CORRELATION BETWEEN METEOROLOGICAL FACTORS AND AIR POLLUTANT CONCENTRATIONS AT URBAN AREAS IN PENINSULAR MALAYSIA

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by

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APPROVAL AND DECLARATION SHEET

This project report titled Correlation between Meteorological Factors and Air Pollutant Concentrations at Urban Areas in Peninsular Malaysia was prepared and submitted by Mahiesha Rubini a/p Kalaiarsu (Matrix Number: 171130586) and has been found satisfactory in terms of scope, quality and presentation as partial fulfillment of the requirement for the Bachelor of Engineering (Hons) (Environmental Engineering) in Universiti Malaysia Perlis (UniMAP).

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KORELASI ANTARA FAKTOR METEOROLOGI DAN KEPEKATAN PENCEMAR UDARA DI KAWASAN BANDAR DI SEMENANJUNG MALAYSIA

ABSTRAK

Kajian ini bertujuan untuk mengenal pasti korelasi antara faktor meteorologi (suhu persekitaran, kelembapan relatif dan kelajuan angin) berdasarkan kepekatan harian pencemar udara SO_2, NO_2, O_3, CO dan PM_{10} di empat lokasi terpilih di Semenanjung Malaysia, iaitu Pulau Pinang (Seberang Perai), Johor Bahru (Pasir Gudang), Wilayah Persekutuan Kuala Lumpur (Batu Muda) dan Terengganu (Kemaman). Data pemantauan kualiti udara selama dua tahun (Januari 2016 – Januari 2018) dianalisis menggunakan Analisis Korelasi Pearson. Berdasarkan hasil yang diperoleh melalui analisis ini, bahan partikel dengan aerodinamik 10 mikron (PM_{10}) telah mencatat tahap kepekatan tertinggi di semua stesen pemantauan. Analisis Korelasi Pearson menunjukkan bahawa secara keseluruhannya pencemar udara NO_2, PM_{10} dan CO telah mencatat korelasi yang signifikan dengan faktor meteorologi di semua stesen pemantauan. Selain itu, ketika monsun barat daya korelasi antara pencemar udara dan faktor meteorologi berkisar antara korelasi lemah hingga sederhana. Namun, berdasarkan analisis, O_3 paling banyak dipengaruhi oleh faktor meteorologi semasa musim kemarau. Semasa monsun timur laut, faktor CO dan meteorologi mencatatkan korelasi minimum di keempat-empat stesen pemantauan. Walaupun begitu, PM_{10} paling banyak dipengaruhi oleh faktor meteorologi dalam tempoh ini. Korelasi antara PM_{10} dan suhu persekitaran, kelembapan relatif dan kelajuan angin berkisar antara korelasi yang sangat lemah sehingga sederhana.

CORRELATION BETWEEN METEOROLOGICAL FACTORS AND AIR POLLUTANT CONCENTRATIONS AT URBAN AREAS IN PENINSULAR MALAYSIA

ABSTRACT

This study aims to determine the correlation between meteorological factors (ambient temperature, relative humidity and wind speed) based on daily concentration of air pollutants SO_2, NO_2, O_3, CO and PM_{10} at four selected locations in Peninsular Malaysia, namely Pulau Pinang (Seberang Perai), Johor Bahru (Pasir Gudang), Kuala Lumpur (Batu Muda) and Terengganu (Kemaman). Air quality data for two years (January 2016 – January 2018) were analyzed using the Pearson Correlation Analysis. Based on the results obtained through this analysis, particulate matter with an aerodynamic of 10 microns (PM_{10}) had recorded the highest concentration level at all monitoring stations. The Pearson Correlation Analysis shows that overall air pollutant NO_2, PM_{10} and CO had recorded significant correlations with meteorological factors at all monitoring stations. Additionally, during the southwest monsoon the correlation between air pollutants and meteorological factors ranges from weak to moderate correlations. However, based on the analysis, O_3 is most affected by meteorological factors during the dry season. During the northeast monsoon, CO and meteorological factors had recorded minimal correlations at all four monitoring stations. Nevertheless, PM_{10} was affected most by meteorological factors during this period. The correlation between PM_{10} and ambient temperature, relative humidity and wind speed ranges from very weak to moderate correlations.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
$\bar{x}$	Mean
x_i	Monitoring data
$\mu g/m^3$	Microgram per cubic meter
μm	Micrometer
API	Air Pollution Index
ASMA	Alam Sekitar Malaysia
C_x	Skewness
CAQM	Continuous Air Quality Monitoring
CO	Carbon monoxide
DOE	Department of Environment
DOS	Department of Statistics
EDC	Environmental Data Centre
EPA	Environmental Protection Agency
EQA	Environmental Quality Act
GLO	Ground level ozone
IT	Interim target
K	Kurtosis
m_3	Third moment
m_4	Fourth moment
m/s	Meter per second

MAAQG	Malaysian Ambient Air Quality Guideline
MAQM	Manual Air Quality Monitoring
MCAQM	Mobile Continuous Air Quality Monitoring
MMD	Malaysian Meteorological Department
n	Number of monitoring data
N	Sample size
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxide
O_3	Ozone
^oC	Degree Celsius
OSHA	Occupational Safety and Health Act of 1970
PM_{10}	Particulate matter with an aerodynamic of 10 microns
ppm	Parts per million
PSI	Pollution Standard Index
r	Pearson correlation
s	Standard deviation
SO_2	Sulphur dioxide
SPSS	Statistical Package for the Social Sciences
UV	Ultra Violet
VOC	Volatile Organic Compound
WHO	World Health Organization
WP	Wilayah Persekutuan
X	Independent variable
Y	Dependent variable

CHAPTER 1

INTRODUCTION

1.1 Introduction to Air Pollution

In the twenty-first century, varying atmospheric conditions that are fueled by air pollution is one of the greatest threats faced by humanity. Health impacts caused by air pollution is the fundamental reason behind air pollution studies (Usmani et al., 2020). Air pollution has become a serious global threat that poses severe and harmful effects towards human health and welfare. Furthermore, population density, energy consumption, industrial processes and mediums of transportation are some factors that has led to the release of complex gases and particulates in urban areas. The release of such contaminants have a negative impact towards public health, damaging agriculture, weather and climate (Pant & Harrison, 2012).

According to a study conducted by Jacob (2010), a vehicle's entire lifecycle contributes to air pollution, which include production, refueling, emissions and disposal of the vehicle. Additional contaminants are produced during the refining and delivery of fuel. Primary and secondary pollutants are two types of pollutants that can be found in the environment. Air pollutants that are emitted straight to the air are known as primary pollutants. However, products that are released as a result of chemical reactions that emerge between the pollutants and other fragment particles are known as secondary pollutants.

Major air pollutants arise mostly from manufacturing activities. According to Dominick et al. (2012), sources of air pollution include power stations, industrial waste boilers, dust released from construction areas and quarries and open fires. In most developing countries, automobiles are the primary source of mobile air pollution in urban areas (Azmi et al., 2010). Hence, scientists as well as economists are concerned regarding the vast influence of the exposure to air pollution. A study also shows that the combination of poor air quality and high temperatures in urban populations especially may suffer from adverse health effects (Mohd Zizi et al., 2018). World Health Organization (2016a), stated that 6.5 million deaths worldwide are caused by more than ninety percent of the world's population breathing contaminated air.

People who live in urban areas are subjected to high quantities of exposure to air pollution. At high quantities, air pollutants can be detrimental to human health. The effect towards human health includes eye, throat and nose irritation, wheezing, coughing, heart problems, heart attacks as well as breathing difficulties. Additionally, air pollutants are also capable of damaging immune systems, causing cancer and even death at extreme concentrations and exposure long term (Liu et al., 2014). Besides that, air pollutants also have negative impacts towards the environment. Some impacts include acid rain, global climate changes, haze and towards wildlife (Kimmel, 2013).

The concentration of pollutants in the atmosphere changes based on meteorological factors, the sources of pollutants and the landscape of the area. However, among these three factors, meteorological factors have the greatest impact on fluctuations of ambient air pollution concentrations (Butler & Whelan, 2017). Air pollutants are transported through the atmosphere which acts as a medium to divert the pollutants away from the source, hence understanding the behavior of meteorological factors such as atmospheric wind speed, wind direction and temperature in the planetary boundary layer is crucial (Bhaskar & Mehta, 2010). Meteorological factors are impacted by the combination between numerous activities such as radiations, transportation and chemical modifications, as well as wet and dry displacements (Demuzere et al., 2009).

Topography, various economies, demographics and meteorological factors usually influences the variation and trend of air pollutants which include nitrogen dioxide (NO_2), particulate matter with an aerodynamic of 10 microns (PM_{10}), ozone (O_3), sulphur dioxide (SO_2), as well as carbon monoxide (CO) (Rodriguez et al., 2016). Due to variations in meteorological parameters, statistical studies employing meteorological and air pollution monitoring data shows that trace gases exhibit typical diurnal, weekly, monthly and annual cycles (Xian et al., 2021).

1.2 Air Pollution in Malaysia

In Malaysia the deterioration in the local air quality is due to the annual open burning phenomenon from Indonesia which produces trans-boundary smoke haze (Mahmud, 2013). The term smoke haze refers to the haze that has been accredited to forest and peat fires in Indonesia. On the other hand, an increase in aerosol loadings or smoke in the atmosphere is contributed by the burning of biomass (Reid et al., 2013). Malaysia has experienced rapid development and targets to become an economically developed country. However, the atmosphere at conurbations are polluted due to this development process (Azmi et al., 2010). The largest three conurbations in Peninsular Malaysia are Klang Valley which contains Kuala Lumpur and several adjoining cities, Greater Penang and lastly Iskandar Malaysia consisting of Johor Bahru and other adjoining cities. The Department of Statistics stated that mobile sources are the dominant benefactor which contributes up to seventy five percent of urban air pollution (Department of Statistics, 2016).

Malaysia is positioned near the equator leading to a hot and humid environment that brings two types of monsoons to the country (Malaysian Meteorological Department, 2013). The monsoon seasons as well as climatic factors which include ambient temperature, relative humidity and wind speed have a consequential influence on the concentration of air pollutants in Malaysia (Juneng et al., 2011). The two monsoon seasons in Malaysia according to Malaysian Meteorological Department (2017), are the southwest monsoon which typically starts in June and ends in September and northeast monsoon which occurs within the period of November till March. Besides that, inter-monsoons which are transitional wind periods occurs in Malaysia from April to May and October to November.

According to a recent study by Mohd Zizi et al. (2018), generally, the air quality in Malaysia is acceptable to tolerable with several bad days observed at various sites around the west and east coasts of Peninsular Malaysia. During the late northeast monsoon which is from February to March and the southwest monsoon which is during May till September and during the dry season, particulate matter with an aerodynamic of 10 microns (PM_{10}) was the predominant pollutant that created unhealthy conditions.

Malaysia is currently in the phase of rapid urbanization and economic growth as it is moving towards becoming an industrialized nation. An increase in anthropogenic activities which includes modernization and transit can seriously affect the air quality of tropical countries including Malaysia. A study conducted by Zainordin et al. (2017), claimed that the diurnal variations for ultraviolet rays in tropical climates may affect the diurnal variability of air pollutants such as ozone concentrations compared to that in temporal countries.

1.3 Problem Statement

Air pollution is a prime issue of current decades due to its serious malignant footprint towards the environment and human health. Air pollution sources originate from micro units of cigarettes and organic sources such as volcanic activities to substantial volumes of emissions from industrial activities alongside from motor engines of automobiles (Habre et al., 2014). There are various pollutants of suspended materials in the atmosphere which include dust, fumes, smokes, mists, gaseous pollutants, hydrocarbons, volatile organic compounds, aromatic hydrocarbons and halogen derivatives. Elevated levels of these pollutants causes vulnerability to a variety of diseases which additionally includes different types of cancers (Loomis et al., 2014; Rodopoulou et al., 2014; Carugno et al., 2016).

Air pollution is the result of the interaction between ambient air with natural as well as manmade contaminants. In addition with trans-boundary haze pollution, Malaysia's overall air pollution is contributed by urban air pollution (Kuwata et al., 2018 & Rahman et al., 2017). According to Zakaria et al. (2010), motor vehicles are the primary mobile source of air pollution in the cities of most developing countries. As Malaysia strives to become an advanced country by 2020 (Abd Rani et al., 2018), urban air pollution must be adequately managed to prevent health difficulties towards the citizens, as industries have the ability to affect general public health via the emissions of various hazardous chemicals into the atmosphere (Bergstra et al., 2018).

Since 1989, the Air Pollution Index (API) has been used in Malaysia, as a measure of air quality. The air contamination record with their possessions are shown in Table 1.1.

These figures are calculated using the sub-index of five criteria of air pollutants that are nitrogen dioxide (NO_2), particulate matter with an aerodynamic of 10 microns (PM_{10}), ozone (O_3), sulphur dioxide (SO_2) and carbon monoxide (CO). API ranges are classified from good, moderate, unhealthy, very unhealthy and hazardous.

Table 1.1: Air Pollution Index (API) in Malaysia (Department of Environment, 2013)

API	Status	Health Effect	Health Advice
0-50	Good	Low pollution without any effect on health	No restriction for outdoor activities to the public. Maintain healthy lifestyle.
51-100	Moderate	Moderate pollution that does not pose any bad effect on health	No restriction for outdoor activities to the public. Maintain healthy lifestyle.
101-200	Unhealthy	Worsen the health condition of high risk people (heart and lung complications)	Limited outdoor activities for the high risk people. Public needs to reduce outdoor activities.
201-300	Very Unhealthy	Worsen the health condition and low tolerance of physical exercises to people with heart and lung complications.	Old and high risk people advised to stay indoors and reduce physical activities. People with health complications are advised to see doctor.
>300	Hazardous	Hazardous to high risk people and public health	Old and high risk people are prohibited for outdoor activities. Public advised to restrict from outdoor activities.

As a result, this study will focus on the correlation between temperature, wind speed and relative humidity and five major air pollutants that is NO_2, PM_{10}, O_3, SO_2 and CO to determine which pollutant is most affected by different weather conditions (southwest and northeast monsoon) in Peninsular Malaysia. The ability of these pollutants in creating antagonistic impact towards human health is one of the major concerns in Malaysia. Therefore, it is essential that we determine the relationship of these five major air pollutants with meteorological factors.

1.4 Objectives

The aim of this study is to determine the relationship between meteorological factors that are temperature, wind speed, relative humidity and five major air pollutants which are NO_2, PM_{10}, O_3, SO_2 and CO in urban areas in Peninsular Malaysia from January 2016 to January 2018. Hence, the objectives stated below will be conducted throughout the course of this research:

i. To identify the characteristics of temperature, wind speed, relative humidity and air pollutants NO_2, PM_{10}, O_3, SO_2 and CO.
ii. To determine the relationship between temperature, wind speed, relative humidity and concentration of pollutants.
iii. To determine the air pollutant that is most impacted by different weather conditions which are the southwest monsoon and the northeast monsoon.

