TREND OF POLLUTANTS CONCENTRATIONS AT URBAN AND INDUSTRIAL MONITORING STATIONS IN NORTHERN REGION OF MALAYSIA

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by

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This project report titled Trend of Pollutants Concentrations at Urban and Industrial Monitoring Stations in Northern Region of Malaysia was prepared and submitted by Norfahanis binti Idris (Matrix Number: 171130600) 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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TREN KEPEKATAN PENCEMARAN DI STESEN PEMANTAUAN BANDAR DAN PERINDUSTRIAN DI WILAYAH UTARA MALAYSIA

ABSTRAK

Oleh kerana pertumbuhan industri yang pesat dan pelepasan sempadan bermusim, pencemaran udara bertambah penting sebagai potensi risiko utama kesihatan awam di Malaysia sejak beberapa dekad yang lalu. Pelepasan dari kenderaan, kilang, dan pembakaran terbuka semuanya telah dikenal pasti sebagai sumber masalah kualiti udara. Tujuan kajian ini adalah untuk mengetahui ciri dan menguji kecenderungan pencemaran udara (PM_{10}, SO_2 dan NO_2), dan juga membandingkan trend kepekatan pencemaran udara (PM_{10}, SO_2 dan NO_2) di stesen pemantauan bandar dan perindustrian di wilayah Utara Malaysia (Alor Setar, Seberang Jaya, Perai, Pegoh, Taiping dan Jalan Tasek). Set data diberikan dari Jabatan Alam Sekitar, Malaysia (JAS) untuk tahun 2016-2019 (4 tahun). Ciri-ciri dan analisis kecenderungan kepekatan PM_{10}, SO_2 dan NO_2 dalam tempoh purata harian dan purata bulanan (2016 - 2019) di Alor Setar, Seberang Jaya, Perai, Pegoh, Taiping dan Jalan Tasek disiasat menggunakan Perisian Statistik SPSS dan kaedah ujian Mann-Kendall. Analisis tren kepekatan PM_{10}, SO_2 dan NO_2 antara stesen pemantauan bandar dan industri dibandingkan dengan menggunakan plot siri masa. Hasil kajian mendapati bahawa analisis trend, kepekatan SO_2 di Alor Setar 2016 telah menunjukkan trend menurun sementara Alor Setar 2019 dan Jalan Tasek 2016 telah menunjukkan trend meningkat. Sementara itu, analisis trend kepekatan NO_2 menunjukkan trend menurun di Pegoh 2016 dan Jalan Tasek 2018 kerana nilai negatif untuk statistik Mann-Kendall. Sebilangan besar analisis trend untuk kepekatan PM_{10}, SO_2 dan NO_2 di enam stesen pemantauan kualiti udara telah menunjukkan trend bercampur untuk keseluruhan tempoh dari 2016 hingga 2019. Kajian ini mendapati bahawa trend kepekatan PM_{10}, SO_2 dan NO_2 di stesen pemantauan industri adalah pencemar tertinggi dan utama yang menyumbang kepada kualiti udara di wilayah Utara Malaysia kerana proses pembakaran dari kenderaan dan industri.

TREND OF POLLUTANTS CONCENTRATIONS AT URBAN AND INDUSTRIAL MONITORING STATIONS IN NORTHERN REGION OF MALAYSIA

ABSTRACT

Due to rapid industrial growth and seasonal trans-boundary emissions, air pollution has grown in importance as a major potential risk to public health in Malaysia over the last few decades. Emissions from vehicles, factories, and open burning have all been identified as sources of air quality issues. The aim of this study was to determine the characteristics and test the trend of air pollutants (PM_{10}, SO_2 and NO_2), as well as to compare the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia (Alor Setar, Seberang Jaya, Perai, Pegoh, Taiping and Jalan Tasek). The data set was given by the Department of Environment, Malaysia (DOE) for the years 2016-2019 (4 years). Characteristics and trend analyses of PM_{10}, SO_2 and NO_2 concentrations in the daily average and monthly average (2016 - 2019) periods in Alor Setar, Seberang Jaya, Perai, Pegoh, Taiping and Jalan Tasek were investigated using the SPSS Statistical Software and the method of the Mann-Kendall test. Trend analyses of PM_{10}, SO_2 and NO_2 concentrations between urban and industrial monitoring stations were compared using a time series plot. The research found that the trend analysis of SO_2 concentration at Alor Setar 2016 has shown a decreasing trend, while Alor Setar 2019 and Jalan Tasek 2016 have shown an increasing trend. Meanwhile, the trend analysis of NO_2 concentration at Pegoh 2016 and Jalan Tasek 2018 shows a decreasing trend due to the negative value of the Mann-Kendal's statistic. Mostly, the trend analysis for PM_{10}, SO_2 and NO_2 concentration over the six air quality monitoring stations has shown mixed trends for the entire period from 2016 to 2019. The study discovered that the trend of PM_{10}, SO_2, and NO_2 concentrations at industrial monitoring stations are the major pollutants that have contributed to deteriorating air quality in Malaysia's Northern region due to vehicle and industrial combustion processes.

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LIST OF SYMBOLS, ABBREVIATIONS, OR NOMENCLATURE

CAQM	Continuous Air Quality Monitoring Stations
DOE	Department of Environment
MAAQS	Malaysian Ambient Air Quality Standard
MK-test	Mann-Kendall test
NO_2	Nitrogen dioxide
PM_{10}	Particulate matter 10 with a diameter of 10 microns
RH	Relative humidity
SO_2	Sulfur dioxide
TEMP	Temperature
WD	Wind direction
WS	Wind speed

CHAPTER 1

INTRODUCTION

1.1 Air Pollution

In 1957, Malaysia began tightening its development policy after independence from the British. As a result, numerous places have been affected and have evolved into industrial and urban regions (Performance Management and Delivery Unit, 2010). Reform has aided agricultural industrialization, which has had a severe impact on the environment. Road density will be affected by industrial expansion, and vehicle numbers will rise. It may cause air quality problems, the environment and health. It also causes the decreasing the quality of life of all people (Colbeck, Nasir & Ali, 2010).

One of the variables of air quality issues is contributed by the major cities through their rapid urbanisation (Ling, Ting, Shaharuddin, Kadaruddin & Yaakob, 2010). Malaysia's 2019 population was extremely expanded with a total population of 32,523,000 million compared to 2016 which is 31,633,500 million. The growth rate of this population is 2.7 %. Most commonly people immigrate to urban and industrial zones for their career. The fact is that the population of urban and industrial areas has been steadily expanding (Department of Statistic, 2020). Impact of that, from road density, human doing, industry running, will increase of particulate matter (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) concentrations to the atmosphere.

In urban and industrial areas, PM_{10}, SO_2, and NO_2 are prevalent ambient air pollutants that have been linked to major health problems such as respiratory and cardiovascular disorders, lung cancer, and high blood pressure in various studies (Koken et al., 2003; Tertre et al., 2002). These pollutants are restricted because they come from anthropogenic (man-made) sources, such as road traffic (vehicle exhaust); brake, wear, and road erosion; resuspension owing to wheel-generated turbulence; and industrial operations (waste management and metal processing) (Thorpe & Harrison, 2008). Natural occurrences such as wind erosion, forest fires, volcanic eruptions, evaporation of organic compounds, pollen dissemination, and natural radioactivity can all contribute to air pollution (Laumbach & Kipen, 2012).

Malaysia is the largest consumer of automobiles in Asia (Jahirul, Saidur, Rahman, Hasanuzzaman, Masjuki & Kalam, 2007). SO_2 and NO_2 are the gases released from motor vehicles (Jahirul et al., 2007). According to Khan et al. (2015), traffic on paved and unpaved roads, construction, agricultural operations, mineral industries, and wind erosion from both agricultural and non-agricultural land are all key sources of fugitive dust emissions that comprise PM_{10}. All of the above activities contribute to the presence of high concentration of PM_{10}, SO_2 and NO_2 in urban and industrial areas because these areas have a big potential in Malaysia's economy (Afroz, Hassan & Ibrahim, 2003; Awang et al., 2000).

In the previous issue, the concentration of air particulate matter was affected by the south-western monsoon wind in Malaysia, and during the dry season, the burning of biomass carried to Malaysia is common (Khan et al., 2015; Lawrence & Lelieveld, 2010). Furthermore, Malaysia is a critical route for Southeast Asian pollution to exit, resulting in significant local emissions of aerosols and pollutants that generate haze from Sumatra, Indonesia (Juneng, Latif, Tangang & Mansor, 2011). In Sumatra, Indonesia, and Indochina, the combustion of peat soil and plant waste sends significant amounts of smoke into the atmosphere, with high levels of PM_{10}, SO_2, and NO_2, contributing to trans-boundary haze (Khan et al., 2015). As stated by Mokhtar (2019), forest fires in Sumatra and Kalimantan triggered a haze event in Malaysia in 2019. A total of 2,649 schools in Selangor, Putrajaya, Kuala Lumpur, Penang and Sarawak were closed due to the haze event. The amount of PM_{10}, SO_2 and NO_2 is mainly affected by local burning of biomass, traffic and industry during normal periods (Lawrence et al., 2010).

This study aims to identify the trend variations of air pollutants (PM_{10}, SO_2, and NO_2) concentrations over urban and industrial areas in Malaysia's Northern region from 2016 to 2019. This is due to the serious implications of air pollution from a wide range of potential sources and is subject to the influence of various factors. It will be investigated in order to improve regional understanding of the differences in air pollution concentrations across the region, as well as the variables that determine their trends and associated characteristics.

1.2 Problem Statement

Particulate matter (PM_{10}), sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are the pollutants that contribute to the air pollution in the atmosphere, especially in urban and industrial areas. According to Abas and Mohamad (2011), this pollutant is divided into two categories of sources which are natural and anthropogenic. Natural sources include erupted volcanoes, accidental forestry fires, ashes, and road ashes (Unger et al., 2010). Meanwhile, emissions from industrial factories, power stations and industrial fuel combustion are commonly produced from anthropogenic sources (Qian, Zhou, Zheng, Dong & Wang, 2014; Davidson, Phalen & Solomon, 2005). After Indonesia and Thailand, Malaysia ranked third highest in Southeast Asia for pollutant emissions (Salahudin, Abdullah & Newaz., 2013). Power plants, automobiles, industrial activities, and other sources have been the main contributors of air pollution in Malaysia in recent decades (Department of Environment, 2017).

Due to the high emission of PM_{10}, SO_2 and NO_2 to the atmosphere, there is a major impact towards human health. High concentrations of PM_{10}, SO_2, and NO_2 may have acute and chronic health effects on humans, resulting in increased mortality and morbidity in the exposed population (Fattore et al., 2011). It is thought to affect the human respiratory system, causing Chronic Obstructive Pulmonary Disease (COPD) and asthma. Lung inflammatory reactions, respiratory issues, cardiovascular system adverse reactions, increased medication use, and higher mortality are among short-term exposure-related effects (Yao, Wu, Zhao & Zhang, 2020). Long-term exposure has been linked to an increase in lower respiratory symptoms, a loss in lung function in children and adults, an increase in chronic obstructive pulmonary disease, and a decrease in life expectancy, all of which are primarily due to cardiopulmonary and lung cancer mortality (World Health Organization, 2006).

Besides that, air pollution results in acidification, where acidic compounds that can cause damage to buildings and plants can be created by chemical reactions involving air pollutants. United States Environmental Policy Agency (USEPA) (2020) stipulated that the sulfuric acid that is emitted into the air can combine with the droplets of water from the clouds, forming acid rain. Acid rain can destroy trees and damage animals if it falls over an area. Furthermore, as acid rain seeps into the soil, vegetation may be damaged, altering the soil's composition and making it unsuitable for living beings that rely on it for shelter or nutrition (Wei et al., 2020; Liu et al., 2017). Meanwhile, damage to buildings caused by air pollution is a serious issue, as building service life is reduced. The degradation of air pollutants is aided by deposition, removal, abrasion, and direct chemical attack, as well as indirect chemical attack and corrosion. The influence of air pollution on materials can be visible in terms of coloring, structural failure and soiling, and material degradation. Because the detrimental impacts of air pollution must be countered by continuous activity and maintenance, it can also result in economic losses (Rao, Rajasekhar & Rao, 2014).

As a result, high particulate matter concentrations in the atmosphere are a major contributor to haze episodes. According to Kim and Bang, (2006) reported that increases in the mass concentration of sulfate, nitrate, and elemental carbon (EC) particles were well linked with increased visibility. Because of the increased loading of fine particles in the atmosphere, the average light extinction coefficient was high. Furthermore, black carbon (BC) has dominated light absorption in the atmosphere, with major contributions from brown carbon and mineral dust. Biomass burning, combustion processes, and dust entrainment are all sources of absorbing aerosols (Cheng et al., 2015). The hazard of the appearance of numerous impacts for the health rises linearly with the rising of fine particulate matter daily values.

Last but not least, In Malaysia, trans-boundary air pollution and periodic haze are becoming more of a problem, as are their health repercussions (Mahiyuddin, Sahani, Aripin, Latif, Thach & Wong, 2013; Latif, Othman, Idris, Juneng, Abdullah, Hamzah & Jaafar, 2018). The degradation of air quality in Malaysia has been related to open biomass burning in neighboring nations, particularly Indonesia and Indochina (Abdullah, Samah, & Jun, 2012; Othman, Sahani, Mahmud & Ahmad, 2014). The haze episode of 1997 was described as the worst in Malaysian air quality history, with the air pollution index (API) reaching deadly levels, due to trans-boundary pollution primarily from Indonesia (Abdullah et al., 2014). According to Sentian, Jemain, Gabda, Franky and Wui (2018), during haze occurrences in September to November 2015, which were also induced by trans-boundary emissions from Indonesia, Malaysian air quality deteriorated, with API values above 200 at 34 of 52 air quality monitoring stations. This is thought to be the worst haze outbreak in decades (Sulong, Latif, Khan, Amil, Ashfold, Wahab & Sahani, 2017). The trend of air pollution in Malaysia is determined not only by the amount of pollutants released, but also by the duration and combination of pollutants present in the atmosphere.

1.3 Research Objectives

The aim of this research is to determine the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia which has been selected. To achieve this, the following objectives of study are planned:

i. To determine the characteristics of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia.
ii. To test the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia from 2016 to 2019.
iii. To compare the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia.

1.4 Scope of Research

This research was focused on PM_{10}, SO_2 and NO_2 because it will affect human health and environmental damage due to high emission (Azam, Zanjani & Mood, 2016; Vallero, 2007). Ambient air quality was monitored continuously by the Pakar Scieno TW Sdn Bhd on behalf of the Malaysian Department of Environment (DOE) using their monitoring station network. PM_{10}, SO_2 and NO_2 were registered at 12 Continuous Air Quality Monitoring (CAQM) stations throughout the Northern region of the country by the Department of Environmental (DOE). However, in this research the air quality monitoring stations focuses in the Northern region to measure PM_{10}, SO_2 and NO_2 for urban area is Alor Setar, Seberang Jaya and Pegoh, while for the industrial area is Perai, Taiping and Jalan Tasek as indicated in Table 3.1. The selection of monitoring stations is based on the availability of data and the probability of urban and industrial effluent and transportation changes on the road.

The research period from January 2016 to December 2019 used the daily and monthly average of PM_{10}, SO_2 and NO_2 concentrations in this research. The dataset was obtained from Air Quality Division, Department of Environment Malaysia (DOE) through continuous air quality monitoring (CAQM) station. Daily average data were used to determine characteristics of the air pollutants (PM_{10}, SO_2 and NO_2) concentrations that come out with minimum, maximum, mean, standard deviation, coefficient of variation, skewness and kurtosis. Besides that, the monthly average was used for the trend analysis of PM_{10}, SO_2 and NO_2 concentrations.

The dataset of PM_{10}, SO_2 and NO_2 concentrations were analyzed by using IBM SPSS Statistical Software version 26 and Mann-Kendall test method. The characteristics and trends of PM_{10}, SO_2, and NO_2 concentrations in northern urban and industrial areas will be analyzed in this simulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Particulate Matter

Particulate matter is the term for a mixture of solid particles and liquid droplets present in the air, often called particle pollution. Any of the particles, such as dust, dirt, soot, or smoke are big or dark enough for the naked eye to see. Others are so small that only an electron microscope can be used to detect them (United States Environmental Protection Agency, 2020). The phrase particulate matter is defined in a variety of ways. According to Godish (2004), particulate matter is a phrase used to describe small, solid, and liquid particles that are present in the atmosphere for short to long periods of time. Otherwise, Kulkarni, Baron and Willeke (2011) describe particulate matter as a single unit of matter with a density that approaches the intrinsic density of the bulk substance. As a result, particulate matter is significant at all levels, from its atomic level to its behavior in the atmosphere. Wal and Janssen (2000) further defined PM_{10} as inhalable particles having an aerodynamic diameter of less than 10 μm.

The scale, shape and chemical features of particulate matter differ, and contain inorganic ions, metallic compounds, elemental carbon, organic compounds and compounds from earth's crust. According to United States Environmental Protection Agency (2020), for air quality regulatory purposes, particles are characterized by their diameter. Those with a diameter of 10 microns or less (PM_{10}) can be inhaled into the lungs and have harmful effects on health. Particles that are 2.5 microns or less in diameter ($PM_{2.5}$) are known as fine particulate matter. Therefore, $PM_{2.5}$ comprises a portion of PM_{10}. Furthermore, it can be divided into two groups based on their origin and creation phase: primary and secondary particles. Primary particles are particles that have been directly discharged into the atmosphere from either natural or artificial causes (Quality of Urban Air Review Group, 1996).

