Investigation of The Ambient Nitrogen Oxides (NO_x) Trends at Tronoh, Perak

by

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Dissertation submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfilment of the requirement for the
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Approved by,

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(Dr Wesam Al Madhoun)

UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR, PERAK
September 2017

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(FARELLE CHARLES JOSEPH)

ABSTRACT

In these days, the emissions of nitrogen oxides and nitrogen dioxide into ambient air has become one of the most concerned issue. As we all aware, the major contributor to these pollutants are industrial activities and vehicles. The area whereby industrial development and increase in number of vehicles is significant, will result in more total nitrogen oxides and nitrogen dioxide emitted to the air. This situation will cause tremendous effect to human, plants, and animals. In fact, these pollutants will become more complex when it reacts with other compounds to form secondary air pollutant. Hence, this study aims to determine the effect of industrial activities and vehicles to the concentration level of nitrogen oxides and nitrogen dioxide in selected area as well as the influence of temperature and relative humidity to the trend of pollutant's concentration.

So, for fulfilment of this study, three air monitoring point location had been selected whereby the first location focuses on the emission from vehicles while the second and third location focuses on the emission from industries in Tronoh. The air monitoring was carried out 12 hours per day in daylight for 1 weekday and 1 weekend for every point location. Aeroqual AQM 60 Station was used to monitor and record required data such as concentration of nitrogen oxides and nitrogen dioxide, ambient temperature, and relative humidity.

From the result and graphical representation of the study, it was found that the concentration of nitrogen dioxide is below 0.16 ppm in one hour averaging time as per stated in Malaysian Ambient Air Quality Standard. The fluctuation of nitrogen oxides concentration was mainly due to the traffic volume, while emission from industries does not contribute to the nitrogen dioxide and nitrogen oxides concentration. The influence of temperature and relative humidity to the concentration of both pollutants was very significant, and this shows that meteorological conditions play an important role in the fluctuation of pollutants. Hence, this study is really important to investigate the correlation and influence of meteorological parameters, industry activities, and traffic volume to the concentration of nitrogen oxides and nitrogen dioxide.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In human life, air is one of the most essential elements of man's environment. Without air, the respiratory circulation of human will eventually stop as it requires oxygen for breathing process. The needs of providing a clean air for living and non-living components on earth had become more or less a controversial topic whereby urban air pollution problems keep arising. Generally, a clean and dry air constitute of about 78% of nitrogen and 21% of oxygen gases, while the remaining 1% is a mixture of several gaseous such as carbon dioxide, helium, argon, krypton, nitrous oxide and xenon, and organic and inorganic compound (M.N Rao & H.V.N Rao, 2001). These gases exist in a closed layer called the earth's atmosphere (Purohit & Kakrani, 2002).

The earth's atmosphere consists of a different layer which is categories based on temperature and altitude from the earth's surface (Purohit & Kakrani, 2002). These layers are Troposphere (0 to 6-17 km), Stratosphere (6 to 17-50 km), Mesosphere (50 to 85 km), and Thermosphere (above 85 km). As time goes on, the air constituent will keep changing because of many factors, which causes it to be harmful and dangerous, and this is where the air pollution occurs. Air pollution can be defined as the immoderate concentration of foreign matter that presence in air which then adversely affects the wellbeing of human or causes damage to property (M.N Rao & H.V.N Rao, 2001). In other words, the air is contaminated by the presence of harmful gases, dusts, fumes, and substances.

The main causes that generate air pollution is the human's activities itself. 'Anthrosphere' is a term that had been used to describe the effects of human's activities towards air quality and it define as the 'part of the environment made or modified by humans and used for their activities' (Purohit & Kakrani, 2002). Of all human's activities, the major sources which give adverse effects on air quality are burning fossil fuels, releasing of harmful gases by industries, agricultural activities, gas emissions from vehicles, and wars (Jain, 2007). Other than that, natural causes would also pollute the ambient air by the gas emissions from volcanoes, marsh gas, and spores of fungi and pollens (Jain, 2007).

The harmful substances released to the ambient air are known as pollutants and it may exist in various types and forms. Air pollutants can be categorised as natural contaminants, aerosols, and gases or vapours (Salpekar, 2008). For natural contaminants, it may exist in the form of fog, pollen grains, bacteria, and volcanic eruption while for aerosols it may release to the air in the form of dust, smoke, mists, and fumes. Air pollutant in the form of gases and vapours are sulphur, nitrogen, oxygen, halogen, organic, and radioactive compounds (M.N Rao & H.V.N Rao, 2001).

Apart from that, air pollutants can also be classified into two general groups, primary air pollutant and secondary air pollutant. Primary air pollutants can be defined as any pollutants that released directly to the ambient air from identifiable sources, while secondary air pollutants are product of two or more primary pollutants which mixed by interaction or reaction in the air (M.N Rao & H.V.N Rao, 2001). Sulphur compounds, oxides of nitrogen, and carbon monoxide are the examples of primary pollutant while ozone, acid mists, and photochemical smog are the examples of secondary pollutant. Table 1.1 shows the various kinds of air pollutants based on primary and secondary pollutants basis.

Table 1.1 : Various kinds of Air Pollutants (Purohit & Kakrani, 2002).

Class	**Pollutant**
Primary pollutants	**Carbon compounds:** carbon dioxide, carbon monoxide
	Sulphur compounds: Carbonyl sulphide (COS), Carbon disulphide (Cs_2), Dimethyl sulphide ($[CH_3]_2s$), Hydrogen sulphide (H_2S), Sulphur dioxide (SO_2), and Sulphate (SO_4^{2-})
	Hydrocarbons: Benzene, Benzpyrene, and Methane (Marsh gas)

	Metals: Zinc, Cadmium, Lead, Mercury, Particulate matter
	Toxic substances: Arsenic, Asbestos, Carbon tetrachloride, Beryllium, Chromium, Copper, Nickel, Polycyclic aromatic
Secondary pollutants	Ozone, Photochemical product (olefin, aldehydes, ozone, PAN and PB_2N), PAN, photochemical smog (O_3, NO_x, hydrogen peroxides, organic peroxides)

In order to monitor the ambient air quality in Malaysia, the Department of Environment under Malaysian Government has established an air index as a guideline known as Air Pollutant Index (API). The API provides sets of range in values to indicate the limit of acceptance criteria. Basically, API is determined based on the average concentration of each five major air pollutants namely sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, and particulate matter. The average concentration of air pollutants is compared to the Malaysia ambient air quality standard as shown in Table 1.3. The dominant air pollutant with the highest concentration is taken as the pollutant for determination of API reading. For example, suppose the measured API in an area is 46, so by referring to the API index the value 46 is in the range of 0 to 50, which then indicate that the area is in good condition in terms of air quality. Table 1.2 shows the Air Pollutant Index that is been implement in Malaysia.

Table 1.2 : Air Pollutant Index implement in Malaysia (DOE, 2017)

API	**Status**
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very Unhealthy
More than 301	Hazardous

Table 1.3 : Malaysia Ambient Air Quality Standard

POLLUTANT	AVERAGING TIME	MALAYSIA GUIDELINES	
		ppm	($\mu g/m^3$)
Ozone	1 hour 8 hours	0.10 0.06	200 120
Nitrogen Dioxide	1 hour 24 hours	0.16 0.04	300 75
Sulphur Dioxide	1 hour 24 hours	0.12 0.035	300 90
Particulate Matter (PM_{10})	1 year 24 hours	- -	45 120
Carbon Monoxide*	1 hour 8 hours	30 9	35 10

*mg/m^3

The degree of air pollution may differ from one place to another due to the meteorological condition. Meteorological condition can be best described as the surrounding or weather condition in an area. The main meteorological parameters that really influence air pollution are wind direction and speed, temperature, relative humidity, and mixing height (M.N Rao & H.V.N Rao, 2001). Even though the total discharge of pollutant into the air in a certain area is constant, the intensity and concentration of the air pollution may differ from time to time because of the difference in meteorological conditions. In other words, the air pollutants that is released by point or area sources are being transported, dispersed, and concentrated by meteorological conditions (Wark, et. al., 1998).

The harmful gases and vapours originated from industrial activities and vehicles will be the main concern in this study since it is the major causes in air pollution. The pollutants emitted may vary from one place to another. Realizing the essentiality of determining the air quality in respected area, this study will analyse the concentration of nitrogen oxides (NO_x) and nitrogen dixide (NO_2) with respect to meteorological parameters, industrial activities and traffic volume.

1.2 PROBLEM STATEMENT

In Tronoh, there are several reports made by the residents claiming that the sight view in certain location is vague and hazy due to polluted ambient air. This problem could be the result of excessive emission of harmful gases from industrial and human activities. As we all aware, the major contributor to the air pollution are industrial activities and vehicles, and both contributor has been expanding rapidly in conjunction with the vast development in technology as well as increasing numbers of people. The area whereby industrial development and increase in numbers of vehicles is significant, will result in more total contaminant emitted to the air. The harmful gases and vapour released to the air will cause tremendous effect to human, plants, animals and even structural elements.

One of the most dangerous air pollutant is nitrogen dioxide (NO_2), generated from highly reactive gases which known as oxides of nitrogen or nitrogen oxides (NO_x). The primary sources of nitrogen dioxide are the burning of fossil fuels, which usually emitted in the form of gases and smokes from cars, trucks, buses, power plants, and factories. Once the nitrogen dioxide is emitted, it will be transported and dispersed by the influence of meteorological conditions such as wind speed and direction, ambient temperature, and atmospheric pressure. The concentration of nitrogen dioxide will differ from one place to another as the meteorological elements is changing with respect to time. The nitrogen dioxide may concentrate and accumulate at certain area only due to poor wind circulation which make the pollutant to trapped for a certain period.

This situation will eventually give adverse effects to living and non-living things in Tronoh area. Breathing air with a high concentration of nitrogen dioxide can contribute to respiratory problems such as reduce the immunity to lung infections, wheezing, coughing, cold, flu and bronchitis. Tendency of acid rain formation will be significant in a high concentration of nitrogen oxides and nitrogen dioxide areas. As it reaches Earth surface, the ecological systems will be badly affected as it carries toxic substances.

Thus, this research will investigate the influence of meteorological parameters, industrial activities, and traffic volume on the concentration of nitrogen oxides and nitrogen dioxide in Tronoh area.

1.3 OBJECTIVES

The objectives that need to be achieved at the end of this study are :

i. To determine the trend and concentration of nitrogen oxides and nitrogen dioxides. The concentration may vary from time to time and trapped or circulate in the area. Hence, it is crucial to determine the concentration level of these pollutants.
ii. To investigate the relationship of nitrogen oxides and nitrogen dioxide with industrial activities and traffic volume. The trend of nitrogen oxides and nitrogen dioxide concentration may highly be affected by the emission from vehicles and industrial activities.
iii. To analyse the correlation between the concentration of nitrogen oxides and nitrogen dioxide to meteorological parameters. This study was focusing on two meteorological parameters which are temperature and relative humidity.

1.4 SCOPE OF STUDY

The study area will be at Tronoh, located on south west of Ipoh city, Perak. Tronoh town covers an area of approximately 3.5 km^2 with estimated population of 10 thousand. This town consists of residential areas, commercial estates, industrial areas and a road linking between Ipoh and Lumut. To satisfy the needs of this study, the concentration of nitrogen dioxide (NO_2) and nitrogen oxides (NO_x) will be taken at three different point location inside the Tronoh area, and it will be focuses on the emission from industries and vehicle. The ambient temperature, relative humidity, and traffic volume will be recorded as well. The air monitoring activities will be done 1 day in weekday and 1 day in weekend for every point location.

CHAPTER 2

LITERATURE REVIEW

2.1 OXIDES OF NITROGEN

2.1.1 DEFINITION

One of the most important air polluting chemical compound that exist in the ambient air is nitrogen dioxide (NO_2) and it is the most prevalent form of nitrogen oxides (NO_x) in the ambient air that generated by anthropogenic activities. Generally, a clean and dry air constitute of approximately 78% of nitrogen (N) element, which make it as the largest amount of inert gas exist in the air. However, the single atom of nitrogen (N) can be very reactive as it has an ionization levels (valence states) from +1 to +5 (CATC, 1999). This means that the nitrogen element can form into several types of oxides. These types of nitrogen oxides are also known as the family of NO_x compounds. Table 2.1.1 shows the various types of nitrogen oxide, NO_x compound.