1.5 Scope of Project

For this study, the study area represents urban areas for four stations that are Seberang Perai, Pasir Gudang, Batu Muda and Kemaman. These locations were selected as a representative of urban areas from the northern region, east coast region, southern region and lastly the central region of Peninsular Malaysia. The pollutants selected to be analyzed in this study are NO_2, PM_{10}, O_3, SO_2 and CO. Meanwhile, for meteorological factors, wind speed, ambient temperature and relative humidity were selected. Daily NO_2, PM_{10}, O_3, SO_2 and CO concentration for January 2016 up to January 2018 are retrieved from the Department of Environment (DOE) as preliminary data to observe the trend of pollution and weather conditions at the selected locations.

To establish the descriptive statistic for each air pollutant and meteorological factors at each location mentioned earlier for two years which is from January 2016 to January 2018, the preliminary data will be evaluated using SPSS, a statistical software. To determine the descriptive statistic, several characteristics (minimum value, maximum value, mean, standard deviation, variance, skewness and kurtosis) of NO_2, PM_{10}, O_3, SO_2

and CO concentration and meteorological factors will be determined. By using the same software, the Pearson Correlation Analysis will also be determined to identify the correlation between three meteorological factors and five major air pollutants.

1.6 Significance of Project

From this study, the expected findings can be used as an early control measure for the authorities to identify suitable and effective countermeasures in order to control emissions. Besides that, emission standards for the air pollutants that have concentrations exceeding the Malaysian Ambient Air Quality Guideline (MAAQG) can be set and altered depending on the level and severity of the pollutant. By conducting this study, we will also be able to identify which pollutant amongst the five major pollutants that are NO_2, PM_{10}, O_3, SO_2, and CO is frequently of high concentration and is most harmful to human health, has the potential of causing severe respiratory as well as cardiovascular diseases. Additionally, this study can also contribute to determine the impacts of monsoon seasons towards the concentration of air pollutants in the environment. Lastly, by conducting this study, we can also predict the concentration of these air pollutants in the future at the selected study area.

CHAPTER 2

LITERATURE REVIEW

2.1 Air Pollutants

Natural and anthropogenic pollutants can lead to the occurrence of air pollution. Anthropogenic pollutants are also known as pollutants that originate as a result of manmade actions, which include polluting residuals from construction and manufacturing activities (Zizi et al., 2018). Moreover, air pollution also occurs as a result of the existence of non-point source pollutants in the atmosphere. However, the provenance of non-point source pollutants cannot be specifically pinned down. Such pollutants can diffusively and indirectly contribute towards the degradation of the environment (Tajudin et al., 2019).

There are three significant origins of air pollution in Malaysia. Automobiles, industries and domestic fossil fuel burning, and open burning are among the sources of air pollution (Ghazali et al., 2010). PM_{10}, NO_2, SO_2, CO and O_3 are primary pollutants that are recorded at the Malaysian air quality monitoring stations (Department of Environment, 2017). Several recent researches by Azmi et al. (2010) and Latif et al. (2011), stated that due to incomplete combustion of automobiles and biomass burning from inter-boundary sources, nitrogen dioxide (NO_2) and particulate matter with an aerodynamic of 10 microns (PM_{10}) concentrations are showing a rising trend. Additionally, the Department of Environment Malaysia (2015), evaluated that the combined air pollutant emission load in 2015 in Malaysia was roughly 2,001,195 metric tonnes of CO, 927 metric tonnes of NO_x and $2x10^6$ metric tonnes of SO_2.

The concentration of NO_2 is particularly high in urban and industrial areas due to the high temperatures at which fuel is consumed in the combustion process. The NO_2 emission load is made up of 28% from automobiles, 69% from power plants and industries, and the remaining 3% originating from other sources (Department of

Environment, 2015). During non-haze episodes, vehicular emissions accounted for more than 70% of the total emissions in urban areas (Rahman et al., 2013). An air quality study that was conducted in the Klang Valley indicated that the concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), and particulate matter with an aerodynamic of 10 microns (PM_{10}) had two distinct daily peaks in the diurnal variations. Vehicular emissions were the main cause of the morning hour peak while the late evening peak was due to meteorological conditions which include atmospheric temperature and wind speed (Afroz et al., 2013).

In urban areas, one of the main pollutants in ambient air is known to be particulate matter with an aerodynamic of 10 microns. The concentration of fine dust particles with an aerodynamic of 10 microns, PM_{10} usually tops the other pollutants which is then subsequently used to determine the API reading (Department of Environment, 2017). In the Klang Valley, total suspended particulate matter was the main pollutant as the concentrations at a few sites often exceeded the Recommended Malaysian Air Quality Guidelines. Usually, the major sources of this type of pollutant comes from automobiles and industrial activities.

Ordinarily, the organic sources of SO_2 are commonly produced from oceans, biological decay, volcanoes, industrial activities and forest fires forest fires (Mohamad et al., 2015). However, in Malaysia volcanic activities are non-existent hence, SO_2 is most likely produced by coal and petroleum combustion from vehicles and power stations. A study by Butler and Whelan (2017), stated that SO_2 mainly originates from the combustion of fossil fuels at power stations and industries.

CO is typically produced as a product of incomplete combustion of vehicle fuel engines. The transportation sector emits up to 75% of CO emission in the entire world (Environmental Protection Agency, 2012). Additionally, vehicle exhaust contains up to 100,000ppm of CO levels and during heavy traffic, the levels of CO can reach between 10 and 12 ppm within passenger compartments of automobiles. Carbon Monoxide is clear and unnoticeable in the atmosphere hence its revelation is often not acknowledged and acute CO toxicity is commonly misdiagnosed (Iqbal et al., 2012a). Incomplete combustion of hydrocarbons releases a by-product of carbon monoxide which is a major component of motor vehicles related pollution, tobacco smoke and gas stove pollution (Vrijheid et al., 2012).

However, the presence of local and regional factors such as precursors including nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of ultraviolet (UV) radiation from sunlight results in the generation of O_3 which is known as a secondary pollutant that has been generated in the atmosphere. The concentration of O_3 is always higher in the afternoon due to the intensity of ultraviolet radiation from sunlight (Azmi et al., 2010). Several studies show that strong solar radiation, elevated temperatures, slight rainfall, low wind speed and minimal relative rainfall tend to advocate higher O_3 concentrations (Latif et al., 2012; Toh et al., 2013). Additionally, ozone is a prime constituent of photochemical smog and plays a significant role as a greenhouse gas (Kleanthous et al., 2014).

2.2 Meteorological Factors

Malaysia has a tropical climate with consistent temperatures and high relative humidity throughout the year. Seasons in Malaysia are distinguished by changes in rainfall and wind circulations (Md Yusof et al., 2009). Atmospheric aerosols are of global importance as they affect the surrounding climate via direct and indirect radiation that adversely impacts human health and the ecosystems. Different sized particles have different origins, different chemical characteristics, causes different health issues and require separate elimination processes (Lee et al, 2012).

Several studies (He at al., 2016; Zhou & Liang, 2013) have stated that air pollution is closely related to meteorological factors and general atmospheric circulation in addition to the level of pollutant emission. One of the important driving factors for the fluctuation of meteorological factors in certain areas is the change of general atmospheric circulation (Wang & Tian, 2018). According to Bandyopadhyay and Chattopadhyay (2007), the seasonal differences in location and intensity of semi-permanent atmospheric activity center affects regional air temperature and indirectly affects regional atmospheric environment and climate system.

According to Bhaskar and Mehta (2010), weather has a critical influence in ambient air pollution distributions. The pace at which air pollutants are emitted into the atmosphere as well as their residence in the atmosphere and the formation of secondary pollutants is determined not only by the rate of which they are emitted but also by wind speed, turbulence level, air temperature and precipitation. Besides that, meteorological driving factors are associated with diurnal concentrations of air pollutants and also influences aerosol composition (Amil et al., 2016).

On the other hand, a study by Xian et al. (2021), stated that the concentration of trace gases and their time in the environment can be influenced by several factors. Climate, landscape and emission sources are among them. Weather parameters influences the spatial-temporal characteristics and concentration levels of atmospheric pollutants and hence play an important role in the transformation, removal and dispersion of atmospheric pollutants from the atmosphere. Atmospheric circulations have a significant impact on pollutant concentrations in the environment. The East Asian summer monsoon, for example, is a prominent meteorological phenomenon in China that affects air mass motion, convection, and precipitation (Zhou et al., 2010).

Malaysia has a hot and humid climate throughout the year due to its proximity to the equator, which brings two types of monsoon to the country which are the northeast monsoon and the southwest monsoon (Syazwani, 2010). During the northeast monsoon, rainfall brings pollutants down to the earth thus lowering the concentration of pollutants in the atmosphere. Pollutants become unstable during the southwest monsoon because warmer air near the surface area rises to higher latitudes resulting in a high level of pollutants in the atmosphere (Barmpadimos et al., 2011). This factor has impacted the concentration of pollutants in the atmosphere in the country.

Hence, air pollution surveillance studies are crucial if air quality management efforts are to be prioritized and improvised. By conducting such studies, long term air quality trends can be detected and the possible sources of air pollutants can be observed and located. Finally, air pollution monitoring studies can also be beneficial in increase the effectiveness of air quality standards.

2.3 Air Pollution Monitoring in Malaysia

Pollution in Malaysia is controlled via a variety of laws and environmental policies, which include the Environmental Quality Act 1974, with subsidiary legislation such as the Environmental Quality (Clean Air) Regulation 2014 and Malaysian Ambient Air Quality Standard 2013. These regulations are proposed to reduce and administer pollutants which include ozone, nitrogen dioxide and particulates that have various origins (Mustafa, 2011). However, the Environmental Quality Act 1974 was revised in 1998 to enhance and reinforce the penalty for open burning offences. In order to strengthen the enforcement capacity, the Department of Environment and the agency entrusted to enforce law against open burning, has administered powers to officers of the fire and rescue department, the Royal Malaysia Police, the Ministry of Health and the local authorities to assist in the investigation of open burning activities (Aghamohammadi & Isahak, 2017).

In Malaysia, ambient air quality is monitored by the Department of Environment (DOE) through a network of fifty two Continuous Air Quality Monitoring (CAQM) stations. These monitoring stations are situated in urban, suburban, industrial and rural areas. The parameters that are monitored include anthropogenic emissions such as nitrogen dioxide (NO_2), particulate matter with an aerodynamic of 10 microns (PM_{10}), ozone (O_3), sulphur dioxide (SO_2) as well as carbon monoxide (CO). To measure total suspended particulates, particulate matter with an aerodynamic of 10 microns (PM_{10}) and heavy metals that is copper, mercury, iron, lead, sodium and etc, Manual Air Quality Monitoring (MAQM) stations using High Volume Samplers were additionally established at fourteen different sites (Department of Environment, 2013b). These parameters are monitored once every six days. Besides that, there are three Mobile Continuous Air Quality Monitoring Stations (MCAQM). Alam Sekitar Malaysia (ASMA) Sdn. Bhd. is responsible to carry out air quality monitoring work for the Department of Environment. To date, under the Concession, ASMA is acknowledged with the installation and management of the continuous air quality monitoring stations. The establishments of Malaysian Air Quality Guidelines in 1989, Air Pollution Index and haze Action Plans in 1977 are amongst the important tools for air quality management that are endorsed and put to practice by the Malaysian Government (Mohd Zizi et al., 2018).

On the other hand, as for Air Pollutant Index (API) calculation, it is based on Pollution Standard Index (PSI) which is recognized internationally by the Environmental Protection Agency (EPA). However, a new Ambient Air Quality Standard has been developed by the Department of Environment to incorporate the measurement of a new pollutant that is particulate matter with an aerodynamic of 2.5 microns ($PM_{2.5}$) as one of the main pollutants for the API system. The measurement of this pollutant was implemented by the National Air Quality Monitoring Station in 2017 (Department of Environment, 2016).

The air pollutant concentration limit is tightened in stages from 2015 up to 2020. Three interim targets has been set which include interim target 1 (IT – 1) in 2015, interim target 2 (IT – 2) in 2018 and the full implementation of the standard in 2020. The ambient standards adopted in Malaysia which forms the basis for calculating the API values is demonstrated in Figure 2.1.

Table 2.1: Malaysian Ambient Air Quality Guidelines (MAAQG) (Department of Environment, 2013)

Pollutants	Averaging Time	Ambient Air Quality Standard		
		IT-1 (2015)	IT-2 (2018)	Standard (2020)
		μg/m^3	μg/m^3	μg/m^3
Particulate Matter with the size of less than 10 micron (PM_{10})	1 Year	50	45	40
	24 Hour	150	120	100
Particulate Matter with the size of less than 2.5 micron ($PM_{2.5}$)	1 Year	35	25	15
	24 Hour	75	50	35
Sulphur Dioxide (SO_2)	1 Year	350	300	250
	24 Hour	105	90	80
Nitrogen Dioxide (NO_2)	1 Year	320	300	280
	24 Hour	75	75	70
Ground Level Ozone (O_3)	1 Hour	200	200	180
	8 Hour	120	120	100
Carbon Monoxide (CO)	1 Hour	35	35	30
	8 Hour	10	10	10

The new Ambient Air Quality Standard adopts six air pollutants which includes nitrogen dioxide (NO_2), particulate matter with an aerodynamic of 10 microns (PM_{10}), ozone (O_3), sulphur dioxide (SO_2), carbon monoxide (CO) and an addition of particulate matter with an aerodynamic of 2.5 microns ($PM_{2.5}$). The DOE has increased the number of CAQM stations to sixty eight (Department of Environment, 2020a). Under the new

Environmental Quality Monitoring Programme (EQMP), the monitoring stations have advanced measuring tools for calculating API and detect tiny particles of 2.5μm in diameter.

Additionally, the National Environmental Data Centre (EDC) has a computerized system that is able to dial up all the CAQM stations every hour if an instant update of air quality is needed. The system has QA/QC in place to ensure that the air quality data collected is accurate. According to the Department of Environment, the CAQM stations are chosen based on results of past and current monitoring, representativeness, accessibility, weather support services such as power and availability of telephone line, security and lastly effects of any specific topography (Department of Environment, 2020b).

2.4 Effects of Air Pollutants to Human Health

In Malaysia, urbanization is increasing rapidly which in turn poses risks to the health of residents (Usmani et al., 2020). Human health is damaged and air quality is worsening due intense human activities and adverse meteorological conditions (Kampa et al., 2008). Cardiovascular and respiratory disorders, diabetes and hypertension, dementia and the abortion risk for pregnancies, psychiatric and mental issues, impaired memory, reduced cognitive ability and life expectancy are examples of health effects that are caused by air pollution. Additionally, serious air pollution can also increase criminal and unethical behaviors, lower urbanites' happiness, decrease solar power potential and cause huge economic damages (Xie et al., 2016). According to World Health Organization (WHO), yearly mortality figures, tobacco use kills 7 million people; AIDS kills 1.2 million people; tuberculosis kills 1.1 million people and malaria kills 0.7 million people yearly. In the same year, 6.4 million people died as a result of air pollution worldwide, with 4.2 million deaths due to ambient pollution and 2.8 million attributed to indoor air pollution (World Health Organization, 2017).

