BEHAVIOUR OF SELECTED CRITERIA AIR POLLUTANTS DURING HIGH PARTICULATE EVENT

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SCHOOL OF CIVIL ENGINEERING
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By

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declare that I have checked and revised the whole draft of dissertation as required by my supervisor.

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ABSTRAK

Nitrogen Dioksida (NO_2), Ozon (O_3), dan zarah terampai yang saiz kurang daripada 10 mikron (PM_{10}) adalah pencemar udara yang diukur dalam Garis Panduan Kualiti Udara Persekitaran Malaysia sejak tahun 1989. Fokus kajian ini adalah interaksi antara setiap pencemar udara serta kesan siang hari (DT), malam (NT), empat musim tengkujuh dan peristiwa zarah tinggi yang berlaku dalam satu tahun. Daripada hasil analisis yang diperoleh, variasi bermusim menunjukkan kesan yang paling minima terhadap trend tahunan bagi setiap bahan pencemar. Walaupun kesan terhadap setiap pencemar adalah kurang, kesannya kepada nilai bulanan menunjukkan bahawa HPE mempunyai nilai kepekatan PM_{10} yang tertinggi sebanyak 116,16 $\mu g/m^3$. Di samping itu, peralihan monsun bulan April-Mei mempunyai kepekatan purata yang paling rendah bagi PM_{10} (24.09 $\mu g/m^3$), O_3 (5.35ppb dan 8.83 ppb) dan NO_2 (6.61 ppb dan 7.93 ppb) manakala peralihan monsoon bulan September-October lebih tinggi daripada bulan April-Mei (PM_{10} dengan 53.20 $\mu g/m^3$; O_3 dengan 22.33 ppb dan NO_2 dengan 8.29 ppb). DT dan NT menunjukkan bahawa O_3 dan NO_2 sangat kepada aktiviti manusia seharian dan cahaya matahari kerana kedua-dua bahan pencemar mempunyai perbezaan yang besar berlaku antara DT dan NT dengan peratusan perbezaan sebanyak 50% untuk O_3 dan 35% untuk NO_2. Selain itu, kajian juga menunjukkan bahawa kepekatan maxima PM_{10} di stesen pemantauan Taiping mempunyai pekali korelasi positif terhadap O_3 yang menunjukkan bahawa peningkatan PM_{10} akan menyebabkan peningkatan O_3. Kajian ini juga memasuki lima kawansan kajian yang berbeza, iaitu CA04, CA07, CA22, CA25, dan CA38 untuk mengkaji pengaruh daripada HPE kepada nilai kepekatan $PM_{10,}$ O_3, NO dan NO_2. Dari hasil pekali korelasi, nilai R bagi pencemar udara semasa HPE adalah lebih rendah daripada semasa bukan HPE.

ABSTRACT

Nitrogen Dioxide (NO_2), Ground Level Ozone (O_3), and Particulate Matter with size less than 10 micron (PM_{10}) are air pollutants measured in Malaysia Ambient Air Quality Guideline since 1989. Focus of this research is the interaction between each air pollutant as well as the effects of daytime (DT), nighttime (NT), 4 monsoon seasons and high particulate events that occurred in one year. Descriptive analysis and diurnal plot is produced by using Microsoft Excel 2016. From the result of the analysis, seasonal variation shows least effect on the annual trends for each pollutant. Even the effect on each pollutant is less significant, the effect to monthly mean value shows that HPE have highest mean value PM_{10} concentration of 116.16 $\mu g/m^3$ while April-May inter-monsoon have the lowest concentration of all three air quality parameters with PM_{10} (24.09 $\mu g/m^3$), O_3 (5.35 ppb and 8.83 ppb) and NO_2 (6.61 ppb and 7.93 ppb) while September-October inter-monsoon has higher mean concentration than April-Mei (PM_{10} with 53.20 $\mu g/m^3$; O_3 with 22.33 ppb dan NO_2 with 8.29 ppb). DT and NT provide the information whereby O_3 and NO_2 are highly dependent on the daily human activities and sunlight as these two pollutants have drastically difference between DT and NT. Besides, study also shown that the mean concentration of PM_{10} in Taiping monitoring station has positive correlation coefficient towards O_3 which dedicate that the increase of PM_{10} will result in increase of O_3. Dissertation also include analysis of 5 different monitoring station, CA04, CA07, CA22, CA25, and CA38 to study the influence of high particulate event on concentration of PM_{10}, O_3, NO, and NO_2. From the results of correlation coefficient, the R value for these air pollutants during HPE is lower than during non-HPE.

