ASSESSMENT OF PM_{10} CONCENTRATIONS FLUCTUATION IN URBAN AND RURAL SCHOOL ENVIRONMENT DUE TO THE INFLUENCE OF METEOROLOGICAL FACTORS

by

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DECLARATION

I declared that this thesis entitled "Assessment of PM_{10} Concentrations Fluctuation in Urban and Rural School Environment due to the Influence of Meteorological Factors" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This study was carried out to determine the difference of concentration of Particulate Matter with aerodynamic diameter less than 10 micron (PM_{10}) between urban and rural area and to investigate the influence of meteorological factors to PM_{10} variation. The samples are statistically analysed to investigate the influence of relative humidity, temperature, rainfall depth and wind speed on the concentration of PM_{10}. The air samples were collected from May until June 2016. The study area chosen for the study are school area at Kubang Kerian for urban area and Batu Melintang for rural area. The concentration of PM_{10} shows that the concentration is higher in urban areas than in rural areas. The concentration was determined by using Gravimetric method and analysed by using Pearson correlation and Multiple Linear Regression (MLR). From the analysis, there were no significant value was found from the correlation but temperature shows a positively correlated in both study area with correlation (r) value 0.599 (urban) and 0.154 (rural). From the MLR analysis, the temperature and rainfall depth shows a high degree of association with concentration of PM_{10} which is for temperature 20% for urban and 15% for rural. Meanwhile for rainfall depth are 30% for urban and 10% for rural. It shows that both of these factors are the most influential factors on concentration of PM_{10}.

Penilaian Turun Naik Kepekatan PM_{10} Persekitaran Sekolah di Bandar dan Luar Bandar di bawah Pengaruh Faktor Meteorologi

ABSTRAK

Kajian ini dijalankan untuk menentukan perbezaan kepekatan zarah terampai dengan aerodinamil diameter kurang daripada 10 mikrometer (PM10) di antara persekitaran sekolah di kawasan bandar dan luar bandar dan mengkaji pengaruh faktor-faktor meteorologi untuk variasi PM_{10}. Sampel PM_{10} dianalisa secara statistik untuk menyiasat pengaruh kelembapan udara, suhu, kelebatan hujan dan kelajuan angin kepada kepekatan PM_{10}. Sampel udara telah dikumpulkan dari bulan Mei hingga Jun 2016. Kawasan kajian yang dipilih adalah kawasan sekolah di Kubang Kerian bagi kawasan bandar dan Batu Melintang bagi kawasan luar bandar. Sampel kepekatan PM_{10} menunjukkan bahawa nilai kepekatan di kawasan bandar lebih tinggi berbanding kawasan luar bandar. Nilai kepekatan ditentukan dengan menggunakan kaedah gravimetrik dan dianalisis dengan menggunakan korelasi Pearson dan Regrasi Linear Berganda (MLR).Berdasarkan keputusan, tiada nilai yang signifikan dari korelasi tetapi suhu menunjukkan korelasi positif di kedua-dua kawasan kajian dengan nilaipekali korelasi (r) 0.599 (bandar) dan 0.154 (luar bandar). Daripada analisis MLR, suhu dan kedalaman hujan menunjukkan nilai yang tinggi dalam darjah ketepatannya dengan kepekatan PM_{10} dimana untuk suhu adalah 20% bagi bandar dan 15% bagi luar bandar. Sementara itu, bagi kelebatan hujan adalah 30% bagi bandar dan 10% bagi luar bandar. Ia menunjukkan bahawa kedua-dua faktor ini adalah faktor yang paling mempengaruhi kepekatan PM_{10}.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Air pollution becomes a major issue in Malaysia due to several occurrences of hazes in the country. Haze happen because of the higher concentration of particulate matter in the air. Particulate matter is an indicator to air pollution because it is one type of atmospheric pollutant that causes air pollution (El-sharkawy & Zaki, 2015). There are other type of pollutant such as sulphur dioxide, carbon monoxide, ozone, lead and nitrogen dioxide (United States Environmental Protection Agency, 2016). Dust can be easily seen by human eyes but, PM_{10} could not be seen by human eyes because their aerodynamic diameter is 10 µm or less (World Health Organization, 2013). Due to their small size PM_{10} can be easily inhaled without being realized by human itself. PM_{10} has been identified as an important atmospheric pollutant in major cities in Southeast Asia, including Malaysia. It is a decisive factor in the computation of the Malaysia Air Pollution Index (Dominick et al., 2012).