2.4.1 Sulphur Dioxide (SO_2)

Sulphur dioxide emissions cause respiratory irritation, bronchitis, mucus production and bronchospasm because it is a sensory irritant that penetrates deeply into the lungs, converts to bisulfite and interacts with sensory receptors leading to bronchoconstriction. According to Chen et al. (2007), those with respiratory disorders are more vulnerable to the effects of sulphur dioxide exposure. Besides that, skin redness, eye and mucous membrane damage, as well as worsening of pre-existing cardiovascular disease was reported. The most prevalent clinical findings due to SO_2 exposure according to the study was pulmonary oedema, pneumotitis and acute airway blockage. On the other hand, a study by Ghorani et al. (2016), stated that respiratory dysfunction and aggravation of existing cardiovascular disease are two main health issues associated with SO_2 exposure at high concentrations.

2.4.2 Nitrogen Dioxide (NO_2)

When inhaled at high levels, nitrogen dioxide is a respiratory irritant as it penetrates deep into the lungs inducing respiratory illnesses such as coughing, wheezing, dyspnea, bronchospasm and even pulmonary oedema (Richmont-Bryant et al., 2017). Concentrations over 0.2 ppm leads to negative impacts in humans because they disrupt T-lymphocytes, particularly CD8+ cells and NK cells that produce our immune response. Additionally, long term exposure to high quantities of nitrogen dioxide can develop chronic lung diseases and can impair one's ability to smell as well. Other symptoms such as irritation to the eyes, throat and nose may be present in addition to respiratory symptoms (Chen et al., 2007).

2.4.3 Ozone (O_3)

Chemical reaction between oxides of nitrogen and volatile organic compounds (VOCs) emitted from natural sources as a result of human activities results in the formation of ground level ozone (GLO). GLO is believed to have plausible association with high risk of respiratory diseases mainly asthma (Gorai et al., 2014). O_3 is a strong oxidant which is fifty two percent stronger than chlorine. It arises in the stratosphere, but it could also arise following chain reactions of photochemical smog in the troposphere (Villanyi et al., 2010). Ozone uptake usually occurs by inhalation and can affect the upper layers of the skin and the tear ducts (World Health Organization, 2019). A study of short term exposure of mice to high levels of ozone showed malondialdehyde formation in the epidermis and also depletion in vitamins C and E. Additionally due to the low water solubility of ozone, inhaled ozone is capable to penetrate deeply into the lungs (Thiele et al., 2012).

2.4.4 Carbon Monoxide (CO)

Carbon monoxide has far more affinity for haemoglobin than oxygen. Hence, those who have been exposed to CO for a long time and in high concentrations are susceptible to significant poisoning. Additionally, disorders such as hypoxia, ischemia and cardiovascular diseases can occur as a result of oxygen loss due to competitive binding of carbon monoxide (Akyol et al., 2014). A study by Ghorani et al. (2016), stated that, dizziness, headache, nausea, vomiting and loss of consciousness are among symptoms of carbon monoxide poisoning caused by inhalation.

2.4.5 Particulate Matter (PM_{10})

Particle pollution is associated with most pulmonary and cardiac associated fatality (Sadeghi et al., 2015). According to the Environmental Protection Agency (EPA), PM was defined as a term for particles with diameters of 10 micrometers or smaller, known as PM_{10}, and extremely fine particles with sizes of 2.5 micrometers or smaller, known as $PM_{2.5}$.

Particulate matter are made up of microscopic liquid or solid particles that can be inhaled and have the tendency to cause major health consequences (Cheung et al., 2011). Even after inhalation, particles that are 10 micrometers or less even can infiltrate the lungs and in some situations reach the bloodstream. The penetrability of these particles are demonstrated in Table 2.2.

Table 2.2: Penetrability according to particle size in human respiratory system (Zhang et al., 2019)

Particle size	Penetration degree in human respiratory system
>11µm	Passage into nostrils and upper respiratory tracts
7 - 11 µm	Passage into nasal cavity
4.7 - 7 µm	Passage into larynx
3.3 – 4.7 µm	Passage into trachea- bronchial area
2.1 – 3.3 µm	Secondary bronchial area passage
1.1 – 2.1 µm	Terminal bronchial area passage
0.65 – 1.1 µm	Bronchioles penetrability
0.43 – 0.65 µm	Alveolar penetrability

Long term chronic consequences include respiratory illnesses and immune system dysfunction (New Hampshire Department of Environmental Science, 2019). Hence, citizens with asthma, pneumonia, diabetes, and those with other respiratory and cardiovascular related health issues are more prone and exposed to the effects of particulate matter with an aerodynamic of 10 microns. PM_{10} can be divided into four main categories depending on their types and size (Heal et al., 2012), which includes particulate contaminants (smog, soot, tobacco smoke, fly ash etc), biological contaminants (bacteria and bacterial spores, viruses, fungi and moulds and allergens), types of dust (atmospheric dust, heavy dust and settling dust) and gasses.

Continuous exposure to high levels of particulate matter with an aerodynamic of 10 microns (PM_{10}) that is present in the atmosphere could lower life expectancy remarkably. The main reasons for a shortened life expectancy are the increment of cardiopulmonary and lung cancer mortality. Additionally, reduced lung functions in children and adults leads to asthmatic bronchitis and chronic obstructive pulmonary disease, which are major disorders that reduces the quality of life (Zhou et al., 2014).

2.5 Environmental Impacts of Air Pollution

In addition to deteriorating human health, air pollution affects the surroundings as well (Ashfaq & Sharma, 2012). Acid rain is referred to as wet or dry precipitation containing excessive levels of nitric and sulphuric acids. These acids are capable of acidifying water and soil environments hence damaging crops and other plantations. They can also damage premises, outdoor carvings and even statues. Besides that, the formation of acid rain involves sulphur and nitrogen oxides and are harmful to plants and marine organisms. According to the Environmental Protection Agency (EPA), SO_2 is capable of reducing the amount of oxygen in water causing the death of marine plant and animal species.

Fine particles that are scattered in the atmosphere reduces the clarity of it and promotes the occurrence of haze. This is mostly caused by emissions from industrial activities, power stations, vehicles and trucks. Furthermore, stratospheric ozone is gradually damaged by ozone depleting substances and allows for ultra violet rays to reach Earth causing crop damage (Teramura, 2006). Ozone penetrates the stomata of plants, causing them to close up which in turn prevents CO_2 transfer and resulting in a slower rate of photosynthesis (Singh et al., 2009). Plants exposed to the effects of ozone have a disruption in photosynthetic rhythm and metabolism (Zuhara & Isaifan, 2018). Additionally, on an ecological aspect, O_3 is capable of reducing carbon incorporation in trees which leads to deforestation and has the possibility of affecting global food security when exposed long term (Fares et al., 2013).

Global climate change is another impact of air pollution (Manderson, 2019). Additionally, anthropogenic activities that results in greenhouse gas emissions and global warming drastically affects flora and fauna, agriculture and the water environment. The study also stated that people living in inadequate premises and in warm climate countries are at higher risk for heat related health issues as temperature continues to rise.

Toxic contaminants from the surrounding atmosphere, on the other hand, burden wildlife, causing animals to suffer health problems when exposed to excessive quantities of pollutants. Veras et al. (2010), stated that harmful contaminants has also been linked to reproductive failure and birth defects in animals. Moreover, eutrophication can also occur when there is an elevation in the concentration of nutrients particularly nitrogen, which promotes the blossoming of aquatic algae resulting in a loss of fish the diversity and their mortality.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, an hourly monitoring data of air pollutants that are NO_2, PM_{10}, O_3, SO_2 and CO and meteorological factors such as relative humidity, ambient temperature and wind speed from four monitoring stations in Peninsular Malaysia has been chosen. The details of the study area will be presented. Following that, the descriptive statistics of all the selected parameters will be analysed for each study area. Next, for bivariate analysis, the Pearson's Correlation will be used to measure the linear association and strength and direction of the relationship between the selected dependent and independent variables (Elbayoumi et al., 2013).

3.2 Study Flowchart

Figure 3.1 illustrates the activities that will be conducted throughout this research. Firstly, the descriptive analysis for NO_2, PM_{10}, O_3, SO_2 and CO and meteorological factors such as relative humidity, ambient temperature and wind speed will be analyzed. The results obtained will be demonstrated via a single line graph. The relationship between the five major air pollutants with meteorological factors will be identified using the Pearson's Correlation analysis. After that, a conclusion as to which air pollutant is most impacted by varying weather conditions will be determined.

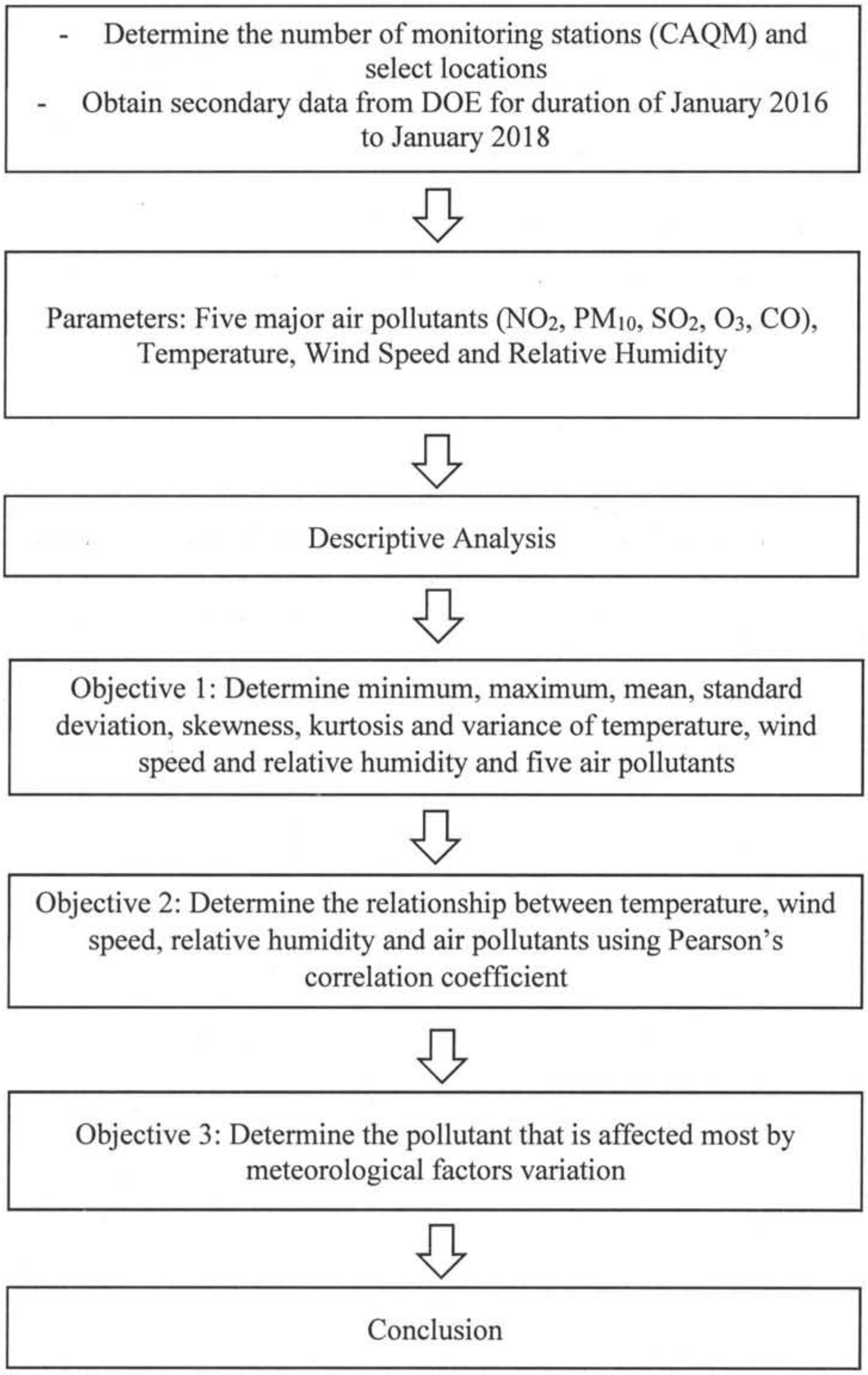


Figure 3.1: Study Flowchart

3.3 Study Area

There are four different monitoring stations that will be analyzed in this study representing urban areas. All the selected locations are in urban areas of Peninsular Malaysia. Figure 3.2 shows the map of Peninsular Malaysia. The states that are selected to be analyzed are Pulau Pinang, Johor, Wilayah Persekutuan and Terengganu. Additionally, the coordinates and details of the monitoring stations are described and illustrated.

Figure 3.2: Map of Peninsular Malaysia (Alias et al., 2014)

3.3.1 Seberang Perai, Pulau Pinang

The urban continuous air quality monitoring (CAQM) station of Penang is located at Sek. Keb. Seberang Jaya II (100.4039472°, 5.3981700°), Perai, Pulau Pinang. Seberang Perai is Malaysian town area located in the north and has been rapidly developed and urbanized. Seberang Perai exhibits a typical tropical monsoon climate, with warm and humid weather throughout the year (Mohd Zizi et al., 2018).

3.3.2 Pasir Gudang, Johor

The location for urban continuous air quality monitoring station in Johor is located at Sek. Men. Pasir Gudang II (103.8934556°, 1.4701222°), Pasir Gudang, Johor. This monitoring station is located in a residential area and is close to main roads as well as industrialized areas (Lee et al., 2012). Pasir Gudang is mostly being developed for industrial and port expansion, particularly for export purposes. The residential areas in this location is located to the north of the industrial and port areas although they are still close to Pasir Gudang's main highways. Thus, there are complaints by residents of the area regarding the air pollution caused by heavy trucks that utilize areas outside of Pasir Gudang to access the port (Abdullah et al., 2012).

3.3.3 Batu Muda, Wilayah Persekutuan Kuala Lumpur

For Wilayah Persekutuan, the CAQM for urban areas is located at Sek. Keb. Batu Muda (101.6822278°, 3.2124389°), Kuala Lumpur, WP. Kuala Lumpur. This continuous air monitoring station is located within the Klang Valley. According to the Department of Statistics Malaysia (2011), Klang Valley is Malaysia's largest economic region, with considerable infrastructure development, industrialization and urbanization. This has led to deterioration in air quality (Ling et al., 2010). Air pollution in Klang Valley has been linked to a rise in respiratory diseases, which are one of Malaysia's top ten causes of death (Ling et al., 2011).

3.3.4 Kemaman, Terengganu

The monitoring station for the urban area at Terengganu is SMK Bukit Kuang (103.4257780°, 4.2621210°), Chukai, Terengganu. Terengganu is located at the northern east of Peninsular Malaysia and is known for its reputation as an industrialized area with high population growth and also with high pollution levels in Malaysia. A developing Malaysian town, Kemaman is surrounded by Kerteh Petrochemical Industrial Area at the north and the industrializing and urbanizing Gebeng Industrial Area at the south (Ismail et al., 2016).

3.4 Materials and Methods

In this section, the preliminary data measurement will be described. The analysis were conducted to determine the dispersion and distribution of the selected parameters to be studied. There are two types of tests that will be used which are the measure of central tendency and measure of dispersion. The preliminary data obtained from the Department of Environment will be sorted daily for all four selected urban monitoring stations. The sorted data can be used for the analysis that will be done using the statistical software.