According to Watt and Hamilton (2003), the principal sources of primary particles include the combustion of petrol and diesel engines, the latter being the source of most black smoke, regulated emissions from chimney stacks, and fugitive emissions in urban and industrial areas. These are varied and controlled, including wind and mechanical turbulence re-suspension of soil, wind re-suspension of surface dust from road and urban surfaces, movement of vehicles and other local air disruption, and pollution from activities such as quarrying, construction of roads and houses, loading and unloading of dusty material (Watt & Hamilton, 2003). In the atmosphere, secondary particles originate as a result of chemical processes involving gases, aerosol particles, and moisture (Godish, 2004). The atmospheric oxidation of sulfur dioxide droplets to sulfuric acid and the oxidation of nitrogen dioxide vapor to nitric acid are the two main causes (Watt & Hamilton, 2003).

2.1.1 Source of Particulate Matter

Particulate matter (PM) sources can be anthropogenic (man-made) or natural in nature (Abas et al., 2011). From both human (anthropogenic) and natural activities, key PM sources are extracted. From a variety of human activities, a significant portion of PM sources are produced. As mentioned by Majra (2011), these types of activities include agricultural operations, manufacturing processes, wood and fossil fuel combustion, building and demolition activities, as well as the introduction of airborne road dust. The overall PM issue also contributes to natural sources (Karagulian et al., 2015). This involves dust and wildfires that are windblown. The detailed breakdown of global PM_{10} sources is shown in Figure 2.1.

Over 80% of particle creation on a worldwide scale comes from natural sources (Colls, 2002). Primary sources, such as soil dust suspension, salt particles from sea spray, forest fires, and volcanic activity, account for 60 % of natural sources. Other than that, 40 % is secondary natural particles such as sulfates, nitrates, and hydrocarbons, which are formed by sulfur, nitrogen, and volatile hydrocarbons being oxidized directly, catalytically, or photochemical (Colls, 2002). Another 20 % of worldwide particle generation comes from anthropogenic (primary and secondary) causes, which have significant impacts on the atmosphere in densely populated places (Godish, 2004).

Anthropogenic or man-made particles are introduced into the atmosphere by human activities such as industrial pollutants, traffic emissions, power generation, agricultural, and home activities. Based on previous research, there are three main contributors of PM_{10} in Malaysia such as vehicular emissions, power stations and industrial sectors. According to the Department of Statistics (2020), resources such as motor vehicles, power plants, and industry produced 27.2 thousand tons of particulate matter in 2019, representing a 13.8 % increase from 2015 to 2019.

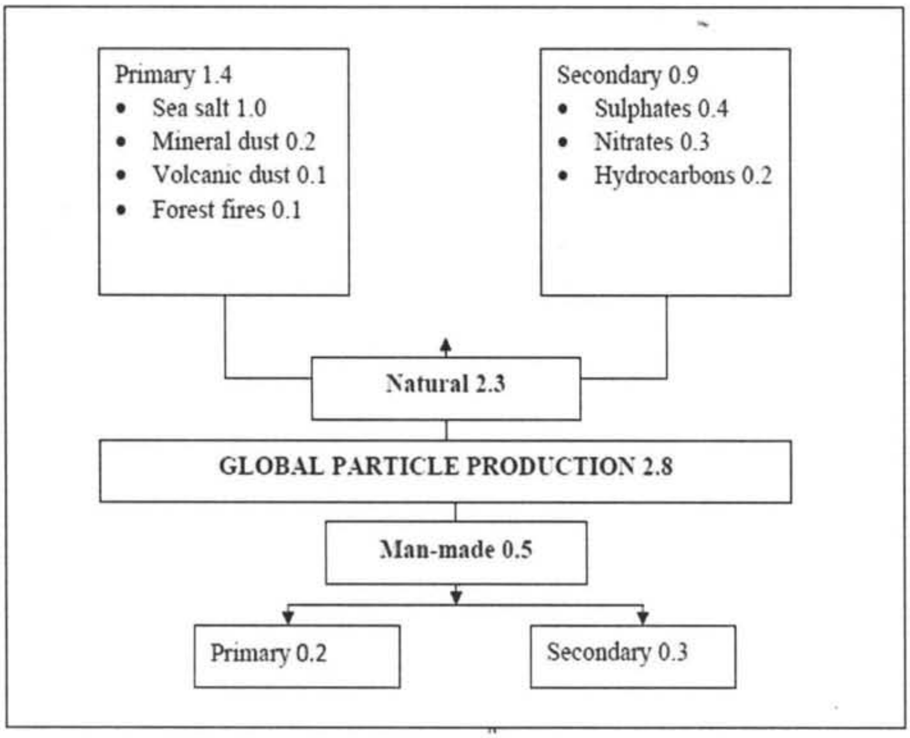


Figure 2.1: Global Practical Production (1 x 10^9 tonne per annual) (Colls, 2002)

2.1.2 Physical Characteristic of Particulate Matter

Size distribution, mass concentration and shape are the most significant physical characteristic of particulate matter. The diameter of a normal density (1000 kg/m^3 or 1 g/cm^3) sphere with the same gravitational settling velocity as the observed particle is commonly used for particle size (Kulkarni et al., 2011). Otherwise the particulate matter is measured in the mass concentration unit, which is the mass particle measurement in the gas volume unit and is represented in g/m^3 or, because particle mass is typically very small, in mg/m^3 or g/m^3. Several factors, such as the source of particle production and meteorological conditions, have a significant impact on particle size and concentration (Kulkarni et al., 2011).

2.1.3 Chemical Characteristic of Particulate Matter

Different chemical compositions of particulate particles were found in the atmosphere. The makeup of a single particle is determined by its source or origin, as well as the subsequent atmospheric backdrop. Due to a wide range of origins, secondary particle generation in the atmosphere, and atmospheric dynamics, particles can include hundreds of different chemical species (Godish, 2004).

PM_{10} is mostly composed of sulfate secondary aerosols, which are produced by the combustion of fossil fuels and biomass in rural and context settings (Putaud et al., 2004). Carbonaceous compounds at the context position were found to be lower (Wu et al., 2003). The acidity in the atmosphere is theoretically increased by sulfate, and then acid rain forms. Sulfates emitted from SO_2 gas may influence the atmosphere by reflecting solar radiation out into space and producing cooling (Mishchenko, Liu, Travis & Lacis, 2004).

2.2 Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a colorless, reactive gas with a strong odor. SO_2 comes from a variety of natural and anthropogenic sources. The primary anthropogenic sources of SO_2 emissions are the burning of high-sulfur coals and heating oils in power plants, followed by industrial boilers and metal smelting. SO_2 pollutants showed an increase of 29.2 % to 270.3 thousand tonnes in 2019 compared to 2015 (Department of Statistics, 2020). This result includes the natural and anthropogenic sources in Malaysia.

When released into the atmosphere, SO_2 can react to form acid rain according to the following reactions:

$$SO_2 + OH \rightarrow HOSO_2$$
$$HOSO_2 + O2 \rightarrow HO_2 + SO_3$$
$$SO_3\ (g) + H_2O\ (l) \rightarrow H_2SO_4\ (aq) \quad (2.1)$$

Or

$$SO_2\ (g) + H_2O \ldots SO_2.H_2O$$
$$SO_2.H_2O \ldots. H+ + HSO_3-$$
$$HSO_3- \ldots H+ + SO_3^{2-} \quad (2.2)$$

SO_2 has a direct impact on human health and is responsible for a variety of respiratory problems.

2.2.1 Source of Sulfur Dioxide (SO_2)

Sulfur dioxide is the most common pollutant gas in the atmosphere, and it is typically found in large concentrations in urban and industrial areas (Sani, 2006). It is produced by volcanoes, in various industrial processes and with other contaminants and moisture (Vallero, 2007). Since Malaysia has no volcanic activities, coal and petroleum combustion from vehicles and power stations generates sulfur dioxide (SO_2). SO_2 pollutants increase of 29.2 % to 270.3 thousand tonnes in 2019 as compared to 2015 (Department of Statistic, 2020). According to Department of Statistic (2020), it comes from the increasing number of motor vehicles and industrial sources can cause severe air pollution if the pollutants emission from both activities were not controlled effectively. As stated by Samsudin, Rahman and Wahid (2016), Malaysia has 41 power plants that use a variety of resources as key combustors. Coal, oil, gas, steam, water (hydro), and biomass are all used in the energy production of these power plants. Many of these power stations that are connected to the national grid are operated by Tenaga Nasional Berhad (TNB), which is electricity supply.

Malaysia, like many other developing countries, relies heavily on the energy sector to propel its economy forward. Malaysia's energy demand has risen in recent years and is projected to continue to rise in the future (Samsudin et al., 2016). Energy demand in the country was projected to have risen from 57,218 ktoe (kg of oil equivalent) in 2016 to an estimated 64,658 ktoe (kg of oil equivalent) in 2018 (Malaysia Energy Information Hub, 2018). As the increased demand, more SO_2 will be released into the atmosphere in the future.

2.2.2 Physical Characteristic of Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a toxic gas that is colorless, non-flammable, and has a pungent odor and acidic taste (Ashar, 2016). The boiling point for sulfur dioxide is −10 °C. It is a lot heavier than air. According to United States Environmental Policy Agency (2019), inhalation is very poisonous, and it can irritate the eyes and mucous membranes. When exposed to fire or heat for an extended period of time, the containers can violently rupture and rocket. Chemicals, paper pulping, metal, and food processing all use this manufacture. It is important to analyze the physical property of condensation points at different pressure and SO_2 concentrations. Table 2.1 below shows the physical properties of SO_2.

Table 2.1: Physical properties of sulfur dioxide (SO_2)

Property	Value
Molecular weight	64.06
Melting point (1013 mb)	−75.5 °C
Latent heat of fusion (at m.p)	115.6 J/g
Dynamic viscosity at 0 °C	368 Pa/s
Density at −10 °C	1.46 g/cm^3
Critical density	0.525 g/cm^3
Critical pressure	78.8 bar
Critical temperature	157.5 °C
Boiling point (1013 mb)	−10 °C
Latent heat of vaporization	
(at b.p.)	402 J/g
Standard density at 0 °C	
(1012 mb)	2.93 kg/m^3
Density relative to air	
(0°C, 1013 mb)	2.263

Continued

Table 2.1: Physical properties of sulfur dioxide (SO_2) (Continued)

Property	Value
Molar volume (0 °C, 1013 mb)	21.9 l/mol
Standard enthalpy of formation	−70.94 kcal/mol
	−4636 J/g
Specific heat, Cp (1013 mb)	
0 °C	586 K/(kg K)
100 °C	662 J/(kg K)
300 °C	754 J/(kg K)
500 °C	816 K/(kg K)
Cp/Cv (15 °C, 1013 mb)	1.29

2.2.3 Chemical Characteristic of Sulfur Dioxide (SO_2)

Sulfur dioxide is very stable; thermal dissociation becomes significant only above 2,000 °C. Shock waves, ultraviolet or X-ray irradiation, or electric discharges may all be used to break it down (Ashar, 2016).

The reaction of sulfur dioxide with oxygen to form sulfur trioxide is industrially the most significant of all its reactions because of its importance in sulfuric acid production. It can only happen in the gas phase at high temperatures, and it involves the presence of a catalyst for a satisfactory yield of sulfur trioxide (Ashar, 2016). According to Kreysa and Schütze (2008), sulfur dioxide is oxidized to sulfuric acid in aqueous solution by air in the presence of activated coke or nitrous gases, or by oxidizing agents such as hydrogen peroxide, at low temperatures.

The use of hydrogen, carbon, or carbon compounds such as methane or carbon monoxide to reduce sulfur dioxide is also of industrial interest (Ashar, 2016). High temperatures, catalysts, or both are needed for these reactions. They produce hydrogen sulfide and elemental sulfur mixtures. Carbon-containing species such as carbon dioxide, carbonyl sulfide, and carbon disulfide can be produced if carbon or a carbon compound is used as the reducing agent (Kreysa & Schütze, 2008).

Ashar (2016) found that sulfur dioxide oxidizes metals at high temperatures, producing metal sulfides and oxides at the same time. Liquid sulfur dioxide is a relatively efficient solvent with some water-like properties. In liquid sulfur dioxide, polar inorganic compounds are normally insoluble or only sparingly soluble, while covalent inorganic and organic compounds are often dissolved, forming mostly stable solutions. Ashar (2016) found that the Edeleanu method, which uses the fact that aromatic hydrocarbons dissolve more readily in sulfur dioxide than aliphatic, is used to extract aromatics from crude oil on a large scale.

2.3 Nitrogen Dioxide (NO_2)

Nitrogen dioxide, or NO_2, is one of a group of similar gases called nitrogen oxides, or NOx, which is an air pollutant gaseous consisting of nitrogen and oxygen. NO_2 forms when fossil fuels such as coal, oil, gas or diesel are burned at high temperatures (World Health Organization, 1997). NO_2 and other nitrogen oxides in the outdoor air contribute to particle pollution and to the chemical reactions that make ozone. It is one of six widespread air pollutants that have national air quality standards to limit them in the outdoor air (United States Environmental Policy Agency, 2016).

2.3.1 Source of Nitrogen Dioxide (NO_2)

According to Popescu and Ionel (2010), nitrogen dioxide is formed in most combustion processes using air as the oxidant. At elevated temperatures nitrogen combines with oxygen to form nitric oxide. The process then concludes when nitric oxide is oxidized in air to form nitrogen dioxide (NO_2). Motor vehicles are responsible for more than 10 % of NO_2 emitted into the atmosphere in Malaysia from 2015 to 2019 (Department of Statistic, 2020). Department of Statistic (2020) stated that in 2019, gross NO_2 emissions from motor vehicles in the country are reported to be around 952.4 metric tonnes. Resources such as motor vehicles, power plants, and industry produced 925.4 thousand tons of sulfur dioxide in 2019, representing a 10.7 % increase from 2015 to 2019 (Department of Statistics, 2020).

2.3.2 Physical Characteristic of Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a reddish-brown gas (or yellow liquid) with a strong, acrid odor. Nitrogen dioxide readily dimerizes to produce N_2O_4. Nitrogen dioxide is non-flammable and toxic gases which showed in Table 2.2. The federal government has established air quality standards for nitrogen dioxide at 0.053 parts per million (ppm), which equals 100 μg (micrograms) per cubic meter. Nitrogen dioxide is highly soluble in water and forms nitric acid (HNO_3), and nitric oxide is slightly soluble and forms nitrous acid (HNO_2) (World Health Organization, 2006).

Nitrogen dioxide is a strong oxidizing agent and causes corrosion. Nitrogen dioxide is used as an oxidizing agent, a catalyst in oxidation reactions, an inhibitor, as a nitrating agent for organic reactions, as a flour bleaching agent, and in increasing the wet strength of paper.

Table 2.2: Physical properties of nitrogen dioxide (NO_2)

Property	Value
CAS registry no.	10102-44-0
Chemical formula	SO_2
Molecular weight	46.01
Physical state	Reddish-brown gas
Melting point	-9.3 °C
Boiling point	21.15 °C
Vapor density (air = 1)	1.58
Solubility in water	0.037 mL at 35 °C
Vapor pressure	720 mm Hg at 20 °C; 800 mm Hg at 25 °C
Flammability	Does not burn
Conversion factor in air	1 ppm = 1.88 mg/m^3 1 mg/m^3 = 0.53 ppm
Reactivity	Decomposes in water forming nitric oxide and nitric acid

2.3.3 Chemical Characteristic of Nitrogen Dioxide (NO_2)

Nitrogen dioxide may be present in the form of a yellowish-brown liquid or a reddish-brown gas above 21.1 °C (70 °F) with a pungent acrid odor. It reacts with water to form nitric and nitrous acid and has a vapor pressure of 720 mmHg. It is also a non-combustible liquid or gas that accelerates the burning of combustible materials. Nitrogen dioxide is more toxic than nitrogen oxide (United States Environmental Policy Agency, 2016).

2.4 Weather Influence

A study by Bhaskar and Mehta, (2010) stated that meteorology plays a crucial role in ambient distributions of air pollution. The concentration of air pollutants varies depending on meteorological factors, the source of pollutants and the local topography. However, of these three factors, the one which most strongly influences variations in the ambient concentration of air pollutants is that of meteorological factors (Banerjee & Srivastava, 2011). Meteorological factors experience complex interactions between various processes such as emissions, transport and chemical transformation, as well as wet and dry depositions (Seinfeld & Pandis, 1998; Demuzere, Trigo, Arellano & Lipzig, 2009). The emission of the air pollutants from the ground surface into the air, as well as their residence in the atmosphere and the formation of secondary pollutants is influenced not only by the rate of emission of the pollutants but also by wind direction, wind speed, air temperature and relative humidity. Previous studies by Rahman et al. (2015) stated that there is a strong seasonality in meteorological variables that modulate air quality level.

2.4.1 Wind Direction

The movement of air is referred to as wind. The wind direction and its persistence are very important factors in predicting the air pollution potential of an area when the principal sources of the pollutants are high-level emitters located near each other in an industrial and urban zoned portion of the city. According to the Malaysian

Meteorological Department (2012), changes in wind flow patterns and rainfall distinguish the seasons in this country. The wind throughout the country is generally light and variable as the country is located near the equator. However, uniform periodic changes in wind flow patterns determine the country's four seasons: the Northeast Monsoon (November to March), a transitional period (April to May), the Southwest Monsoon (June to September) and a second transitional period (October to November) (Battista et al., 2016).