The particulates matter and gaseous are disperse in the atmosphere by the present of wind and it can leave the sources thus reducing its concentration (Hewson, 1956). The concentration of particulate matter can be different due to the activity occur at the places. For instance, the concentration of particulate matter at urban area can be higher and might contain harmful material as compared to lower concentration at rural area and less in harmful material. Human population also effect on air pollution, where when

human population are increasing the usage of vehicles also increasing and contribute to air pollution.

In Malaysia, an urban areas is been gazetted when the total population of the area is 10,000 or more (Yaakob et al., 2010). Data on the urbanization of Malaysia also revealed that the number of people living in urban areas has increase since 1911 to 2000.

Particulate matters also can effects on the environment like global warming, haze and acid rain. It can fasten the corrosion of metals as well as damage the paints, sculptures and soil-exposed surfaces on man-made structure because of acid rain (National Geographic Home, 2016). The damage made is depending on the physical and chemical properties of the particulate matter itself. It also can change the climate through the formation of cloud and snow and it can contribute in acid deposition. Solar radiation can be absorbed and reduce the visibility (United Nations Environment Programme, 2016). In extend, PM also capable cause acid rains, consequently contributed to acidic lakes and streams by changing the nutrient balance and coastal water and large basins. Particulate matter can cause aesthetic damage by staining and damaging the stone and other materials, including the culturally important objects (United States Environmental Protection Agency, 2016).

1.2 Problem Statement

Malaysian Ministry of Health reported that, disease related to respiratory problem is rank number two from the total of ten list of hospital admission in the year 2013 (Ministry of Health, Malaysia, 2016). Air pollution can be one of the factors that effect on respiratory diseases because there is a clear connection between the air pollution on human health and also the environment. Among the effect of PM_{10} towards human health such as, eye irritation, lung and throat irritation, trouble in breathing, lung cancer, problems with babies at birth and also heart disease. Every human can be affected to this but there are some that are susceptible group, such as, older adults, babies and children and also people with heart or lung disease like asthma (Centers for Disease Control and Prevention, 2014). Previous study reported that an individual inhales more than 14,000 liters of air per day, so it is obvious that air pollutant effect on human health (Dimitriou & Christidou, 2011).

Meteorological factor are wind speed, temperature, relative humidity and rainfall depth. These factors can directly influence the particulate matter concentration fluctuation. It cannot be avoided because it is a natural phenomenon that occurs every day at any time. The condition of meteorological factors can give different effects to the concentration of particulate matter based on the result of previous studies (Payus et al., 2013; Li et al., 2015). This study use Kelantan as the study area because of the previous research that has been carried out only focused on Klang Valley which is the most urbanized area in Malaysia. Whereas, Kelantan was located at the East Coast of Peninsular Malaysia which is characteristically different with Klang Valley. Kelantan also experienced heavy rain due to monsoonal trend and changes. The study areas are

located at school to know whether the school children are affected with the air pollution and how severe does the air pollution occur at the area.

1.3 Objective

The objectives of this study are as follow:

1. To determine the concentration of PM_{10} at two different school area; urban and rural area.
2. To investigate the influence of meteorological factor with concentration of PM_{10} at two different areas.
3. To determine the effect of meteorological factor towards PM_{10} concentration at urban and rural area using Multiple Linear Regression (MLR).

1.4 Significant of Study

The purpose of this study is to provide information about how meteorological factors can influence the concentration of PM_{10} which is one of pollutant that can effect in air pollution. It also gives a brief view of the air quality of Kelantan area where not many researchers have done the study before. The concentration of PM_{10} can be determined and compared with the Recommended Malaysia Air Quality Guidelines to ensure the quality of air at the area. The fluctuation of PM_{10} concentration can be seen by doing the analysis to get the r value for Pearson correlation and adjusted R^2 value from MLR.

CHAPTER 2

LITERATURE REVIEW

2.1 Air Pollution

Higher concentration of PM_{10} can effect air pollution. These particulate matters produced from sources such as industrial, incomplete combustion of fossil fuel, open burning and emission from factories. Particulate matter also depending on meteorological factors because of the natural emissions, transport, chemistry and deposition (El-sharkawy & Zaki, 2015). Air pollution also becomes a major concern in Malaysia due to several occurrences of hazes episodes through 1997, 2006, 2013 and 2015 (Payus et al., 2013). Hazes are mostly occurring in urban areas due to high number of activities that trigger the production of particulate matter. Due to hazes, air pollution now becomes a major concerns (Mitran & Ilie, 2014). Table 2.1 show lists of previous study about PM_{10} in Malaysia.