3.4.1 Descriptive Statistics of Air Pollutants and Meteorological Factors

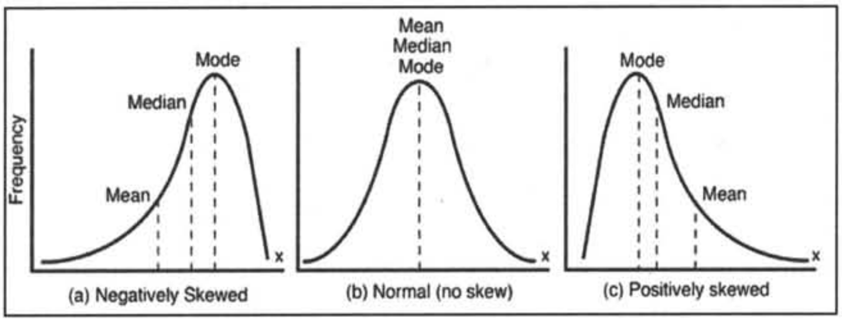
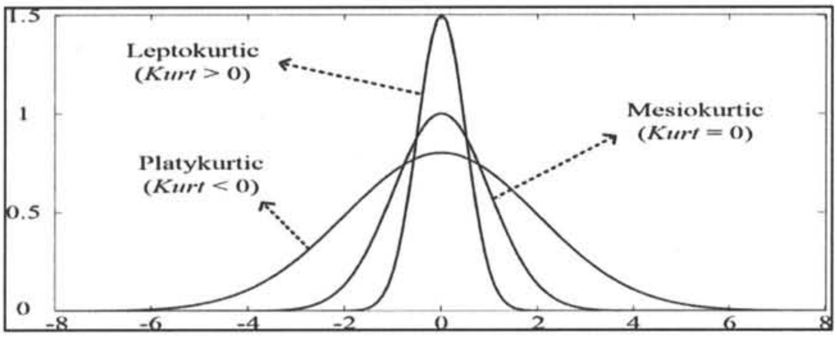
Descriptive statistics is done to gather information from data sets that includes the process of collecting, organizing, summarizing and presenting the data. The test of measures for central tendency include the minimum, maximum and mean whereas measures of dispersion include skew, variance, standard deviation and kurtosis. The summarized formulas for calculating the descriptive statistics are shown in Table 3.1.

Table 3.1: Descriptive Statistics

Analysis	Formula/Description
Minimum	The minimum/ smallest value of the variable
Maximum	The maximum/ largest value of the variable
Mean	The average of values $\bar{X} = \frac{\sum_{i=1}^{n} Xi}{n}$
Measures of Dispersion	Known to spread the average value of the data set 1) Variance $s^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$ 2) Standard deviation $s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$
$\bar{x}$ = mean xi = monitoring data n = number of monitoring data s = standard deviation	
Skewness	The degree and direction of asymmetry $C_x = \frac{m_3}{s^3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)^3}$ C_x = skewness m_3 = third moment $\bar{x}$ = mean x_i = monitoring data n = number of monitoring data s = standard deviation • Normal distribution (skewness = 0) • Positively skewed (right). Data lies on the left of the mean (skewness > 0) • Negatively skewed (left). Data lies on the right of the mean (skewness < 0)

Continued

Table 3.1: Descriptive Statistics (Continued)

	
Kurtosis	A measure of tail extremity reflecting the presence of outliers in a distribution $$\mathrm{K} = \frac{m_4}{m_2^2} = \frac{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{n}}{\frac{\left[\sum_{i=1}^{n}(x_i - \bar{x})^2\right]^2}{n^2}} = n\,\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left[\sum_{i=1}^{n}(x_i - \bar{x})^2\right]^2}$$ K = kurtosis m_4 = fourth moment m_2 = second moment $\bar{x}$ = mean x_i = monitoring data n = number of monitoring data 

3.4.2 Pearson's Correlation Analysis

The correlation analysis is utilized to measure the strength of association between two variables. To find a correlation between at least two continuous variables, the Pearson Correlation (*r*) is used (Dominick et al., 2012). The Pearson correlation is denoted as '*r*' and the general formula of '*r*' is shown in the equation (3.1). In the equation, N represents the sample size, X constitutes the value of the independent variable and Y is the value of the dependent variable.

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sqrt{\sum X^2} - \frac{(\sum X)^2}{N})\,(\sqrt{\sum Y^2} - \frac{(\sum Y)^2}{N})}} \tag{3.1}$$

The '*r*' value can fall between -1 and +1. A perfect negative relationship between the two variables would indicate a value of '*r*' = -1. The graph obtained will be a perfect straight line with a negative slope. If '*r*' = 0 it indicates that there is no linear relationship and a lack of correlation, this graph will be scattered. Lastly, a value of '*r*' = +1 equates to a perfect positive correlation whereby the data lies on a straight line with a positive slope showing that both variables increase and decrease together (Schober et al., 2018).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results of this study will be presented according to the driven objectives. Firstly, the descriptive statistics analysis includes the measurement of central tendency as well as measures of dispersion. Next, the relationship of five major air pollutants that are NO_2, PM_{10}, O_3, SO_2 and CO and meteorological factors such as relative humidity, wind speed and ambient temperature was determined for four locations at urban areas in Peninsular Malaysia for the two years period using Pearson Correlation Analysis. However, in 2017 the data for all eight parameters were unavailable from April 15th to July 3rd for the whole of Peninsular Malaysia. Finally, this chapter will also discuss the relationship of the five major air pollutants and meteorological factors during different seasons in Malaysia that is the southwest monsoon and the northeast monsoon.

4.2 Descriptive Statistics

Descriptive statistics is the characteristics of the data sets such as the mean, median and mode. The first objective of this study is to determine the characteristics of three meteorological factors and five major air pollutants at the four selected monitoring stations. The line graphs in Figure 4.1 to Figure 4.8 shows the daily concentration of all the meteorological factors and the major air pollutants. Additionally, Tables 4.1 to 4.8 shows the summary of descriptive statistics for ambient temperature, relative humidity, wind speed and the daily concentration of NO_2, PM_{10}, O_3, SO_2 and CO for Seberang Perai, Pasir Gudang, Batu Muda and Kemaman from January 2016 to January 2018.

4.2.1 Descriptive for Ambient Temperature

Wang et al. (2018), stated that reduced solar radiation and the temperature rise of the upper layer by solar radiation absorption or backscattering is due to a reduction in solar radiation surface temperature which results in the atmospheric stratification becoming more stable. Figure 4.1 will show the graph of daily ambient temperature reading at the four selected monitoring stations. Additionally, Table 4.1 will demonstrate the descriptive statistics for ambient temperature during the two years period.

The figure shows that from January 2016 to January 2018 the overall daily ambient temperature ranges from 22.0 °C to 32.0 °C. However, by comparing the four monitoring stations in the two year period, the highest temperature was recorded at Kemaman in 2016. Consecutively, the lowest temperature recorded was observed at the same monitoring station and the same year as well. Besides, the graph also shows that there was a significant drop in daily temperature at Batu Muda for a few days whereby the temperature dropped to almost 22.0 °C.

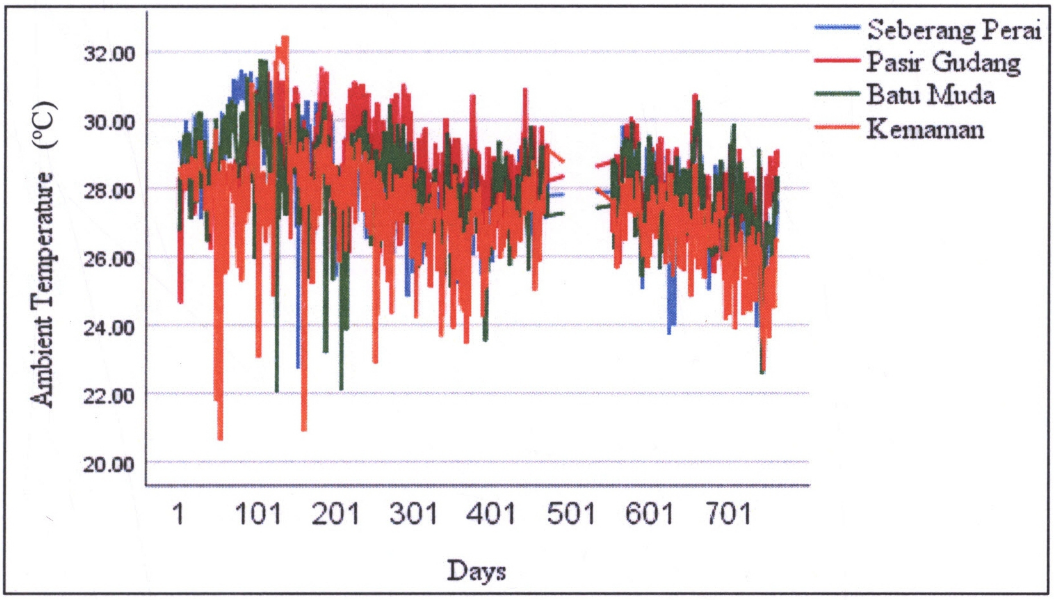


Figure 4.1: Daily ambient temperature from 2016 – 2018

Table 4.1 shows that for ambient temperature the smallest minimum value recorded is 20.63 °C in 2016 at Kemaman whereas the highest minimum value obtained was 25.09 °C which was observed at Pasir Gudang in 2017. Additionally, the highest maximum value was obtained at Kemaman in 2016 with a value of 33.47 °C in 2016 whereas the smallest maximum value recorded was 27.66 °C at Seberang Perai in 2016. Furthermore, the highest mean is 28.88 °C which was recorded at Pasir Gudang in 2016 whereas the lowest mean recorded was 25.22 °C in 2018 at Kemaman. As for standard deviation and variance, the highest value obtained was 1.64 °C and 2.7 °C respectively at Kemaman in 2016. Meanwhile, the lowest standard deviation and variance value was obtained at the Seberang Perai monitoring station in 2018 with a recorded value of 0.84 °C and 0.71 °C respectively. Next, for skewness all the monitoring stations in the two years period recorded a negative value. Based on the table the highest value was observed at Pasir Gudang in 2018 with a value of -1.00 whereas the smallest value was -0.02 in 2017 at Batu Muda and Pasir Gudang as well. Finally, for kurtosis, the highest positive value recorded was 3.00 at Kemaman in 2016 as well while the smallest negative value recorded was -0.01 at Seberang Perai in 2016.

Table 4.1: Descriptive statistics for ambient temperature at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	22.73	24.65	22.06	20.63	23.75	25.09	23.54	23.88	23.95	23.59	22.58	22.68
Maximum	31.46	31.60	31.78	32.47	29.85	30.91	30.55	29.15	27.66	29.14	29.16	26.69
Mean	28.69	28.88	28.38	27.78	27.69	28.08	27.66	26.89	26.22	27.24	26.53	25.22
Std. Deviation	1.43	1.23	1.44	1.64	1.11	1.12	1.11	0.97	0.84	1.16	1.40	1.08
Variance	2.05	1.52	2.07	2.70	1.23	1.25	1.22	0.93	0.71	2.59	1.95	1.16
Skewness	-0.42	-0.10	-0.70	-0.45	-0.50	-0.02	-0.02	-0.55	-0.59	-1.00	-0.92	-0.72
Kurtosis	-0.01	-0.06	1.61	3.00	0.15	-0.40	-0.07	0.33	0.46	-0.07	1.42	-0.36

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.2 Descriptive for Relative Humidity

Liu et al. (2018), stated that the urban heat island, global warming and an increase in anthropogenic aerosol emissions, as well as the inconsistency of atmospheric water vapor have an influence towards relative humidity. Figure 4.2 shows the graph of daily percentage of relative humidity for all four locations in this study. Besides, Table 4.2 shows the descriptive for relative humidity during the two year study period.

Figure 4.2 represents the daily percentage of relative humidity at Seberang Perai, Pasir Gudang, Batu Muda and Kemaman monitoring stations for two years which is from January 2016 to January 2018. From the figure it was observed that at Kemaman there was a significant decrease twice in 2016 at which the daily relative humidity was below 40.00 %. This percentage was the lowest recorded as compared to the other three monitoring stations. As for the maximum values of relative humidity, the graph shows that the daily percentage ranges from 87.00 % to almost 100.00 %. However, the highest percentage of relative humidity was observed at Kemaman in 2016 followed with Batu Muda in 2017.

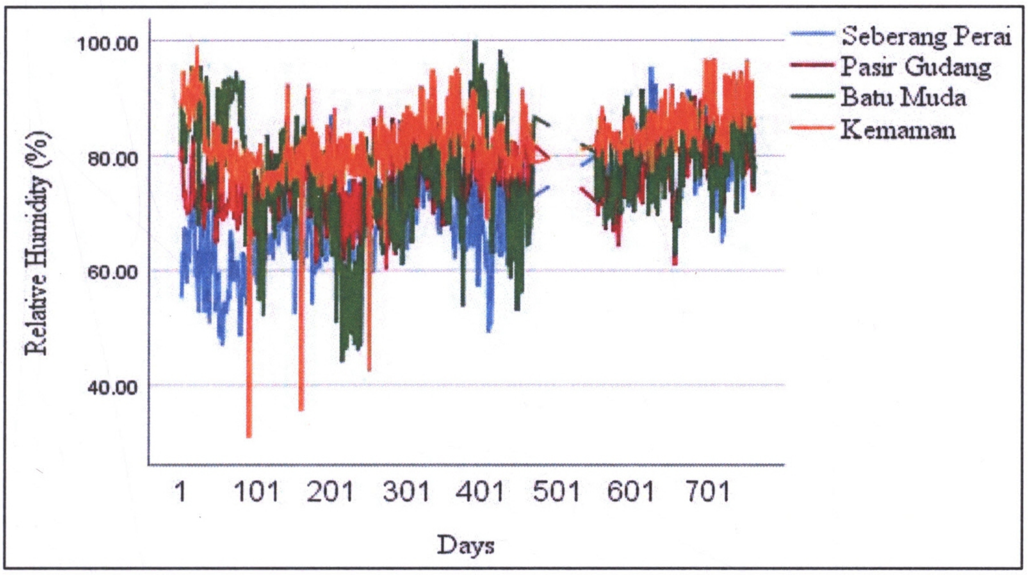


Figure 4.2: Daily relative humidity from 2016 – 2018

Next, from the results, it was observed that the lowest minimum value obtained was 30.87 % at Kemaman in 2016 and the highest minimum value was recorded in 2018 at Kemaman as well with a value of 84.10 %. Meanwhile, the highest maximum value obtained was 99.79 % at Batu Muda in 2017 whereas the lowest maximum value observed was 87.46 % at two monitoring stations that are Seberang Perai and Pasir Gudang in 2016. Furthermore, based on the table the highest mean value obtained was 89.64 % at Kemaman, 2018 while the lowest mean was observed at Seberang Perai in 2016 with a value of 66.85 %. For standard deviation and variance, the highest value observed was 10.46 % and 109.41 % respectively at Batu Muda in 2016 whereas the lowest value recorded was 3.48 % and 12.07 % at the same monitoring station however in 2018. Lastly, for skewness and kurtosis some stations recorded a negative value while some recorded positive values. The highest positive value obtained for skewness was 0.42 at Kemaman in 2017 while the smallest negative skew value obtained was -0.13 at Batu Muda in 2017. On the other hand, for kurtosis the highest positive value obtained was 1.26 in 2018 at Seberang Perai. Meanwhile, the smallest negative value was -0.14 at Batu Muda in 2017.

