pollution parameters at industrial area in Peninsular Malaysia. The data obtained from the Department of Environment Malaysia was taken for three years from 4th July 2017 to 6th July 2020. This also determined two main objectives. For the first objective which is to determine the characteristic of air pollution data in Peninsular Malaysia at industrial area is done by using IBM SPSS Software Version 26. Five main air pollution parameters were selected such as Particulate Matter (PM_{10} and $PM_{2.5}$), SO_2, NO_2 and O_3 are observed their descriptive statistics to analyse air pollution characteristics based on daily data air pollution concentration in five selected industrial monitoring station (Perai, Pulau Pinang, Tasek Ipoh, Perak, Klang, Selangor, Pasir Gudang Johor and Paka, Terengganu) PM_{10} and $PM_{2.5}$ can be said as the major parameter from industrial activity influenced to the atmosphere from 2017 until 2019. This also proves by Klang monitoring station which contributes the most PM_{10} and $PM_{2.5}$ pollutant to the atmosphere throughout the year. However, there is sudden drop in value on year 2020 due to the non-operating factories cause by Movement Control Order. The result also was compared to the Malaysian Air Ambient Quality Standards to determine whether the mean value has exceeded the standard limit. However, none of the parameter has exceeded the limit value and still under the control even there is some extreme event happen throughout the three consecutive years. Klang monitoring station are reported to be the biggest contribution in pollutant to the atmosphere among the other four monitoring station.

The second objective is to investigate the relationship between air pollution parameters using Granger Causality Test and illustrate the causality of air pollution parameters at industrial areas in Peninsular Malaysia using graphical view of causality from July 2017 until July 2020. Eviews software are been used to determine the granger causality of each parameter and also to observed the dependent and independent relationship between parameter. Finally, the result for each parameter in each selected monitoring station are illustrated in graphical view with their own significant causal directional relationship for better understanding. To conclude this, locations that have many heavy industries such as Perai, Klang and Pasir Gudang shows a huge amount of causality relationship between air pollution parameters and small significant value below 5 % significant level which indicates a higher risk between pollutant. The bidirectional relationship also exists in the three stations which indicates there is two-way interacts between parameter that granger cause to each other and increase the air pollution in that area. From the findings, the significant causal relationship between the parameters is different due to the different factors of industrial activity in each area. However, the causality between air pollutants parameter shows that the significant causal relationship at most industrial areas is between PM_{10}, $PM_{2.5}$, SO_2 and NO_2.

5.2 Recommendation for Future Research

Causality is the approached in determined the relationship between one parameter with another parameter and can be seen so clearly. The researcher or the government might then consider strategies to minimise pollution in that specific area. However, because these air pollution criteria are delicate and difficult to notice with the naked eye, it is preferable to conduct this investigation with metrological considerations in mind like add on the wind speed, wind direction, ambient temperature and relative humidity. The composition of air pollution is also small, making it more vulnerable to climatic conditions that might readily transport such particles. Apart from that, it is suggested that the future researcher conduct a causality study in an industrial urban region, which may produce a lot of information and better knowledge to anticipate the future.

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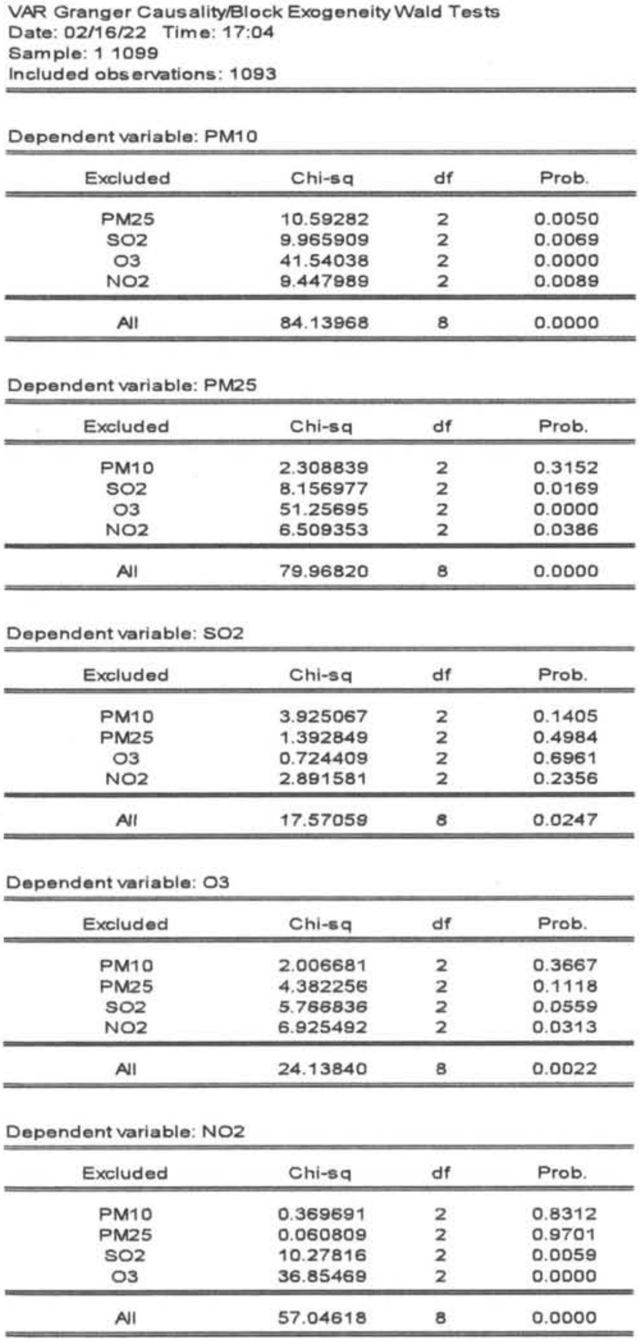
APPENDICES

Appendix A: Granger Causality Test for Seberang Perai Monitoring Stations



```
VAR Granger Causality/Block Exogeneity Wald Tests
Date: 02/16/22   Time: 17:04
Sample: 1 1099
Included observations: 1093

Dependent variable: PM10

     Excluded          Chi-sq        df        Prob.

     PM25              10.59282      2         0.0050
     SO2               9.965909      2         0.0069
     O3                41.54038      2         0.0000
     NO2               9.447989      2         0.0089

     All               84.13968      8         0.0000

Dependent variable: PM25

     Excluded          Chi-sq        df        Prob.

     PM10              2.308839      2         0.3152
     SO2               8.156977      2         0.0169
     O3                51.25695      2         0.0000
     NO2               6.509353      2         0.0386

     All               79.96820      8         0.0000

Dependent variable: SO2

     Excluded          Chi-sq        df        Prob.

     PM10              3.925067      2         0.1405
     PM25              1.392849      2         0.4984
     O3                0.724409      2         0.6961
     NO2               2.891581      2         0.2356

     All               17.57059      8         0.0247

Dependent variable: O3

     Excluded          Chi-sq        df        Prob.

     PM10              2.006681      2         0.3667
     PM25              4.382256      2         0.1118
     SO2               5.766836      2         0.0559
     NO2               6.925492      2         0.0313

     All               24.13840      8         0.0022

Dependent variable: NO2

     Excluded          Chi-sq        df        Prob.

     PM10              0.369691      2         0.8312
     PM25              0.060809      2         0.9701
     SO2               10.27816      2         0.0059
     O3                36.85469      2         0.0000

     All               57.04618      8         0.0000
```