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LIST OF ABBREVIATIONS

AM	**A**pril – **M**ay Inter-monsoon
API	**A**ir **P**ollution **I**ndex
CAQM	**C**ontinuous **A**ir **Q**uality **M**onitoring
DoE	**D**epartment of **E**nvironment Malaysia
DT	**D**aytime
HPE	**H**igh **P**articulate **E**vent
MAAQG	**M**alaysia **A**mbient **A**ir **Q**uality **G**uidelines
NE	**N**ortheast Monsoon
NO	**N**itrogen **O**xide
NO_2	**N**itrogen **D**ioxide
NT	**N**ighttime
O_3	**O**zone
PM_{10}	**P**articulate **M**atter with aerodynamic diameter less than 10 micron
SO	**S**eptember – **O**ctober Inter-monsoon
SW	**S**outhwest Monsoon
UV	**U**ltraviolet
VOC	**V**olatile **O**rganic **C**ompound

CHAPTER 1

INTRODUCTION

1.1 Background

Air Pollutant Index (API) is established to provide easily understandable information about air pollution for the public. Hourly API readings are published to the public so citizen can be informed and prepare themselves if the air quality worsens. Air pollutants measured in Malaysia Ambient Air Quality Guideline are Sulphur dioxide (SO_2), Nitrogen Dioxide (NO_2), Ground Level Ozone (O_3), Carbon Monoxide (CO), and Particulate Matter with size less than 10 micron (PM_{10}). In New Malaysia Ambient Air Quality Standard, particulate matter with size less than 2.5 micron ($PM_{2.5}$) also introduced by Department of Environment Malaysia at 2015.

Based on statistical result from DOE Malaysia, total amount of air pollutants that released into air have been increased annually since 2005 and reached a total of 3,024,900 tonnes in 2014. The main source of air pollutants in Malaysia is from motor vehicles as the number of vehicles also increase gradually over the years. According to Afroz et al. (2003), main sources of air pollutants in Malaysia are from land vehicles, operating industrial, and biomass burning whereas PM_{10} and NO_2 are the primary pollutants. Besides, proof of O_3 and PM_{10} to be the indication of health risk occurred in many major cities in developing countries are worrying (WHO, 2005)

In Malaysia, there are 51 monitoring stations that designed to monitor and record the air quality continuously for 24 hours per day. These monitoring station are scattered around Malaysia. All the stations are divided into 4 categories which are industrial area, urban area, sub-urban area and background area. Besides, there are also another type of monitoring that collects only PM_{10} and other heavy metals at 19 monitoring stations.

Even though the monitoring stations able to provide reading from times to times, occurrence of high particulate episodes are rarely yet devastating. According to A Guide of Pollutant Index (API) in Malaysia 2000, air quality is descripted to indicate the health impacts to human life by using API system. There are 5 stage of health effects which have shown in Table 1.1-1 (DOE Malaysia, 2000). Malaysia has been suffered from numerous particulate pollutions since 1994. For example, the El Niño/Southern Oscillation (ENSO) phenomena give harsh consequences to southeast Asia especially Indonesia and Malaysia as it supports the conditions for haze event to occur easier. Indeed, for recent haze episodes at 2013 in Malaysia, highest API reading was recorded in Muar District, Johor in which API level had reached to more than 500. Therefore, air pollution required more concerns to study the behavior of each pollutant. Effect of these haze episodes are not only limited to human health but as well as towards economy, plants and vegetation (Somaia and Ramli, 2012)

Table 1-1 General Human Health Effect Measured by API System (DOE, 2000)

API	Descriptor
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very unhealthy
> 300	Hazardous

1.2 Problem Statement

Ground level ozone is one of the major pollutants formed via a complex photochemical reaction of sunlight and nitrogen oxides (NO_X) facilitated by a variety of volatile organic compounds (VOCs). Both natural and anthropogenic sources contribute to the emission of ground-level ozone precursors and the spatial variation of emission sources has been widely studied. Long term exposure of ground level ozone also affects agricultural and crop activity throughout the nation (World Bank Group, 1998).

Besides, there are only few studies related to airborne pollutants under effect of seasonal monsoon. In Malaysia, there are two major monsoon seasons. From early June to end of September, southwest monsoon (SW) and northeast monsoon (NE) from early November to late March. Two inter-monsoon are said to occurred during the exchanging of monsoon season happened on April-May (AM) and late September to October (SO). (Masseran et al., 2016).

Air pollution are greatly affected by ambient temperature as well as meteorological effect. Daytime and Nighttime in tropical country as rather to be more consistent compare to country with four seasons of winter, spring, summer, and autumn. It was approximately 12 hours of daytime and 12 hours of nighttime occurred daily in Malaysia. The effect of sunlight towards photochemical transformation of ground level ozone and anthropogenic activities that leads to production of NO_2 also affects result from DT and NT.