Table 4.2: Descriptive statistics for relative humidity at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	46.96	60.25	44.00	30.87	49.08	60.90	52.92	68.75	70.73	73.77	69.97	84.10
Maximum	87.46	87.46	95.67	99.08	95.43	93.29	99.79	96.88	93.28	92.40	92.99	96.71
Mean	66.85	73.75	75.99	80.89	75.39	77.82	78.50	83.76	83.11	83.29	81.86	89.64
Std. Deviation	7.65	5.48	10.46	6.70	7.74	5.33	8.64	4.20	4.54	5.03	5.32	3.48
Variance	58.52	30.06	109.41	44.83	59.91	28.41	74.64	17.61	20.64	25.32	28.35	12.07
Skewness	0.04	0.17	-0.55	-2.30	-0.55	-0.04	-0.13	0.42	-0.70	0.33	0.10	0.18
Kurtosis	-0.24	-0.36	0.22	0.13	0.50	-0.16	-0.14	0.82	1.26	-0.81	-0.20	-1.04

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.3 Descriptive for Wind Speed

The distribution rates of pollutants are influenced by the strength of wind, the nature of turbulent fields and wind shears depending on land/sea surface characteristics (Coccia, 2020). The highest level of pollutants are usually observed under still weather conditions whereby the wind velocity is relatively low and that higher wind velocities have significant influence towards the air status. Still conditions in the atmosphere causes the pollutants to be confined near ground level hence the increase of pollutants (Zhong et al, 2018). Figure 4.3 shows the daily wind speed recorded at four urban monitoring stations whereas Table 4.3 will demonstrate the descriptive statistics.

Based on Figure 4.3, firstly, the wind speed in 2016 at Pasir Gudang, and Kemaman were relatively similar. Meanwhile, at the Batu Muda the daily wind speed was lower. The highest value of wind speed observed had slightly exceeded 10.00 m/s but the graph also shows that there were several days at which the wind speed had exceeded 6.00 m/s. In 2016, the daily wind speed recorded in Seberang Perai was significantly higher compared to the other stations. Additionally, it was observed that in the two year period the overall daily minimum value of wind speed roughly ranges from 0.50 m/s up to 1.60 m/s. Besides that, there was a decrease in the speed of wind in 2017 and 2018 as compared to that of 2016. The maximum wind speed for these two years however was recorded at Kemaman monitoring station with a peak value exceeding 2.5 m/s in 2018.

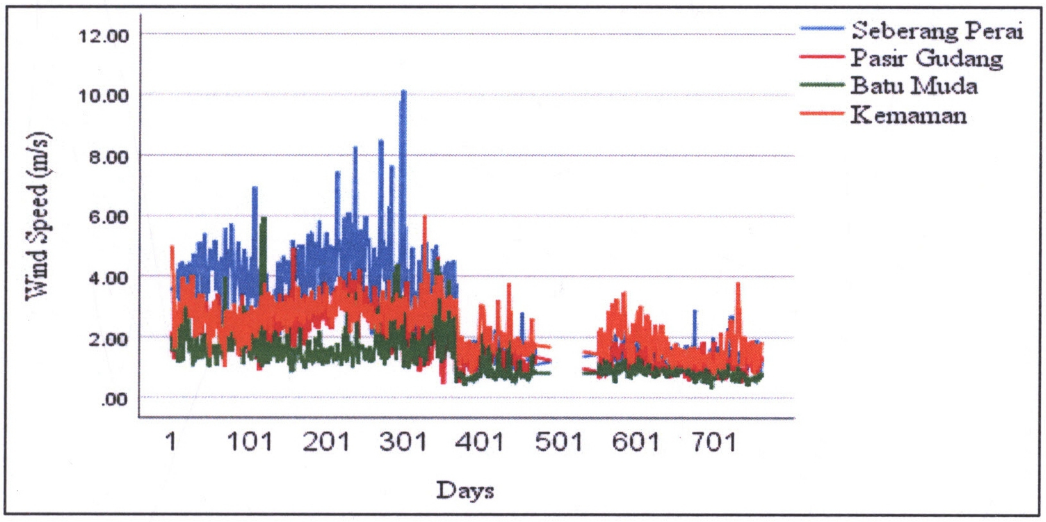


Figure 4.3: Daily wind speed from 2016 – 2018

On the other hand, from the results obtained from Table 4.3, it was observed that the smallest minimum value obtained was 0.32 m/s at Batu Muda in 2017 while the highest minimum value recorded was 1.55 m/s at Seberang Perai in 2016. Conventionally, the highest maximum value was obtained at Seberang Perai in 2016 with a value of 10.13 m/s whereas the lowest maximum value was recorded at Batu Muda in 2018 with a value of 1.80 m/s. Next, the highest mean observed was 4.02 m/s at Seberang Perai in 2016 whereas the lowest mean was seen at Batu Muda in 2018 with a value of 0.68 m/s. Besides, for standard deviation and variance, the highest value observed was 1.17 m/s and 1.37 m/s respectively at Seberang Perai in 2016. Meanwhile, the lowest value observed was 0.11 m/s and 0.01 m/s at Batu Muda in 2018. For skewness, all monitoring stations recorded a positive value through the study period except for in 2018 at Batu Muda (-0.45). However, the highest value obtained was 2.33 at Batu Muda in 2016. Finally, for kurtosis, Pasir Gudang had a negative value of -0.05 in 2016 and -0.46 in 2017. Conversely, a positive value of 0.35 was recorded in 2018. In 2018 however, Batu Muda had a negative value of -0.43. Additionally, the highest positive kurtosis value obtained was 8.16 at Batu Muda in 2016 whereas the smallest positive value was observed at Seberang Perai in 2018 with a value of 0.07.

Table 4.3: Descriptive statistics for wind speed at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	1.55	0.44	0.84	1.02	0.71	0.50	0.32	0.78	0.71	0.50	0.39	0.79
Maximum	10.13	4.93	5.95	6.02	2.91	2.34	2.12	3.81	2.06	1.80	0.85	2.96
Mean	4.02	2.40	1.79	2.84	1.45	1.17	0.86	1.81	1.30	1.08	0.68	1.60
Std. Deviation	1.17	0.71	0.68	0.55	0.35	0.33	0.25	0.57	0.32	0.28	0.11	0.47
Variance	1.37	0.50	0.46	0.30	0.12	0.11	0.06	0.33	0.10	0.08	0.01	0.22
Skewness	1.04	0.18	2.33	0.41	1.02	0.36	1.88	0.86	0.51	0.32	-0.45	1.16
Kurtosis	3.90	-0.05	8.16	3.46	2.22	-0.46	5.58	0.73	0.07	0.35	-0.43	2.35

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.4 Descriptive for Sulphur Dioxide (SO_2)

The main origin of SO_2 in the atmosphere is the combustion of fossil fuels by power stations as well as various industries. Volcanoes, locomotives and emissions from industrial activities such as ore extraction from metal are examples of smaller sources of SO_2, (Environmental Protection Agency, 2019). Figure 4.4 shows the graph of daily sulphur dioxide concentrations at four urban monitoring stations. In addition to that, Table 4.4 will show the descriptive statistics for SO_2 at the selected locations from January 2016 to January 2018.

Based on Figure 4.4, high daily sulphur dioxide concentrations were recorded at Pasir Gudang monitoring station in 2016. From the graph the highest concentration of SO_2 recorded was exceeding 0.01 ppm in both 2016 and 2017. Additionally, by comparing the daily concentration values, it was observed that overall Pasir Gudang has the highest concentration of SO_2 in the atmosphere in the two year period as compared to the other three stations. Moreover, it was observed that there was a peak in SO_2 concentration in 2017 at Seberang Perai. However, in 2018 the monitoring station that recorded the lowest emissions is Kemaman. The level of emission at Seberang Perai and Kemaman in 2018 is lesser whereas at Batu Muda towards the end of 2017 there is a rise in emission. Lastly, the minimum concentrations of sulphur dioxide in 2017 were significantly lower at all four stations than that in 2016 and 2017.

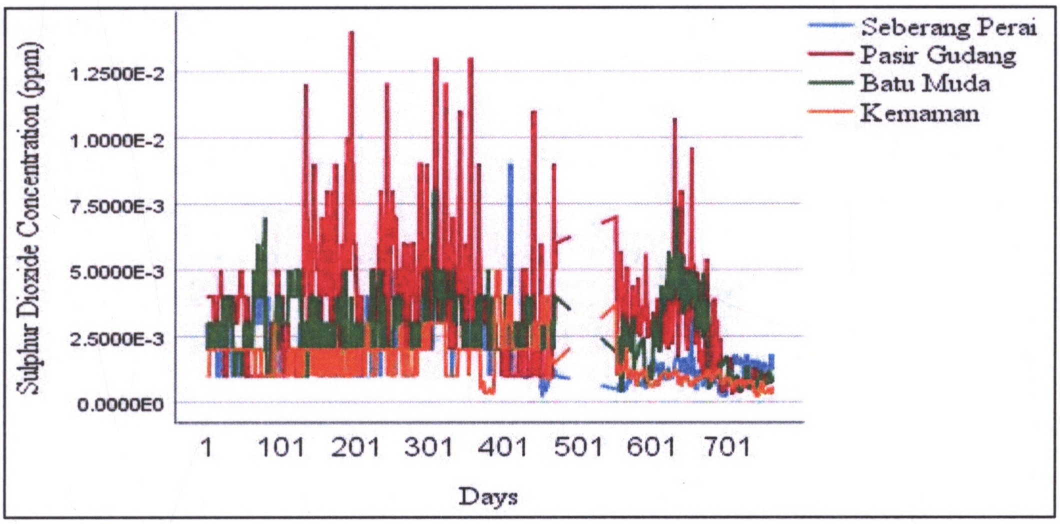


Figure 4.4: Daily SO_2 concentrations from 2016 – 2018

Firstly, for Sulphur Dioxide (SO_2), from Table 4.4, it was observed that the smallest minimum value obtained was 0.0002 ppm which was recorded at Seberang Perai in 2017. In addition to that, most monitoring stations recorded a similar minimum value of 0.001 ppm during the study period. This includes three stations which are Seberang Perai, Pasir Gudang and Kemaman in 2016 whereas in 2018 it was at Batu Muda instead of Kemaman. On the other hand, the highest maximum value recorded was 0.014 ppm at Pasir Gudang in 2016. Moreover, the highest mean obtained was 0.004 ppm. This was observed at Pasir Gudang in 2016. However, the lowest mean value obtained for this air pollutant is 0.000 ppm which was observed at Kemaman in 2018. Based on the Malaysian Ambient Air Quality Guidelines (MAAQG), the guideline for 24 hours averaging time is 0.04 ppm. Hence, the concentration of SO_2 at all four monitoring stations is within stipulated standards for the duration of this study. Next, for standard deviation the highest value obtained was 0.003 ppm at Pasir Gudang in 2016. In 2018 all four monitoring stations recorded a value of 0.000 ppm. For variance, all monitoring stations in the two year period recorded a value of 0.000 ppm. Besides that, in 2016, Kemaman had a negative skew value of -0.247 and in 2018, Seberang Perai recorded a value of -0.315 while all other stations were positively skewed. The highest positive skewness value however was 3.484 at Seberang Perai in 2017. Finally for kurtosis, in 2016, Kemaman recorded a negative value of -0.449 while the other three monitoring stations recorded positive values whereas in 2017, Batu Muda recorded a negative value of -0.221 and lastly Kemaman and Seberang Perai in 2018 with a value of -0.738 and -0.807 respectively. However, the highest positive kurtosis value was recorded at Seberang Perai in 2017 with a value of 25.735.

Table 4.4: Descriptive statistics for sulphur dioxide (SO_2) at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	0.001	0.001	0.004	0.001	0.0002	0.0003	0.0004	0.0003	0.001	0.001	0.001	0.002
Maximum	0.006	0.014	0.008	0.003	0.009	0.011	0.007	0.005	0.002	0.001	0.001	0.001
Mean	0.002	0.004	0.003	0.002	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.000
Std. Deviation	0.001	0.003	0.001	0.001	0.001	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skewness	0.867	1.145	0.549	0.110	3.484	1.377	0.432	1.665	-0.315	1.328	0.272	0.378
Kurtosis	0.047	1.717	1.367	-0.449	25.735	2.872	-0.221	2.215	-0.807	2.766	0.016	-0.738

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.5 Descriptive for Nitrogen Dioxide (NO_2)

Nitrogen dioxide represent a cluster of extremely irritable gases known as oxides of nitrogen. NO_2 along with NOx interacts with different elements in the atmosphere to produce particulate matter with an aerodynamic of 10 microns (PM_{10}) and ozone. Additionally, NO_2 and NOx are able to react with water, oxygen and other atmospheric elements resulting in acid rain (Environmental Protection Agency, 2019). Figure 4.5 shows the graph of daily nitrogen dioxide concentration. In addition to that, Table 4.5 will demonstrate the descriptive statistics for nitrogen dioxide for the two year study period at four different locations.

From Figure 4.5 the peak nitrogen dioxide concentration was observed at Pasir Gudang in 2016 and at Kemaman monitoring station during the two year period. Additionally, the graph also shows that there was a peak in NO_2 concentration in 2017 at Batu Muda in 2017. Despite the sudden peak, the concentration of nitrogen dioxide at these monitoring stations then decreased. Additionally, from the graph, daily concentration of nitrogen dioxide at Batu Muda had exceeded 0.03 ppm several times. Furthermore, the graph also shows that Kemaman had the lowest concentration of NO_2 in the two year period as compared to the other three monitoring stations.