The movement of air pollutants usually follows the pattern of wind direction base on the Northeast Monsoon and Southwest Monsoon. The Southwest Monsoon usually brings the high amount of particulate matter to Malaysia due to biomass burning in Sumatera and Kalimantan, Indonesia. During the Northeast Monsoon there are also indicators of the influence of biomass burning particularly in Peninsular Malaysia from Indochina region (Juneng et al., 2009).

2.4.2 Wind Speed

The effect of an increase in wind speed on the concentrations resulting from low-level sources of emissions is to dilute the pollutants. The concentration of pollutants in a downwind location from a ground-level source is inversely proportional to the wind speed. High air pollution potential forecasts for most large urban areas where low level emissions are the principal sources of pollution include light wind speed as one of the criteria (Abas, Oros & Simoneit, 2004).

2.4.3 Temperature

Temperature measurement aids in the assessment, modeling, and forecasting of air quality. The chemical processes that occur in the atmosphere to generate photochemical smog from other pollutants are influenced by temperature and sunlight (Donev, Afework, Hanania & Stenhouse, 2018). Increased smog concentrations can occur when conditions are favorable. Malaysia has a tropical climate with consistent temperatures and high relative humidity throughout the year. According to the

Malaysian Meteorological Department (2012), temperatures in Peninsular Malaysia are quite high yet constant (between 23 °C and 31 °C), with high relative humidity and high rainfall (about 2500 mm annually).

2.4.4 Relative Humidity

Many thermal and photochemical reactions in the atmosphere rely on water vapor, which is influenced by temperature and sun light (Queensland Government, 2017). Water molecules are tiny and polar, allowing them to bond tightly to a variety of substances. They will greatly increase the amount of light scattered by particles suspended in the air if they are connected to them (measuring visibility). If corrosive chemicals, such as sulfur dioxide, bind to water molecules, the gas can dissolve in the water and form an acid solution that can harm people and property (Nunez, 2019).

At a given temperature, the water vapor content of air is expressed as a percentage of the saturation vapor pressure of water. The relative humidity is represented by this amount. The content of water vapor in the atmosphere varies greatly depending on geographic position, the proximity of water sources, wind speed, and air temperature. During the summer, when temperatures and rainfall are higher, the relative humidity is also higher (Queensland Government, 2017).

2.5 Trend of Air Pollutants

Air pollution is caused by a variety of localized and trans-boundary sources. Localized sources, such as stationary and mobile, are used. According to Afroz et al., (2003) reported that emissions from mobile sources such as vehicles, airplanes, and engine equipment, which account for at least 70 % to 75 % of overall air pollution in Malaysia, were the primary source of pollutants. The second largest group includes emissions from cement plants, power plants, industrial waste incinerators, iron and steel mills in suburban and industrial areas, dust emissions from urban construction and quarries, plantation burning of old oil palm trees, and open burning at some solid waste dumpsites. Around 20 % - 25 % contributed to this form of source. Indonesia's open biomass burning trans-boundary emissions generating smoke haze has become an annual phenomenon and contributes to degradation in the local air quality in Malaysia (Mahmud, 2013). Air pollution from forest fires was transmitted not only in this country, but also in neighboring countries in the region, such as Brunei and Singapore (Islam, Pei & Mangharam, 2016).

Particulate matter (PM_{10}), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) were among the five air contaminants regularly assessed at 65 locations (Department of Environment, 2018) . According to Sentian et al. (2018), the PM_{10} concentrations is increasing trend for five monitoring stations namely Ipoh, Shah Alam, Jerantut, Kuantan and Kota Bharu and 15 (Kangar, Perai, USM, Cheras, Petaling Jaya, Port Klang, Kuala Terengganu, Seremban, Melaka, Muar, Kota Tinggi, Kuching, Bintulu, Miri and Kota Kinabalu) monitoring stations showed decreasing trends. There were no significant trends in most stations in the study and it was concluded that the PM_{10} concentrations in Malaysia showed mixed trends for all regions that were shown in Figure 2.2. The significant emission of dust particles and gaseous pollutants into the atmosphere was attributed to the large biomass burning in the region that comes from Sumatera, Indonesia and coincidence with the long dry spell in the region due to the El-Niño event (Sentian et al., 2018).

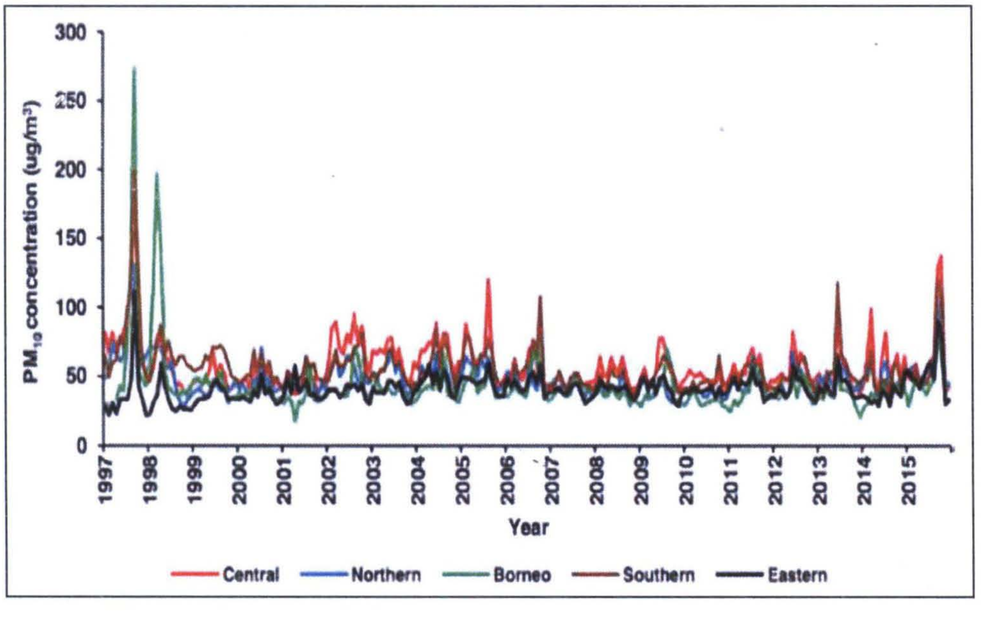


Figure 2.2: Monthly average concentration of PM_{10} in each region in Malaysia over the period from 1997 to 2015 (Sentian et al., 2018)

In addition, according to Latif et al., (2015), the highest concentration of NO_2 was recorded in Petaling Jaya. This is related to its location in that it is surrounded by many industries, residential and commercial areas. The high levels of NO_2 in Petaling Jaya are probably related to motor vehicle emissions (Abdullah et al., 2012). In 2019, 1,258.5 thousand of new motor vehicles were registered in Malaysia, an increase of 11.8 % from 1,125.8 thousand recorded in 2017 (Department of Statistic Malaysia, 2020). The high temperature and pressure combustion of the fuel oxidizes the nitrogen in the fuel to create NO_2 with sufficient oxygen and another main source of NO_2 in air comes from industrial processes (United States Environmental Protection Agency, 2010). Open combustion, long-term transport of air pollutants and domestic sources of fuel also added to the amount of NO_2 (Rajab et al., 2011). Figure 2.3 was showed the hourly trends (1-hour averaging time) of NO_2 in the Klang Valley from 2007 to 2011. The hourly average concentrations of all pollutants in this study were below the Malaysia Ambient Air Quality Guideline (MAAQG) standard.

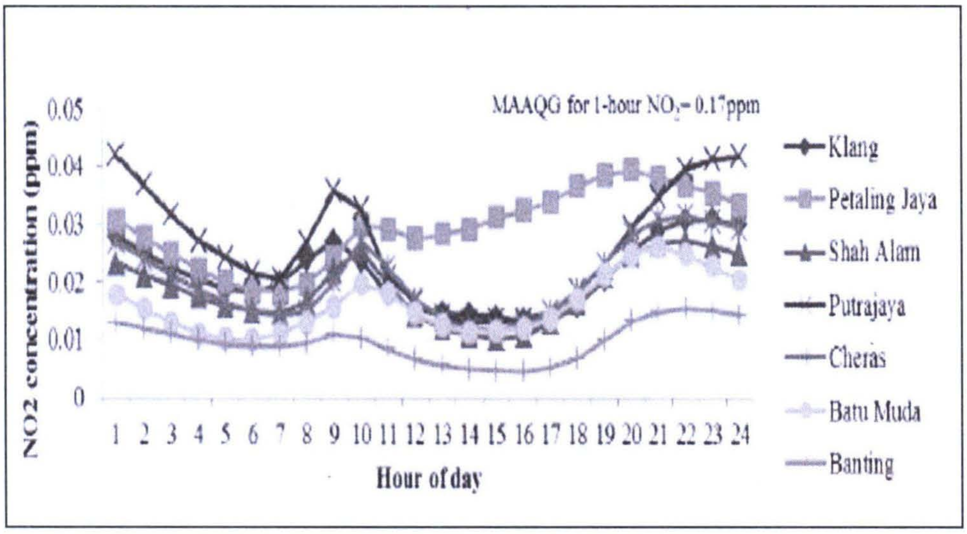


Figure 2.3: The hourly trends of NO_2 (ppm) in the Klang Valley from 2007 to 2011 (Rahman et al., 2015)

2.6 Health Impact due to Air Pollutants

Air pollution poses a significant health risk to the environment (World Health Organization, 2014). PM_{10}, SO_2, and NO_2 are prevalent ambient air pollutants in urban and industrial regions, and multiple studies have shown that they cause major health problems such as respiratory and cardiovascular disorders, lung cancer, and high blood pressure (Koken et al., 2003; Tertre et al., 2002). Additionally, it has the potential to result in death. World Health Organization (2014) recorded that in 2012, ambient air was estimated to cause 3.7 million premature deaths worldwide in both cities and rural areas. In low and middle income nations, some 88 % of those premature deaths occurred, and the largest number occurred in the Western Pacific and South East Asia regions of the World Health Organization (World Health Organization, 2014).

Figure 2.4 depicts the health impacts of air pollution in the form of a pyramid, emphasizing the magnitude and severity of these effects, particularly ground-level ozone and fine particles. The Benefits Mapping and Analysis Program (BenMAP) of the United States Environmental Protection Agency (EPA) created this pyramid (Environmental Protection Agency, 2020). The pyramid of effects depicts the relationship between pollution incidence and severity. Asthma attacks and cardiac consequences are less severe and affect a large population at the bottom. As we approach closer to the top of the pyramid, heart attacks and hospital admissions become more severe, and they affect a smaller fraction of the population.

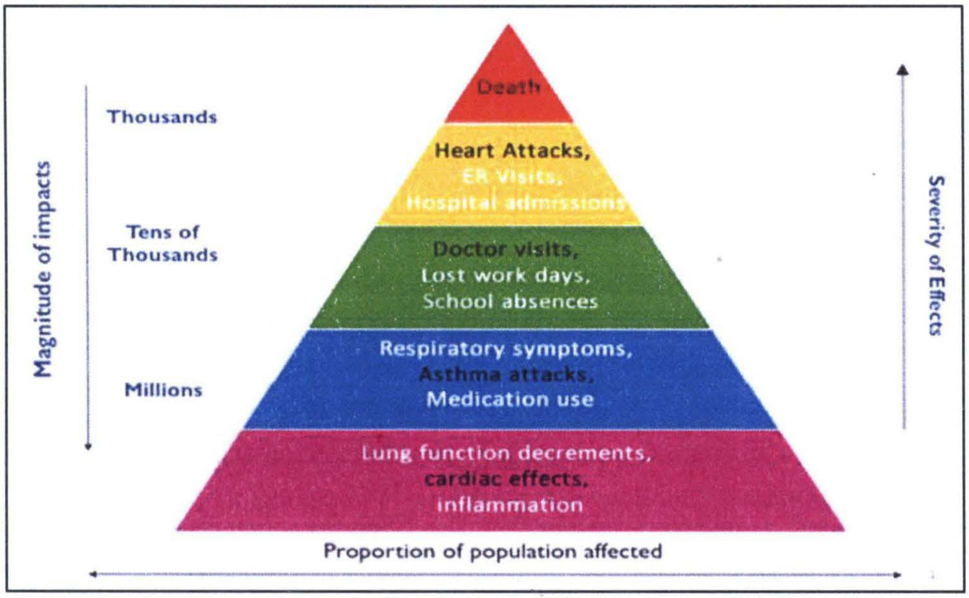


Figure 2.4: The pyramid of effects from air pollution (Environmental Protection Agency, 2020)

2.7 Malaysia Ambient Air Quality Standard

The ambient air quality has become an important predictor of air quality obtained from PM_{10}, SO_2 and NO_2 measurements of the contaminants. It has been seen all over the world. It is easy to consider the stakeholders and to interact clearly. Referring to the Department of Environmental (2018), the selected pollutants were monitored due to their presence as major air pollutants, which is in line with the criteria pollutants from other countries and the World Health Organization (WHO). Table 2.3 show the environmental requirements implemented by the Malaysia Ambient Air Quality Standard (MAAQS) that used by DOE. Since the year 2020 is still not reached, the data for PM_{10}, SO_2, and NO_2 in 2016, 2017, 2018, and 2019 will be compared to the Malaysian Ambient Air Quality Standard Interim Target 2 (IT-2).

Table 2.3: Malaysia Ambient Air Quality Standard (MAAQS)

Parameter	Averaging Time	Unit	Existing Guidelines	Malaysian Ambient Air Quality		
				IT-1 (2015)	IT-2 (2018)	Standard (2020)
PM_{10}	1 Year	$\mu g/m^3$	50	50	45	40
	24 Hours	$\mu g/m^3$	150	150	120	100
$PM_{2.5}$	1 Year	$\mu g/m^3$	-	35	25	15
	24 Hours	$\mu g/m^3$	-	75	50	35
SO_2	1 Hour	$\mu g/m^3$	350	350	300	250
		ppm	0.135	0.135	0.115	0.095
	24 Hours	$\mu g/m^3$	105	105	90	80
		ppm	0.040	0.040	0.035	0.030
*CO	1 Hour	mg/m^3	35	35	35	30
		ppm	30.6	30.6	30.6	26.2
	8 Hours	mg/m^3	10	10	10	10
		ppm	8.75	8.75	8.75	8.75
NO_2	1 Hour	$\mu g/m^3$	320	320	300	280
		ppm	0.170	0.170	0.160	0.150
	24 Hours	$\mu g/m^3$	75	75	75	70
		ppm	0.040	0.040	0.040	0.037
O_3	1 Hour	$\mu g/m^3$	200	200	200	180
		ppm	0.100	0.100	0.100	0.090
	8 Hours	$\mu g/m^3$	120	120	120	100
		ppm	0.060	0.060	0.060	0.050

Note: *mg/m^3

CHAPTER 3

METHODOLOGY

3.1 Research Flowchart

The research flowchart is shows in Figure 3.1. The details on air quality monitoring stations, characteristic and trend of PM_{10}, SO_2 and NO_2 by using Mann-Kendall Test and IBM SPSS Statistical Software version 26 experiments are discussed in the following sections.

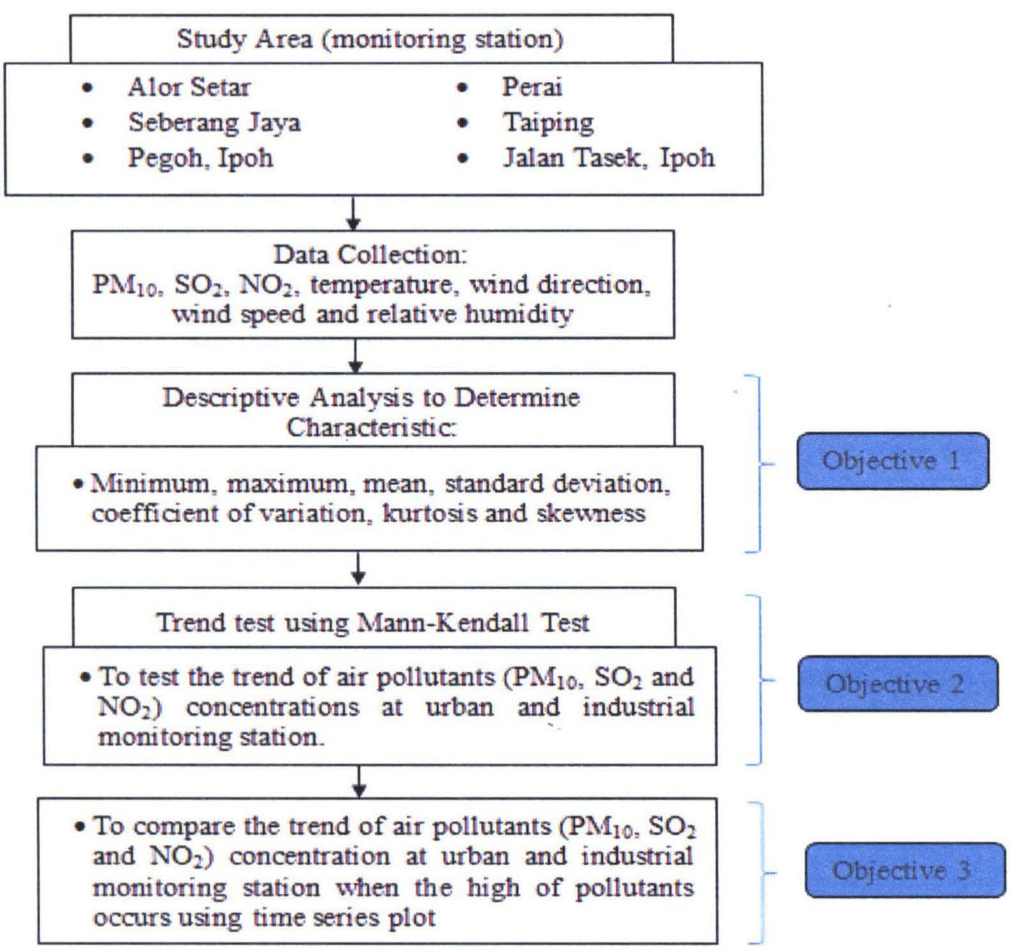


Figure 3.1: Research flowchart

3.2 Air Quality Monitoring Station

The research focuses on the analysis of PM_{10}, SO_2 and NO_2 at six monitoring stations in the Northern region of Peninsular Malaysia. Six Air Quality Monitoring Station were selected to be analyzed which are Alor Setar, Seberang Jaya, Pegoh, Perai, Taiping and Jalan Tasek that involved in urban and industrial areas to detect any significant change in the air quality which may be harmful to human health and the environment which shown in Table 3.1 and Figure 3.2. This network is Continuous Air Quality Monitoring Stations (CAQM) for PM_{10}, SO_2 and NO_2 concentrations that collect for daily (24 hours in every 1 hour) and annually data.