It is crucial to understood the interaction between ground level ozone and other air pollutants such as particulate matter less than 10μm (PM_{10}) and nitrogen dioxide (NO_2). PM_{10} are particulate matter that released from combustion of agricultural activities and forest biomasses burning (Brassard et al., 2014). NO_2 are production of burning fuel in land vehicles and factories waste gaseous (Ghazali et al., 2010) Both gases are considered as primary pollutants whereas Ozone is considered as secondary pollutant (Abdul Wahab et al., 2005). However, even the transformation process of ground level ozone does not require PM_{10} as precursor, it is essential to understand the relationship between concentration of PM_{10} and O_3 as well as O_3 and NO_2.

1.3 Objective

The research has carried these three objectives:

a. To study behavior of air pollutants during non-high particulate event and during high particulate event.

b. To study diurnal variation of air pollutants;

c. To establish the influence of PM_{10} concentration towards concentration of O_3, NO and NO_2

1.4 Scope of work

The research focus on data collection and analysis of concentration of O_3, NO_2, and PM_{10} to study their behavior based on each criteria and condition. Department of Environment Malaysia has provided the 3 types of air pollutants data which are PM_{10}, NO_2, and O_3 at Taiping monitoring station during year 2014 to carry out the objectives mentioned above. The data analysis looking into effect of seasonal monsoons, high particulate event, daytime and nighttime. Then the monthly concentration of air pollutants will be compare and contrast using descriptive analysis and graphical analysis. Correlation coefficient will be used to analysis relationship between PM_{10} with O_3 and O_3 with NO_2. Besides, 5 different monitoring sites data, namely CA04, CA07, CA22, CA25, and CA38 has been used to determine effect of presence of high particulate event towards concentration of other pollutants such as O_3, NO, and NO_2. The duration of dataset used for this section is September and October of 2015 only. Focus in this section is to identify the HPE duration by looking

for concentration of PM_{10} more than 150 $\mu g/m^3$ for 72-hours. For this study, new Malaysia Ambient Air Quality Standards 2015 has been used as the guideline. Limit value on targeted standard in 2020 is selected.

1.5 Dissertation outline

Chapter 1 Introduce the background studies of the research as well as stating the problem statements and objectives of the whole research. Focus of the study was mentioned as well.

Chapter 2 cover the essential literature review that provide information and definition of terminologies and methodologies used in this research. Previous studies that are important to justify the direction of this research are conclude in this chapter

Chapter 3 explained the methodologies and equations that used in these research such as descriptive analysis, box and whisker plot, diurnal and time series plot, imputation technique, and correlation coefficient.

Chapter 4 discuss and display the results from data analysis. Descriptive analysis of seasonal variation and HPE, hourly fluctuation of air pollutants as well as the results from correlation coefficient are interpret in this chapter.

Chapter 5 summaries all the finding in this study and to conclude the objective of this research. Besides, important recommendation is provided to ensure better justification in the future study.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

New Ambient Air Quality Standard was established in order to replace the older Malaysia Ambient Air Quality Guideline that has been used since 1989. MAAQG is introduced to act as a standard that provide a recommended limit for the concentration of ambient air pollutants and also used for air pollutant index calculation.

As mentioned, calculation of API reading is based on Table 2.1 whereby exceeding the given value will means increasing the value of each sub-indices which represent by each pollutants. The highest sub-index will state specifically as predominant parameter and determine the API value. Besides the given limit above, if any sub-indices have value higher than 100, the respective pollutants shall be reported immediately (DOE Malaysia, 2000). Generally, PM_{10} has the highest concentration amongst all the pollutants. However, studies show that ozone concentration has much more tendency to exceed 100 ppb limit than other pollutants (Awang et al., 2015, Latif et al., 2012). The daily mean value does not provide the accurate indication for O_3 to be dominant as the concentration of ozone fluctuated along with the presence of sunlight and its precursors NO_2 (Venkanna, 2015).