Table 2.1.1 : Nitrogen Oxides, NO_x (CATC, 1999)

Formula	Name	Nitrogen Valence	Properties
N_2O	Nitrous oxide	1	-colourless gas -water soluble
NO N_2O_2	Nitric oxide Dinitrogen dioxide	2	-colourless gas -slightly water soluble
N_2O_3	Dinitrogen trioxide	3	-black solid -water soluble,decomposes in water

NO_2 N_2O_4	Nitrogen dioxide Dinitrogen tetroxide	4	-red-brown gas -very water soluble, decomposes in water
N_2O_5	Dinitrogen pentoxide	5	-white solid -very water soluble, decomposes in water

As mentioned earlier, nitrogen dioxide is the most abundant types of nitrogen oxides in the ambient air and hence it reacts in the atmosphere to form ground level ozone (O_3). Generally, nitrogen dioxide is generated from the reaction of nitric oxide (NO) with oxygen, whereby nitric oxide is a free radical exists in atmosphere and unstable compound. In other words, the nitric oxide is oxidized by oxygen in the air. Equation 1 shows the reaction between nitric oxide and oxygen.

$$2\ NO + O_2 \longrightarrow 2\ NO_2 \qquad \text{(Eq. 1)}$$

Nitrogen dioxide exists at two different colours which is determine by the surrounding temperature. It has brown colour at temperatures below 21.5˚C and is at liquid state, whereas at temperatures of below -11˚C, it is colourless at solid state (Kindzierski et. al., 2007). In ambient temperatures, nitrogen dioxide exists in the form of gases state and has a reddish-brown colour, very corrosive, non-combustible, and pungent in odour (Kindzierski et. al., 2007). Table 2.1.2 summarise the general properties of nitrogen dioxide, NO_2.

Table 2.1.2 : Properties of Nitrogen Dioxide, NO_2 (Kindzierski et. al., 2007)

Property	**Value / Description**
Formula	NO_2
Structure	O = N = O
Molecular weight	46.01 g.mol^{-1}
Physical state	Clear colourless volatile liquid

Melting Point	-9.3˚C
Boiling Point	21.12˚C
Density (liquid)	1.448 (at 20 ˚C)
Density (gas) (air=1)	1.58
Solubility in water	React with water, decomposes forming nitric acid and nitric oxide
Solubility	Soluble in concentrated sulphuric acid, nitric acid, carbon disulphide, chloroform

2.1.2 SOURCES

The sources of nitrogen oxides and nitrogen dioxide can be divided into two large group, which is natural sources and anthropogenic sources. Natural sources or also known as biogenic of nitrogen oxides can comes from the forest fires, atmospheric lightning discharge, and biogenic oxidation in soil containing nitrogen compound (Kindzierski et. al., 2007). The major contributor to the formation of nitrogen oxides and nitrogen dioxide is combustion processes, which mainly because of man-made activities, or also known as the anthropogenic emissions. These includes the combustion of fuel for vehicles, combustion of coal, oil and natural gas for industrial purposes, and the usage of electrical appliances for daily routine (CATC, 1999). Mostly, the gases that released through combustion are in the form of nitric oxide (NO), and some of it is already in the form of nitrogen dioxide (NO_2) but very small in amount. During combustion process, the nitrogen elements will react with air as an oxidant as shown in equation 2.

$$N_2 + O_2 \longrightarrow 2\ NO \qquad \text{(Eq. 2)}$$

Since the nitric oxide is chemically reactive, with the presence of sufficient oxygen, it will then react with oxygen again to form nitrogen dioxide as shown in equation 3.

$$2\ NO + O_2 \longrightarrow 2\ NO_2 \qquad \text{(Eq. 3)}$$

The nitrogen dioxide emission could be disintegrate back to nitric oxide in the presence of sufficient sunlight as shown in Eq. 4. This will lead to the formation of ozone and nitric acid as shown in Eq. 5.

$$NO_2 \longrightarrow NO + O\ (^3P) \qquad \text{(Eq. 4)}$$

$$O\ (^3P) + O_2 \longrightarrow O_3 \qquad \text{(Eq. 5)}$$

Nitrogen dioxide also could be formed from the reaction of nitric oxide with hydroperoxyl radicals (HO_2), alkylperoxy radicals (RO_2), and ozone (O_3) radicals as shown in Eq. 6, 7, and 8.

$$HO_2 + NO \longrightarrow NO_2 + HO \qquad \text{(Eq. 6)}$$

$$RO_2 + NO \longrightarrow NO_2 + RO \qquad \text{(Eq. 7)}$$

$$O_3 + NO \longrightarrow NO_2 + O_2 \qquad \text{(Eq. 8)}$$

Thus, by interpreting these equations, we can say that the more the fuel combustion occurs, the higher the concentration of nitrogen oxide and nitrogen dioxide are being emitted to the ambient air. Furthermore, the increase of both pollutants concentration in ambient air will eventually increase the formation of ozone in troposphere layer.

2.1.3 EFFECTS

The concerns on the direct effect of nitrogen oxides and nitrogen dioxide towards human health and environment had been highlighted since ages and there had been tremendous numbers of research done. Nitrogen dioxide is one of the most important pollutant due to its ability to directly affect human’s respiratory system. Direct exposure to ambient air containing nitrogen dioxide will cause airways irritation in the human respiratory system. Furthermore, respiratory symptoms such as coughing, wheezing, and difficulty in breathing will occur if exposed to nitrogen dioxide even for a short period of times. The higher the concentration of nitrogen dioxide in the ambient air, the higher the tendency of a person to get asthma, bronchitis, lungs infection, severe coughing, eye and throat irritation.

The emission of nitrogen dioxide to the ambient air will result in several major effects to the environment such as acid rain, eutrophication and haze. When rain fall occurs in area whereby the intensity of nitrogen dioxide in the ambient air is high, a nitrogen dioxide – water reaction will occur, which then leads to the formation of nitric acid. As a result, any structures or plants which in contact with the acid rain will be badly affected. Furthermore, the acid rain will cause the nitrogen element in bodies of water to be altered. Once the ratios of nitrogen to other elements in water bodies altered, it may induce changes in the growth of phytoplankton and sometimes generate unwanted organisms. This situation which known as eutrophication will cause death to other plants in the water as the oxygen content has depleted. Smog that produce from nitrogen dioxide will cause haze as the sunlight encounters tiny pollution particles in the air, which make the light to scattered and reduce the clarity of the air.

2.2 EFFECT OF METEOROLOGICAL CONDITIONS

Concentration of air pollutant in an area is highly affected by the meteorological conditions of the area. Meteorology can be define as the science of atmosphere and characteristics of the weather elements (Verma & Desai, 2008), and it becomes the major influence to the air pollutant concentration. Generally, the degree to which air pollutants discharged from various sources, concentrate into a particular area depends on meteorological conditions. There are several meteorological parameters that is really influence the concentration of air pollutant which are wind speed and direction, temperature, atmospheric stability, and mixing height. These parameters define the dispersion and transportation of air pollutant in particular area such as whether the pollutant is being diluted into the atmosphere or just simply concentrate onto the ground. Table 2.2.1 shows the influence of meteorological parameters towards the dispersion and transportation of air pollutant.

Table 2.2.1 : Effects of meteorological parameters towards air pollution

Meteorological Parameter	Effects on Air Pollution
Wind speed and direction	• The wind direction at a given time determines the general area into which a mass of gas or cloud of pollutant will move. • The wind speed specifies the rapidness of the pollutant will advance into the area. • Wind control the drift and diffusion of pollutants discharge near the ground level. The more the wind speed and direction at the point of pollutant discharge, the faster the pollutant to be carried away from the source. This will cause the pollutant to be dispersed and the pollutant's concentration will decrease as it is diluted with the greater volume of air.

Atmospheric stability and Temperature	• Atmospheric stability affects the vertical movements of air. Generally, the larger the extent of vertical mixing, the better the air quality is. • Atmospheric stability is related to the variation of temperature and pressure with respect to altitude. As altitude increases, atmospheric pressure and air temperature decreases, which create a variation of air parcel with less dense to more dense air parcel. This will result in warm air rises and cools, while cool air descends and warms. The phenomena of air rises and falls influence the vertical dispersion of air pollutant. • When air temperature increases with altitude, an inversion occurs whereby warm air overlying cooler air. This situation will bring air pollutant to descend and trapped near the ground. Inversion is related to the pollutant concentration in the ambient air as it inhibits vertical movements and dispersion of air pollutant.
Mixing height	• Mixing height refers to the height from above ground surface to which air pollutant will extend through the action of the atmospheric turbulence. Usually, mixing height is determined by the observation of the atmospheric pressure. • Air pollutant tend to rise as it is warmer that the ambient temperature. However, once it becomes colder than the ambient

	temperature, it will slow down and stop. The height at which the air pollutant stop to rise from ground surface determine the mixing height. • Mixing height also refers to the height from ground surface to the inversion layer. Colder layer beneath warm layer create a stable temperature profile that restricts vertical mixing that cause pollutant to stagnant and do not dissipate. Hence, mixing height determines the vertical distance in which the pollutant is trapped.

2.4 CRITICAL REVIEW

According to regulatory agency called CAI-Asia. (2006), the major source of air pollution in Malaysia is the emissions from mobile sources which contributing at least 70% to 75% of the total air pollution, while emissions from stationary sources such as factories and industrial activities generally contribute 20% to 25% of the total air pollution. They reported that transport sector accounted for the majority of nitrogen oxides emissions in Malaysia and hence becomes the main air pollutant in the country. Malaysia's high-quality transportation infrastructure and its relatively high economic status have encouraged private motorized transportation to be regarded as the primary mode of transportation in most cities in Malaysia (CAI-Asia, 2006).

The emission of nitrogen oxides and nitrogen dioxide to the ambient air will eventually cause a tremendous effect to the health of human being. A research done by Jamal et. al. (2004) on the health impact and risk assessment of urban air pollution in Klang Valley, Malaysia, stated that the nitric acid and related particles formed when nitrogen oxides reach with ammonia, moisture, and other compound, have human health implications. The implications include effects on respiratory system, damage to lung tissue, and premature death. Moreover, it can worsen respiratory diseases such as chronic obstructive pulmonary diseases (COPD), which include emphysema and bronchitis as well as aggravate existing heart disease (Jamal et. al., 2004).

There are several researches done regarding the effects on air pollutant with respect to the meteorological conditions. Study done by Kim et. al. (2015) which is the effect of meteorological conditions on the transport of air pollutant in a roadway area proves that the concentration of specific air pollutant that emitted from vehicular near the road is ten times higher than that at two hundred meters away from the road and the average concentrations of air pollutant is increasing with respect to the increasing of traffic volume. This clearly shows that the influence of traffic volume is very significant and contribute the most in the concentration of air pollutants.

Apart from that, research done by Verma et. al. (2008) which is the influence of meteorological conditions on the dispersion of air pollutant in Surat City found that whenever the ambient air temperature is high, the degree to which the air pollutant dispersed is increase, which then results to a better air quality. Based on the study, three meteorological parameters are being consider which are wind speed, ambient air temperature, and atmospheric stability, and the most influential parameter to the distribution of air pollutant in atmosphere is wind speed.

However, there are some cases whereby the meteorological conditions can give adverse impact to neighbouring area. According to Zhang et. al. (2015), wind direction play an important role in the transportation of air pollution as it may bring the air pollution to neighbouring area, and it is proven when they found out that the concentration of particular air pollutant in Beijing is increase due to east wind that brought the air pollutant from another area where it is emitted. Besides, they also found that the air pollution concentration is at highest in winter season and is at its lowest in summer season due to the seasonal variation of the atmospheric boundary layer, whereby lower boundary layer occurs during winter and higher boundary layer occurs during summer. This clearly shows the influence of ambient temperature to the vertical movement of air pollution.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

To conduct this study, a well-planned methodology was constructed which covers from the beginning until the end of the study. The method was selected wisely so that it can be executed in the planned timeframe and within the scope of study. To ensure that the objective is achieved, several stages were constructed starting with gathering information regarding the Tronoh area, followed by air pollution monitoring using Aeroqual 60 Station, and lastly analysis on the concentration of nitrogen oxides and nitrogen dioxide with respect to the traffic volume and industrial activities as well as meteorological parameters. The air pollution monitoring was done in three different location within Tronoh area and it focuses on the emission from industries and vehicles. All data collected were analysed by using time series model analysis so that the trend of nitrogen oxides and nitrogen dioxide with respect to meteorological parameters and traffic volume can be observed with uniform intervals.