Table 3.1: Air Quality monitoring station in Northern region of Malaysia

Location	Monitoring Station	Area Status (2016-2017)	Area Status (2017-2019)	Latitude (N)	Longitude (E)
Alor Setar	Sek. Men. Agama Kedah, Mergong	Urban	Sub urban	6.1370833°	100.3468639°
Pegoh, Ipoh	SM. Pegoh, Ipoh	Urban	Sub urban	4.3315°	101.04856°
Seberang Jaya	Sek. Keb. Seberang Jaya II	Urban	Urban	5.3981700°	100.4039472°
Perai	Sek. Keb. Cenderawasih, Taman Inderawasih, Perai	Industrial	Urban	5.23470°	100.23213°
Taiping	Sek. Keb. Ayer Puteh, Taiping	Industrial	Sub urban	4.53940°	100.40782°
Jalan Tasek, Ipoh	Sek. Men. Keb. Jalan Tasek, Ipoh	Industrial	Urban	4.37781°	101.06964°

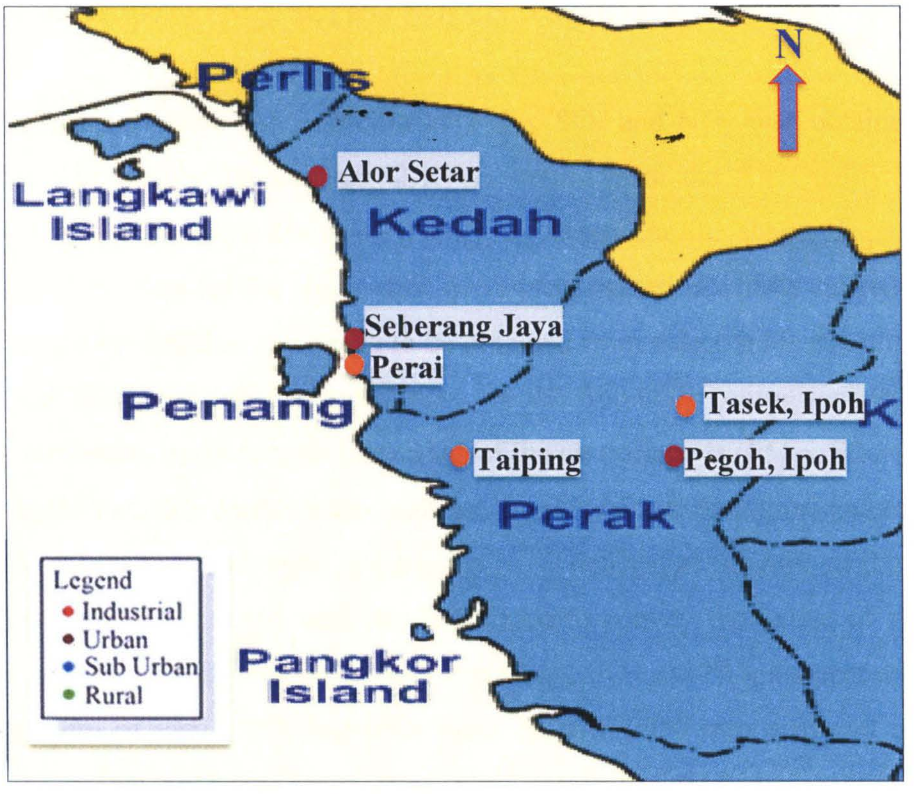


Figure 3.2: Air quality monitoring station in Northern region of Malaysia

3.3 Data Collection

The data used in this study was hourly and daily concentration of PM_{10} ($\mu g/m^3$), SO_2 (ppm) and NO_2 (ppm) from six air monitoring stations based on four years observation (2016-2019). All the data were secondary data that provided by the Department of Environment (DOE). The secondary data from DOE was supplied by Pakar Scieno TW Sdn. Bhd (PSTW) that working on collection of primary monitoring data. The instrument used by PSTW to monitor PM_{10} is Particle Analyzer-TEOM 1405DF while SO_2 and NO_2 using Gas Analyzer. The air pollutant (PM_{10}, SO_2 and NO_2) concentrations were continuously monitored by Pakar Scieno TW Sdn Bhd (PSTW) for 24 hours each day, which is controlled from the Continuous Air Quality Monitoring Station (CAQM). Hourly data were used to form a daily average for statistical analysis, while daily data were used to form a monthly average for trend analysis.

3.4 Characteristic of PM_{10}, SO_2 and NO_2 Concentration

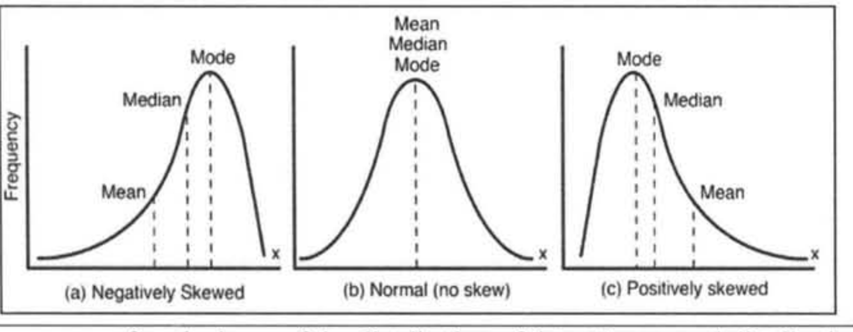
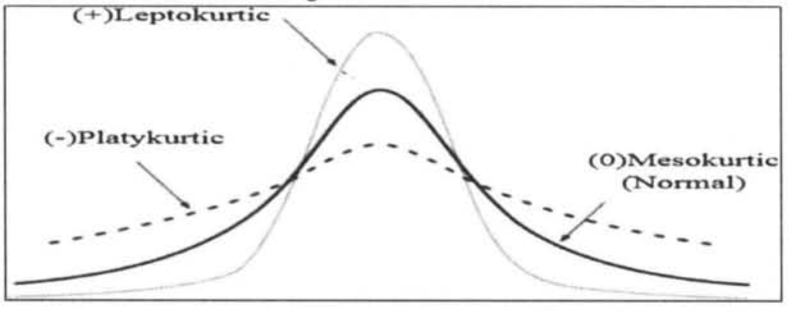
The daily average concentration of PM_{10}, SO_2 and NO_2 was obtained by the Continuous Air Quality Monitoring (CAQM) station from the Air Quality Division, Department of Environment Malaysia (DOE). To determine the shape, dispersion and distribution of the data for the study area, descriptive statistics will be carried out. The most important information that needs to be obtained from a data set is the central trend indicator and the variability measure. These are the following central tendency scales, including minimum, maximum and mean (μ) of the air pollutants (PM_{10}, SO_2 and NO_2). In addition, the variability calculation includes the standard deviation (σ) and coefficient of variation (CV). The coefficient of variation (CV) defined as the ratio of the standard deviation (σ) to the mean (μ) was also calculated to convey the extent of variability during the study period in relation to the mean PM_{10}, SO_2 and NO_2 concentrations. The daily variability of PM_{10}, SO_2 and NO_2 from 2016 to 2019 was analyzed using this coefficient. In this analysis, using IBM SPSS Statistical Software version 26, the descriptive statistics for every collection of data were analyzed. There are some of the formulas summarized for the calculation of descriptive statistics in Table 3.2.

Table 3.2: Descriptive statistics (Ali and Bhaskar, 2016)

Notation	Description/Formula
Mean, $\bar{x}$	The average set of monitoring data $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$
Minimum	The smallest value in the set of monitoring data
Maximum	The largest value in the set of monitoring data
Standard deviation, s	The average difference of each monitoring data to the mean $s = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$
Variance	The measure of dispersion of data points in a monitoring data around the mean $CV = \frac{s}{\bar{x}}$
$\bar{x}$ is the mean x_i is the monitoring data n is the number of monitoring data s is standard deviation CV is coefficient of variation	

Continued

Table 3.2: Descriptive statistics (Ali and Bhaskar, 2016) (Continued)

Notation	Description/Formula
Skewness, C_s	The measure of asymmetry of the distribution of data about its mean $$C_s = \frac{m_3}{s^3} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\sqrt{\frac{1}{n-1\sum_{i=1}^{n}(x_i - \bar{x})^2}}\right)^3}$$ C_s is the skewness m_3 is the third moment $\bar{x}$ is the mean x_i is the monitoring data n is the number of monitoring data s is standard deviation • Normal distribution (skewness = 0) • Positively skewed (right). The data mostly lie on the left of the mean (skewness > 0) • Negatively skewed (left). The data mostly lie on the right of the mean (skewness < 0) 
Kurtosis, K	The measure of peakedness of the distribution of data. For normal distribution data, the kurtosis will give a value of zero. $$K = \frac{m_4}{m_2^2} = \frac{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{n}}{\frac{\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^2}{n^2}} = n\,\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^2}$$ K is the kurtosis m_4 is the fourth moment m_2 is the second moment $\bar{x}$ is the mean x_i is the monitoring data n is the number of monitoring data 

3.5 Trend Analysis

Trend analysis was used to analyze temporal dynamics in the exploration of the monthly average dataset of PM_{10}, SO_2 and NO_2 concentrations over six air quality monitoring stations in the Northern region of Malaysia. The Mann-Kendall test (MK-test) was used to evaluate patterns in the time series of monthly PM_{10}, SO_2 and NO_2 concentration values. The Mann-Kendall test (MK-test) is used to detect a monotonic pattern of a time series without seasonal or other cycles (Sentian et al., 2018).

Monthly data was analyzed using the Mann Kendall test (MK-test), which has been commonly used to examine trends in climatological and hydrological time series (Guerreiro, Foltescu & deLeeuw, 2014; Koudahe et al., 2017). This test is used to evaluate data collected over time for upward or downward trends which is called monotonic trends that are consistently. The advantage of the MK-tests is that it is a non-parametric analysis. This means that it works for all distributions, including non-normally distributed results. As less as four samples, the test can also be used to find trends (Guerreiro et al., 2014). Nevertheless the more data points analyzed, the greater the probability or as opposed to chance of discovering a true trend. Thus, the minimum number of measurements recommended is at least eight to 10 (Colette et al., 2011; Karmeshu, 2015; Pohlert, 2015).

The trend will be compared due to the zones which are for urban and industrial. By compared the dataset, the statistically relevant trends in the rate of change of slopes will reveal upward arrow (↑: increasing trend) and downward arrow (↓: decreasing trend) and left-right arrow (↔: no trend). In other words, negative or positive numerical values may be gained by trend (Sharma, 2020).

3.5.1 Mann-Kendall Analysis

This method is used to determine the magnitude of a trend in time series results. The Mann-Kendall theory is based on the principle of statistical(S). Each pair value is observed for the existence of a pattern in this process (Rahman & Begum, 2013; Mustapha, 2013; Hu, Maskey & Uhlenbrook, 2010).

Let X_1, X_2, ……X_n represent the n data points at time i and j respectively, then the Mann-Kendall test(S), is calculated as:

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} sign(X_j - X_i) \tag{3.1}$$

Where,

X_j is the sequential air pollutants (PM_{10}, SO_2 and NO_2) monitoring data values,

n is the length of the time series of air pollutants (PM_{10}, SO_2 and NO_2)

$$sign(X_j - X_i) = \begin{cases} 1 & \text{if } (X_j - X_i) > 0 \\ 0 & \text{if } (X_j - X_i) = 0 \\ -1 & \text{if } (X_i - X_j) < 0 \end{cases} \tag{3.2}$$

The hypothesis of this test is:

The null hypothesis, H_0: There is no trend in the air pollutants (PM_{10}, SO_2 and NO_2) concentrations data.

An alternative hypothesis, H_1: There is a trend in the air pollutants (PM_{10}, SO_2 and NO_2) concentrations data.

(Yadav & Mishra, 2015)

3.5.2 Trend Detection

The Mann-Kendall test is calculated as:

$$\tau = \frac{S}{n(n-1)/2} \tag{3.3}$$

Where,

S = Mann-Kendall test

n = number of data pairs

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \quad (3.4)$$

and $$VAR(S) = \frac{n(n-1)(2n+5) - \sum_{t=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \quad (3.5)$$

Where t_i is the number of ties for the t^{th} values and m is the number of tied values (Chattopadhyay, Chakraborthy & Chattopadhyay, 2012).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

All the selected pollutants have been analyzed for four years (2016 - 2019) from January until December. The data was taken from the monitoring station in the Northern region of Malaysia, located in Alor Setar, Pegoh, Seberang Jaya, Perai, Taiping and Jalan Tasek. The concentration of PM_{10}, SO_2 and NO_2 was taken based on the daily average to determine the characteristics of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia. The monthly average to determine the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia from 2016 to 2019 and to compare the trend of air pollutants (PM_{10}, SO_2 and NO_2) concentrations at urban and industrial monitoring stations in the Northern region of Malaysia.

4.2 Descriptive Analysis of Air Pollutants and Meteorological Factor at Urban Monitoring Stations

Alor Setar, Pegoh and Seberang Jaya are urban monitoring stations in the Northern region of Malaysia. The compilation of data from the three air quality monitoring stations (Alor Setar, Pegoh and Seberang Jaya), the three recognized air quality parameters (PM_{10}, SO_2 and NO_2) and the meteorological factor from 2016 to 2019 with their comparison to the Malaysian Ambient Air Quality Standard are summarized in Table 4.1.

Table 4.1: Daily average concentration of PM_{10}, SO_2 and NO_2 and meteorological factor from 2016 to 2019 at urban monitoring stations

Parameters	Year	Stations	Average	Minimum	Maximum	Standard Deviation	Coefficient Variation	Skewness	Kurtosis	MAAGS
PM_{10} ($\mu g/m^3$)	2016-2019	Alor Setar	41.375	37.764	48.757	5.056	12.22	1.704	2.881	120
		Pegoh	**55.044**	49.680	59.519	4.076	7.41	-0.627	1.349	
		Seberang Jaya	53.141	49.372	57.792	4.320	8.13	0.172	-5.000	
SO_2 (ppm)	2016-2019	Alor Setar	0.0014	0.0011	0.0017	0.000	21.43	1.129	2.227	0.035
		Pegoh	0.0016	0.0015	0.0018	0.000	6.25	1.414	1.500	
		Seberang Jaya	**0.0025**	0.0021	0.0027	0.000	12.00	-1.813	3.483	
NO_2 (ppm)	2016-2019	Alor Setar	0.0132	0.0118	0.0152	0.002	11.36	1.069	0.759	0.040
		Pegoh	0.0171	0.0133	0.0201	0.003	18.71	-0.416	-3.108	
		Seberang Jaya	**0.0266**	0.0231	0.0302	0.004	14.29	0.007	-5.790	
TEMP (^0C)	2016-2019	Alor Setar	29.04	21.80	32.30	4.93	17.00	3.02	3.02	
		Pegoh	32.23	27.59	33.94	3.10	9.63	3.90	3.90	
		Seberang Jaya	**32.33**	31.84	33.02	0.58	1.78	-3.40	-3.40	
WD (^{0})	2016-2019	Alor Setar	312.55	295.62	336.01	17.36	5.55	0.79	0.79	
		Pegoh	283.79	254.76	311.96	26.08	9.19	-3.25	-3.25	
		Seberang Jaya	**325.93**	314.08	337.36	10.63	3.26	-3.30	-3.30	
WS (m/s)	2016-2019	Alor Setar	**3.14**	2.84	3.70	0.49	15.46	0.00	0.00	
		Pegoh	3.08	2.42	4.12	0.78	25.20	-0.13	-0.13	
		Seberang Jaya	3.05	1.79	4.63	1.19	39.09	1.06	1.06	
RH (%)	2016-2019	Alor Setar	**92.37**	91.79	92.87	0.44	0.48	1.52	1.52	
		Pegoh	80.85	57.27	90.33	15.86	19.62	3.61	3.61	
		Seberang Jaya	88.52	82.77	91.50	3.94	4.45	3.00	3.00	
Bold denotes as higher average										

MAAQS= Malaysian Ambient Air Quality Standard

According to Table 4.1, the average PM_{10} concentration at Alor Setar was 41.375 μg/m^3, with a minimum of 37.764 μg/m^3 and the maximum of 48.757 μg/m^3. The average and maximum PM_{10} concentration was found to be far below the Malaysian Ambient Air Quality Standard (MAAQS), which is 120 μg/m^3. The values of standard deviation and coefficient variation for PM_{10} concentration are 5.056 and 12.22 %. While PM_{10} has a skewness of 1.704, it is skewed to the right, and the kurtosis is positive (2.881). Besides that, the average value of PM_{10} concentration at Pegoh from 2016 to 2019 was recorded at 55.044 μg/m^3 with a range 49.680 μg/m^3 (minimum) and 59.519 μg/m^3 (maximum). The concentration of PM_{10} in Pegoh was under the limit of Malaysian Ambient Air Quality Standard (MAAQS). The standard deviation and coefficient variation values were 4.076 and 7.41 % respectively, and the PM_{10} concentration at Pegoh is skewed to the left (-0.627) with a positive kurtosis of 1.349. Meanwhile, the average value of PM_{10} concentration for Seberang Jaya is 53.141 μg/m^3 with the minimum and maximum values of 49.372 μg/m^3 and 57.792 μg/m^3 respectively. The values of standard deviation and coefficient variation are 4.320 and 8.13 % and show that the skewness is skewed to the right and has a negative kurtosis. Overall, based on the three air quality monitoring stations (Alor Setar, Pegoh and Seberang Jaya), Pegoh shows the highest value for the average of PM_{10} concentration, which is 55.044 μg/m^3. Ismail, Abdullah and Samah (2017) found that the Pegoh area has a significant number of cars and, within 3 km, contains three of the largest industrial areas, with the majority of industries focusing on metal, wood, plastic, and paper manufacturing. Around Perak, there were 17.86 % rubber mills and 82.14 % oil palm mills, which could lead to PM_{10} emissions (Ismail et al., 2017). All of the average values of PM_{10} concentration were still under the Malaysian Ambient Air Quality Standard (MAAQS), which is 120 μg/m^3.