Table 2-1 New Malaysia Ambient Air Quality Standard (DOE, 2015)

Pollutants	Averaging Time	Ambient Air Quality Standard
		Standard (2020)
		$\mu g/m^3$
Particulate Matter with the size less than 10 micron (PM_{10})	1 Year	40
	24 Hour	100
Particulate Matter with the size less than 2.5 micron ($PM_{2.5}$)	1 Year	15
	24 Hour	35
Sulphur Dioxide (SO_2)	1 Hour	250
	24 Hour	80
Nitrogen Dioxide (NO_2)	1 Hour	280
	24 Hour	70
Ground Level Ozone (O_3)	1 hour	180
	8 Hours	100
Carbon Monoxide (CO)	1 hour	30
	8 Hours	10

2.2 Particulate Matter

PM_{10} are considered as fine particulate matter which represents particle masses that can enter the respiratory tract easily (WHO, 2005). Particulate matter (PM) are materials that confine of solid or liquid state that move freely in the air with a large scale of classification according to the sizes. All particulate matter is different size, shape and chemical composition (Ramli, 2017). Particulate matter is often affected by monsoon seasons and occurrence of high particulate event. From a study by Md. Yusof (2010), high concentration of PM_{10} was recorded for 2000, 2001, 2002, and 2004 during southwest monsoon with value exceeding the recommended value from MAAQG. Besides, most of the haze episodes that result from biomass burning often carried lots of dust which mainly composed of particulate matter. According to MAAQG, the recommended value for PM_{10} for 24 hours is 150 $\mu g/m^3$ and being reduced to 100 $\mu g/m^3$ in the new standard. For annual mean value, the recommended is 50 $\mu g/m^3$ and reduce to 40 $\mu g/m^3$.

Long term and short term exposure to PM_{10} has evidence that adversely affect human health. For short term exposure, observation of increase in hospital admission for asthma and chronic obstructive pulmonary disease (COPD) for person elder than 65 years for every 10 $\mu g/m^3$ increase in PM_{10} concentration in Europe. Same as increase in 0.5% of mortality. For long term exposure of PM_{10}, the result of dropping growth rate of lungs in childhood has been observed (Brunekeef, 2002).

2.3 Ozone (O_3)

Ozone is a bluish gas, 1.6 times heavier than air and a very reactive oxidant. Ozone is naturally present in relatively large concentrations in the stratosphere, an upper atmospheric layer which act as a protective layer which have a function to absorb UV radiation and preventing this radiation from reaching the earth surface (Jeannie Allen, 2002). Ground level ozone, also known as tropospheric ozone, are secondary pollutant which is major constituent of photochemical smog (Sharma et al., 2017).

2.3.1 Ground Level Ozone Health Related Issue

Based on official websites of United States Environmental Protective Agency, long-term exposure to ozone is linked to aggravation of asthma, and is likely to be one of many causes of asthma development. Long-term exposures to higher concentrations of ozone may also be linked to permanent lung damage, such as abnormal lung development in children. Less research has done on effect of ground level ozone to vegetation. Pleijel (1999) suggested that very high concentration of ozone for even a short period can injured the leaves for different kind of plants various plants.

Ground-level ozone can affect everyone severely but slowly. Due to the fact that ozone originates from cities commonly transport towards less urban area or rural areas, these areas are likelihood to be suffered from higher ground level ozone concentration than the source of precursors. Effect of the consequences is the productivity of crops and plants are adversely

affected. Eventually, high concentration of ozone along with other drastic condition can put plant life into more severe condition (Jeannie Allen, 2002).

Based on old MAAQG, the recommended mean concentration of ozone is 100 ppb for 1 hour and 60 ppb for 8 hours. However, in the new MAAQG to be implemented, the recommended value reduces to 90 ppb for 1 hour and 50 ppb for 8 hours as same with WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide

2.3.2 Formation of Ground Level Ozone

Transformation of ground level ozone is an interchangeable reaction between O_3 and NO_2 as well as NO in the presence of photons with wavelength shorter than 424 nm (Awang et al., 2016). According to Ghazali et al. (2010), there are no direct emissions ozone observed in the atmosphere because all the ground level ozone located are formed by the photochemical reaction by its precursors, NO_2. NO_2 was breaking by radiant energy ($h\nu$) into NO and a reactive radical form of oxygen. This process results in formation of ozone by combining the oxygen atom with a molecule of oxygen gas. In the presence of volatile organic compounds (VOCs), VOCs provide "free radical" to combine with NO to form NO_2. If VOCs does not present in the air, the NO will then have reverse effect with ozone to form NO_2 and O_2 back.

$$NO_2 + hv \rightarrow NO + O\ (reactive) \quad (2.1)$$

$$O\ (reactive) + O_2 \rightarrow O_3 \quad (2.2)$$

$$O_3 + NO \rightarrow NO_2 + O_2 \quad (2.3)$$

$$Free\ Radical\ (from\ VOCs) + NO \rightarrow NO_2 + By\ product \quad (2.4)$$

Therefore, with presences of ozone precursors which is NO_2 and VOCs along with sunlight, ground level ozone can be formed completely. However, equation (4) shows that once concentration of VOCs dropped, equation (3) can be executed and the ozone concentration will be reduced as the conversion of NO_2 and O_3 is interchangeable.