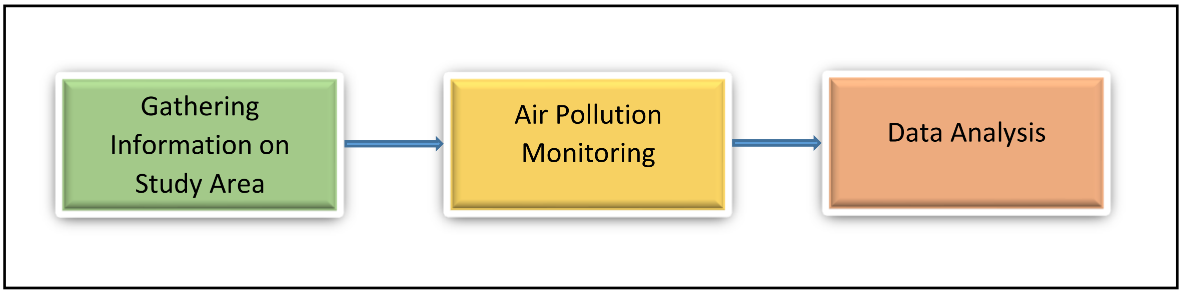


Figure 3.1 : Flowchart of research methodology.

3.2 STUDY AREA

Tronoh is a small town located at south-west of the main town, which is Ipoh. Tronoh town covers an area of approximately 3.5 km^2 with estimated population of 10 thousand. This small town consists of mainly a residential areas, commercial estates, and a few manufacturing factories. The main road is used to link between Ipoh and Lumut town as a bypass. This indicate that the rate of vehicles either cars, trucks, or busses is very significant.

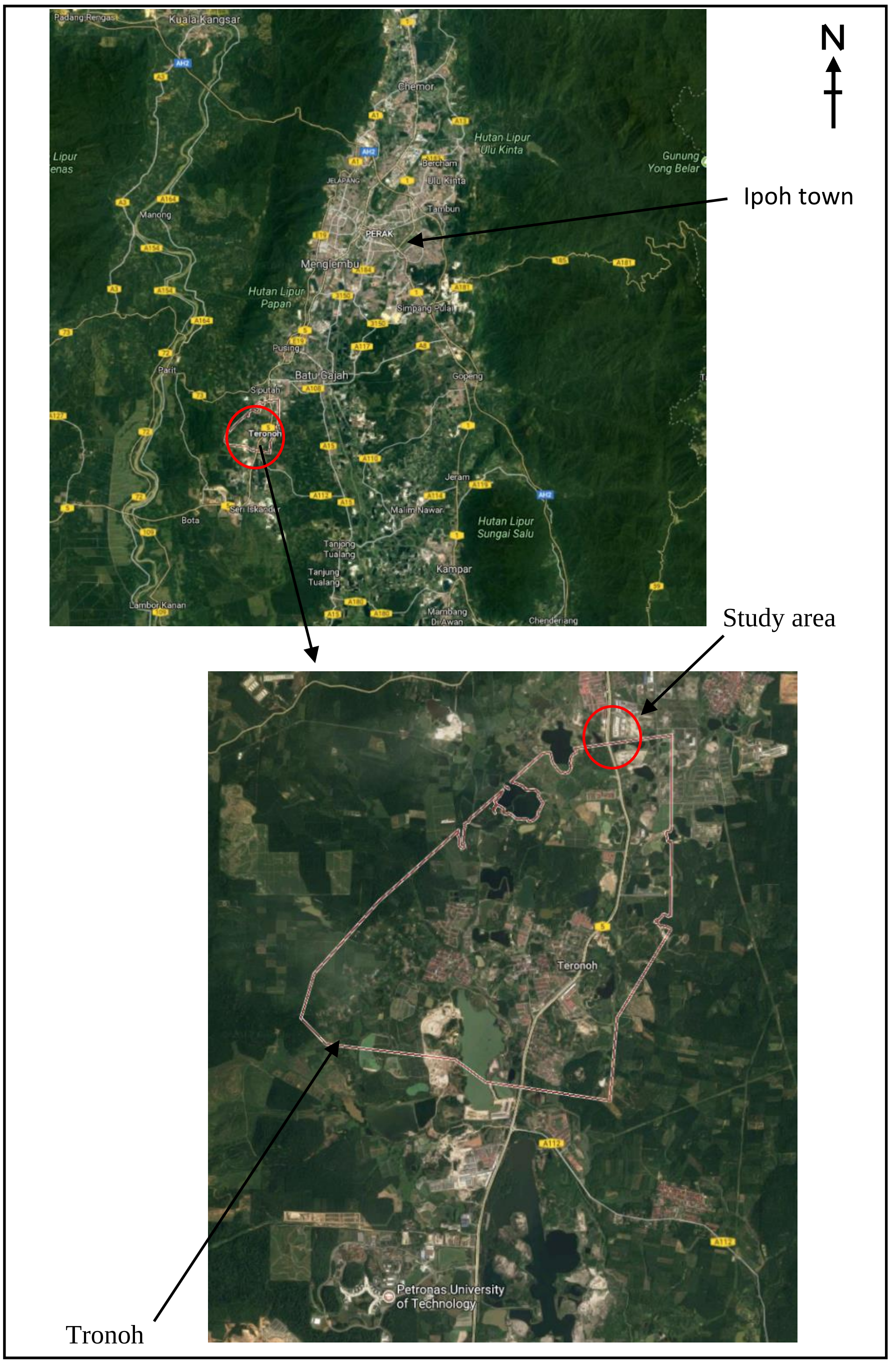


Figure 3.2.1 : Map of Study Area Location

The air pollution monitoring was conducted at three different point located in Tronoh town where it is reported that there is occurrence of air pollution. The study area consists of mainly a roadway with a flyover that link Ipoh city and Tronoh town, residential areas, commercial estates, and a few manufacturing factories. The location of air pollution monitoring was selected so that it covered the whole area which affected by the pollutants. Aeroqual AQM 60 Station was placed and installed at the selected point location for 12 hours to record the concentration of nitrogen oxides and nitrogen dioxide as well as the ambient temperature and relative humidity.

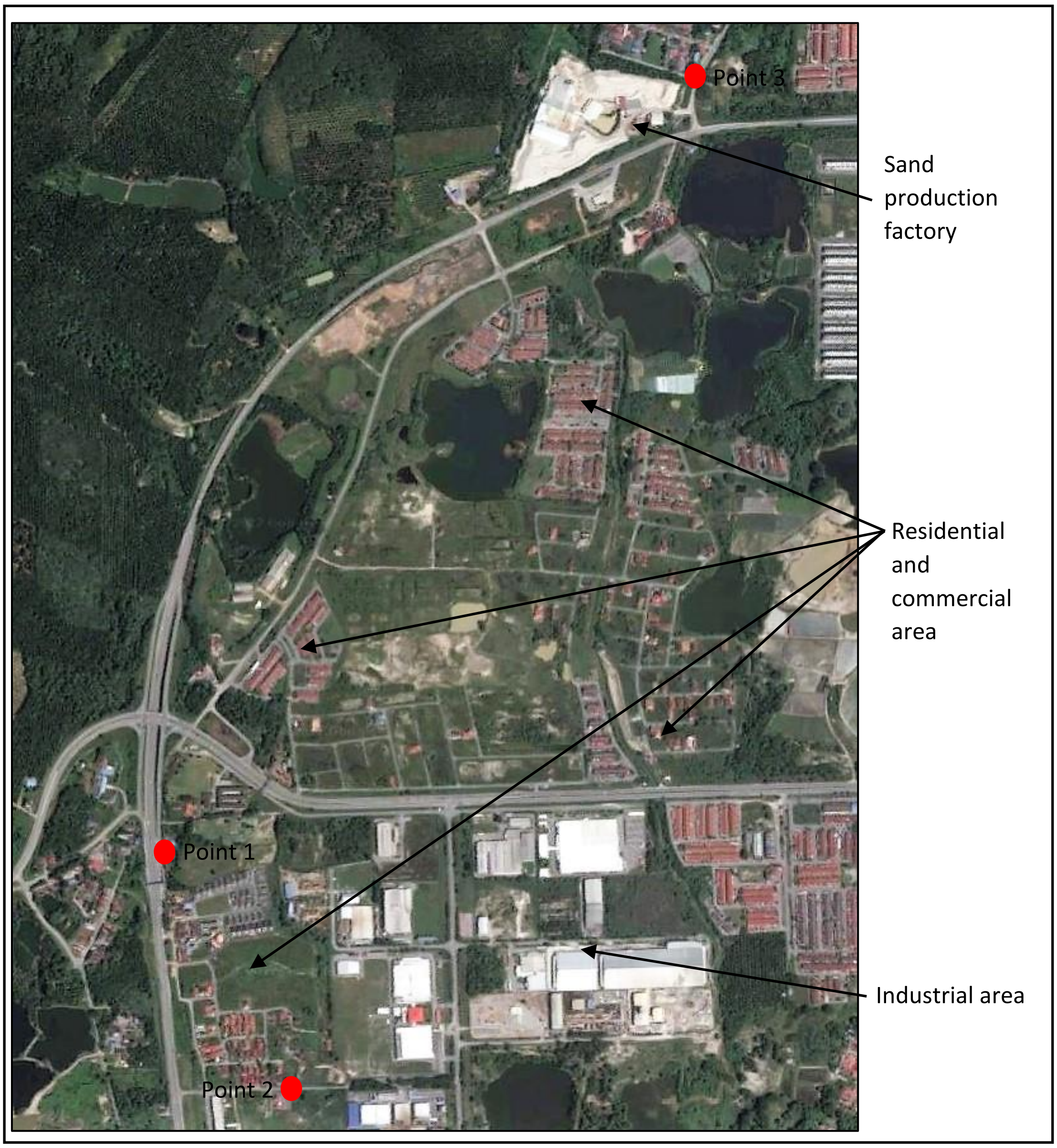


Figure 3.2.2 : Air pollution monitoring location.

3.3 DATA COLLECTION

3.3.1 POLLUTANT CONCENTRATION

In this study, all the data collection and sampling was conducted using Aeroqual AQM 60 Station. The station was set up and installed in three different locations within the study area to record the concentration of nitrogen oxides, nitrogen dioxide, temperature, and relative humidity. All these data were recorded throughout a sampling period of 6 days within 3 weeks and the readings were taken by the station at a constant interval time of 2 minutes interval for 12 hours per day starting from 06:00 a.m until 06:00 p.m. The air pollution was sampled for 1 day in weekdays and 1 day in weekend for every location. The number of vehicles was recorded manually in one monitoring location to correlate the effect of traffic to the concentration of nitrogen oxides and nitrogen dioxide.

The changes of air pollutants concentration was analyse in relation with the number of vehicles, ambient temperature, and relative humidity to know the real-time trend of the air pollutants throughout the day of sampling. By doing so, the correlation of the traffic volume and meteorological parameters towards the concentration of nitrogen oxides and nitrogen dioxide can be analysed more precise and accurate.

3.3.2 EQUIPMENT

Aeroqual AQM 60 Station is a compact air quality monitoring equipment which designed for low cost and easy deployment equipment (Aeroqual, 2010). Aeroqual AQM 60 Station is a flexible instrument platform configuration which require less maintenance, small footprint, and easy to handle. This equipment is suitable for monitoring continuous time range for air profiling, trending as well as air quality assessment. The built-in sensors located inside the station is used to measure major air pollutants including ozone (O_3), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), volatile organic compounds (VOC), hydrogen sulphide (H_2S), non-methane hydrocarbons (NMHC), carbon dioxide (CO_2), particulate matter (PM_{10}, $PM_{2.5}$). Aeroqual AQM 60 Station is also designed to measure common meteorological parameters such as temperature, relative humidity, wind speed and direction.