Besides that, the average value of SO_2 concentration from 2016 to 2019 at Alor Setar was 0.0014 ppm, while at the Pegoh and Seberang Jaya it was 0.0016 ppm and 0.0025 ppm. The minimum value at Alor Setar, Pegoh and Seberang Jaya was 0.0011 ppm, 0.0015 ppm and 0.0021 ppm, while the maximum value was 0.0017 ppm, 0.0018 ppm and 0.0027 ppm. It is shown the standard deviation for these three monitoring stations was 0.000 ppm, but it actually has small values and the coefficient variation for each monitoring stations was 21.43 %, 6.25 % and 12 %. The skewness of SO_2 concentration at Alor Setar and Pegoh was skewed to the right, while at Seberang Jaya it was skewed to the left. Kurtosis values for Alor Setar, Pegoh, and Seberang Jaya are 2.227, 1.500, and 3.483, respectively. Based on these three monitoring stations, Seberang Jaya has recorded the highest average value of SO_2 concentration with a value of 0.0025 ppm compared to other stations. The average and maximum values of SO_2 concentration were still under the 0.035 ppm which is the limit of Malaysian Ambient Air Quality Standard (MAAQS). Due to having road networks that connect to the North, South, East, and Penang Island, Seberang Jaya has the highest SO_2 concentration due to the highest resident population, and traffic flow is quite congested, especially during the morning and late afternoon (Ismail et al., 2017).

In addition, the average value of NO_2 concentration from 2016 to 2019 at Alor Setar was 0.0132 ppm, while at Pegoh and Seberang Jaya it was 0.0171 ppm and 0.0266 ppm. The minimum value of NO_2 concentration at Alor Setar, Pegoh and Seberang Jaya was 0.0118 ppm, 0.0133 ppm and 0.0231 ppm, while the maximum value of NO_2 concentration was 0.0152 ppm, 0.0201 ppm and 0.0302 ppm. It is shown the standard deviation for these three monitoring stations was 0.002 ppm, 0.003 ppm and 0.004 ppm. The coefficient variation shows the values for Alor Setar, Pegoh and Seberang Jaya were 11.36 %, 18.71 % and 14.29 %. Pegoh has shown a small value of NO_2 concentration, but the largest coefficient variation. The skewness of Alor Setar and Seberang Jaya has been skewed to the right, while at Pegoh it is skewed to the left. Only Alor Setar has positive kurtosis values, while the other two monitoring stations have negative values. Overall, Seberang Jaya has recorded the highest maximum of NO_2 concentration with a value of 0.0266 ppm. However, the average NO_2 concentration remained below the Malaysian Ambient Air Quality Standard (MAAQS), which is 0.040 ppm. The air monitoring station in Seberang Jaya was 2 km away from the air monitoring station in Perai, which had an impact on air pollution in Seberang Jaya (Ismail et al., 2017).

Moreover, the average temperatures in Alor Setar, Pegoh and Seberang Jaya were recorded with values of 29.0 ^{0}C, 32.0 ^{0}C and 32.3 ^{0}C. The minimum value of the temperature at Alor Setar, Pegoh and Seberang Jaya is 21.8 ^{0}C, 27.6 ^{0}C and 31.8 ^{0}C while for the maximum value of temperature are 32.3 ^{0}C, 33.9 ^{0}C and 33.0 ^{0}C. According to a study by Azmi, Latif, Ismail, Juneng and Jemain (2010), the amount of biomass burned and the evaporation of soil dust from the earth's surface are both increased by high temperatures. The standard deviation of these three monitoring stations is 4.935, 3.103 and 0.576, while for the coefficient variation is 17.00 %, 9.63 % and 1.78 %. Besides that, the skewness of Alor Setar and Pegoh was skewed to the right, while Seberang Jaya was skewed to the left. Kurtosis is negative only in Seberang Jaya, while it is positive in Alor Setar and Pegoh.

The wind direction was measured at maximum wind speed in the study by Kamisan et al. (2011). Furthermore, the highest average wind speed is at Alor Setar, followed by Pegoh and Seberang Jaya with values of 3.14 m/s (312.55^0), 3.08 m/s (283.79^0) and 3.05 m/s (325.93^0). The minimum value of wind speed at Alor Setar, Pegoh and Seberang Jaya are 2.84 m/s, 2.42 m/s and 1.79 m/s while for the maximum value of wind speed are 3.70 m/s, 4.12 m/s and 4.63 m/s. The standard deviation for wind speed at Alor Setar, Pegoh and Seberang Jaya is 0.485, 0.775 and 1.191 while having a large coefficient variation with values of 15.46 %, 25.20 % and 39.09 % respectively. Besides that, only at Pegoh the skewness was skewed to the left while the two monitoring stations (Alor Setar and Seberang Jaya) were skewed to the right. Alor Setar and Seberang Jaya had positive kurtosis, whereas Pegoh had a negative value of kurtosis.

Finally, the highest average of relative humidity is at Alor Setar followed by Seberang Jaya and Pegoh with values 92.37 %, 88.52 % and 80.85 %. The minimum value of relative humidity at Alor Setar, Pegoh and Seberang Jaya is 91.79 %, 57.27 % and 88.52 %, while for the maximum value of relative humidity is 92.87 %, 90.33 % and 91.50 %. The standard deviation for relative humidity at Alor Setar, Pegoh and Seberang Jaya is 0.444, 15.86 and 3.937 while the coefficient variation is 0.48 %, 19.62 % and 4.45 % respectively. Besides that, the skewness of these three air monitoring stations has skewed to the right and has positive values of kurtosis. According to Barmpadimos, Hueglin, Keller, Henne and Prevot (2011), high relative humidity prevents particulate matter from floating about in the air, resulting in a low PM_{10} concentration. It was proven by the highest average of relative humidity at Alor Setar, which is 92.37 %, and the lowest of average PM_{10} concentration at Alor Setar was 41.37 $\mu g/m^3$.

4.3 Descriptive Analysis of Air Pollutants and Meteorological Factor at Industrial Monitoring Stations

Perai, Taiping and Jalan Tasek are industrial monitoring stations in the Northern region of Malaysia. The compilation of data from the three air quality monitoring stations (Perai, Taiping and Jalan Tasek), the three recognized air quality parameters (PM_{10}, SO_2 and NO_2) and the meteorological factor from 2016 to 2019 with their comparison to the Malaysian Ambient Air Quality Standard are summarized in Table 4.2.

Table 4.2: Daily average concentration of PM_{10}, SO_2 and NO_2 and meteorological factor from 2016 to 2019 at industrial monitoring stations

Parameters	Year	Stations	Average	Minimum	Maximum	Standard Deviation	Coefficient Variation	Skewness	Kurtosis	MAAGS
PM_{10} ($\mu g/m^3$)	2016-2019	Perai	45.848	40.079	49.325	4.300	9.38	-1.016	-0.399	120
		Taiping	**82.686**	64.566	92.366	12.554	15.18	-1.584	2.465	
		Jalan Tasek	50.986	46.200	55.475	3.847	7.55	-0.218	0.680	
SO_2 (ppm)	2016-2019	Perai	**0.0028**	0.0018	0.0040	0.0009	32.14	0.601	0.830	0.035
		Taiping	0.0016	0.0011	0.0020	0.0004	25.00	-0.358	0.257	
		Jalan Tasek	0.0021	0.0016	0.0025	0.0004	19.05	-0.701	-1.653	
NO_2 (ppm)	2016-2019	Perai	0.0215	0.0204	0.0225	0.0011	5.12	-0.056	-5.595	0.040
		Taiping	**0.0161**	0.0126	0.0187	0.0026	16.15	-0.906	1.307	
		Jalan Tasek	0.0234	0.0218	0.0243	0.0012	5.13	-1.363	1.294	
TEMP (^0C)	2016-2019	Perai	**32.01**	31.52	32.51	0.55	1.71	-5.93	-5.93	
		Taiping	31.68	29.90	32.97	1.32	4.18	0.60	0.60	
		Jalan Tasek	28.32	21.22	33.36	5.94	20.99	-3.47	-3.47	
WD (^{0})	2016-2019	Perai	334.14	331.17	337.10	2.42	0.73	1.43	1.43	
		Taiping	**350.13**	346.46	353.25	3.16	0.90	-3.45	-3.45	
		Jalan Tasek	327.41	305.12	350.39	20.16	6.16	-2.50	-2.50	
WS (m/s)	2016-2019	Perai	**3.97**	3.92	4.02	0.05	1.15	-3.20	-3.20	
		Taiping	3.52	2.51	5.25	1.26	35.82	0.33	0.33	
		Jalan Tasek	3.89	2.45	6.33	1.78	45.87	0.41	0.41	
RH (%)	2016-2019	Perai	89.65	85.86	91.71	2.61	2.92	2.67	2.67	
		Taiping	**96.43**	95.76	97.05	0.60	0.63	-3.86	-3.86	
		Jalan Tasek	74.24	58.08	90.09	17.21	23.18	-5.82	-5.82	
Bold denotes as higher average										

MAAQS= Malaysian Ambient Air Quality Standard

Based on Table 4.2 above, the average PM_{10} concentration from 2016 to 2019 at Perai, Taiping and Jalan Tasek was recorded with values of 45.848 $\mu g/m^3$, 82.686 $\mu g/m^3$ and 50.986 $\mu g/m^3$. The minimum value of PM_{10} concentration at Perai, Taiping and Jalan Tasek is 40.079 $\mu g/m^3$, 64.566 $\mu g/m^3$ and 46.200 $\mu g/m^3$, while the maximum value is 49.325 $\mu g/m^3$, 92.366 $\mu g/m^3$ and 55.475 $\mu g/m^3$ respectively. Meanwhile, the values of standard deviation for these three monitoring stations (Perai, Taiping and Jalan Tasek) are 4.300, 12.554 and 3.847, while the coefficient variation is at a value of 9.38 %, 15.18 % and 7.55 %, respectively. Besides that, the skewness of PM_{10} concentration at Perai and Taiping was skewed to the left and only Jalan Tasek was skewed to the right. Finally, Perai has a negative kurtosis value of -0.399, whereas Taiping and Jalan Tasek have positive values of 2.465 and 0.680, respectively. According to the results above, Taiping has the highest average PM_{10} concentration, with a value of 82.686 $\mu g/m^3$. However, the average PM_{10} concentration remained below the Malaysian Ambient Air Quality Standard (MAAQS), which is 120 $\mu g/m^3$. Ismail et al. (2017) found that rubber gloves, metals, non-metals, printing, textiles, food, and plastics are some of the industries found near the Taiping monitoring station. Heavy industry in the area includes an oil palm mill and a pulp and paper plant which can release more PM_{10} concentrations.

Besides that, the average value of SO_2 concentration from 2016 to 2019 at Perai was 0.0028 ppm, while at Taiping and Jalan Tasek it was 0.0016 ppm and 0.0021 ppm. The minimum value at Perai, Taiping and Jalan Tasek was 0.0018 ppm, 0.0011 ppm and 0.0016 ppm, while the maximum value was 0.0040 ppm, 0.0020 ppm and 0.0025 ppm. The standard deviation for these three monitoring stations was 0.0009 ppm, 0.0004 ppm, and 0.0004 ppm, respectively, with the coefficient variation for each monitoring station being 32.14 %, 25.00 %, and 19.05 %. The skewness of SO_2 concentration at Perai was skewed to the right, while at Taiping and Jalan Tasek it was skewed to the left. Kurtosis values for Perai and Taiping are 0.830 and 0.257, respectively, while Jalan Tasek is -1.653. Based on these three monitoring stations, Perai recorded the highest average value of SO_2 concentration with a value of 0.0028 ppm compared to the other stations. The average and maximum values of SO_2 concentration were still under the 0.035 ppm which is the limit of Malaysian Ambient Air Quality Standard (MAAQS). The highest SO_2 concentration in Perai is attributable to pollution emissions from various industries close to the monitoring station, including electronics (27.52 %), chemical industries (24.77 %), metals (39.45 %), wood industries (2.75 %), and rubber industries (5.50 %) (Azmi et al., 2010).

In addition, the average value of NO_2 concentration from 2016 to 2019 at Perai was 0.0215 ppm, while at Taiping and Jalan Tasek it was 0.0161 ppm and 0.0234 ppm. The minimum value of NO_2 concentration at Perai, Taiping and Jalan Tasek was 0.0204 ppm, 0.0126 ppm and 0.0218 ppm, while the maximum value of NO_2 concentration was 0.0225 ppm, 0.0187 ppm and 0.0243 ppm. The standard deviation for these three monitoring stations was 0.0011 ppm, 0.026 ppm, and 0.0012 ppm, respectively. The coefficient variation shows the values at Perai, Taiping and Jalan Tasek were 5.12 %, 16.15 % and 5.13 %. Taiping has shown the small value of average NO_2 concentration but the largest coefficient variation. The skewness of Perai, Taiping and Jalan Tasek has been skewed to the left. Perai is the only monitoring station with a negative kurtosis value, while the other two are positive, Jalan Tasek recorded the highest maximum NO_2 concentration with a value of 0.0234 ppm. However, the average NO_2 concentration remained below the Malaysian Ambient Air Quality Standard (MAAQS), which is 0.040 ppm. The Tasek area is home to a number of heavy businesses, including the Tasek, Bercham, and IGB Industrial Areas. Rubber bases, plastics, non-metal, printing, food and wood bases are among the industries found in Tasek Industrial Area and there are two landfill disposal quarries located 3 km from the air monitoring station that will lead to the emission of NO_2 concentration (Ismail et al., 2017).

Moreover, the average of the temperature at Perai, Taiping and Jalan Tasek was recorded at a value of 32.01 ^{0}C, 31.68 ^{0}C and 28.32 ^{0}C. The minimum value of the temperature at Perai, Taiping and Jalan Tasek is 31.52 ^{0}C, 29.90 ^{0}C and 21.22 ^{0}C, while the maximum value of the temperature is 32.51 ^{0}C, 32.97 ^{0}C and 33.36 ^{0}C. According to a study by Azmi et al. (2010), high temperatures increase the amount of biomass burned and the evaporation of soil dust from the earth's surface. The standard deviation of these three monitoring stations is 0.55, 1.32 and 5.94, while the coefficient variation is 1.71 %, 4.18 % and 20.99 %. Besides that, the skewness of Perai and Jalan Tasek was skewed to the left, while Taiping was skewed to the right. Only Taiping has a positive kurtosis value, while Perai and Jalan Tasek have a negative kurtosis value.

The wind speed was recorded at maximum wind speed (Kamisan et al., 2011). Furthermore, the highest average wind speed is at Perai, followed by Jalan Tasek and Taiping with values of 3.97 m/s (334.14^0), 3.89 m/s (327.41^0) and 3.52 m/s (350.13^0). The minimum value of wind speed at Perai, Taiping and Jalan Tasek is 3.92 m/s, 2.51 m/s and 2.45 m/s, while the maximum value of wind speed is 4.02 m/s, 5.25 m/s and 6.33 m/s. The standard deviation for wind speed at Perai, Taiping and Jalan Tasek is 0.05, 1.26 and 1.78 while the coefficient variation value 1.15 %, 35.82 % and 45.84 % respectively. Besides that, only at Perai the skewness was skewed to the left while the two monitoring stations (Taiping and Jalan Tasek) were skewed to the right. Taiping and Jalan Tasek had positive kurtosis, whereas Perai had a negative value of kurtosis.