2.4 Nitrogen Dioxide (NO_2)

Nitrogen dioxide is one of the primary pollutants that can act as precursors for photochemical transformation of ground level ozone. Oxides of nitrogen exist in various of form. The natural sources for atmospheric NO_x are anaerobic biological processes, lightning and volcanic eruption (World Bank Group, 1998). Complete combustion of vehicle fuels are the main contributors of NO_2 (Mohd. Talif et al., 2013). Study from epidemiologist have shown that with the increase in annual concentration of NO_2, there is also increase in bronchitic symptoms of asthmatic children and reduce in growth rate of lung function in children at current North American and European (WHO, 2005). Currently, guideline provide the recommendation value of 36 ppb for short term concentration and 142 ppb for long tern concentration (DOE, 2015).

2.5 High Particulate Event (HPE)

For now, there are only 51 monitoring stations throughout Malaysia. However, the Department is exploring alternatives on mobile equipment to wider the coverage. So for now, these 51 stations are sufficient enough for the public to know the API readings at their respective states and places near them. Smoke haze related to biomass burning is a recurring environmental problem in Southeast Asia which affects air quality not only in the source regions, but also in the surrounding areas. Biomass burning may be related to forest clearing, wild fires during drought years, or agricultural practice (Somaia et al., 2012). In this study, high particulate event can be defined when the API value for the station more than 100 for 72 hours consecutively or percentage of captured records were more than 80% for the concentration of O_3 and NO_2. (Dewi, 2016)

2.6 Monsoon Seasons

Peninsular Malaysia experiences tropical monsoon climate due to its geographical location around the world. Results from exist of annual low or high pressure zone at Inner China and Australia, Malaysia undergoes two major monsoon seasons along with two inter-monsoon seasons. During November to end of March, the Southeast Asia countries are exposed to the northeast monsoon (NE), Then, between April to May, the wind direction begin to turn to opposite direction due to seasonal change of two continental masses at the north and south, there is a transition monsoon (AM). Next, Malaysia experience southwest monsoon (SW) since the early of June to end of September. Before the next NE, there is also a transition period occurred from end of September to end of October (SO). These monsoon seasons

govern the main meteorological conditions for the transport of air pollutants as well as the rainfall intensity.

2.7 Daytime and Nighttime

The context of daytime and nighttime is determine based on the availability of sunlight to the surrounding environment. Airborne pollutants such as ground level ozone and nitrogen dioxide are greatly affected by meteorological condition due to the photochemical process of formation of ozone. Awang et al. (2015) suggested that daytime can be considered as from 7.00 a.m. to 7.00 p.m. while nighttime can be considered as 7.00 p.m. to 7.00 a.m. each with 12 hours.

2.8 Summary

Air pollution is hard to control and monitor. Department of Environment Malaysia notice the necessity to introduce $PM_{2.5}$ as new air quality parameter and reduce the recommended limit for air pollutants in the Malaysia Ambient Air Quality Standard give an initiative for improving the ambient quality.

PM_{10} and O_3 are air pollutants that are under most attention from many researches as well as NO_2 that act as precursor of ground level ozone. Photochemical reaction of ground level ozone is greatly affected by presence of UV light and its precursors. However, effect of presence of PM_{10} usually have been ignore because of the inactivity of both air pollutants.

From the literature review, a few criterions have been set for the objectives of this research. Daytime and nighttime in Malaysia is approximately 12 hours each from 7.00 a.m. to 7.00 p.m. and 7.00 p.m. to 7.00 a.m. respectively. Besides, monsoon seasons have great impact on influence the concentration of PM_{10}. Therefore, 4 monsoon seasons have set for this study.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explained the methodologies used to conduct the research. Besides, the data analysis method is shown as well. The data analysis is conduct using Microsoft Excel 2016.

For objective 1, descriptive analysis as well as box and whisker plot are used to study the behavior of the air pollutants under influence of the meteorological conditions. Hourly mean values are generally use to compare the results from the analysis. Besides, time-series plot also used for the 5 different monitoring station of CA04, CA07, CA22, CA25, and CA38 during non-HPE and HPE periods.

Diurnal plots are used for objective 2 whereby the fluctuation of PM_{10}, O_3, and NO_2 is studied to understand the trend and behavior of these air pollutants in one-year period.

Lastly, correlation coefficient is introduced in order to study the relationship of air pollutants, PM_{10} with other pollutants and O_3 with NO_2 and NO.