Typical applications of Aeroqual AQM 60 Station includes :

- Urban monitoring – Air quality of local area, Environment Impact Assessment
- Road monitoring – Road and weather information systems (RWIS), Motorways and highways
- Perimeter monitoring – Construction site, Point sources pollution emitters, Power generation plants, Waste sites and landfills
- Open space monitoring – Forest, Natural Environment Studies, Natural parks and reserves

The station consists of several main components :

- Outside components – TSP Inlet, Air Sampling Inlet, Solar Radiation Shields, External USB Port, Thermal Management System (TMS), Power module
- Enclose components – Gas Treatment Module, Gas Modules, Control Module, Particle Monitor, PM Flow Module, Communication Module, External USB Port, Calibration tubes, Wire connectors.

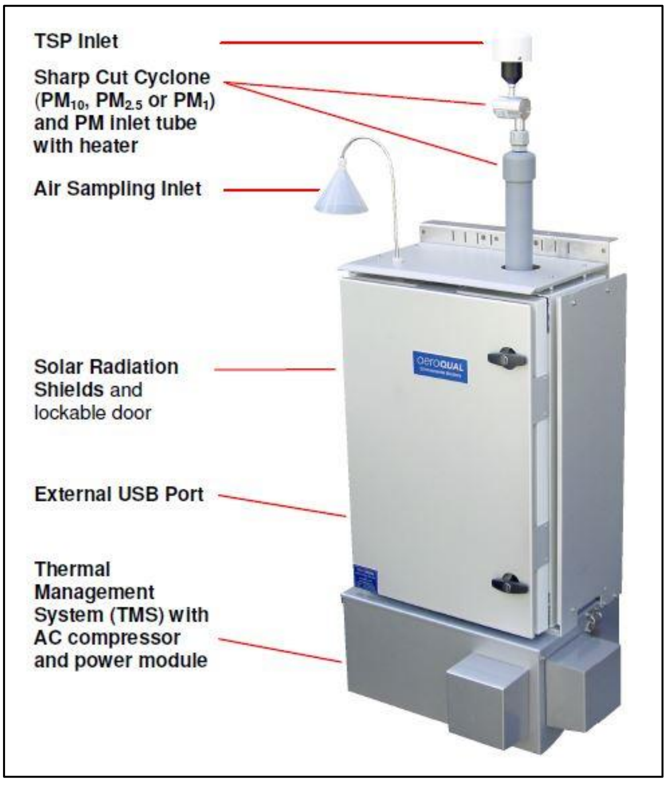


Figure 3.3.2.1 : Aeroqual AQM 60 Station outside components.

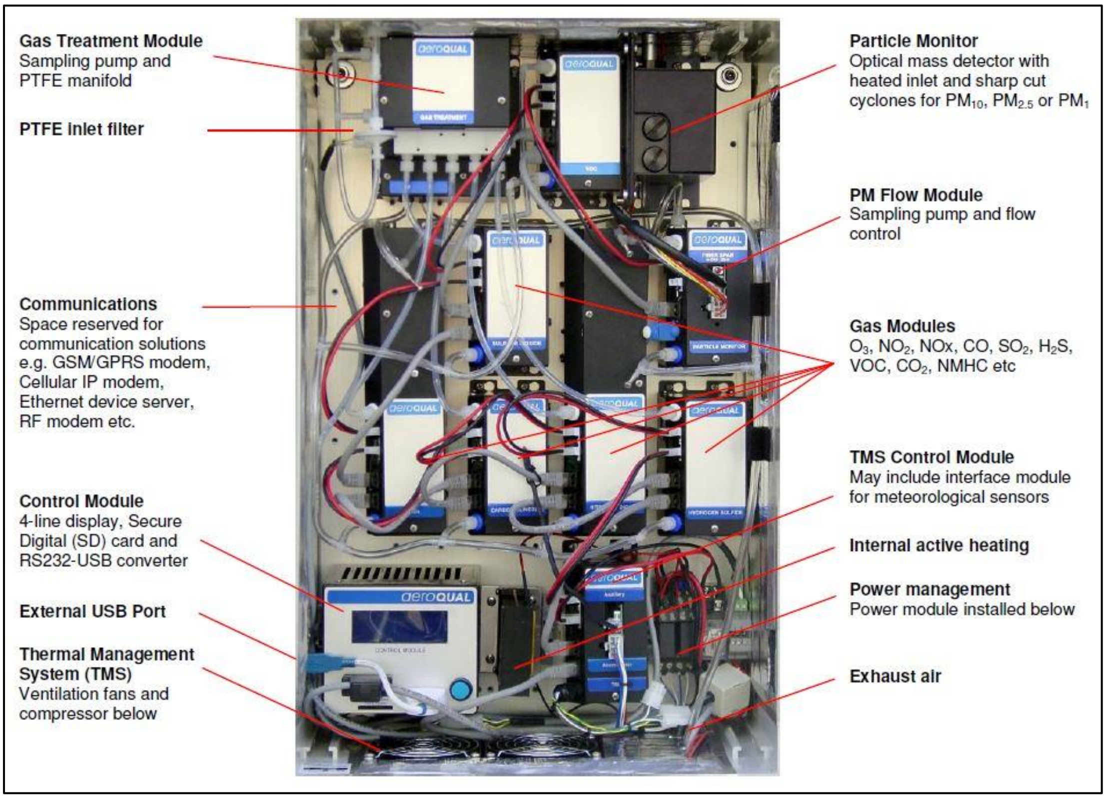


Figure 3.3.2.2 : Aeroqual AQM 60 Station enclose components.

3.4 DATA ANALYSIS

Data that is collected from the monitoring activity using Aeroqual AQM 60 Station was tabulated in a table form using Microsoft Office Excel software. All data was arranged properly and analysed using graphical approach based on the pollutants concentration with respect to meteorological parameters, traffic volume and sampling time intervals. As mentioned earlier, this study will focus on two air pollutants which are nitrogen oxides and nitrogen dioxide. The data collected was also analysed using time series analysis to determine the correlation between one or more variables. By using the time series model, the trend of pollutant concentration with respect to meteorological parameters and traffic can be observed. For first monitoring point location, the numbers of vehicles that passing by including commercial car, motorbike, lorry, truck, and bus were recorded manually and then converted to passenger car unit (PCU) to be a unified factor. Conversion was done using formula as shown below.

$$\textit{Passenger Car Unit, PCU} = Car + (0.33\times Motorbike) + (1.75\times Lorry) + (2.25\times Truck) + (2.25\times Bus)$$

3.5 GANTT CHART

To ensure that this research is done on track successfully, a gantt chart was tabulated. The gantt chart comprises of the project activities, targeted weeks to complete particular works, and research process.

Table 3.5.1 : Final Year Project 1 Gantt Chart

Project activity / Work	**Week**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Project title selection	■													
Preliminary research work		■												
Literature review		■	■	■	■									
Submission of Extended Proposal						■ ●								
Revised on Literature Review							■	■						
Research work									■					
Proposal defense									■	●				
Project work											■	■	■	
Site Visit												■		
Draft Report													■	
Submission of Interim Report														■ ●

● Key Milestone

Table 3.5.2 : Final Year Project 2 Gantt Chart

Project activity / Work	**Week**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Data Collection & Sampling	■	■												
Submission of Progress Report		●												
Data Analysis			■	■	■									
Data Modelling					■	■	■							
Conclusion & Recommendation								■	■					
Draft Final Report										■	■			
Submission of Project Dissertation (soft bound)												●		
Submission of Technical Paper												●		
Viva Presentation													●	
Submission of Project Dissertation (hard bound)														●

● Key Milestone

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter, the data obtained from the air monitoring activities was analysed. The air monitoring activity was carried out for 2 days in every 3 weeks for three different sampling locations starting from 23th October 2017 until 13th November 2017. All three sampling locations was selected within the perimeter of study area, which is in Tronoh area. Aeroqual AQM 60 Station was used for the data collection for 12 hours with the time interval of 2 minutes starting from 6 a.m until 6 p.m.

The data obtained from the air monitoring activities was tabulated using Microsoft Office Excel in terms of hourly average of air pollutant concentration. Time series analysis was used to analyse the trends of the concentration of nitrogen oxides and nitrogen dioxide over time. Moreover, the correlation of air pollutant's concentration with traffic and meteorological parameters such as temperature and relative humidity was analyse to see the relationship. The analysis of the result is done according to two categories which are analysis based on traffic volume and analysis based on industrial activities.

4.2 MONITORING POINT 1 – ROAD SIDE

The first monitoring location was conducted mainly to focus on the emission from vehicles during weekday and weekend. The air monitoring station was placed beside the main road to detect the occurrence of nitrogen dioxide and nitrogen oxides. The numbers of vehicles that passing by including commercial car, motorbike, lorry, truck, and bus were recorded manually and then converted to passenger car unit (PCU) to be a unified factor. Conversion was done using formula as shown below.

$$\text{Passenger Car Unit, } PCU = Car + (0.33 \times Motorbike) + (1.75 \times Lorry) + (2.25 \times Truck) + (2.25 \times Bus)$$

The ambient temperature and relative humidity were also recorded by Aeroqual AQM 60 Station and presented using time series analysis to see the effect of both meteorological parameters towards the concentration of nitrogen dioxide and nitrogen oxides. The concentration of nitrogen dioxide and nitrogen oxides were presented based on peak hour because these hour shows the highest traffic volume and emit the highest amount of pollutants. The peak hour was selected based on the highest PCU between 06:00 a.m to 06:00 p.m.

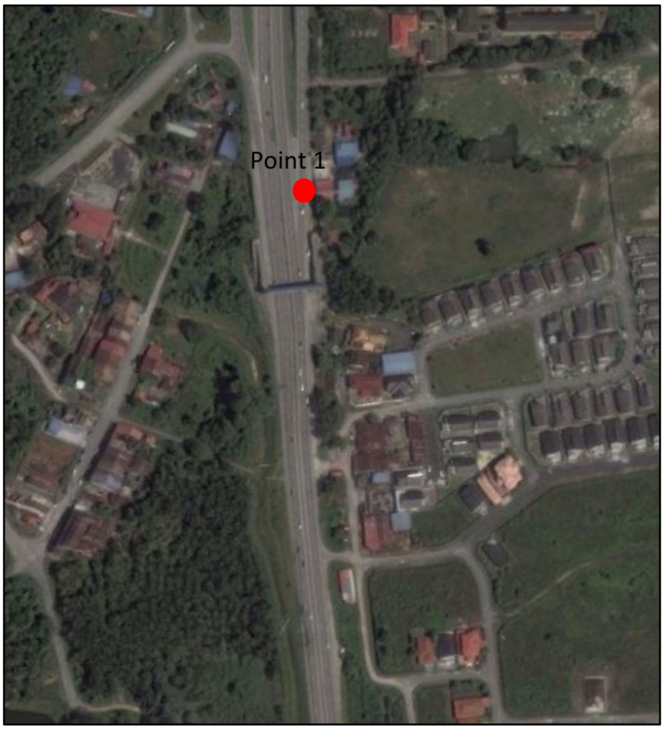


Figure 4.2 : Location of Point 1

4.2.1 CORRELATION OF POLLUTANTS WITH TRAFFIC VOLUME

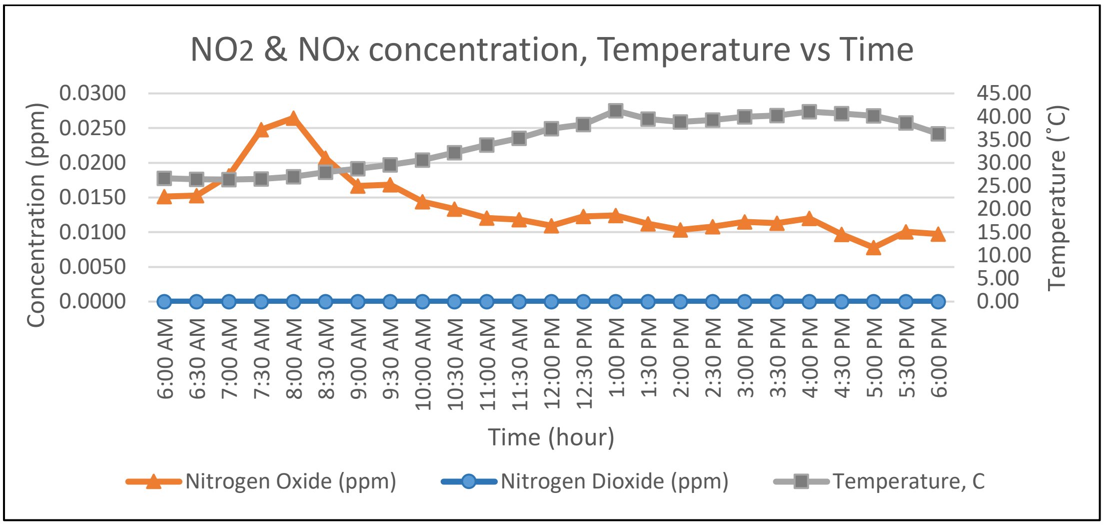
Peak hours	Weekday			Weekend		
	NO2 (ppm)	NOx (ppm)	PCU	NO2 (ppm)	NOx (ppm)	PCU
6.00 - 8.00 a.m	0.0	0.0177	128	0.0025	0.0050	90.8
12.00 - 2.00 p.m	0.0	0.0114	225	0.0003	0.0021	174
4.00 - 6.00 p.m	0.0	0.0083	229	0.0013	0.0030	111.4

Table 4.2.1 : Pollutants concentration and PCU for peak hour.