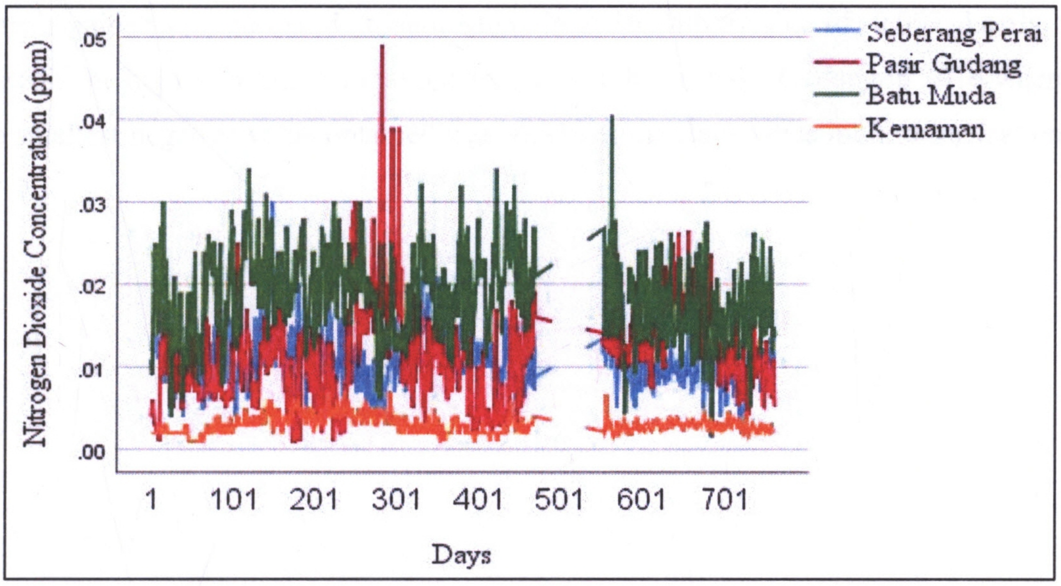


Figure 4.5: Daily NO_2 concentrations from 2016 – 2018

Next, Nitrogen Dioxide (NO_2), based on Table 4.5, it was observed that in 2016 two monitoring stations had the smallest minimum value of 0.001 ppm which are Pasir Gudang and Kemaman. In 2017, Kemaman also recorded a minimum value of 0.001 ppm. However, the largest minimum value obtained was observed at three monitoring stations in 2018 which are Seberang Perai, Pasir Gudang and Batu Muda with a value of 0.005 ppm. As for the highest maximum value, it was observed at Pasir Gudang in 2016 with a value of 0.049 ppm whereas the lowest maximum value was observed at Kemaman in 2016 and 2017 with a value of 0.007 ppm. The highest mean was observed during 2016 and 2017 at the same location which is in Batu Muda with a value of 0.019 ppm. The lowest mean obtained was 0.002 ppm at Kemaman in 2018. By comparing these values to the MAAQG, the 24 hours average guideline that was set for NO_2 was 0.04 ppm similar to that of SO_2. Having said that, the concentration of NO_2 at all the monitoring stations was in compliance with the guideline as it did not exceed the limit set. Consecutively, the smallest standard deviation value recorded was 0.0004 ppm at Kemaman in 2018 while the highest value was 0.007 ppm which was observed at Pasir Gudang in 2016. For variance, the results obtained were similar to that of SO_2 whereby all monitoring stations during the study period recorded a value of 0.000 ppm. As of skewness, the highest positive value obtained was 1.623 which was at Pasir Gudang in 2016 while the lowest value obtained was 0.249 at the same location in 2018. The highest negative skew value was observed at Seberang Perai in 2018 with a value of -0.499 while the smallest negative skew obtained was observed at Batu Muda in 2016 with a value of -0.007. Lastly, for kurtosis the highest positive value obtained was 4.901 at Pasir Gudang in 2016 whereas the smallest negative value obtained was -0.339 at the Batu Muda monitoring station in 2017.

Table 4.5: Descriptive statistics for nitrogen dioxide (NO_2) at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	0.004	0.001	0.004	0.001	0.003	0.002	0.002	0.001	0.005	0.005	0.005	0.002
Maximum	0.030	0.049	0.034	0.007	0.022	0.027	0.041	0.007	0.014	0.016	0.026	0.003
Mean	0.012	0.011	0.019	0.003	0.010	0.012	0.019	0.003	0.010	0.009	0.018	0.002
Std. Deviation	0.004	0.007	0.005	0.001	0.003	0.006	0.005	0.001	0.002	0.003	0.005	0.0004
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skewness	0.631	1.623	-0.007	0.348	0.396	-0.040	0.305	0.824	-0.499	0.553	-0.446	0.249
Kurtosis	1.474	4.901	-0.339	-0.345	0.943	-0.611	0.145	2.454	0.158	0.364	0.206	-1.043

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.6 Descriptive for Ozone (O_3)

According to the Environmental Protection Agency (EPA), ground level ozone is said to be the primary constituent of urban smog and is a secondary pollutant formed in the atmosphere via photochemical reactions involving nitrogen oxides and volatile organic compounds. A study (Speight, 2018) stated that O_3 is a strong oxidant and can oxidize contaminants through the formation of hydroxyl radicals or directly. Ozone should be produced onsite and delivered to closed spaces such as air sparging wells as it is highly reactive and unstable. Figure 4.6 demonstrates the line graph representing the daily concentration of O_3 from January 2016 to January 2018. In addition to that, Table 4.6 shows the descriptive statistics for Ozone for the four urban monitoring stations.

From the figure, it is observed that in 2016, the highest concentration of O_3 was recorded at Kemaman at which the concentration exceeded 0.045 ppm whereas in 2017 there was a peak in the daily concentration at Seberang Perai whereby the concentration was 0.060 ppm. Additionally, in 2016 at Batu Muda, the daily concentration exceeded 0.040 ppm for a few days which then slowly decreased. However, on the other days the maximum daily concentration at all four monitoring stations range from 0.035 ppm to 0.04 ppm. In the two year period, we can also see that the lowest concentration of O_3 was recorded in 2017 at Pasir Gudang and Batu Muda and in 2018 at Batu Muda.

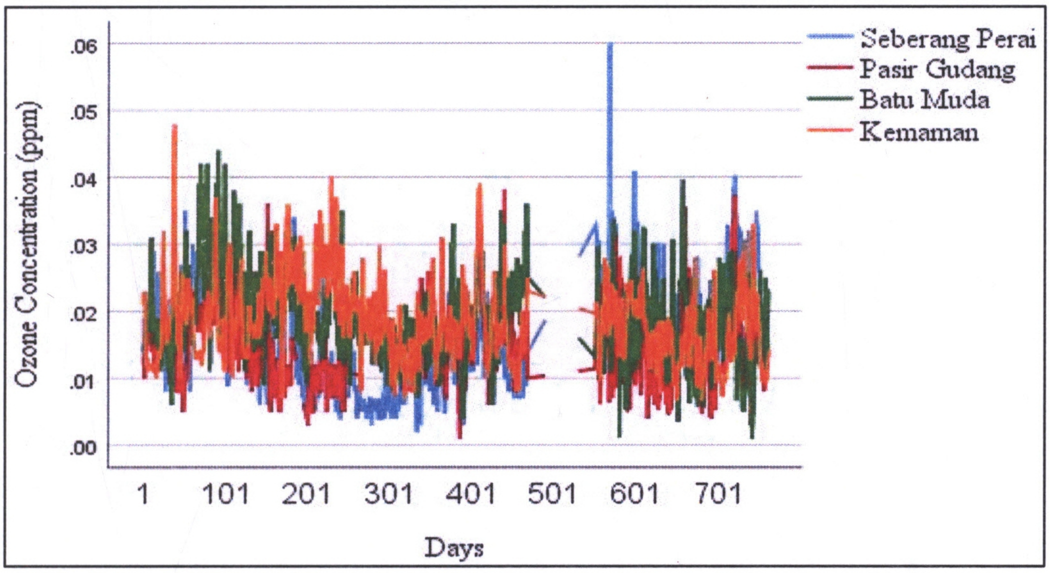


Figure 4.6: Daily O_3 concentrations from 2016 – 2018

Subsequently, for Ozone (O_3), from Table 4.6 shows that the smallest minimum value obtained was 0.001 ppm at two monitoring stations in 2017 which are Pasir Gudang and Kemaman and one station in 2018 which is Batu Muda while the highest minimum value was observed at Seberang Perai in 2018 with a value of 0.01 ppm. On the other hand, the highest maximum value obtained was 0.060 ppm at Seberang Perai in 2017 whereas the smallest maximum value was recorded at Pasir Gudang in 2018 with a value of 0.02 ppm. Next, the highest mean was observed in 2016 at Batu Muda and in 2018 at Seberang Perai with a value of 0.02 ppm. The lowest mean was obtained at Pasir Gudang in 2016 with a value of 0.01 ppm. For O_3 the guideline set by MAAQG is 0.06 ppm. In addition to that, the Malaysian Ambient Air Quality Guidelines were set based on 8 hours averaging time. From this, the mean concentration value obtained did not exceed the limit set. Furthermore, the highest standard deviation value obtained was 0.008 ppm which was recorded at three stations which are Seberang Perai and Pasir Gudang in 2016 and Seberang Perai in 2017. Similar to that of SO_2 and NO_2, the variance value for this air pollutant is 0.000 ppm in four all monitoring stations for the two year period. The skew value obtained were positive in all stations except at Pasir Gudang (-0.393) in 2018. However, the highest skew value obtained was 0.955 at Seberang Perai in 2017. Lastly, for kurtosis the highest positive value obtained was 1.850 at Seberang Perai in 2017 while the smallest negative kurtosis value obtained was at Pasir Gudang in 2018 with a value of -0.119.

Table 4.6: Descriptive statistics for ozone (O_3) at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	0.002	0.003	0.006	0.007	0.003	0.001	0.001	0.007	0.010	0.003	0.001	0.009
Maximum	0.035	0.036	0.044	0.048	0.060	0.038	0.040	0.039	0.035	0.020	0.026	0.033
Mean	0.014	0.010	0.020	0.019	0.019	0.016	0.019	0.017	0.020	0.013	0.014	0.018
Std. Deviation	0.008	0.008	0.007	0.007	0.008	0.007	0.007	0.006	0.007	0.004	0.007	0.007
Variance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skewness	0.694	0.132	0.887	0.646	0.955	0.748	0.254	0.886	0.698	-0.393	0.221	0.621
Kurtosis	-0.350	-0.966	0.775	0.672	1.850	0.529	-0.089	1.548	-0.795	-0.119	-0.783	-0.691

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.7 Descriptive for Carbon Monoxide (CO)

According to Occupational, Safety and Health Act of 1970 (2012), carbon monoxide is an ordinary industrial threat that results due to the incomplete burning of materials such as gasoline, natural gas, kerosene, oil and etc. A study by (Mullinger and Jenkins, 2014) stated that carbon monoxide is usually formed as the first step in the oxidation of carbon char and a primary product of fuel pyrolysis. Figure 4.7 shows the graph of daily carbon monoxide concentration at four urban locations. Moreover, Table 4.7 will show the descriptive statistics for CO from January 2016 to January 2018 at the selected monitoring stations.

From figure 4.7, by comparing the CO concentration from January 2016 to January 2018, the lowest concentration was recorded in 2016 at Pasir Gudang. Consecutively, Batu Muda in 2016 also recorded low values whereby the concentration did not exceed 0.10 ppm. The graph also shows that the highest concentration of CO was at Batu Muda at which the daily concentration was 1.50 ppm in 2016. Moreover, as for 2017, the highest concentration observed exceeded 1.40 ppm which can be seen at two monitoring stations which are Seberang Perai and Batu Muda. Meanwhile, the lowest value observed in 2017 was at Kemaman monitoring station. Lastly, from the graph the daily concentration at all four monitoring stations were smaller in 2018 compared to that of 2016 and 2017.

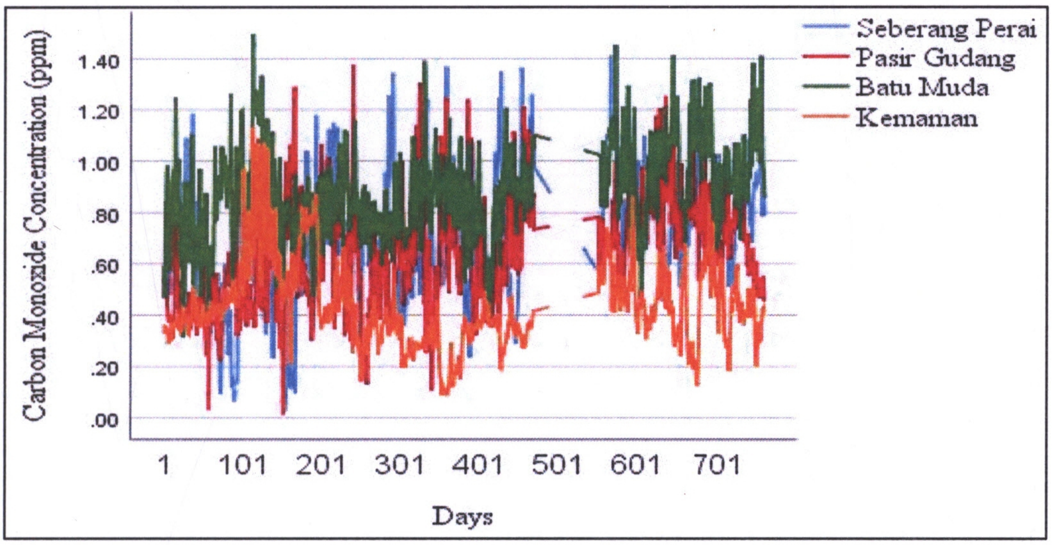


Figure 4.7: Daily CO concentrations from 2016 – 2018

Table 4.7 demonstrates the descriptive statistic for Carbon Monoxide (CO). Based on the table the smallest minimum value obtained is 0.02 ppm which was observed at one monitoring station in 2016 which is at Pasir Gudang while the largest minimum value recorded was 0.79 ppm at Batu Muda in 2018. Besides, the highest maximum value is 1.50 ppm at Batu Muda in 2016 whereas the smallest maximum value was observed at Pasir Gudang in 2018 with a value of 1.00 ppm. Additionally, the highest mean value obtained was 0.93 ppm during 2017 at Batu Muda whereas the lowest mean value obtained was 0.39 ppm at Kemaman in 2018. As for CO, the Malaysian Ambient Air Quality Guidelines were set similar to that of O_3 which is based on 8 hours averaging time. For CO the set limit is 9.0 ppm. Having said that, through the descriptive obtained, the concentration of CO did not exceed the limit. Besides that, the highest standard deviation and variance value obtained was 0.25 ppm and 0.06 ppm respectively at Seberang Perai in 2016. In 2016, Seberang Perai had a negative skew value of -0.10 while in 2017, Batu Muda had a negative skew value of -0.08 and lastly in 2018, a negative skew value was observed at Kemaman with a value of -0.76. Finally, for kurtosis, in 2017, two monitoring stations which are Pasir Gudang and Kemaman recorded a negative value of -0.11 and -0.01 respectively. In 2018, Kemaman also recorded a negative kurtosis value of -0.49. However, the highest positive value obtained was 1.29 at Pasir Gudang in 2018.

Table 4.7: Descriptive statistics for carbon monoxide (CO) at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	366	366	366	366	286	286	286	286	31	31	31	31
Missing	-	-	-	-	79	79	79	79	-	-	-	-
Minimum	0.11	0.02	0.32	0.09	0.24	0.32	0.40	0.12	0.68	0.46	0.79	0.20
Maximum	1.37	1.38	1.50	1.14	1.42	1.25	1.45	0.87	1.14	1.00	1.41	0.52
Mean	0.65	0.59	0.83	0.45	0.78	0.74	0.93	0.42	0.87	0.61	1.05	0.39
Std. Deviation	0.25	0.24	0.18	0.19	0.21	0.19	0.18	0.14	0.10	0.13	0.17	0.08
Variance	0.06	0.06	0.03	0.04	0.04	0.03	0.03	0.02	0.01	0.02	0.03	0.01
Skewness	-0.10	0.56	0.36	0.98	0.10	0.19	-0.08	0.40	0.54	1.16	0.62	-0.76
Kurtosis	0.44	0.22	0.69	1.16	0.05	-0.11	0.12	-0.01	0.67	1.29	-0.49	0.29

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

4.2.8 Descriptive for Particulate Matter (PM_{10})

Particulate matter with an aerodynamic of 10 microns (PM_{10}) comprises of a wide spectrum of chemically and physically varying molecules that is present in the atmosphere as discrete suspended particles (Stanek & Brown, 2019). Besides, a study by (El Morabet, 2018), stated that PM_{10} is able to take up and transport multitude of pollutants which results in its composition variation. Figure 4.8 shows a line graph that represents the daily concentration of PM_{10} at four urban locations. Additionally, Table 4.8 demonstrates the descriptive statistic for PM_{10} at the selected monitoring stations for the two year period of this study.