3.2 Research Methodology

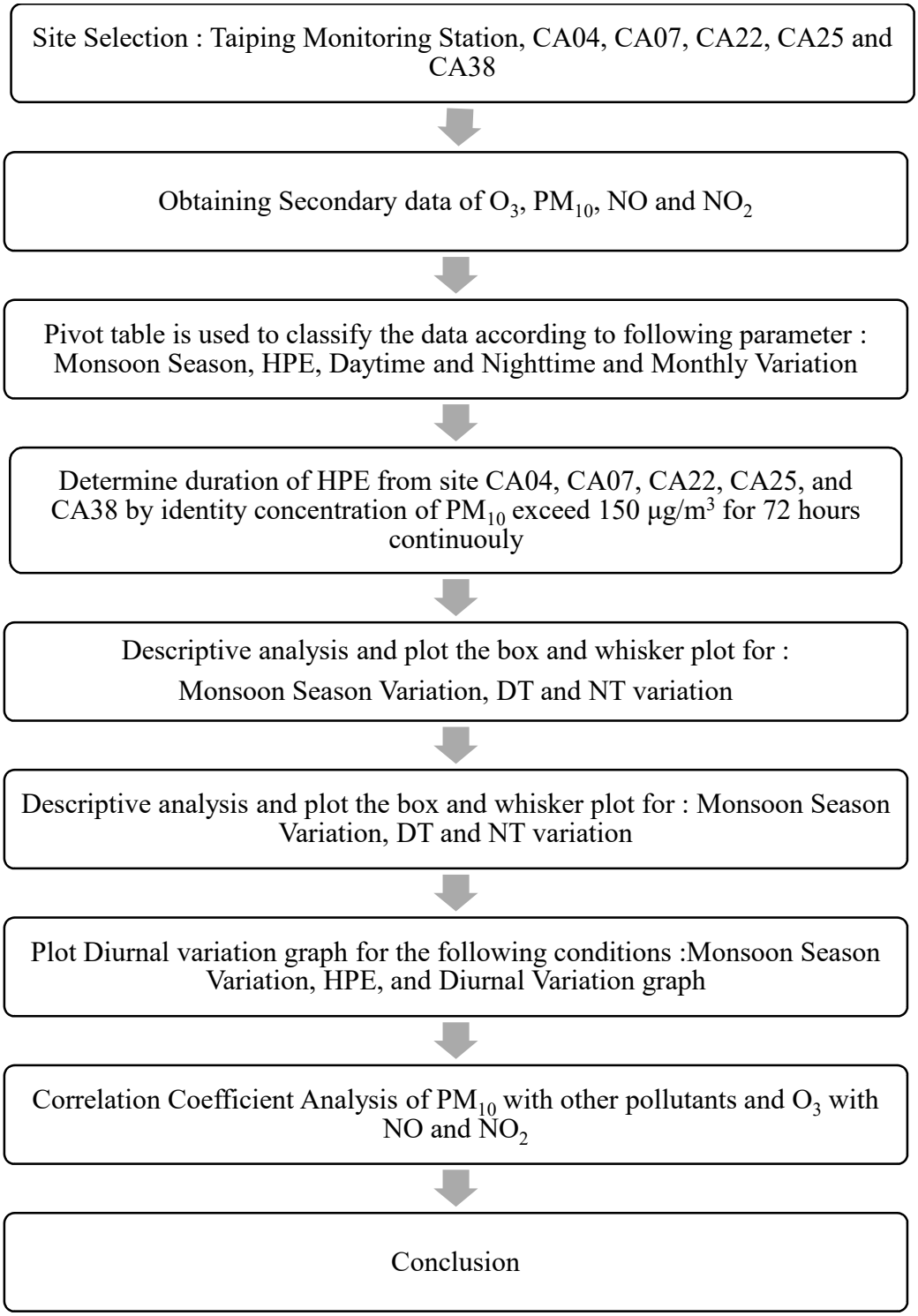

Figure 3-1 Flow Chart of Methodologies

3.3 Taiping Monitoring Station

Taiping monitoring station (4°53'56.5"N 100°40'44.3"E) is located at Sekolah Kebangsaan Ayer Puteh, around 10 km away from Taiping town and 1.5 km away from Plaza Toll Taiping Utara (Google Map, 2017). According to DOE Malaysia, Taiping monitoring station categorizes as industrial area. Taiping monitoring station is selected because it is the nearest monitoring station to USM Engineering Campus. Aside from that, there are not much study about ambient air quality of Taiping monitoring station. From Figure 3-2 and Figure 3-3, the main contributors of ozone precursors are vehicle emission from expressway as well as during school hours. Average temperatures of Taiping is around 29°C and annual rainfall intensity of 537.3 mm with relative humidity of Taiping is around 85%.