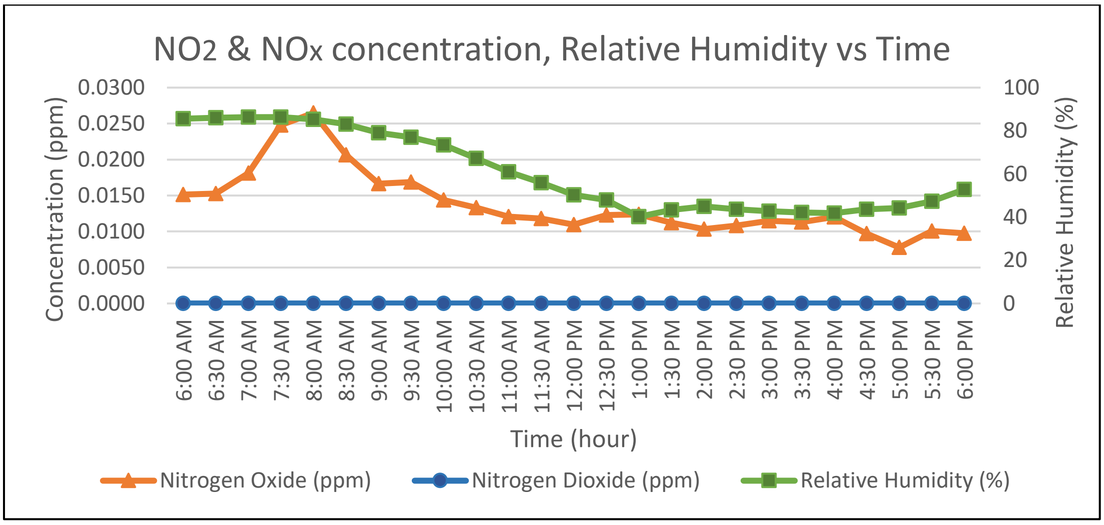
Based on Table 4.2.1, there are three peak hours for weekday and weekend which are 06:00 a.m to 08:00 a.m, 12:00 a.m to 02:00 p.m, and 04:00 p.m to 06:00 p.m. During weekday, the traffic flow was high at these hours because people start to go to their respective working place at morning hours, having their lunch at noon hours, and get back to their home at evening hours. For weekend, the traffic flow shows a slightly different trend compared to weekday whereby the traffic flow is low and had almost the same volume during peak and regular hours. This is due to low human activities and movement during weekend as they perhaps spend most of their time in home. These situations whereby the differences in traffic flow during weekday and weekend is significant, create a significant difference in the amount of nitrogen dioxide and nitrogen oxides released to the ambient air.

The concentration of nitrogen oxides during weekday is much higher compared to the concentration of nitrogen oxides during weekend because of heavy traffic volume and people's movement during weekday. As for the nitrogen dioxide, there is no occurrence during weekday as it had been converted to ground level ozone and nitrogen oxide when it reacts with direct sunlight. There is slight occurrence of nitrogen dioxide during weekend due to rain, which prevent it from converted to ground level ozone and nitrogen oxide as rain prevent the direct sunlight reaction. In short, it can be said that the concentration of nitrogen dioxide and nitrogen oxides is depending on the traffic volume, because when the traffic volume is increase, the concentration of pollutants is increase as more amount of pollutants emitted to the ambient air.

4.2.2 CORRELATION OF POLLUTANTS WITH METEOROLOGICAL PARAMETERS



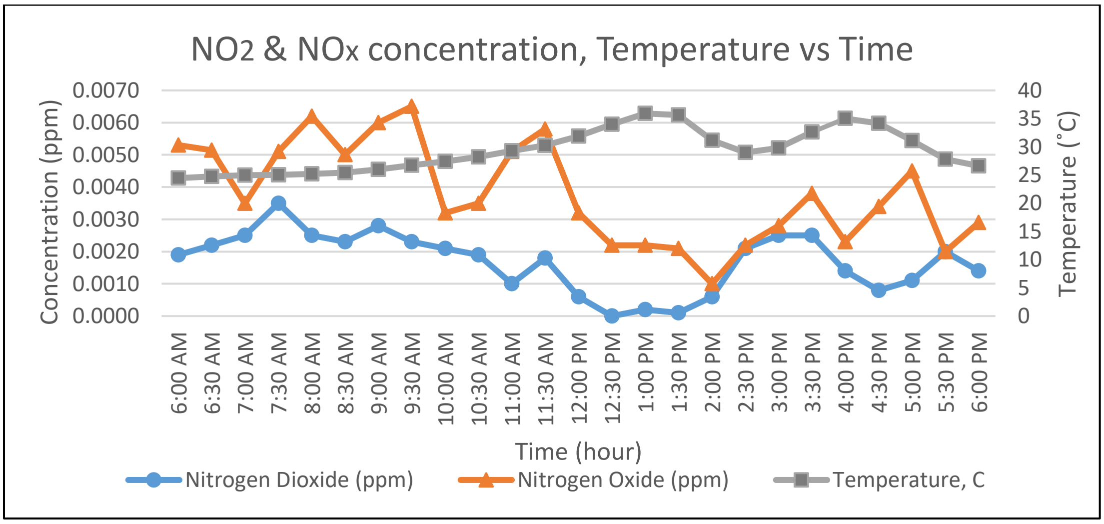
Graph 4.2.2.1 : Correlation between pollutant concentration and temperature during weekday.



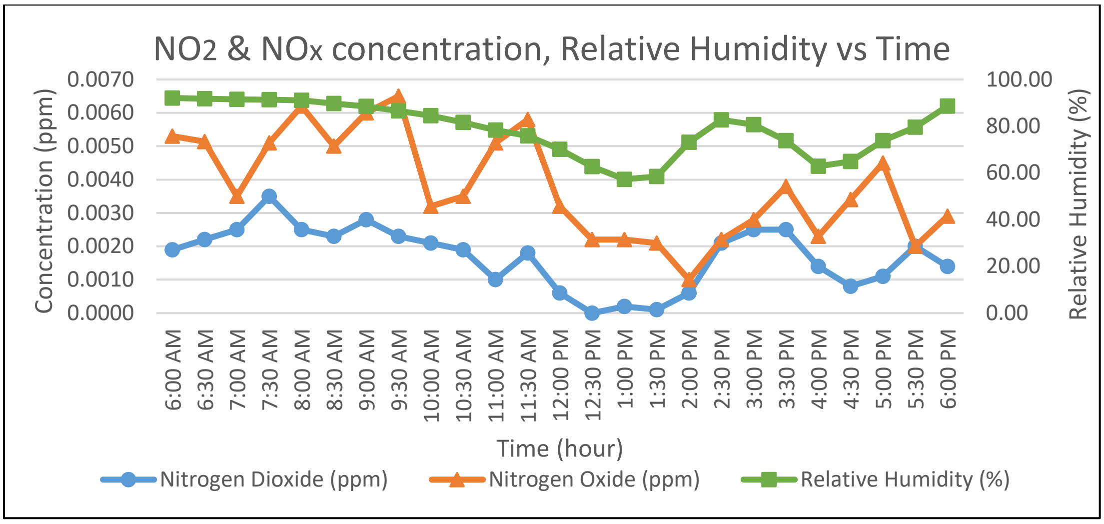
Graph 4.2.2.2 : Correlation between pollutant concentration and relative humidity during weekday.

Based on Graph 4.2.2.1, it can be seen that the ambient temperature started to increase consistently from 06:00 a.m until it reaches highest value of 41.29˚C at 01:00 p.m before it started constantly until 06:00 p.m. However, the trend of relative humidity is inversely correlated to the ambient temperature as shown in Graph 4.2.2.2. This is because the ratio of water vapour in the air decrease as the ambient temperature increase. The surrounding relative humidity shows highest value in the morning hours starting from 06:00 a.m until 08:00 a.m with value of 86%. As the ambient temperature increase, the relative humidity started to decrease until it reaches lowest point at 01:00 p.m with 40% and started to constant until 06:00 p.m.

Based on Graph 4.2.2.2, the concentration of nitrogen oxides somehow follows the trend of relative humidity starting from 08:30 a.m until 06.00 p.m and it decreases when relative humidity decrease. This is due to the amount of pollutant parcel that the water vapour can hold. The concentration of nitrogen oxides increases drastically from 07:00 a.m to 08:00 a.m and reaches its highest point with 0.0265 ppm due to emission from trucks that stop near the monitoring station. However, there is no occurrence of nitrogen dioxide throughout the period as it had been converted to ground level ozone and nitrogen oxide due to reaction with direct sunlight.



Graph 4.2.2.3 : Correlation between pollutant concentration and temperature during weekend.



Graph 4.2.2.4 : Correlation between pollutant concentration and relative humidity during weekend.

Based on Graph 4.2.2.3, the ambient temperature during weekend is slightly different compared to the temperature during weekday whereby the temperature fluctuates at 01:30 p.m until 06:00 p.m due to rain. This situation causes the relative humidity to fluctuate at the same hours as shown in Graph 4.2.2.4 because as the rain falls, it causes the ambient temperature to decrease and make the water vapour increase. Both parameters show inverse relationship from morning to noon period as it correlated to each other.

From both graph, it can be said that the concentration of nitrogen oxides is fluctuating throughout the period and is slightly follows the trend of relative humidity from 11:30 a.m until 06:00 p.m. The fluctuation could be due to the nonconsistency of traffic flow throughout the period. The occurrence of nitrogen dioxide during weekend is due to less direct sunlight reaction over the period. The average temperature during weekend is low compared to the average temperature during weekday, and there is rainfall observed throughout the period. This indicates that the weekend weather is moist, and it create a less direct sunlight reaction, which prevent the conversion of nitrogen dioxide to ground level ozone and nitrogen oxide.

4.3 MONITORING POINT 2 – INDUSTRIAL AREA

The second monitoring location was conducted mainly to focus on the emission from industrial activities. The air monitoring station was placed about 100 meters from the industrial area and between industrial and residential area. After conducting an observation on the area, there were several manufacturing factories that possibly contribute to the emission of air pollutants into the ambient air of Tronoh. Table 4.3 summarized several industries which is believed to have emit air pollutants and their activities.