Finally, the highest average of relative humidity is at Taiping, followed by Perai and Jalan Tasek with values of 96.43 %, 89.65 % and 74.24 %. The minimum value of relative humidity at Perai, Taiping and Jalan Tasek is 85.86 %, 95.76 % and 58.08 %, while the maximum value of relative humidity is 91.71 %, 97.05 % and 90.09 %. The standard deviation for relative humidity at Perai, Taiping and Jalan Tasek is 2.61, 0.60 and 17.21, while the coefficient variation is 2.92 %, 0.63 % and 23.18 %, respectively. Besides that, the skewness at Taiping and Jalan Tasek was skewed to the left, while at Perai it was skewed to the right. Only Perai has a positive kurtosis value of 2.67, while Taiping and Jalan Tasek have negative values of -3.86 and -5.82, respectively. According to Barmpadimos et al. (2011), high relative humidity holds particulate matter suspended in the air, thus producing a low concentration of PM_{10}. But in this case, the highest average of relative humidity is in Taiping, which is 96.43 %, and Taiping has the highest average of PM_{10} concentration. Maybe there are other factors that contributed to the highest PM_{10} concentration, such as haze events from Indonesia's open biomass burning trans-boundary emissions generating smoke haze has become an annual phenomenon and contributes to degradation in the local air quality in Malaysia (Mahmud, 2013).

4.4 Trend Test Analysis of PM_{10}, SO_2 and NO_2 Concentrations at Urban Monitoring Stations

In this section, trend analysis of PM_{10}, SO_2 and NO_2 in three air quality monitoring stations (Alor Setar, Seberang Jaya and Pegoh) is carried out for the Mann-Kendall test. The Mann-Kendall test (MK-test) was used to evaluate patterns in the time series of the monthly average of PM_{10}, SO_2 and NO_2 concentration values. The Mann-Kendall (MK-test) test is used to detect a monotonic pattern of a time series without seasonal or other cycles (Sentian et al., 2018).

4.4.1 Trend Test Analysis for PM_{10} Concentration

Table 4.3 shows the result of trend test analysis for PM_{10} concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Alor Setar, Seberang Jaya and Pegoh for urban areas.

Table 4.3: Trend test analysis of PM_{10} concentrations at urban monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Alor Setar	Urban	2016	12	-18.000	-0.273	0.2437
		2017	12	-13.000	-0.198	0.4095
		2018	12	-16.000	-0.242	0.3037
		2019	12	-12.000	-0.182	0.4507
Seberang Jaya	Urban	2016	12	18.000	0.273	0.244
		2017	12	-11.000	-0.168	0.492
		2018	12	16.000	0.242	0.304
		2019	12	-18.000	-0.273	0.244
Pegoh	Urban	2016	12	17.000	0.260	0.271
		2017	12	9.000	0.137	0.582
		2018	12	4.000	0.061	0.837
		2019	12	-8.000	-0.121	0.631

For the retrieved data of PM_{10} at Alor Setar, it can be observed from the results of Table 4.3 that for all the four periods, 2016, 2017, 2018 and 2019, the corresponding p-values are 0.2437 (τ = -0.273), 0.4095 (τ = -0.198), 0.3037 (τ = -0.242) and 0.4507 (τ = -0.182) respectively, which is more than the significant value of 0.05. H_0 is accepted and no trend is detected in the data. For Seberang Jaya, no trend is estimated due to higher p-values of 0.244 (τ = 0.273), 0.492 (τ = -0.168), 0.304 (τ = 0.242) and 0.244 (τ = -0.273). It was followed by Pegoh with a p-value of 0.271 (τ = 0.260), 0.582 (τ = 0.137), 0.837 (τ = 0.061) and 0.631 (τ = -0.121). P-values of PM_{10} concentration for all air quality monitoring stations are more than 0.05, H_0 has been established and no trend exists for PM_{10} over the past years.

4.4.2 Trend Test Analysis for SO_2 Concentration

Table 4.4 shows the result of trend test analysis for SO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Alor Setar, Seberang Jaya and Pegoh for urban areas.

Table 4.4: Trend test analysis of SO_2 concentrations at urban monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Alor Setar	Urban	2016	12	-33.000	-0.504	**0.028***
		2017	12	-11.000	-0.168	0.492
		2018	12	-14.000	-0.212	0.373
		2019	12	38.000	0.576	**0.011***
Seberang Jaya	Urban	2016	12	21.000	0.321	0.169
		2017	12	15.000	0.233	0.333
		2018	12	-26.000	-0.394	0.086
		2019	12	-15.000	-0.229	0.336
Pegoh	Urban	2016	12	2.000	0.030	0.945
		2017	12	-11.000	-0.168	0.492
		2018	12	-12.000	-0.182	0.451
		2019	12	20.000	0.303	0.193
***denotes monotonic trend is significant**						

Table 4.4 shows that H_0 for Alor Setar is rejected for 2016 and 2019 due to the existence of a trend in the SO_2 concentration data. Kendall's Tau statistic is the negative value for 2016, which is -0.504 (p-value = 0.028) indicates a decreasing trend and the positive value for 2019, which is 0.576 (p-value = 0.011) indicates a rising trend. For 2017 and 2018, no trend is estimated due to higher p-values, which are 0.492 (τ = -0.168) and 0.373 (τ = -0.212). For the retrieved data of SO_2 in Seberang Jaya, it can be observed from the results of Table 4.4 that for all the four periods, 2016, 2017, 2018 and 2019, the corresponding p-values are 0.169 (τ = 0.321), 0.333 (τ = 0.233), 0.086 (τ

= -0.394) and 0.336 (τ = -0.229) respectively, which is more than the significance value of 0.05. H_0 is accepted and there is no trend in the data. It was followed by Pegoh with a p-value of 0.945 (τ = 0.030), 0.492 (τ = -0.168), 0.451 (τ = -0.182) and 0.193 (τ = 0.303).

4.4.3 Trend Test Analysis for NO_2 Concentration

Table 4.5 shows the result of the trend test analysis for NO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Alor Setar, Seberang Jaya and Pegoh for urban areas.

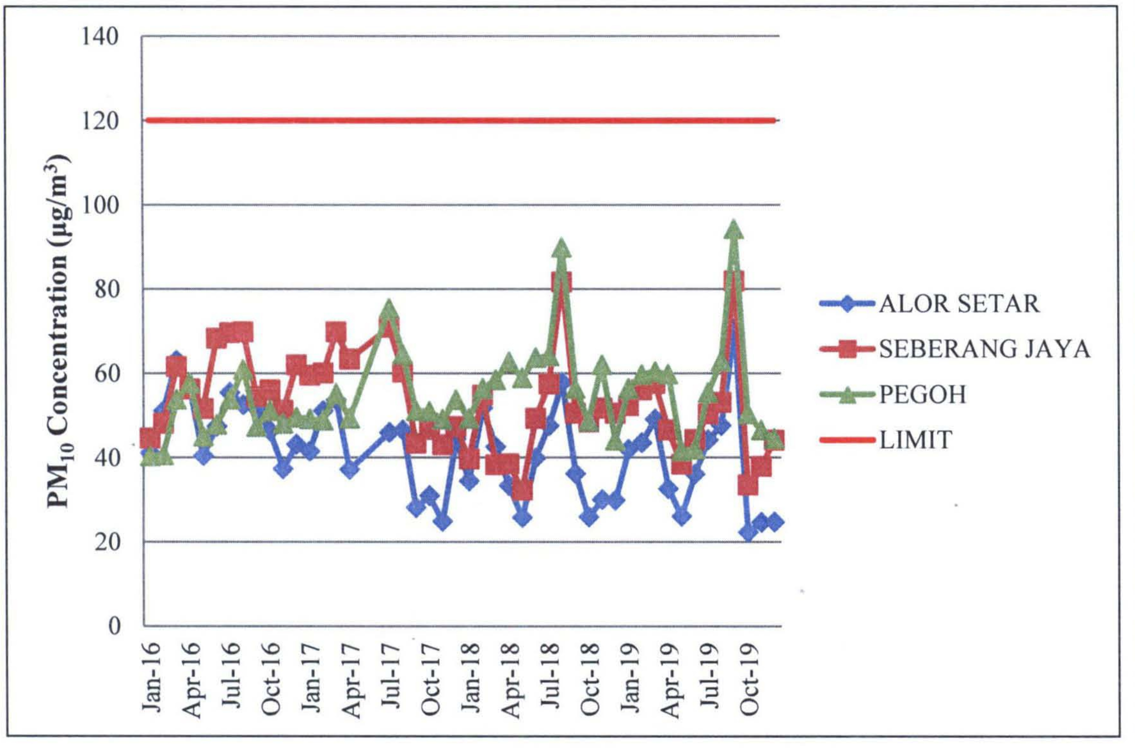
Table 4.5: Trend test analysis of NO_2 concentrations at urban monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Alor Setar	Urban	2016	12	6.000	0.091	0.732
		2017	12	1.000	0.015	1.000
		2018	12	22.000	0.333	0.150
		2019	12	4.000	0.061	0.837
Seberang Jaya	Urban	2016	12	-8.000	-0.121	0.631
		2017	12	25.000	0.388	0.097
		2018	12	0.000	0.000	1.000
		2019	12	-18.000	-0.273	0.244
Pegoh	Urban	2016	12	-37.000	-0.565	**0.013***
		2017	12	19.000	0.295	0.213
		2018	12	-22.000	-0.333	0.150
		2019	12	-12.000	-0.182	0.451
***denotes monotonic trend is significant**						

For the retrieved data of NO_2 in Alor Setar, it can be observed from the results of Table 4.5 that for all the four periods, 2016, 2017, 2018 and 2019, the corresponding p-values are 0.732 (τ = 0.091), 1.000 (τ = 0.015), 0.150 (τ = 0.333) and 0.837 (τ = 0.061) respectively, which is more than the significance value of 0.05. H_0 is accepted and there is no trend in the data. For Seberang Jaya, no trend is estimated due to higher p-values of 0.631 (τ = -0.121), 0.097 (τ = 0.388), 1.000 (τ = 0.000) and 0.244 (τ = -0.273). H_0 was rejected in Pegoh 2016, and there is a trend in the pollutant data. The p-value is below the significance level and the Kendall Tau statistic has a negative value, which is 0.013 and -0.565. It has indicated a decreasing trend in the NO_2 concentration at Pegoh in 2016. However, for the periods of 2017, 2018 and 2019 at Pegoh, there was no trend due to the higher p-values shown.

4.5 Monthly Trend Analysis of PM_{10}, SO_2 and NO_2 Concentrations at Urban Monitoring Stations

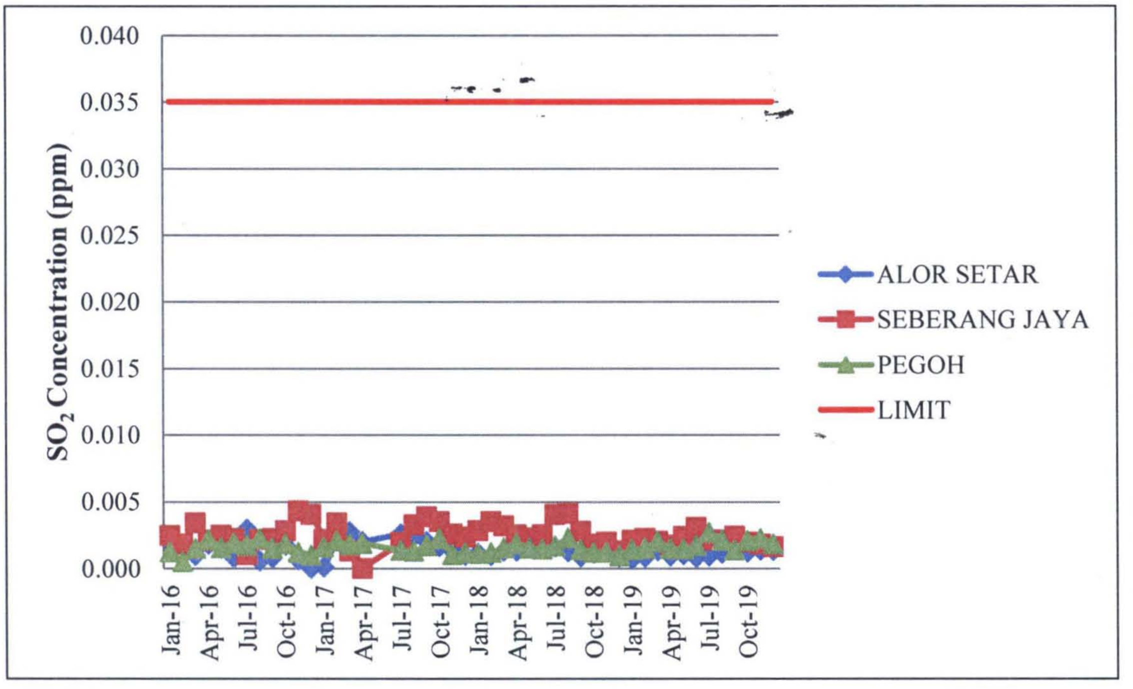
Figure 4.1 below shows the result of the average of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which is Alor Setar, Seberang Jaya and Pegoh for urban areas.



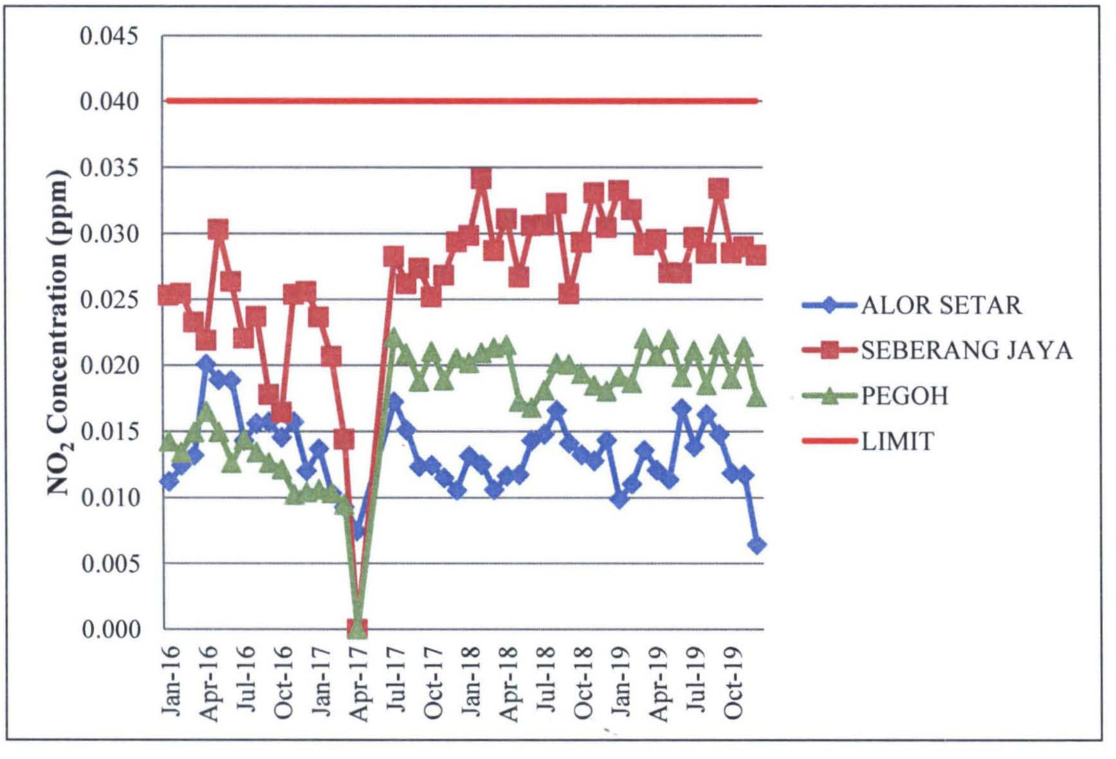
a) Monthly average of PM_{10} concentration

Continued

Figure 4.1: Average of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 at urban monitoring stations



b) Monthly average of SO_2 concentration



c) Monthly average of NO_2 concentration

Figure 4.1: Average of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 at urban monitoring stations (Continued)

Figure 4.1 (a) depicts the average monthly plots of PM_{10} concentration at Alor Setar over a four-year period (2016 – 2019). PM_{10} concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for a 24-hour averaging time, which is for PM_{10} is 120 $\mu g/m^3$ (IT-2 2018). The highest value of PM_{10} concentration at Alor Setar was 70.55 $\mu g/m^3$ in September 2019. Besides that, the highest value of PM_{10} concentration at Seberang Jaya was in August 2018, which was 81.64 $\mu g/m^3$. In addition, the highest value of PM_{10} concentration was recorded at Pegoh in September 2019, which was 94.36 $\mu g/m^3$. Overall, the monthly average of PM_{10} concentrations at these three monitoring stations is still under the Malaysian Ambient Air Quality Standard (MAAQS) limits. Figure 4.1 shows that PM_{10} concentrations are highest in August and September due to the Southwest Monsoon season (May - September), when a trans-boundary haze originating from Sumatra, Indonesia, releases high concentrations of particulate matter due to large and intense burning of peat soil and plant residues (Sentian et al., 2018).