Figure 3-2 Street View of Taiping monitoring station from the Main Road Jalan Kamunting Lama (Google Map, 2017)

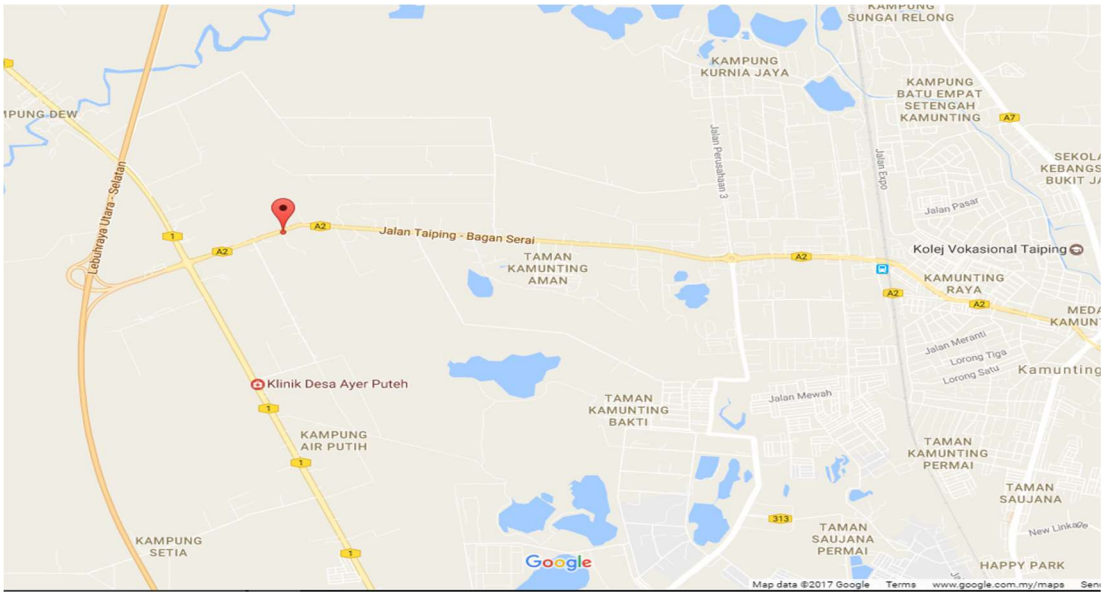

Figure 3.3- Map View of Taiping Monitoring Station, CA04, CA07, CA22, CA25, and CA38 (Google Map, 2017)

3.4 Air Pollution Data

Taiping monitoring hourly data retrieved from CAQM under permission of DOE and subjected to strict regulation to ensure the confidential usage of the data. The data provided are hourly average wind speed (m/s), hourly average concentration of NO_2 (ppm), hourly average concentration of O_3 (ppm), and hourly average concentration of PM_{10} ($\mu g/m^3$). Temperature (^oC) and Humidity is not provided. Total first set of hourly data used is 8760 hours or approximately whole year of 2014.

For secondary data that are either lost or missing, imputation technique is used. Imputation technique is considered as “nearest neighbour method” whereby the gaps of missing data between two available data are considered as half of the summation of the two neighbouring data (Latif et al., 2009)

Data retrieved from monitoring station are recording in hour basis. To be accurate, the actual data recorded are represent average data from 60 minutes of continuous monitoring. For example, 10 ppb of ozone records at 7.00 p.m. is representing 10 ppb of ozone recorded from 7.00 p.m. until 7.59 p.m.

From the monitoring data provided by the Department of Environment Malaysia, there are only one period of time whereby the concentration of PM_{10} fulfil the requirement mentioned in Chapter 2 which is API value more than 100 for more than 72 hours, which is from 11.00 p.m. of 20 July 2014 to 2.00 a.m. of 24 July 2014.

Besides, 5 different monitoring stations data from September to December are used to analyze for the relationship between PM_{10} and other pollutants during high particulate event. The five monitoring station are namely CA04, CA07, CA22, CA25, and CA38. For this section, high particulate event is declared when PM_{10} concentration is exceed 150 $\mu g/m^3$ for more than 72 hours. Naming for HPE episode is using "Site name" "Month". Correlation coefficient is used for this study.

3.5 New Malaysia Ambient Air Quality Standards (MAAQS)

This study adopted the New MAAQS for concentration of PM_{10}, O_3, and NO_2 as a guideline for data analysis. According to the new MAAQS, standard value for 24 hours' basis of PM_{10} is 100 $\mu g/m^3$ and 90 ppb for hourly basis of ozone concentration. For NO_2 concentration, the guideline given a limit of 70$\mu g/m^3$ which is 36 ppb for one-hour basis. There are three interim

for new MAAQS, namely IT-1 (2015), IT – 2 (2018), and target standard (2020). For this research, targeted standard (2020) is applied for all the air quality parameters.