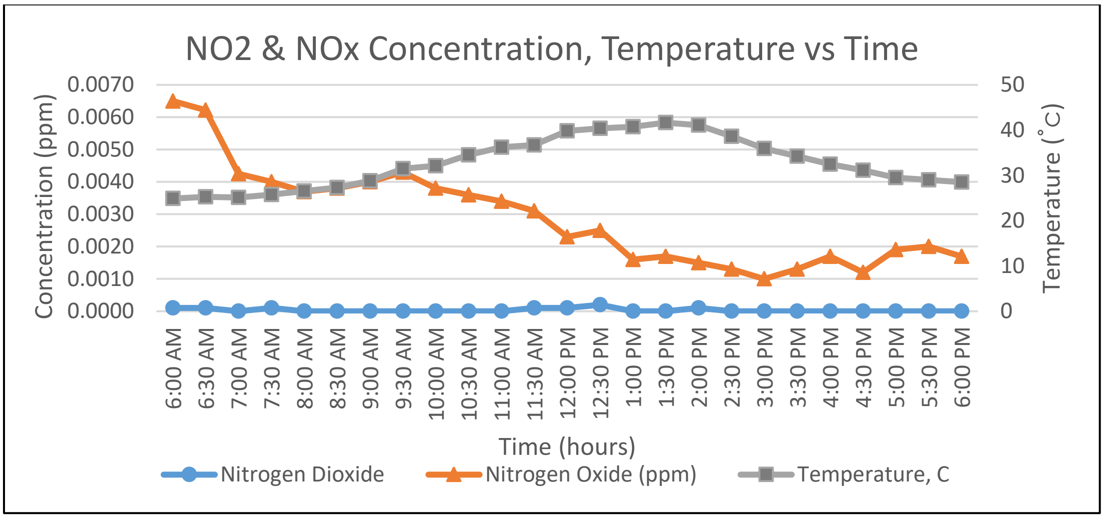
Manufacturing Industry	Activities
Manufacturing Industry 1	Manufacture electrical and electronic components
Manufacturing Industry 2	Manufacture plastic and natural rubber
Manufacturing Industry 3	Manufacture infrastructural pre-cast concrete components
Manufacturing Industry 4	Manufacture contract filling can and bottle for beverages
Manufacturing Industry 5	Manufacture industrial air filter facilities
Manufacturing Industry 6	Manufacture latex based product for dental and health application
Manufacturing Industry 7	Manufacture ceramic and tiles

Table 4.3 : Manufacturing Industry in Tronoh.

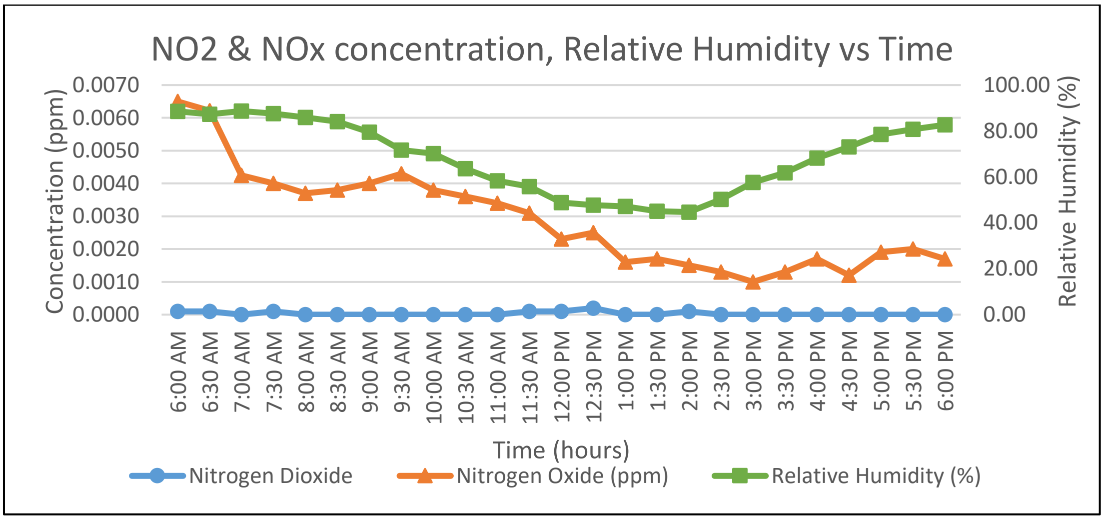
These manufacturing industries are most likely contributing to the air pollutants emission due to its activities. Same data were recorded for this monitoring location except for traffic volume as this point only focuses on the emission from industrial activities. The monitoring activity was done for weekday and weekend. The concentration of nitrogen oxides and nitrogen dioxide was plotted with respect to time starting from 06:00 a.m until 06:00 p.m. The correlation between the air pollutants concentration with ambient temperature and relative humidity was analysed to study the influence of meteorological parameters to the air pollutants.

Figure 4.2 : Location of Point 2

4.3.1 CORRELATION OF AIR POLLUTANTS WITH METEOROLOGICAL PARAMETERS



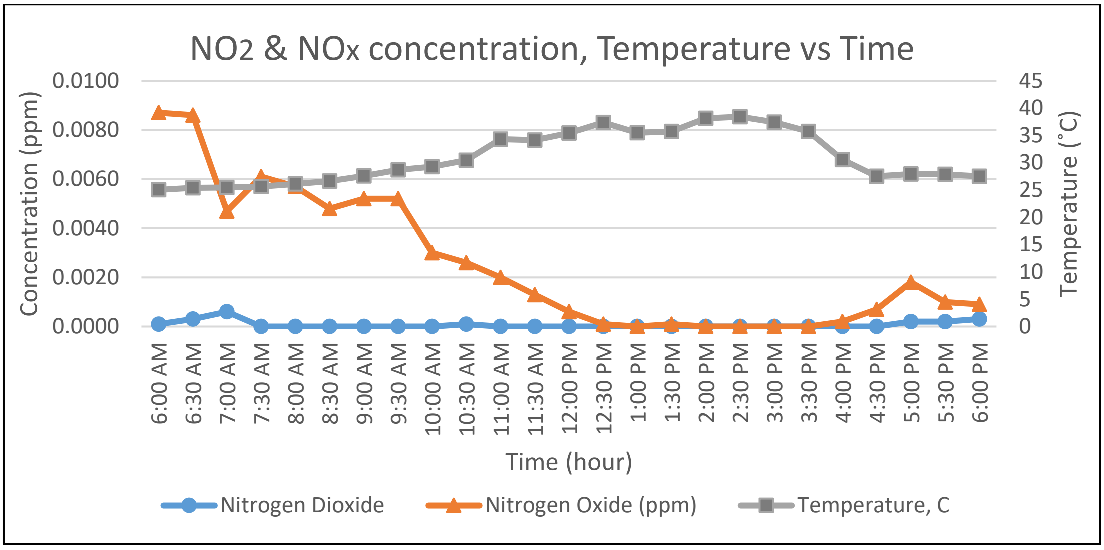
Graph 4.3.1.1 : Correlation between pollutant concentration and temperature during weekday.



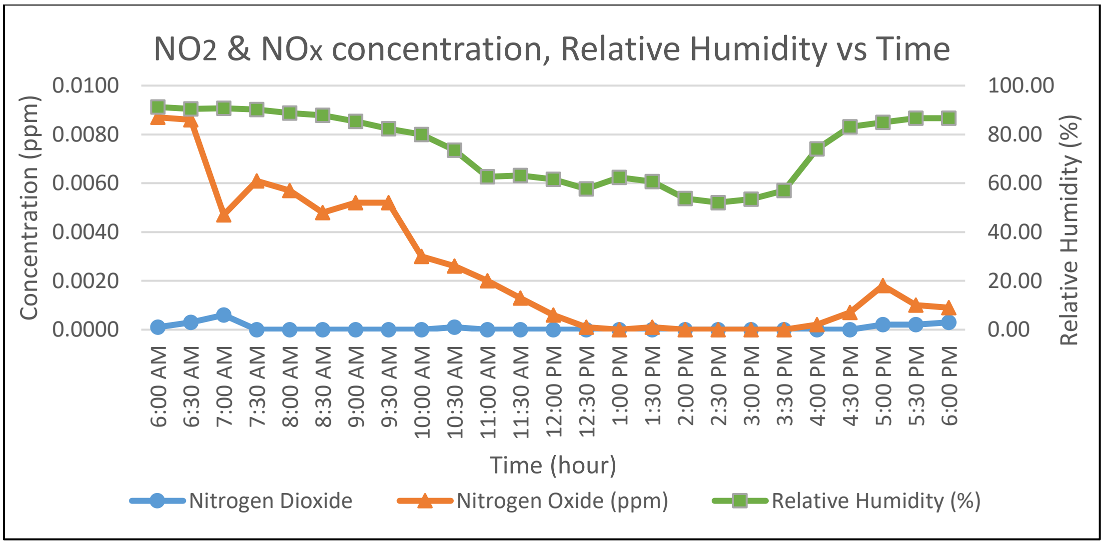
Graph 4.3.1.2 : Correlation between pollutant concentration and relative humidity during weekday.

Based on both graphs, it can be said that the manufacturing industries did not contribute to the emission of nitrogen oxides and nitrogen dioxide during the industrial operational period because the concentration of both pollutants is very low and it might be because of emission from vehicles that passing near the air monitoring station. Based on observation, all these manufacturing industries had almost the same operational period which is typically starting from 08:00 a.m and end at 05:00 p.m. The highest concentration of nitrogen dioxide was 0.0065 ppm at 06:00 a.m when it started to fluctuate and drop consistently until it reaches the lowest point at 03.00 p.m with 0.001 ppm. The concentration of nitrogen dioxide did not show any correlation with the industry operational hours, whereby the concentration supposedly reaches its highest value during the operational hours. This situation indicates that the main sources of nitrogen oxides may come from vehicles.

From Graph 4.3.1.1, it can be seen that the ambient temperature is constantly increasing starting from 06.00 a.m until it reaches highest temperature at 01:30 p.m with 41.65˚C , and after that it decrease constantly until 06:00 p.m. The surrounding relative humidity shows inverse correlation with the temperature as shown in Graph 4.3.1.2 as ratio of water vapour in the air start to decrease when temperature increase. The concentration of nitrogen oxides somehow shows a significant correlation with relative humidity. From Graph 4.3.1.2, as the relative humidity decrease, the concentration of nitrogen oxides decreases, and vice versa. This indicates that the fluctuation of nitrogen oxides concentration was caused by temperature and relative humidity. However, there were very little occurrence of nitrogen dioxide because only small portion of nitrogen oxide were converted to nitrogen dioxide when it reacts with oxygen. Some of the nitrogen dioxide may be converted to ground level ozone and recycled back to become nitrogen oxides when it reacts with direct sunlight.



Graph 4.3.1.3 : Correlation between pollutant concentration and temperature during weekend.



Graph 4.3.1.4 : Correlation between pollutant concentration and relative humidity during weekend.

On weekend, the trend of both pollutants concentration is nearly the same during weekday. As for weekend, there is no emission from the manufacturing industries because they were not operated, and this situation create less traffic volume as weekend is a holiday and not a working day. The less traffic volume had brought the nitrogen oxides concentration to dropped nearly to 0 ppm starting from 12:00 p.m until 04:00 p.m as shown in both graphs. The concentration of nitrogen oxides shows a slight fluctuation in the morning period due to the residential activities near the air monitoring station. However, there were very little occurrence of nitrogen dioxide because only small portion of nitrogen oxide were converted to nitrogen dioxide when it reacts with oxygen. Some of the nitrogen dioxide may be converted to ground level ozone and recycled back to become nitrogen oxides when it reacts with direct sunlight.

From both graphs, it can be seen that the trend of ambient temperature and relative humidity seems to have the same trend during weekday, except the sudden changes at 03:30 p.m to 04:30 p.m due to rainfall. When rain falls, the surrounding temperature will decrease as the amount of water vapour in the air increase, and as a result the relative humidity will increase. The trend of nitrogen oxides concentration tends to follow the trend of relative humidity due to the dependency of water vapour to hold pollutant parcel with it. The higher the ratio of water vapour in the ambient air, the higher the relative humidity, and this indicates that more air pollutant parcel that the water vapour can hold.