Figure 4.8 shows the line graph that represents the daily concentration of particulate matter with an aerodynamic of 10 micron (PM_{10}). Based on the graph, it was observed that the highest concentration of PM_{10} was recorded at Pasir Gudang monitoring station in 2016 with concentration exceeding 140 μg/m^3 followed by Batu Muda monitoring station in the same year which recorded a high concentration of 140 μg/m^3. Furthermore, the daily concentration was relatively decreasing in the two year study period. Significantly low concentrations of PM_{10} was seen for several days from the graph in 2016 which is at Seberang Perai, Pasir Gudang and Batu Muda and additionally Pasir Gudang in 2017 whereby the concentration did not exceed 5 μg/m^3. Finally, the graph shows that the concentration of PM_{10} decreased over the two year period.

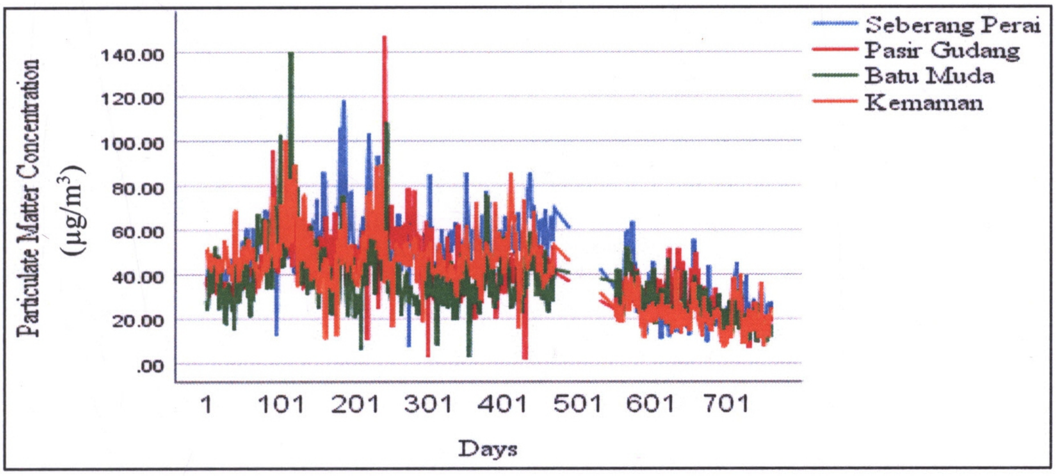


Figure 4.8: Daily PM_{10} concentrations from 2016 – 2018

Lastly, for Particulate Matter with an aerodynamic of 10 micron (PM_{10}), from Table 4.8 the smallest minimum value obtained was 1.88 $\mu g/m^3$. This was observed at Pasir Gudang monitoring station in 2017. The largest minimum value observed was however at Seberang Perai in 2018 with a value of 13.46 $\mu g/m^3$. On the other hand, the highest maximum value recorded was 147.00 $\mu g/m^3$ which was recorded at Pasir Gudang in 2016 while the smallest maximum value recorded was 27.01 $\mu g/m^3$ at Batu Muda in 2018. Meanwhile, the highest mean obtained was in 2016 with a value of 53.08 $\mu g/m^3$ at Seberang Perai while the lowest mean was observed at Pasir Gudang in 2018 which was 16.99 $\mu g/m^3$. According to the Malaysian Ambient Air Quality Guidelines (MAAQG), the guideline for 24 hours averaging time of PM_{10} is 150 $\mu g/m^3$. This shows that the concentration of PM_{10} did not exceed the standards set. As for standard deviation and variance, the highest value was recorded at Seberang Perai in 2017 with a value of 18.50 $\mu g/m^3$ and 342.25 $\mu g/m^3$ respectively whereas the lowest value was recorded at Pasir Gudang at 2018 with values of 4.10 $\mu g/m^3$ and 16.79 $\mu g/m^3$ respectively. As for skewness, Pasir Gudang and Batu Muda recorded negative values of -0.001 and -0.04 in 2018. The highest positive skew value however was observed at Batu Muda in 2016 with a value of 1.66. Lastly, the highest positive kurtosis value obtained was 8.90 whereas the smallest negative kurtosis value obtained was -0.25 at Batu Muda in 2018.

Table 4.8: Descriptive statistics for particulate matter (PM_{10}) at four different stations from January 2016 – January 2018

Statistics	2016				2017				2018			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
Valid	365	366	366	364	286	286	286	286	31	31	31	31
Missing	1	-	-	2	79	79	79	79	-	-	-	-
Minimum	7.63	3.21	2.96	11.00	3.67	1.88	8.72	7.08	13.46	6.90	9.59	7.78
Maximum	118.25	147.00	140.08	100.42	85.75	58.25	75.25	85.58	34.74	27.56	27.01	36.27
Mean	53.08	46.67	41.42	48.42	35.49	33.05	31.44	32.30	22.59	16.99	17.57	18.56
Std. Deviation	14.24	13.59	16.88	11.89	18.50	9.84	10.84	15.68	5.51	4.10	4.41	5.81
Variance	202.75	184.57	284.86	141.34	342.25	96.84	117.58	245.98	30.37	16.79	19.48	33.71
Skewness	1.24	1.53	1.66	0.48	0.34	0.002	0.92	0.79	0.53	-0.001	-0.04	0.87
Kurtosis	4.36	8.90	5.20	3.24	-1.06	-0.34	1.74	0.05	-0.45	1.08	-0.25	1.50

S1 = Seberang Perai
S2 = Pasir Gudang
S3 = Batu Muda
S4 = Kemaman

Overall, it can be said that the air quality during the period of January 2016 to January 2018 at Seberang Perai, Pasir Gudang, Batu Muda and Kemaman was relatively good. The mean concentration of the five major air pollutants were below the limit set by the Malaysian Ambient Air Quality Guideline.

4.3 Pearson Correlation Analysis

In this study, the Pearson correlation between NO_2, PM_{10}, O_3, SO_2 and CO and meteorological factors including ambient temperature, relative humidity and wind speed were analyzed using the Pearson correlation analysis to disclose the relationship between the three stated meteorological factors and the five major air pollutants. Additionally, the analysis will be used to identify if whether meteorological factors can significantly affect air quality. The analysis is demonstrated in Table 4.9.

4.3.1 The Pearson Correlation Analysis between Air Pollutants and Meteorological Factors

Table 4.9 shows the correlation between the three meteorological factors mentioned earlier and five major air pollutants (NO_2, PM_{10}, O_3, SO_2 and CO) at four urban monitoring stations which are Seberang Perai, Pasir Gudang, Batu Muda and Kemaman in Peninsular Malaysia.

From the table, most of the air pollutants and meteorological factors recorded at Seberang Perai were found to correlate with each other except, wind speed with CO and O_3. The highest positive significant correlation was between O_3 and ambient temperature (r = 0.571). On the other hand, the lowest negative significant correlation was between SO_2 and wind speed (r = -0.135). For the next station, Pasir Gudang, the highest positive significant correlation was between CO and relative humidity (r = 0.442) whereas the lowest negative significant correlation was between ambient temperature and CO (r = -0.157). However, at this station, there were no significant correlation observed between SO_2 and O_3 with wind speed and NO_2 with ambient temperature.

Nevertheless, Batu Muda station showed that the strongest significant positive correlation were between O_3 and ambient temperature (r = 0.793) which was similar to Seberang Perai. Meanwhile, the lowest significant negative correlation was between PM_{10} and relative humidity (r = -0.157). At this monitoring station, there was no significant correlation between SO_2 with ambient temperature, relative humidity and wind speed, O_3 with relative humidity and PM_{10} with wind speed. For the last station of this study, Kemaman, the highest significant positive correlation was between NO_2 with relative humidity (r = 0.477) whereas the lowest negative significant correlation was between wind speed and CO (r = -0.124). Moreover, the analysis shows that there were no significant correlation between O_3 and all three meteorological factors, CO with relative humidity and PM_{10} with wind speed.

Having said that, the correlation among air pollutants shows that there was no significant correlation between O_3 and SO_2 at Seberang Perai. The highest significant correlation however was observed between CO and NO_2 (r = 0.421). Additionally, at Pasir Gudang the highest significant correlation was observed between NO_2 and SO_2 (r = 0.351) but no significant correlation were observed between CO and NO_2. However, all air pollutants had a significant correlation amongst each other at Batu Muda with the highest correlation being between PM_{10} and O_3 (r = 0.504). Conversely, at Kemaman the highest significant correlation was observed between NO_2 and CO (r = 0.407) while O_3 and PM_{10} recorded no significant correlations with SO_2. Lastly, the analysis also shows that ambient temperature, relative humidity and wind speed significantly correlate with each other at the four monitoring stations.

Table 4.9: Pearson correlation analysis for meteorological factors and air pollutants

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Seberang Perai	Ambient temperature	1							
	Relative humidity	-0.581**	1						
	Wind speed	0.237*	-0.310*	1					
	SO_2	-0.179*	0.113*	-0.135*	1				
	NO_2	-0.137*	0.239**	-0.159*	0.215**	1			
	O_3	0.571**	-0.437**	-0.116	0.146	-0.264**	1		
	CO	-0.297**	0.270**	-0.009	-0.171*	0.421**	0.355**	1	
	PM_{10}	0.379**	-0.351**	0.174*	0.218*	0.391**	-0.143*	0.370**	1
Pasir Gudang	Ambient temperature	1							
	Relative humidity	-0.391**	1						
	Wind speed	0.339**	-0.154**	1					
	SO_2	0.231**	0.219**	-0.094	1				
	NO_2	-0.127	0.197*	-0.316**	0.351**	1			
	O_3	0.193*	-0.315**	-0.107	-0.392**	-0.121*	1		
	CO	-0.157*	0.442**	-0.169*	0.278**	0.11	-0.341**	1	
	PM_{10}	0.369**	-0.355**	0.217*	0.291**	0.169*	-0.403**	0.411**	1

Continued

Table 4.9: Pearson correlation analysis for meteorological factors and air pollutants (Continued)

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Batu Muda	Ambient temperature	1							
	Relative humidity	-0.433**	1						
	Wind speed	0.236*	-0.133*	1					
	SO_2	-0.110	0.064	0.287	1				
	NO_2	-0.308**	0.337**	0.217*	0.331**	1			
	O_3	0.793**	-0.118	-0.159*	0.177*	0.256**	1		
	CO	-0.108*	0.301**	0.153*	0.266**	0.319**	0.158**	1	
	PM_{10}	0.353**	-0.157**	0.07	0.362**	0.353**	0.504**	0.426**	1
Kemaman	Ambient temperature	1							
	Relative humidity	-0.478**	1						
	Wind speed	0.236**	0.319**	1					
	SO_2	0.319**	0.156*	-0.181*	1				
	NO_2	0.301**	0.477**	0.239*	0.271*	1			
	O_3	0.218	-0.343	0.09	-0.064	0.319**	1		
	CO	-0.135**	0.007	-0.124*	-0.259**	0.407**	0.328**	1	
	PM_{10}	-0.183**	0.214*	-0.009	0.014	0.140*	0.257**	0.317**	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

4.4 Relationships between Air Pollutants and Meteorological Factors during Monsoon Seasons in Peninsular Malaysia

In this study, the third objective is to determine the correlation between the three meteorological factors (ambient temperature, relative humidity and wind speed) with five major air pollutants (SO_2, NO_2, O_3, CO and PM_{10}) as discussed earlier during different weather conditions. Malaysia experiences two seasonal variations which are the southwest monsoon and the northeast monsoon. Additionally, the movement of air pollutants usually follows the patterns of wind direction based on the southwest and the northeast monsoon.

4.4.1 Pearson Correlation during the Southwest Monsoon

The southwest monsoon in occurs from June and lasts for approximately four months and is expected to end around September. Based on the results obtained, it can be seen that the influence degree of meteorological factors on the five major air pollutants during this period varies with that from the yearly correlation. Peninsular Malaysia is characterized by quite high but uniform temperatures (Malaysian Meteorological Department, 2012). The southwest monsoon is an annual occurrence. Table 4.10 shows the correlation during the southwest monsoon between meteorological factors and air pollutants at four urban monitoring stations in Peninsular Malaysia.

During this period, it was observed that the highest positive significant correlation at Seberang Perai and Batu Muda was between O_3 and ambient temperature ($r = 0.528$) and ($r = 0.518$) respectively. On the other hand, at Pasir Gudang it was between ambient temperature with CO ($r = 0.423$). As of Kemaman, the highest positive significant correlation was for NO_2 and relative humidity ($r = 0.315$). Along with that, the lowest negative significant correlation at all Seberang Perai station was between PM_{10} and wind speed whereby $r = -0.\ 171$. At Pasir Gudang and Kemaman the lowest correlation was observed between CO and wind speed with values of ($r = -0.215$) and ($r = -0.271$) respectively. Lastly, at Batu Muda, the lowest negative significant correlation was between O_3 and relative humidity with a value of $r = -0.249$.

On top of that, during this period, it was observed that there was no significant correlation between several meteorological parameters and air pollutants at all four stations. At Seberang Perai this was seen between SO_2 and wind speed as well as with NO_2 and relative humidity. Furthermore, at Pasir Gudang there was no significant correlation between SO_2 with relative humidity, NO_2 with ambient temperature and PM_{10} with wind speed and relative humidity. The analysis also shows that at Batu Muda there was no significant correlation recorded between two pollutants which are NO_2 and PM_{10} with relative humidity. Finally, at Kemaman no significant correlation were observed between NO_2 with ambient temperature and wind speed, CO and relative humidity and between PM_{10} and wind speed.

Additionally, for correlation among air pollutants, the analysis shows that at Seberang Perai the highest positive significant correlation was between PM_{10} and O_3 (r = 0.415). However, pollutants that did not significantly correlate were only between CO and SO_2. For the next station, Pasir Gudang, the highest significant correlation was observed between PM_{10} and SO_2 (r = 0.414) whereas there was no significant correlation observed between NO_2 and CO with SO_2. At Batu Muda station however, the highest positive correlation was seen between CO and NO_2 (r = 0.597) while no significant correlation was observed between O_3 and SO_2. Lastly, at Kemaman, the analysis shows that the highest positive correlation was between PM_{10} and SO_2 (r = 0.401). At this monitoring station, all pollutants had significant correlation that ranges from negative and positive, weak to moderate correlations except between PM_{10} and CO. As for the correlation between meteorological factors with each other, significant correlations were recorded at all stations.