Table 3-1 New Malaysia Ambient Air Quality Standards 2015 (DOE, 2015)

Pollutants	Averaging Time	Ambient Air Quality Standard
		Standard (2020)
		$\mu g/m^3$
Particulate Matter with the size less than 10 micron (PM_{10})	1 Year	40
	24 Hour	100
Particulate Matter with the size less than 2.5 micron ($PM_{2.5}$)	1 Year	15
	24 Hour	35
Sulphur Dioxide (SO_2)	1 Hour	250
	24 Hour	80
Nitrogen Dioxide (NO_2)	1 Hour	280
	24 Hour	70
Ground Level Ozone (O_3)	1 hour	180
	8 Hours	100
Carbon Monoxide (CO)	1 hour	30
	8 Hours	10

3.6 Monsoon Season

As mentioned in Chapter 2, hereinafter the monsoon seasons are categorized into 4 categories as following:

1. Early November until late march is Northeast monsoon termed as NE.
2. Early April until late May is the first inter-monsoon season termed as AM.
3. Early June until late September is Southwest monsoon which termed as SW.
4. Late September until late October is the second inter-monsoon season which term as SO. For September – October inter-monsoon season, only October is taken as SO as later September

3.7 Daytime and Nighttime

Daytime is termed as DT and nighttime is termed as NT. Time duration for DT is 7.00 a.m. until 7.00 p.m. while NT is dedicated as 7.00 p.m. till 7.00 a.m. In actually, these raw data provided as in hourly basis whereby hourly concentration of any air quality pollutant is considered as average of 60 number of data per 60 minutes.

3.8 Data Analysis

All air quality parameters were analyzed using Microsoft Excel 2016 in order to identify the behavior of these pollutants towards influence from monsoon seasons, HPE, DT and NT are $PM_{10,}$ O_3, and NO_2. Besides, the data also analyzed by hourly, daily and monthly. Method to understand the interact between two variables are also been analyzed.

3.8.1 Pivot Table for classification of data

Pivot table is one of the most powerful function of Microsoft Excel. A set of raw data can be tedious and irritating to classify into a simple data table for analysis. Pivot table provides the solution to do the grouping and ungrouping of a few sets of parameters along with the variables very quickly using the same sets of data. Besides, pivot table reduce the mistakes to be done when re-classify a group of data and able to summarize the results easily. Pivot table required users to arrange the raw data in form of columns before proceed to it. The raw data regroups are regroup into monthly variation and hourly variation.

- Monthly variation (From January to December). The table can be sort accordingly to be further classified into November - March representing northeast monsoon (NE), June - September for southwest monsoon (SW), April – May (AM) and October (SO) for inter-monsoon.

- Hourly variation with sorted Daytime (DT) and Nighttime (NT)

3.8.2 Descriptive Analysis

Descriptive analysis is the basic steps to analyze the data to obtain the essential information such as mean, standard deviation, median, maximum and minimum value. Besides, the uses of boxes and whisker plot are important to illustrate and ease the interpretation of the result of descriptive analysis. In this study, the raw data from monitoring station have been classified according to the criteria field based on the objectives. Table 3.2 explained the important information that can be obtained from a box and whisker plot whereas Figure 3-4 shown the illustration of a box plot.

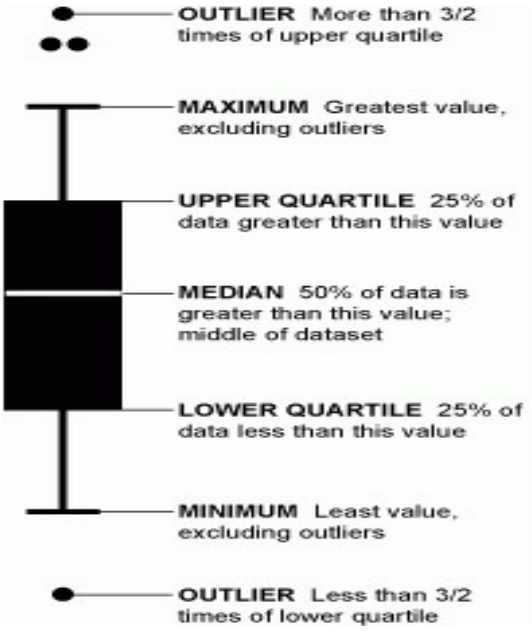

Figure 3-4 Illustration of a Box and Whisker Plot