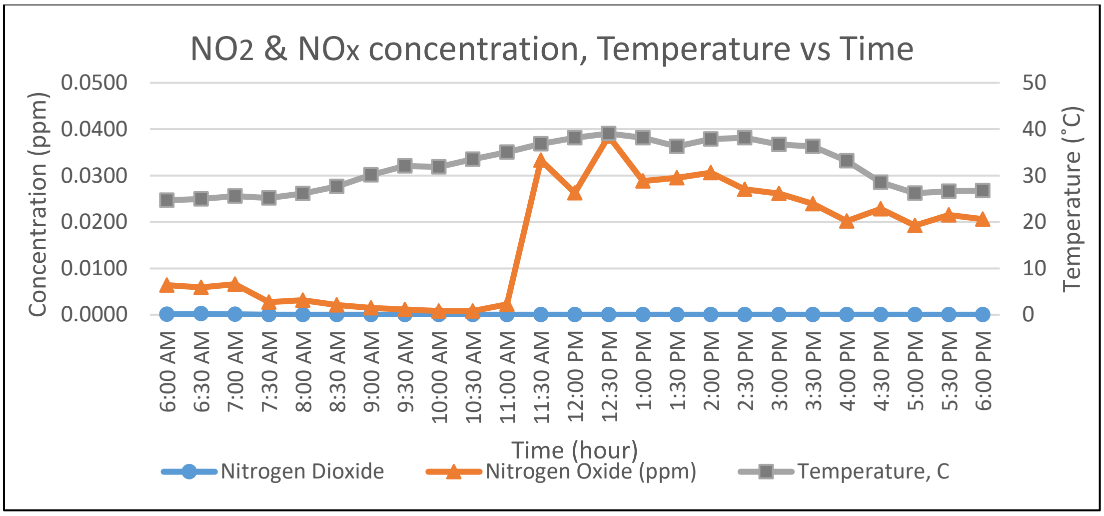
4.4 MONITORING POINT 3 – INDUSTRIAL AREA

The third monitoring location was conducted mainly to focus on the emission from industrial activities. For this particular point location, only one industry that was focused on. The air monitoring station was placed about 50 meters away from the industry and the point located in between the industry and residential area. After conducting an observation in the area, it is found that the industry is basically a batching plant for sand production. The main activity that this industry does include sand processing, manufacturing, and delivering. The emission of air pollutants may come from this industry as it occupies large area and produce big amount of manufactured sand in one time.

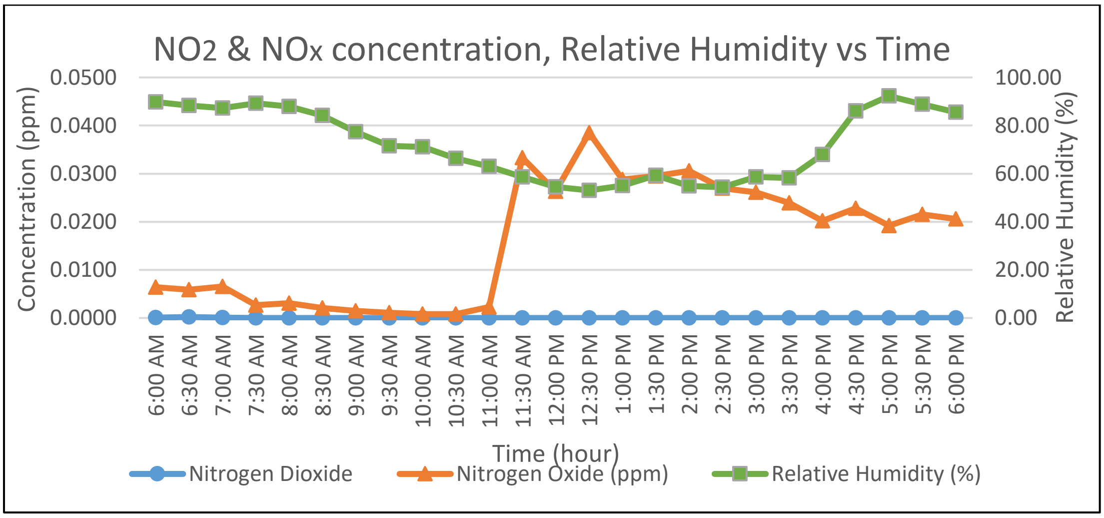
The monitoring period was done exactly the same as in point location 2 whereby the monitoring was done for 1 day in weekday and 1 day in weekend. The monitoring activity starts at 06:00 a.m until 06:00 p.m. The concentration of nitrogen oxides and nitrogen dioxide, ambient temperature, and relative humidity were recorded using the air monitoring station. The analysis was done based on the pollutants trend towards the ambient temperature and relative humidity to see the correlation.

Figure 4.4 : Location for Point 3

4.4.1 CORRELATION OF POLLUTANT WITH METEOROLOGICAL PARAMETERS



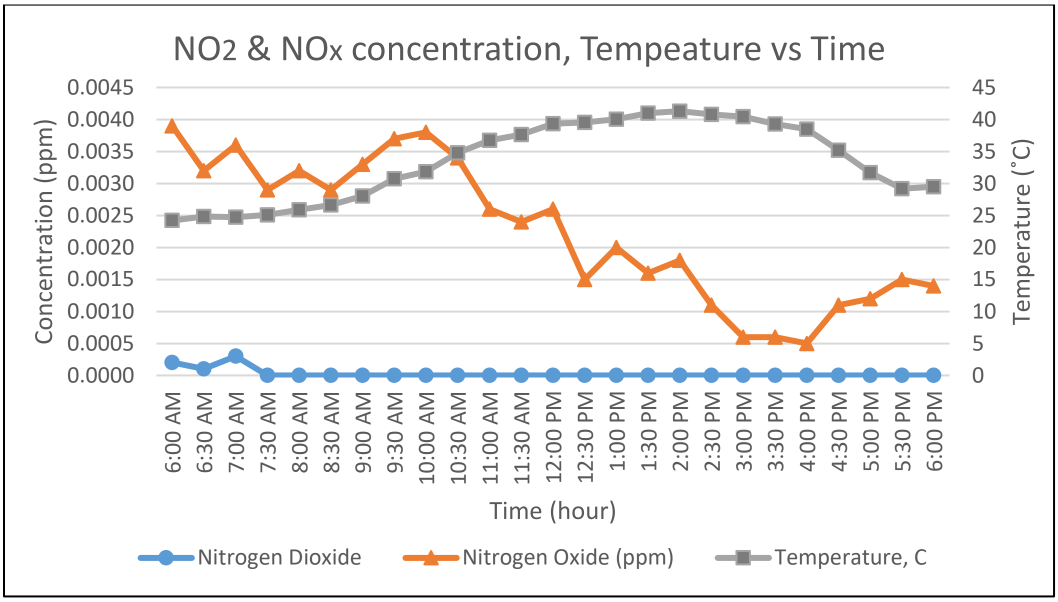
Graph 4.4.1.1 : Correlation between pollutant concentration and temperature during weekday.



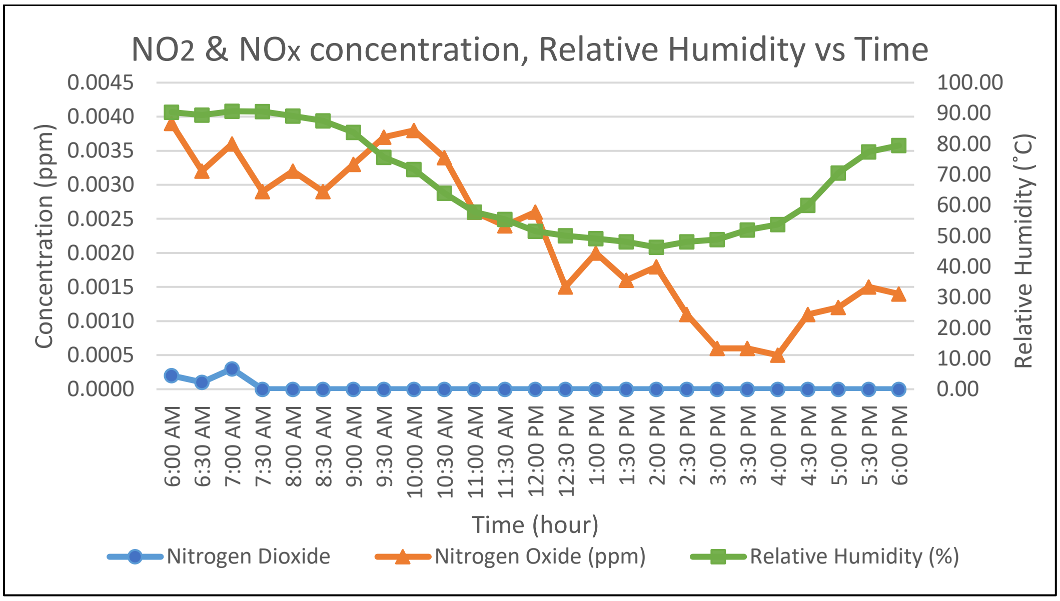
Graph 4.4.1.2 : Correlation between pollutant concentration and relative humidity during weekday.

Based on Graph 4.4.1.1, the concentration of nitrogen oxides is low at morning hours with average concentration of 0.003 ppm. However, the concentration drastically increases at 11:00 a.m to 11:30 a.m with an increment of 0.0311 ppm before it fluctuates until 06:00 p.m with high average concentration of 0.0263 ppm. This situation happened not because of the direct emission from the industrial, but it occurs as a result of high traffic flow at nearby area. Moreover, the drastic increment of nitrogen oxides concentration occurs due to sudden increase in the amount lorries and trucks that enter the industry for delivery purposes. However, there were very little occurrence of nitrogen dioxide because only small portion of nitrogen oxide were converted to nitrogen dioxide when it reacts with oxygen. Some of the nitrogen dioxide may be converted to ground level ozone and recycled back to become nitrogen oxides when it reacts with direct sunlight.

From Graph 4.4.1.1, it can be seen that the ambient temperature started to increase consistently from 06:00 a.m until it reaches highest value of 39.1˚C at 12:30 p.m before it started to decrease until 06:00 p.m. The decrease in ambient temperature is due to rainfall. The trend of relative humidity is inversely correlated to the ambient temperature as shown in Graph 4.4.1.2. This is because the ratio of water vapour in the air decrease as the ambient temperature increase, and vice versa. The surrounding relative humidity shows highest value in the morning hours starting from 06:00 a.m until 08:00 a.m with value of 87%. As the ambient temperature increase, the relative humidity started to decrease until it reaches lowest point at 12:30 p.m with 53% and after that it increase as a result of increase in water vapour in air due to rainfall. However, there is no correlation between pollutants concentration and meteorological during the monitoring period because of the heavy traffic phase and vigorous emission from lorries and trucks.



Graph 4.4.1.3 : Correlation between pollutant concentration and temperature during weekend.



Graph 4.4.1.4 : Correlation between pollutant concentration and relative humidity during weekend.

Based on Graph 4.4.1.3 and 4.4.1.4, the concentration of nitrogen oxides during weekend is much lower compared to the concentration during weekday. This significant difference is due to the reduction of heavy traffic flow. The reduction in traffic flow happened because of less movement by the nearby resident, and hence less pollutant emission from vehicles. There is no correlation between the emission from the industry and the concentration of nitrogen oxides because the industry is not operated during weekend. The concentration of nitrogen dioxide is negligible because it had been converted either to ground level ozone or recycled back to nitrogen oxides when it reacts with direct sunlight.

Based on Graph 4.4.1.4, it can be seen that the ambient temperature started to increase consistently from 06:00 a.m until it reaches highest value of 41.3˚C at 02:00 p.m before it started to decrease until 06:00 p.m. The trend of relative humidity is inversely correlated to the ambient temperature as shown in Graph 4.4.1.4. This is because the ratio of water vapour in the air decrease as the ambient temperature increase, and vice versa. The surrounding relative humidity shows highest value in the morning hours starting from 06:00 a.m until 08:00 a.m with average value of 90%. As the ambient temperature increase, the relative humidity started to decrease until it reaches lowest point at 02:00 p.m with 46.3% and after that it increase as a result of increase in water vapour in air and reduction in temperature. The trend of nitrogen oxides concentration somehow follows the trend of relative humidity due to the dependency of water vapour to hold pollutant parcel with it. The higher the ratio of water vapour in the ambient air, the higher the relative humidity, and this indicates that more air pollutant parcel that the water vapour can hold.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The concentration of air pollutants is really dependent on two main factors which are the amount of pollutants emission from direct sources and the influence of meteorological conditions of the area. The concentration of air pollutants may vary from one place to another and from time to time depending on the characteristics of sources emission and several meteorological parameters such as temperature, relative humidity, wind speed and direction. The needs of ambient air quality assessment are therefore really helpful in determining whether the concentration of air pollutants is within the standard limit as per stated by authorised organizations or required action and solution need to be taken.