Table 4.10: Pearson correlation analysis during the southwest monsoon

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Seberang Perai	Ambient temperature	1							
	Relative humidity	-0.922**	1						
	Wind speed	0.481**	-0.623*	1					
	SO_2	-0.337*	0.215*	-0.156	1				
	NO_2	0.375**	-0.233	-0.191*	0.251**	1			
	O_3	0.528**	-0.371**	0.153*	0.341**	-0.211*	1		
	CO	0.211*	0.347**	0.258*	-0.157	0.379**	-0.217*	1	
	PM_{10}	0.412**	-0.503**	-0.171*	0.305**	0.213*	0.415**	0.213*	1
Pasir Gudang	Ambient temperature	1							
	Relative humidity	-0.625**	1						
	Wind speed	-0.275**	-0.279*	1					
	SO_2	-0.283**	0.015	-0.273*	1				
	NO_2	-0.012	0.411**	-0.388**	0.068	1			
	O_3	0.289**	-0.241*	0.118*	-0.311**	-0.323**	1		
	CO	0.423**	-0.327**	-0.215*	0.143	0.129*	-0.118*	1	
	PM_{10}	0.228*	0.116	-0.068	0.414**	0.352**	0.153*	0.217*	1

Continued

Table 4.10: Pearson correlation analysis during the southwest monsoon (Continued)

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Batu Muda	Ambient temperature	1							
	Relative humidity	-0.322*	1						
	Wind speed	0.215*	-0.159*	1					
	SO_2	0.196*	-0.291**	0.153*	1				
	NO_2	0.259**	-0.185	0.271**	0.417**	1			
	O_3	0.518**	-0.249*	0.261*	0.019	-0.219*	1		
	CO	-0.313**	-0.355**	0.401**	0.349**	0.597**	-0.222*	1	
	PM_{10}	0.159*	-0.189	0.211*	0.191*	0.361**	0.210*	0.519**	1
Kemaman	Ambient temperature	1							
	Relative humidity	-0.323**	1						
	Wind speed	0.294*	-0.350*	1					
	SO_2	-0.496**	0.211*	0.201*	1				
	NO_2	0.116	0.315**	0.115	0.296**	1			
	O_3	0.317**	-0.357**	0.135*	0.191*	-0.381**	1		
	CO	0.275**	0.175	-0.271*	-0.377**	0.123*	-0.279**	1	
	PM_{10}	0.192*	0.262*	0.086	0.401**	0.320**	0.331**	0.103	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

The southwest monsoon is usually associated with the generation of haze episodes in Peninsular Malaysia due to biomass burning from Sumatra, Indonesia (Elhadi et al., 2018). Based on the results, a positive correlation between O_3 with wind speed, ambient temperature or both is observed during this period. Hassan et al. (2015), stated that O_3 concentrations can be greatly affected by downwind effect. The movement of gaseous pollutants, particularly O_3 precursors from one area to another often results in high levels of O_3 concentrations because of photochemical reactions. Moreover, the analysis shows that there is a positive correlation between PM_{10} and ambient temperature at all monitoring stations. A high temperature usually induces chemical reactions in the atmosphere which results in the formation of particulate matter with an aerodynamic of 10 microns (Afzali et al., 2014). Furthermore, there is a positive correlation observed between CO and ambient temperature at Seberang Perai, Pasir Gudang and Kemaman. A positive correlation indicates that carbon monoxide is involved with chemical reactions in the atmosphere that can produce ozone which can increase surrounding temperature.

The correlation between PM_{10} and CO is positive at four all monitoring stations. This finding is consistent with Mansouri et al. (2011), who reported positive correlations between both these air pollutants. This is because incomplete combustion of fossil fuels produces carbon that consists of soot hence causing an increase in particulate pollution. The analysis also shows that the correlation between PM_{10} and O_3 is positive, weak to moderate correlations. According to Atkinson et al. (2014), this is due to hot weather conditions as a result of high temperature which induces the formation of pollutants. Additionally, the correlation between O_3 and CO during this period are negative, very weak to weak correlations. This finding is similar to that of Real et al. (2008), who found that a negative relationship between these pollutants which indicates that hydrocarbon oxidation uses O_3 and produces CO. Besides that, a negative correlation was observed between O_3 and NO_2 at all four monitoring stations. By referring to Gao et al. (2017), an increase in O_3 levels are associated with a drop of NO_2 due to the oxidation of this precursor.

4.4.2 Pearson Correlation during the Northeast Monsoon

The northeast monsoon in Peninsular Malaysia typically starts in November and lasts up to March. According to the Malaysian Meteorological Department (2012), variation in wind movements and rainfall differentiates the seasons in our country. The wind throughout the country is generally light and can vary as Malaysia is located near the equator. According to Liss and Johnson (2014), the rainfall intensity during this period is high resulting in pollutants being diminished from the atmosphere via wet deposition processes. A study conducted by Varikoden et al. (2010), stated that based on the four different regions in Peninsular Malaysia which are the south coast, east coast, west coast and highland regions, the diurnal variation in frequency of rain occurrence is different for different locations. Table 4.11 demonstrates the correlation between the meteorological factors and air pollutant concentration at four selected urban monitoring stations during the northeast monsoon in Peninsular Malaysia.

From the table the highest positive significant correlation during the northeast monsoon period was between PM_{10} and ambient temperature at Seberang Perai (r = 0.439). Meanwhile, for Pasir Gudang it was observed between SO_2 and ambient temperature (r = 0.352). At Batu Muda the highest positive correlation was observed between O_3 and ambient temperature (r = 0.499) whereas at Kemaman it was between ambient temperature and O_3 (r = 0.361). On the other hand, the lowest negative significant correlation at Seberang Perai was between SO_2 and relative humidity (r = -0.311). For Pasir Gudang and Batu Muda station, the lowest correlation was between NO_2 and wind speed (r = -0.135) and (r = -0.186). At Kemaman however, this pattern was observed between CO and ambient temperature (r = -0.109).

Based on the results obtained, at Seberang Perai station, there's no significant correlation between CO with relative humidity and wind speed only. Moving on to Pasir Gudang station, there was no significant correlation observed between wind speed with SO_2 and CO with wind speed and between CO and relative humidity. At Batu Muda there was no significant correlation between CO with all three meteorological factors. Subsequently, at Kemaman the results show that no significant correlation were observed between NO_2 and O_3 with wind speed and between CO and relative humidity.

As for correlation among air pollutants during the northeast monsoon, the analysis show that the highest positive correlation at Seberang Perai was between PM_{10} and O_3 (r = 0.449). However, no significant correlations were observed between PM_{10} with SO_2 and NO_2. Moving on to Pasir Gudang station, the highest correlation was observed between NO_2 and $S0_2$ with a value of r = 0.519. Additionally, at this station all air pollutants had significantly correlated with each other. Next, at Batu Muda station, the highest correlation was between CO and NO_2 with a value of r = 0.418. However, there was no significant correlation between PM_{10} and NO_2. Lastly at Kemaman station the highest positive correlation was between PM_{10} and O_3 (r = 0.515) while there was no significant correlation between SO_2, O_3 and CO and NO_2. Besides that, the analysis also show that ambient temperature, relative humidity and wind speed had correlated with each other during the northeast monsoon.

Table 4.11: Pearson correlation analysis during the northeast monsoon

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Seberang Perai	Ambient temperature	1							
	Relative humidity	-0.615**	1						
	Wind speed	-0.213*	0.297**	1					
	SO_2	0.279*	-0.311**	0.253**	1				
	NO_2	-0.277*	0.249*	0.413**	0.311**	1			
	O_3	0.233**	-0.451**	-0.318**	-0.165*	-0.214*	1		
	CO	0.215*	0.103	0.061	-0.129*	0.182*	-0.237**	1	
	PM_{10}	0.439**	-0.502**	-0.129*	0.086	0.077	0.449**	0.206*	1
Pasir Gudang	Ambient temperature	1							
	Relative humidity	-0.416**	1						
	Wind speed	0.318**	-0.263*	1					
	SO_2	0.352**	-0.266*	0.017	1				
	NO_2	0.185*	0.160*	-0.135*	0.519**	1			
	O_3	0.165*	-0.473**	-0.262*	-0.182*	-0.255**	1		
	CO	-0.185*	0.105	-0.037	0.355**	0.321**	-0.429**	1	
	PM_{10}	0.293**	-0.350**	-0.218*	0.398**	0.212*	0.159*	0.279**	1

Continued

Table 4.11: Pearson correlation analysis during the northeast monsoon (Continued)

Stations	Variables	Ambient temperature	Relative humidity	Wind speed	SO_2	NO_2	O_3	CO	PM_{10}
Batu Muda	Ambient temperature	1							
	Relative humidity	-0.514**	1						
	Wind speed	-0.213**	-0.171*	1					
	SO_2	0.262**	-0.334**	0.258**	1				
	NO_2	-0.261**	0.312**	-0.186*	0.328**	1			
	O_3	0.499**	-0.461**	-0.262**	-0.109*	0.185*	1		
	CO	-0.119	0.174	0.115	0.269**	0.418**	-0.303**	1	
	PM_{10}	0.192*	-0.267**	-0.337**	0.157*	0.004	0.241*	0.293**	1
Kemaman	Ambient temperature	1							
	Relative humidity	-0.478**	1						
	Wind speed	0.252*	0.307**	1					
	SO_2	-0.397**	-0.273**	-0.185*	1				
	NO_2	0.291**	0.174*	0.107	-0.016	1			
	O_3	0.361**	-0.396**	-0.131	0.207*	-0.116	1		
	CO	-0.109*	-0.125	-0.263**	0.350**	0.131	0.471**	1	
	PM_{10}	0.130*	-0.350**	-0.293*	0.201*	-0.226*	0.515**	0.219*	1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

The diffusion, dilution and accumulation of pollutants are often affected by meteorological conditions (Xian et al, 2021). The northeast monsoon on the other hand is usually connected to the wet season and therefore does not contribute to anthropogenic sources, mainly burning of biomass. Based on the results obtained, the correlation between relative humidity and O_3 is negative. According to Xie and Zhu (2020), relative humidity corresponds to wet conditions. Wet conditions or a high relative humidity causes low temperature which will generally reduce O_3 formation due to insufficient sunlight. Additionally, high humidity is related to the number of rain occasions which then reduces the number of particles as a result from the wash out processes of the atmospheric aerosols in the atmosphere Mohd Zizi et al. (2018). Hence, there is a negative correlation between humidity and PM_{10}. Besides that, the analysis also shows that the correlation between PM_{10} and atmospheric temperature is positive at all four monitoring stations. According to Bodor et al. (2020), this is due to the atmospheric pressure being high at colder seasons forming an anticyclone-like system which then reduces wind speed and creates a stable atmospheric condition hence reducing the dispersion level of the pollutant.

From the results it was observed that mainly SO_2, NO_2, O_3 and PM_{10} had significant correlation with the three meteorological factors. However, SO_2 and NO_2 recorded very weak to weak correlations with meteorological factors. According to Rahman et al. (2015), air pollutants during the winter monsoon are usually associated more to local environmental factors such as emissions from industries, urbanization and motor vehicles rather than meteorological factors. From the results, there was a positive correlation observed between CO and relative humidity at Seberang Perai, Pasir Gudang and Batu Muda. According to Kayes et al. (2019), during winter the concentration of CO in the atmosphere is most likely from vehicular sources, hence there is a positive correlation with humidity. The analysis also shows that at Seberang Perai, Pasir Gudang and Kemaman there is a negative correlation between relative humidity and PM_{10}. According to Ng and Awang. (2018) and Gvozdic et al. (2011) high humidity is related to high precipitation when then decreases PM_{10} concentration in the atmosphere due to high rainfall.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion.

In this chapter, the findings derived based on the data analysis that had been conducted in Chapter 4 will be concluded. The objectives of this study are accomplished hence the analysis can be considered successful. The statistical characteristics for weather parameters which are ambient temperature, relative humidity, wind speed and five major air pollutant which are NO_2, PM_{10}, O_3, SO_2 and CO had been explored using descriptive statistics and the line graph at four selected monitoring stations in Peninsular Malaysia which are Seberang Perai, Pasir Gudang, Batu Muda and Kemaman.

Firstly, the descriptive statistics indicated that among the five major air pollutants, the air pollutant with the highest mean value is PM_{10} when compared to NO_2, O_3, SO_2 and CO. However, the station with the highest PM_{10} concentration amongst the four monitoring stations is at Seberang Perai. This could be influenced by the level of activity, number of industries, number and type of vehicles in the area which leads to higher levels of PM_{10} concentration. Although the pollutant concentration level was high, it did not exceed the Malaysian Ambient Air Quality Guideline set. This also applies for the other air pollutants analyzed in this study.

For the second objective, Pearson's Correlation Analysis was utilized to see the relationship between air pollutants and meteorological factors. The analysis indicated that mostly there was a significant correlation between air pollutants and meteorological factors at the studied locations. Besides that, in the duration of two years the analysis shows that ambient temperature, relative humidity and wind speed correlate with each other. Additionally, the correlation among most air pollutants are significant at all stations in the duration of this study. Based on the analysis, O_3 did not have significant correlation with wind speed at three stations excluding Batu Muda. However, at Kemaman, the results obtained show that there is no significant correlation between O_3 and any meteorological factors. This analysis was similar the correlation between SO_2 and meteorological factors at Batu Muda.

Lastly, for the third objective for this study the Pearson Correlation Analysis was used to determine the correlation between air pollutants and meteorological factors during different seasons in Peninsular Malaysia. The seasons that Malaysia experiences are the southwest and northeast monsoon. From the results obtained, during both seasons there's a significant correlation between all three meteorological factors with each other. Hence, it can be said that ambient temperature, relative humidity and wind speed correlate with each other all throughout. However, in the dry season the analysis shows that the relationship between air pollutants and meteorological factors ranges from weak to moderate relations. Additionally, Kemaman recorded the least correlation between meteorological factors and air pollutants during this season whereby, there was no significant correlation between NO_2 with ambient temperature and wind speed, CO with relative humidity and between PM_{10} and wind speed. Based on the analysis, O_3 had recorded consistent significant correlations with meteorological factors at all four monitoring stations by having a positive relationship with ambient temperature and wind speed and a negative relationship with relative humidity. Hence, it can be said that during the dry season O_3 is affected most by meteorological factors. Contrarily, during the Northeast monsoon the analysis shows that there is no significant correlation between CO and PM_{10} with wind speed at Seberang Perai, Pasir Gudang and Batu Muda. The analysis also shows that overall among the five air pollutants, the relationship between CO and meteorological factors were minimal during this season. Other than CO, the other air pollutants mostly had significant correlations with meteorological factors. However, the analysis shows that PM_{10} was most affected by ambient temperature, relative humidity and wind speed. PM_{10} recorded significant positive relationship with ambient temperature and negative relationships with relative humidity and wind speed at all four monitoring stations. The correlation values recorded ranges from very weak to moderate correlations.

5.2 Recommendations for Future Study

The study conducted is beneficial as it can help identify suitable measures to control the level of air pollution at the study area. In order to achieve the best prediction accuracy other analysis models should be used. Additionally, the study should also be carried out using a wider range of data to obtain better results. Increasing the number of monitoring stations for urban areas can be beneficial in determining the type of pollutant that is most abundant in the atmosphere. Besides that, having an expanded range of results, it will also be plausible to estimate the rates of respiratory diseases and mortalities that are caused as a result of air pollution in Peninsular Malaysia. Having identified that, pollution abatement plans can be established especially at critical urban regions.

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