Figure 4.1 (b) shows the average monthly plots of SO_2 concentration at Alor Setar from 2016 to 2019. SO_2 concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for a 24-hour averaging time, which is for SO_2 is 0.035 ppm (IT-2 2018). The highest SO_2 concentration recorded at Alor Setar was 0.0029 ppm in July 2016. Meanwhile, the highest SO_2 concentration at Seberang Jaya was 0.004 ppm in November 2016, and the highest SO_2 concentration at Pegoh was 0.0027 ppm in July 2019. However, the monitoring stations at Alor Setar, Seberang Jaya and Pegoh that used the monthly average of SO_2 concentration were still under the Malaysian Ambient Air Quality Standard (MAAQS) limits.

Based on Figure 4.1 (c), it shows the most significant difference where the trend in Seberang Jaya shows the highest reading between the two monitoring stations, which are Pegoh and Alor Setar. The highest value of NO_2 concentration at Seberang Jaya was in February 2018, which was 0.034 ppm. Furthermore, the highest NO_2 concentration was recorded at Pegoh in July 2017, at 0.022 ppm, while the highest NO_2 concentration at Alor Setar was in April 2016, at 0.02 ppm. NO_2 concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for 24-hour averaging time, which is for NO_2 is 0.040 ppm (IT-2 2018). The monthly average of NO_2 concentration at

Seberang Jaya, Pegoh and Alor Setar is still under the Malaysian Ambient Air Quality Standard (MAAQS) limits.

4.6 Trend Test Analysis of PM_{10}, SO_2 and NO_2 Concentrations at Industrial Monitoring Stations

In this section, trend analysis of PM_{10}, SO_2 and NO_2 in three air quality monitoring stations (Perai, Taiping and Jalan Tasek) is carried out for the Mann-Kendall test. The Mann-Kendall test (MK-test) was used to evaluate patterns in the time series of the monthly average of PM_{10}, SO_2 and NO_2 concentration values. The Mann-Kendall test (MK-test) is used to detect a monotonic pattern of a time series without seasonal or other cycles (Sentian et al., 2018).

4.6.1 Trend Test Analysis for PM_{10} Concentration

Table 4.6 shows the result of the trend test analysis for PM_{10} concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Perai, Taiping and Jalan Tasek for industrial areas.

Table 4.6: Trend test analysis of PM_{10} concentrations at industrial monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Perai	Industrial	2016	12	-22.000	-0.333	0.150
		2017	12	17.000	0.260	0.271
		2018	12	4.000	0.061	0.837
		2019	12	-8.000	-0.121	0.631
Taiping	Industrial	2016	12	4.000	0.061	0.837
		2017	12	11.000	0.168	0.492
		2018	12	-28.000	-0.424	0.064
		2019	12	-12.000	-0.182	0.451
Jalan Tasek	Industrial	2016	12	6.000	0.091	0.732
		2017	12	3.000	0.046	0.891
		2018	12	-6.000	-0.091	0.732
		2019	12	-12.000	-0.182	0.451

Based on the results in Table 4.6 above, there is no significant trend in PM_{10} concentrations at Perai, Taiping and Jalan Tasek for the periods of 2016, 2017, 2018 and 2019. PM_{10} concentrations for Perai were recorded with a p-value of 0.150 (τ = -0.333), 0.271 (τ = 0.260), 0.837 (τ = 0.061) and 0.631(τ = -0.121), Taiping with p-value 0.837 (τ = 0.061), 0.492 (τ = 0.168), 0.064 (τ = -0.424) and 0.451 (τ = -0.182). Lastly, Jalan Tasek has a p-value 0.732 (τ = 0.091), 0.891 (τ = 0.046), 0.732 (τ = -0.091) and 0.451 (τ = -0.182). P-values of PM_{10} concentration for all air quality monitoring stations are more than 0.05, H_0 has been established and no trend exists for PM_{10} over the past years.

4.6.2 Trend Test Analysis for SO_2 Concentration

Table 4.7 shows the result of the trend test analysis for SO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Perai, Taiping and Jalan Tasek for industrial areas.

Table 4.7: Trend test analysis of SO_2 concentrations at industrial monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Perai	Industrial	2016	12	14.000	0.212	0.373
		2017	12	9.000	0.137	0.582
		2018	12	-6.000	-0.091	0.732
		2019	12	-2.000	-0.030	0.945
Taiping	Industrial	2016	12	27.000	0.412	0.074
		2017	12	-17.000	-0.260	0.271
		2018	12	-20.000	-0.303	0.193
		2019	12	0.000	0.000	1.000
Jalan Tasek	Industrial	2016	12	38.000	0.576	**0.011***
		2017	12	1.000	0.015	1.000
		2018	12	4.000	0.061	0.837
		2019	12	-20.000	-0.303	0.193
***denotes monotonic trend is significant**						

For the retrieved trend test analysis data of SO_2 concentration in Perai, it can be observed from the results of Table 4.7 that for all the four periods, 2016, 2017, 2018 and 2019, the corresponding p-values are 0.373, 0.582, 0.732 and 0.945 respectively, which is higher than the significance value of 0.05. H_0 is accepted and there is no trend in the data. Moreover, there was no significant evidence of an upward or downward trend for the Taiping monitoring station with a p-value of 0.074 ($\tau = 0.412$), 0.271 ($\tau = -0.260$), 0.193 ($\tau = -0.303$) and 1.000 ($\tau = 0.000$). Perai and Taiping have no trend estimated due to higher p-values for the period from 2016 until 2019. In the case of SO_2 concentrations at Jalan Tasek, H_0 was rejected in 2016, and there is a trend in the pollutant data. The p-value is less than the significance level, and the Kendall Tau statistic is positive, with values of 0.011 and 0.576. It was indicated that there was a rising trend in SO_2 concentration at Jalan Tasek in 2016. Due to the higher p-values shown, there is no trend for the years 2017, 2018, and 2019.

4.6.3 Trend Test Analysis for NO_2 Concentration

Table 4.8 shows the result of the trend test analysis for NO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Perai, Taiping and Jalan Tasek for industrial areas.

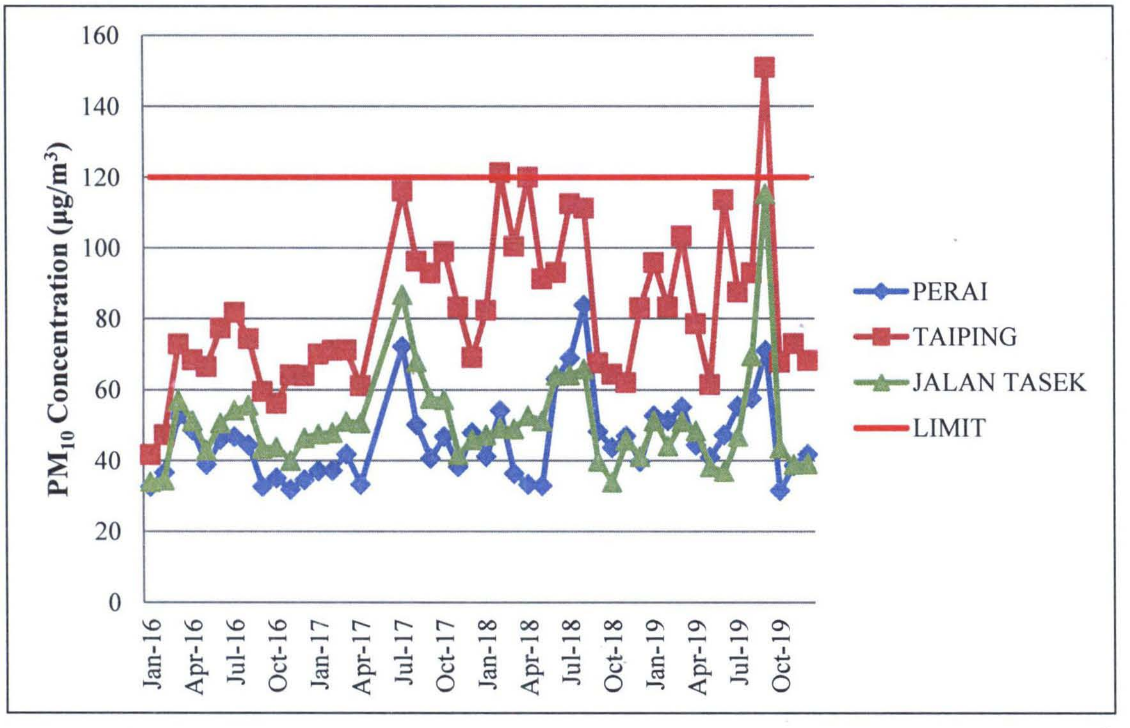
Table 4.8: Trend test analysis of NO_2 concentrations at industrial monitoring stations

Location	Category	Year	n	Kendall Score	Kendall's Tau statistic	P-value
Perai	Industrial	2016	12	16.000	0.242	0.304
		2017	12	-7.000	-0.109	0.678
		2018	12	0.000	0.000	1.000
		2019	12	-26.000	-0.394	0.086
Taiping	Industrial	2016	12	4.000	0.061	0.837
		2017	12	25.000	0.382	0.099
		2018	12	8.000	0.121	0.631
		2019	12	0.000	0.000	1.000
Jalan Tasek	Industrial	2016	12	-16.000	-0.242	0.304
		2017	12	-5.000	-0.076	0.783
		2018	12	-30.000	-0.455	**0.047***
		2019	12	-22.000	-0.333	0.150
***denotes monotonic trend is significant**						

Based on the result of the trend NO_2 concentration in Table 4.8 above, there was no significant evidence of an upward trend for the Perai monitoring station for 2016 until 2019 with $\tau = -0.242$ (p-value = 0.304), $\tau = -0.109$ (p-value = 0.678), $\tau = 0.000$ (p-value = 1.000) and $\tau = -0.394$ (p-value = 0.086). Followed by Taiping, the trend analysis at this monitoring station has no trend due to the higher p-values for 2016 until 2019. For Jalan Tasek in the 2016, 2017 and 2019 periods, the p-value is 0.304 (τ = -0.242), 0.783 (τ = -0.076) and 0.150 (τ = -0.333). That is more than the 0.05 value. The H_0 is established, and no trend exists for NO_2 concentration. However, at Jalan Tasek in 2018, H_0 was rejected, indicating the existence of a trend. Kendall's Tau statistic has a negative value, which is -0.455 and it indicates a decreasing trend.

4.7 Monthly Trend Analysis of PM_{10}, SO_2 and NO_2 Concentrations at Industrial Monitoring Stations

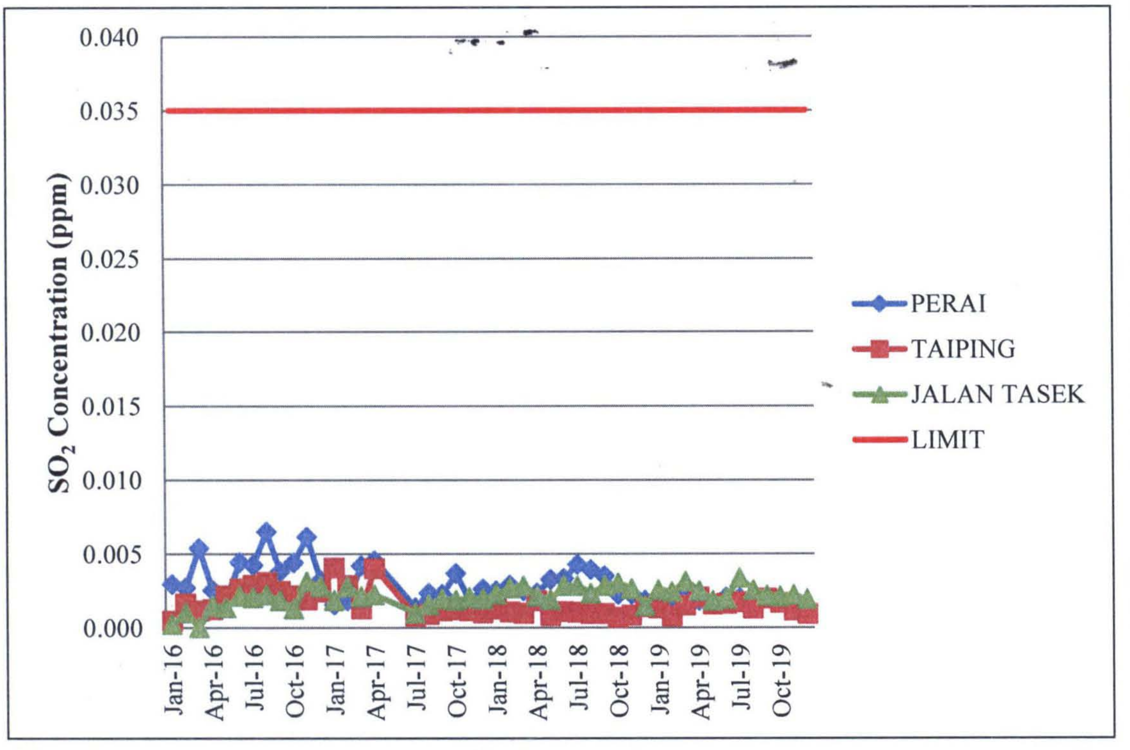
Figure 4.2 below shows the result of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 in each of the air quality monitoring stations in the Northern region of Peninsular Malaysia, which are Perai, Taiping and Jalan Tasek for industrial areas.



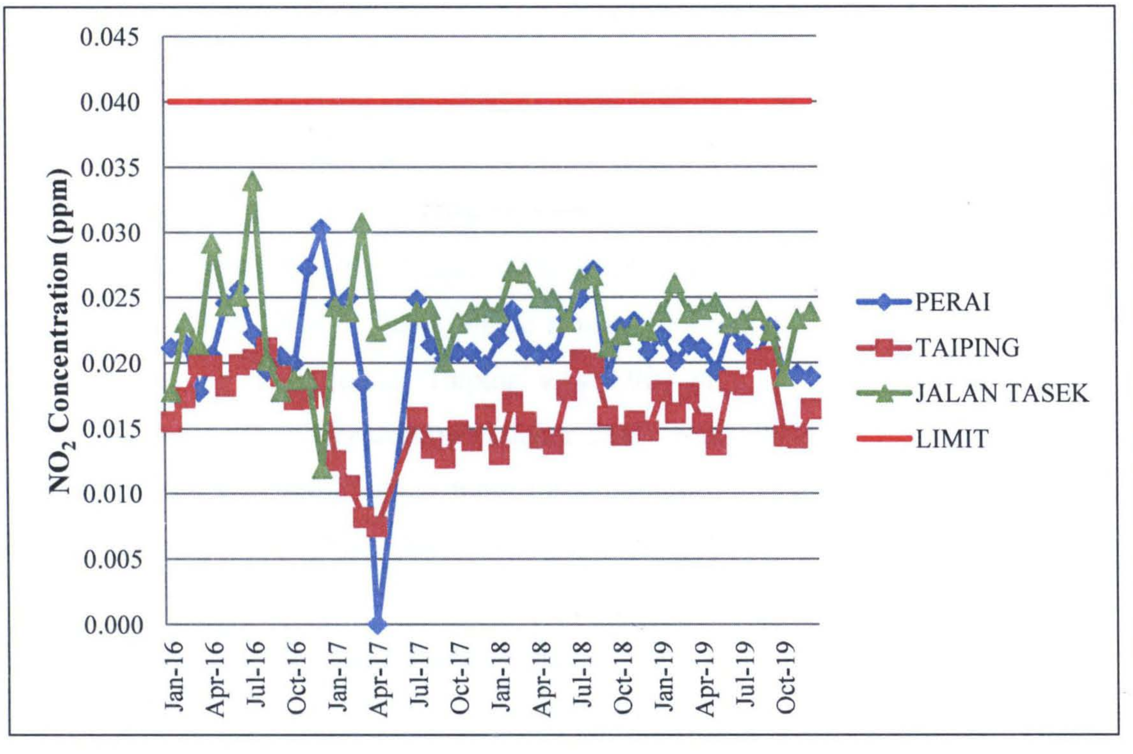
a) Monthly average of PM_{10} concentration

Continued

Figure 4.2: Average of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 at industrial monitoring stations



b) Monthly average of SO_2 concentration



c) Monthly average of NO_2 concentration

Figure 4.2: Average of monthly trend analysis for PM_{10}, SO_2 and NO_2 concentration for 2016 to 2019 at industrial monitoring stations (Continued)

Monthly average plots of PM_{10} concentration at Perai, Taiping and Jalan Tasek for 2016 until 2019 were shown in Figure 4.2 (a). PM_{10} concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for a 24-hour averaging time, which is for PM_{10} is 120 $\mu g/m^3$ (IT-2 2018). The highest value of PM_{10} concentration was recorded at Perai in August 2018, which was 83.73 $\mu g/m^3$. Ismail, Abdullah and Samah (2017) found that the wood industries, electronics, metals, chemical industries, and rubber industries have all contributed to the emission of PM_{10} concentration in Perai regions. Meanwhile, the highest PM_{10} concentration in Taiping was 150.94 $\mu g/m^3$ in September 2019. Other than that, in February 2018 and April 2018, PM_{10} concentrations also exceeded the limit with a value of 121.30 $\mu g/m^3$ and 120.08 $\mu g/m^3$ respectively. Because of the trans-boundary haze event caused by forest fires in Sumatra and Kalimantan, it exceeded the MAAQS (Utusan Borneo Online, 2019). Furthermore, Taiping is classified as an industrial area, which emits a significant amount of particulate matter from industry. In addition, the highest value of PM_{10} concentration at Jalan Tasek was in August 2018, which was 115.34 $\mu g/m^3$. Only Taiping exceeded the Malaysian Ambient Air Quality Standard (MAAQS) PM_{10} concentration limits, while Perai and Jalan Tasek did not.