By completing this study, the trends of nitrogen oxides (NO_x) and nitrogen dioxide (NO_2) in Tronoh area can be determine, whereby the maximum nitrogen oxides concentration is 0.0333 ppm while for nitrogen dioxide is 0.0035 ppm. Next, the relationship between the concentration of nitrogen oxides and nitrogen dioxide with the industrial activities and traffic volume can be clearly seen and analysed. Furthermore, the correlation and influence of temperature and relative humidity towards the air pollutant concentration can be determined and analysed precisely. This indicates that the objectives of the study have been achieved successfully.

From the analysis, the major contributor to the concentration of nitrogen oxides in Tronoh is from vehicle emissions including car, motorbike, bus, truck, and lorry. For industrial activities, all selected manufacturing industry in Tronoh does not contribute to the direct emission of nitrogen oxides and nitrogen dioxide. The occurrence of nitrogen dioxide is very small and below 0.16 ppm as per stated by the Malaysia Ambient Air Quality Standard because it had been converted into ground level ozone and recycled back to nitrogen oxides when it reacts with direct sunlight. Both meteorological parameters, which are temperature and relative humidity affects the concentration of nitrogen oxides.

This study can be improved by adding some modifications as follows:

1. Increase the number of air monitoring point location so that the distribution of air pollutants can be determine more accurately.
2. Increase the air monitoring period to 24 hours so that the pollutant's trend can be analysed precisely.
3. Increase the scope of study by adding more types pollutant such as Ozone (O_3) to analysed the correlation between pollutants.

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APPENDICES

1. Monitoring Point 1 – Weekday result

Time	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)	PCU	Nitrogen Dioxide (ppm)
6:00 AM	0.0151	26.67	85.64	54	0
6:30 AM	0.0153	26.47	86.05	64	0
7:00 AM	0.0181	26.38	86.31	156	0
7:30 AM	0.0248	26.53	86.28	164	0
8:00 AM	0.0265	26.99	85.36	200	0
8:30 AM	0.0207	27.97	83.09	217	0
9:00 AM	0.0167	28.73	79.13	172	0
9:30 AM	0.0169	29.53	77.03	129	0
10:00 AM	0.0144	30.57	73.39	124	0
10:30 AM	0.0133	32.16	67.27	125	0
11:00 AM	0.0121	33.85	61.01	150	0
11:30 AM	0.0118	35.30	55.94	193	0
12:00 PM	0.0109	37.42	50.35	189	0
12:30 PM	0.0123	38.26	47.93	229	0
1:00 PM	0.0124	41.29	40.15	233	0
1:30 PM	0.0112	39.44	43.36	247	0
2:00 PM	0.0103	38.83	44.93	228	0
2:30 PM	0.0108	39.23	43.57	220	0
3:00 PM	0.0115	39.97	42.78	215	0
3:30 PM	0.0113	40.25	42.13	219	0
4:00 PM	0.0120	41.03	41.86	238	0
4:30 PM	0.0097	40.63	43.64	231	0
5:00 PM	0.0078	40.13	44.29	217	0
5:30 PM	0.0101	38.65	47.33	229	0
6:00 PM	0.0097	36.27	52.81	230	0

2. Monitoring Point 1 – Weekend result

Time	Nitrogen Dioxide (ppm)	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)	PCU
6:00 AM	0.0019	0.0053	24.45	92.10	32
6:30 AM	0.0022	0.0051	24.77	91.80	46
7:00 AM	0.0025	0.0035	24.96	91.49	97
7:30 AM	0.0035	0.0051	25.02	91.36	122
8:00 AM	0.0025	0.0062	25.20	91.06	157
8:30 AM	0.0023	0.0050	25.43	89.73	182
9:00 AM	0.0028	0.0060	26.01	88.43	197
9:30 AM	0.0023	0.0065	26.75	86.59	163
10:00 AM	0.0021	0.0032	27.40	84.49	154
10:30 AM	0.0019	0.0035	28.23	81.61	157
11:00 AM	0.0010	0.0051	29.26	78.36	164
11:30 AM	0.0018	0.0058	30.25	75.81	141
12:00 PM	0.0006	0.0032	31.86	70.13	168
12:30 PM	0.0000	0.0022	33.99	62.70	177
1:00 PM	0.0002	0.0022	35.91	57.30	151
1:30 PM	0.0001	0.0021	35.63	58.52	179
2:00 PM	0.0006	0.0010	31.15	73.15	195
2:30 PM	0.0021	0.0022	29.00	82.75	160
3:00 PM	0.0025	0.0028	29.77	80.71	142
3:30 PM	0.0025	0.0038	32.60	73.75	145
4:00 PM	0.0014	0.0023	35.01	62.87	150
4:30 PM	0.0008	0.0034	34.13	64.94	121
5:00 PM	0.0011	0.0045	31.09	73.82	98
5:30 PM	0.0020	0.0020	27.78	79.57	101
6:00 PM	0.0014	0.0029	26.62	88.59	87

3. Monitoring Point 2 – Weekday result

Time	Nitrogen Dioxide (ppm)	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)
6:00 AM	0.0001	0.0065	24.89	88.56
6:30 AM	0.0001	0.0062	25.23	87.33
7:00 AM	0.0000	0.0043	25.13	88.68
7:30 AM	0.0001	0.0040	25.77	87.64
8:00 AM	0.0000	0.0037	26.52	85.86
8:30 AM	0.0000	0.0038	27.29	84.15
9:00 AM	0.0000	0.0040	28.81	79.52
9:30 AM	0.0000	0.0043	31.52	71.65
10:00 AM	0.0000	0.0038	32.15	70.10
10:30 AM	0.0000	0.0036	34.52	63.53
11:00 AM	0.0000	0.0034	36.23	58.28
11:30 AM	0.0001	0.0031	36.74	55.85
12:00 PM	0.0001	0.0023	39.83	48.83
12:30 PM	0.0002	0.0025	40.37	47.68
1:00 PM	0.0000	0.0016	40.77	47.09
1:30 PM	0.0000	0.0017	41.65	45.03
2:00 PM	0.0001	0.0015	41.09	44.68
2:30 PM	0.0000	0.0013	38.65	50.22
3:00 PM	0.0000	0.0010	35.94	57.60
3:30 PM	0.0000	0.0013	34.22	61.76
4:00 PM	0.0000	0.0017	32.46	68.13
4:30 PM	0.0000	0.0012	31.14	73.02
5:00 PM	0.0000	0.0019	29.49	78.45
5:30 PM	0.0000	0.0020	29.05	80.80
6:00 PM	0.0000	0.0017	28.54	82.69

4. Monitoring Point 2 – Weekend result

Time	Nitrogen Dioxide (ppm)	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)
6:00 AM	0.0001	0.0087	25.03	91.23
6:30 AM	0.0003	0.0086	25.43	90.42
7:00 AM	0.0006	0.0047	25.45	90.67
7:30 AM	0.0000	0.0061	25.62	90.20
8:00 AM	0.0000	0.0057	26.13	88.80
8:30 AM	0.0000	0.0048	26.66	87.85
9:00 AM	0.0000	0.0052	27.55	85.28
9:30 AM	0.0000	0.0052	28.71	82.26
10:00 AM	0.0000	0.0030	29.24	79.99
10:30 AM	0.0001	0.0026	30.43	73.48
11:00 AM	0.0000	0.0020	34.31	62.64
11:30 AM	0.0000	0.0013	34.15	63.11
12:00 PM	0.0000	0.0006	35.44	61.61
12:30 PM	0.0000	0.0001	37.37	57.65
1:00 PM	0.0000	0.0000	35.48	62.44
1:30 PM	0.0000	0.0001	35.70	60.66
2:00 PM	0.0000	0.0000	38.13	53.73
2:30 PM	0.0000	0.0000	38.42	52.09
3:00 PM	0.0000	0.0000	37.44	53.46
3:30 PM	0.0000	0.0000	35.71	56.98
4:00 PM	0.0000	0.0002	30.56	74.01
4:30 PM	0.0000	0.0007	27.52	83.17
5:00 PM	0.0002	0.0018	27.92	84.95
5:30 PM	0.0002	0.0010	27.87	86.59
6:00 PM	0.0003	0.0009	27.51	86.62

5. Monitoring Point 3 – Weekday result

Time	Nitrogen Dioxide (ppm)	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)
6:00 AM	0.0001	0.0064	24.67	89.74
6:30 AM	0.0002	0.0059	24.98	88.32
7:00 AM	0.0001	0.0066	25.56	87.26
7:30 AM	0.0000	0.0027	25.17	89.25
8:00 AM	0.0000	0.0031	26.14	87.93
8:30 AM	0.0000	0.0021	27.67	84.17
9:00 AM	0.0000	0.0015	30.14	77.36
9:30 AM	0.0000	0.0011	32.05	71.57
10:00 AM	0.0000	0.0008	31.88	71.08
10:30 AM	0.0000	0.0008	33.52	66.33
11:00 AM	0.0000	0.0023	35.07	63.06
11:30 AM	0.0000	0.0333	36.83	58.67
12:00 PM	0.0000	0.0263	38.17	54.49
12:30 PM	0.0000	0.0385	39.07	53.03
1:00 PM	0.0000	0.0288	38.15	55.02
1:30 PM	0.0000	0.0295	36.27	59.26
2:00 PM	0.0000	0.0306	37.89	54.91
2:30 PM	0.0000	0.0270	38.17	54.37
3:00 PM	0.0000	0.0261	36.67	58.65
3:30 PM	0.0000	0.0239	36.32	58.15
4:00 PM	0.0000	0.0202	33.19	67.95
4:30 PM	0.0000	0.0228	28.57	86.05
5:00 PM	0.0000	0.0192	26.18	92.25
5:30 PM	0.0000	0.0215	26.62	88.78
6:00 PM	0.0000	0.0206	26.77	85.55

6. Monitoring Point 3 – Weekend result

Time	Nitrogen Dioxide (ppm)	Nitrogen Oxide (ppm)	Temperature, C	Relative Humidity (%)
6:00 AM	0.0002	0.0039	24.21	90.34
6:30 AM	0.0001	0.0032	24.85	89.42
7:00 AM	0.0003	0.0036	24.74	90.66
7:30 AM	0.0000	0.0029	25.08	90.55
8:00 AM	0.0000	0.0032	25.89	89.12
8:30 AM	0.0000	0.0029	26.64	87.53
9:00 AM	0.0000	0.0033	28.04	83.80
9:30 AM	0.0000	0.0037	30.73	75.70
10:00 AM	0.0000	0.0038	31.85	71.70
10:30 AM	0.0000	0.0034	34.80	63.95
11:00 AM	0.0000	0.0026	36.75	57.76
11:30 AM	0.0000	0.0024	37.64	55.42
12:00 PM	0.0000	0.0026	39.32	51.55
12:30 PM	0.0000	0.0015	39.53	50.12
1:00 PM	0.0000	0.0020	40.06	49.14
1:30 PM	0.0000	0.0016	40.97	48.12
2:00 PM	0.0000	0.0018	41.30	46.29
2:30 PM	0.0000	0.0011	40.80	48.11
3:00 PM	0.0000	0.0006	40.42	48.82
3:30 PM	0.0000	0.0006	39.29	51.91
4:00 PM	0.0000	0.0005	38.51	53.72
4:30 PM	0.0000	0.0011	35.20	59.95
5:00 PM	0.0000	0.0012	31.70	70.57
5:30 PM	0.0000	0.0015	29.21	77.46
6:00 PM	0.0000	0.0014	29.47	79.48