Figure 4.2 (b) shows the monthly average plots of SO_2 concentration at Perai, Taiping and Jalan Tasek for four years (2016 – 2019). SO_2 concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for a 24-hour averaging time, which is for SO_2 is 0.035 ppm (IT-2 2018). The highest SO_2 concentration was recorded in August 2016 at Perai, where it was 0.0065 ppm. Furthermore, the highest value of SO_2 concentration at Taiping was 0.004 ppm in January 2017, while the highest value of SO_2 concentration at Jalan Tasek was 0.0034 ppm in July 2019. The average of SO_2 concentrations at these three monitoring stations was found to be far below the Malaysian Ambient Air Quality Standard (MAAQS).

Besides that, average monthly plots of NO_2 concentration at Perai, Taiping and Jalan Tasek for 2016 until 2019 were shown in Figure 4.2 (c). NO_2 concentration was compared to the Malaysian Ambient Air Quality Standard (MAAQS) for 24-hour averaging time, which is for NO_2 is 0.040 ppm (IT-2 2018). The highest NO_2 concentration was recorded at Perai in December 2016, at 0.030 ppm, while the highest NO_2 concentration was recorded at Taiping in August 2016, at 0.021 ppm. Lastly, the highest value of NO_2 concentration at Jalan Tasek was in July 2016, which was 0.034 ppm. All of these three monitoring stations were still under the Malaysian Ambient Air Quality Standard (MAAQS) the NO_2 concentration.

4.8 Comparison Trend of Air Pollutants (PM_{10}, SO_2 and NO_2) Concentrations in Northern Region of Malaysia in 2016 to 2019

The comparison trend of air pollutants (PM_{10}, SO_2 and NO_2) concentration in the Northern region of Malaysia in 2016 to 2019 involved the urban and industrial monitoring stations, which are Alor Setar, Seberang Jaya, Pegoh, Perai, Taiping and Jalan Tasek.

4.8.1 Trend of PM_{10} Concentration in Northern Region of Malaysia in 2016 to 2019

Figure 4.3 below shows the comparison of PM_{10} concentration in the Northern region of Malaysia in 2016 to 2019. There are three monitoring stations in urban areas (Alor Setar, Seberang Jaya and Pegoh) and three monitoring stations in industrial areas (Perai, Taiping and Jalan Tasek).

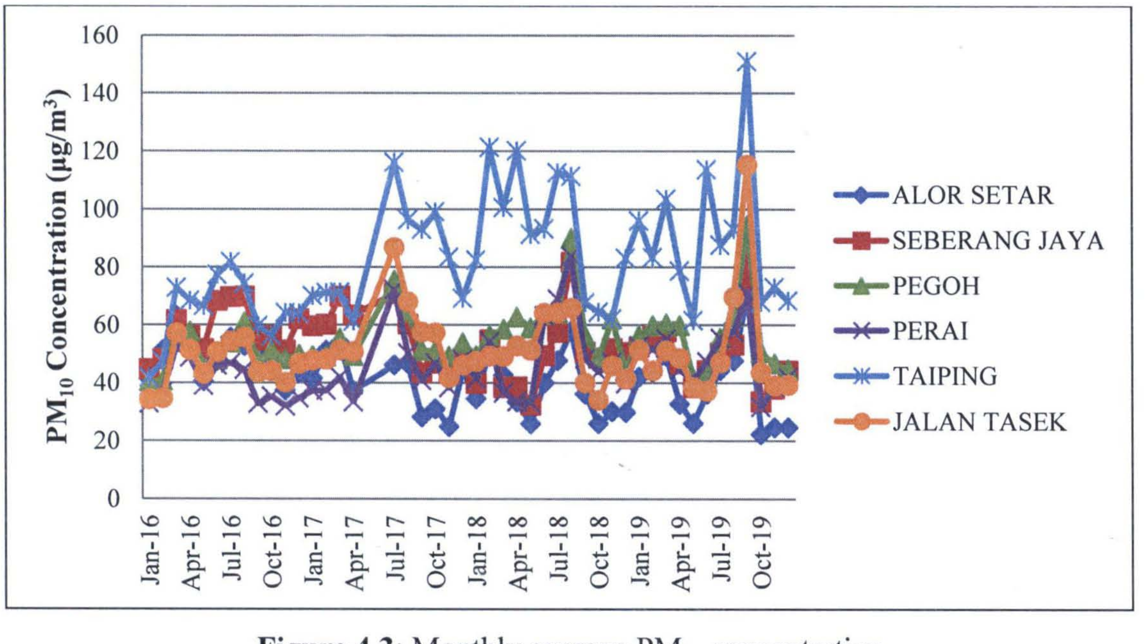


Figure 4.3: Monthly average PM_{10} concentration

According to Figure 4.3, the monthly average of PM_{10} concentration in Taiping is higher than in Alor Setar, Seberang Jaya, Pegoh, Perai, and Jalan Tasek. This is because Taiping is categorized as an industrial area which emits more particulate matter from the industry sector. The highest PM_{10} concentration occurred in September 2019, which was 150.94 $\mu g/m^3$. This exceeds the Malaysian Ambient Air Quality Standard (MAAQS) for 24-hour averaging time, which is for PM_{10} of 120 $\mu g/m^3$ (IT-2 2018). A haze event occurred in 2019 due to the low likelihood of heavy rains and the possibility of uncontrolled open burning in neighboring Indonesia (The Straits Times, 2019). The Taiping monitoring station recorded the highest plot from March 2016 to December 2019 compared to the other monitoring stations due to low wind speed based on Table 4.2 and it will reduce the dilution of the pollutants. Most of the emissions of PM_{10} concentration come from the poor combustion process in the industries near the Taiping monitoring station, which are oil palm mills, lime manufacturing and metal, rubber gloves, printing, textiles, food and plastics industries (Ismail et al., 2017). In Figure 4.3, there is no data from either urban or industrial monitoring stations from 15 April 2017 to 3 July 2017 due to the exchange of concessions and the exchange of new tools from the Department of Environment (DOE) for all monitoring stations in Peninsular Malaysia. Even though the area status in Taiping changed from industrial to sub-urban, Taiping still contributed to the highest plot due to the advanced new tools for measuring PM_{10} concentrations.

4.8.2 Trend of SO_2 Concentration in Northern Region of Malaysia in 2016 to 2019

The comparison of SO_2 concentrations in Malaysia's Northern area from 2016 to 2019 is shown in Figure 4.4. Three monitoring stations are located in urban areas (Alor Setar, Seberang Jaya, and Pegoh) and three monitoring stations are located in industrial areas (Alor Setar, Seberang Jaya, and Pegoh) (Perai, Taiping and Jalan Tasek).

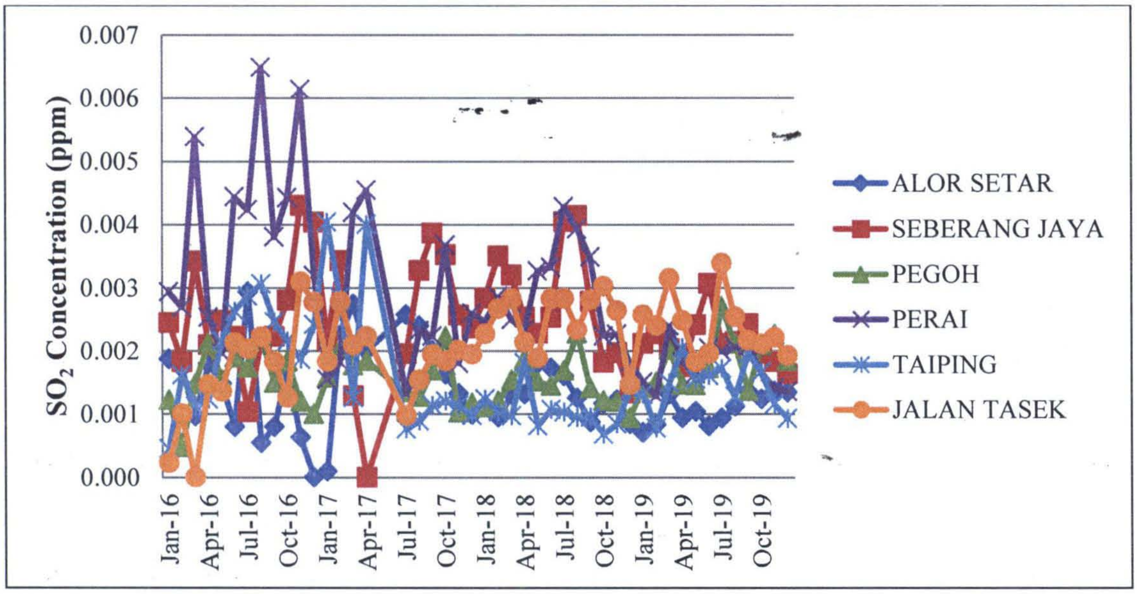


Figure 4.4: Monthly average of SO_2 concentration

Figure 4.4 depicts the highest monthly average of SO_2 concentration that was recorded at Perai. In August 2016, Perai had the highest plot with 0.0065 ppm in comparison to other air quality monitoring stations in Alor Setar, Seberang Jaya, Pegoh, Taiping, and Jalan Tasek. Perai is categorized as an industrial area which mostly burns oil in power plants, factories and manufacturing near the monitoring station. The highest temperature at Perai influenced the highest concentrations of SO_2 due to chemical processes that occur in the atmosphere to generate photochemical smog (Donev et al., 2018). But somehow, the average concentration of SO_2 was still under the threshold limit stipulated in the Malaysian Ambient Air Quality Standard (MAAQS), which is 0.035 ppm. Due to the exchange of concessions and new tools from the Department of Environment (DOE) for all monitoring stations in Peninsular Malaysia, all monitoring stations, whether urban or industrial, were shut down from 15 April 2017 to 3 July 2017 and no data was collected in this range. However, SO_2 concentrations in Perai decreased in the plot from 2017 to 2019 when compared to previous years. This is because Malaysia has agreed to set a national target to reduce pollutant emissions by reducing greenhouse gas emissions to 45 % based on the Gross Domestic Product by 2030 (Department of Statistics, 2016). In addition, the change in the area status in Perai from industrial to urban shows that the air pollutants are decreasing and this may be because the tools are more advanced and accurate in measuring.

4.8.3 Trend of NO_2 Concentration in Northern Region of Malaysia in 2016 to 2019

The comparison of NO_2 concentrations in Malaysia's northern area from 2016 to 2019 is shown in Figure 4.5. Three monitoring stations are located in urban areas (Alor Setar, Seberang Jaya, and Pegoh) and three monitoring stations are located in industrial areas (Alor Setar, Seberang Jaya, and Pegoh) (Perai, Taiping and Jalan Tasek).

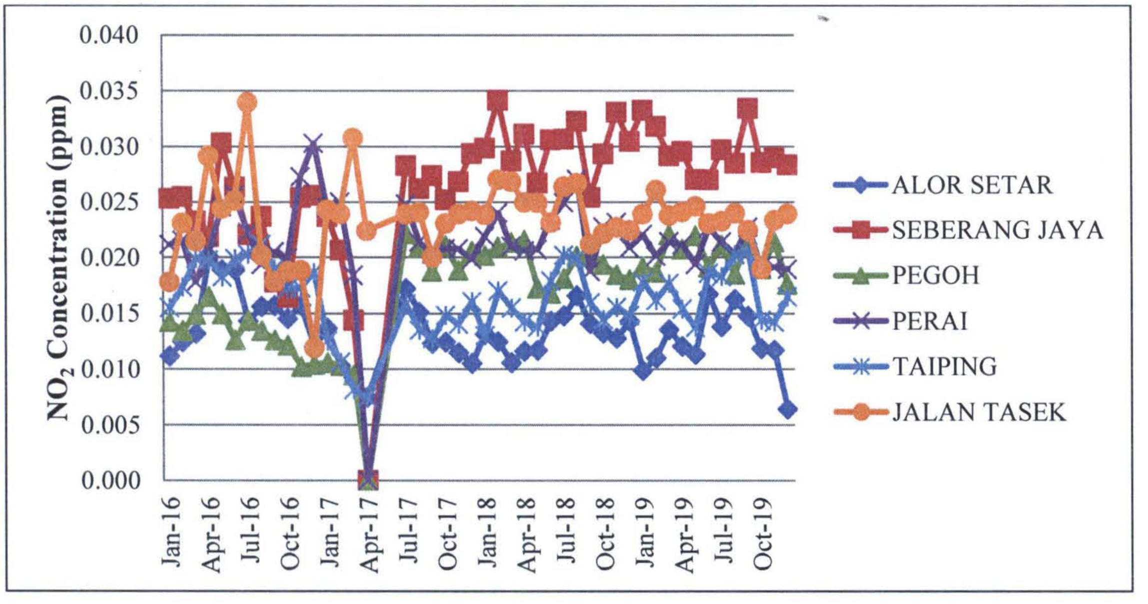


Figure 4.5: Monthly average of NO_2 concentration

Among the four years in Figure 4.5, Seberang Jaya recorded the highest monthly average of NO_2 concentration in February 2018 with a value of 0.034 ppm respectively. All monitoring stations in Peninsular Malaysia, whether urban or industrial, were shut down from 15 April to 3 July 2017 due to the Department of Environment (DOE) exchanging concessions and new instruments for all monitoring stations in Peninsular Malaysia. None of these concentrations exceeded the Malaysian Ambient Air Quality Standard (MAAQS) suggested value, which is 0.040 ppm for a 24-hour averaging time. However, according to the Department of Environment (2019), the highest value of NO_2 concentration might be due to the atmospheric conditions and emissions from motor vehicles in urban areas that enhance its formation. Seberang Jaya has a high temperature, which causes an increase in biomass burning and evaporation of soil dust from the earth's surface, as well as low dilution due to the low wind speed. Furthermore, according to Ismail et al. (2017), Seberang Jaya is a popular area and the heart of Penang, which is located in the center of the Penang mainland.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion.

This research has analyzed the statistical characteristics and trends of air pollution in the Northern region of Malaysia using air quality datasets from six monitoring stations which spanned from 2016 to 2019. It has resulted in the distribution and dispersion of PM_{10}, and SO_2 concentrations at industrial monitoring stations recording the highest value compared to at the urban monitoring stations in the Northern region of Malaysia from 2016 to 2019. However, the highest average NO_2 concentration was recorded at the Seberang Jaya monitoring station, which is classified as an urban monitoring station. For the highest statistical characteristic, the daily average concentration of PM_{10} at Taiping was recorded at a value of 82.69 $\mu g/m^3$. The daily average concentration of these six air quality monitoring stations was found to be far below the Malaysian Ambient Air Quality Standard (MAAQS) of (120 $\mu g/m^3$). While the higher daily average concentration of SO_2 was recorded at Perai with a value of 0.0028 ppm, respectively. In this case, all of the air quality monitoring stations are still under the Malaysian Ambient Air Quality Standard (MAAQS) limits, which are at 0.035 ppm. For the daily average of NO_2 concentration, the highest value was recorded at Seberang Jaya, which is 0.0266 ppm. The NO_2 concentration remains below the Malaysian Ambient Air Quality Standard (MAAQS) limit of 0.040 ppm.

Besides that, the rising and decreasing trend of PM_{10}, SO_2 and NO_2 concentrations at urban and industrial monitoring stations is related to consistently higher and lower average emissions of pollutant concentrations and is also influenced by meteorological factors. For the trend analysis, SO_2 concentration at Alor Setar 2016 has shown a decreasing trend, while Alor Setar 2019 and Jalan Tasek 2016 have shown an increasing trend. Meanwhile, the trend analysis of NO_2 concentration shows a decreasing trend due to the negative value of the Mann-Kendal's statistic. Mostly, the trend analysis for PM_{10}, SO_2 and NO_2 concentration over the six air quality monitoring stations has shown mixed trends for the entire period from 2016 to 2019.

Finally, the research discovered that the trend of PM_{10}, SO_2, and NO_2 concentrations at industrial monitoring stations are the major pollutants that have contributed to deteriorating air quality in Malaysia's Northern region due to vehicle and industrial combustion processes.

5.2 Recommendations for Future Study

Air pollution comes from a wide range of sources in the Northern region of Malaysia, including commercial and industrial development, motor vehicles, open burning and trans-boundary haze where it contains PM_{10}, SO_2 and NO_2, the same as in this research. The parameters of air pollutants such as particulate matter ($PM_{2.5}$), ozone (O_3), carbon monoxide (CO), and benzene, toluene, ethylbenzene and xylene (BTEX), which are contained in air pollution in the atmosphere, should be added to this research. It can be seen among the pollutants, which is one of all the pollutants listed that contribute the most to environmental pollution in the Northern region of Malaysia. Aside from that, the research used data from a four year period from 2016 to 2019 to determine the trend. However, most of the results show no significant trend in air pollutants at urban and industrial monitoring stations in the Northern region of Malaysia. To determine the clear trend of pollutants in these areas, which can be an upward trend or a downward trend, the period of air pollutant data used should be increased to another six to seven years. In addition, we will maintain and strengthen the existing measurement programs that are essential for detecting and understanding global air quality changes. High priority should be given to programs which aid in assessing long-term trends in PM_{10}, SO_2, NO_2 and also other gases which can harm people and the environment. Monitoring the trends of air pollutants helps in assessing the level of pollution in relation to the ambient air quality standards. Standards are a regulatory measure to set the target for pollution reduction and achieve clean air. Robust monitoring helps in the prevention of extreme occurrences by notifying people and causing them to take action.

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