There is other atmospheric pollutant such as ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, toxic air pollutant, stratospheric ozone depletion, and greenhouse gases. All of it are from different sources and give different effect to human and environment (United States Environmental Protection Agency, 2016). There are many chemicals that can effect in human health in many ways such as irritation, respiratory, digestive and few other diseases (Baird, 1999).

Table 2.1: Previous study in other part of Malaysia.

Researcher	Title	Finding
Carolyn Payus, Noraini Abdullah, Norlela Sulaiman (2013).	Airborne Particulate Matter and Meteorological Interactions during the Haze Period in Malaysia.	Temperature plays an important factor in the concentration of PM_{10} because it can increase in quantity of biomass burning and the evaporation of materials.
Doreena Dominick, Mohd Talib Latif, Hafizan Juahir, Ahmad Zaharin Aris, Sharifuddin M. Zain (2012).	An assessment of influence of meteorological factors on PM_{10} and NO_2 at selected stations in Malaysia.	Increase in temperature can increase the concentration of PM_{10} but increase in humidity can decrease the concentration because it will lead to the amount of water vapour and the rain will wash away the pollutants.
N. Amil, M. T. Latif, M. F. Khan, M. Mohamad (2015).	Meteorological-gaseous influences on seasonal $PM_{2.5}$ variability in the Klang Valley urban-industrial environment.	The sources of PM are influenced and characterized by meteorological factor that varied with season. It shows that PM has positive correlation with temperature and negative with relative humidity.
Romina Hayati,Nik Meriam Nik Sulaiman, Brahim Si Ali (2014).	Forecasting of Air Pollution Potential for a Selected Region in Malaysia.	The correlation between temperature and Meteorological air pollution potential (MPI) are the most significant while there are no clear correlation with other meteorological factor. Temperature are also confirmed that it is key factor influencing both Air Pollution Index (API) and MPI.

2.2 Particulate Matter

Particulate matter is an air pollutant that consist mixture of solid and liquid particles that suspended in the air that varies in location. The common constituents of particulate matter are sulfates, nitrates, ammonium and other inorganic ions. Particulate matter also consists of biological components such as allergens and microbial compounds (World Health Organization, 2013). These particles can be directly emitted into the air and formed in the atmosphere. It can be from man-made and natural sources.

Man-made sources are known such as combustion of fossil fuels in motor vehicles, industrial activities and open burning. For natural sources, it can be from dust and its re-suspension that occur in particularly in arid areas or governed by mechanical factors such as vehicular (World Health Organization, 2013). There are coarse particles and fine particles where it is different in size. Coarse particles also can be seen with human eyes but not fine particles where it is smaller in size; 10, 2.5 and 0.1 µm of diameter. Due to the small size it can be easily inhaled by human without noticing it.

The general sources for particulate matter are solid or liquid air pollutants mainly emitted by power plants and the transportation sector, mining and incinerators (Dimitriou & Christidou, 2011). There are three major sources of particulate matter in Malaysia which come from motor vehicles, domestic fossil fuel burning and open burning (Dominick et al., 2012). Based on Air Pollution Index (API), PM_{10} has been identified as an important atmospheric pollutant in major cities in Southeast Asia, including Malaysia (Dominick et al., 2012). Table 2.2 shows the list of particulate matter and its sources whether it is from natural sources or anthropogenic sources. These are the result of urbanization. With the increase of these factors, the emission of particulate matter also increases and leads to higher air pollutants concentration thus inducing many effects to the human health and the environment as shown in Table 2.3.

Table 2.2: List of particulate matter and it sources. (Sources: United States Environmental Protection Agency, 2016)

Type Of Particulate Matter	Sources
Dust Dirt	Natural
Soot Smoke Drops of liquid	Anthropogenic

Table 2.3: Effect that cause from the particulate matter.

Effect To Human	Effect To Environment
• Premature death in people with heart or lung disease. • Non-fatal heart attacks. • Irregular heartbeat. • Decreased lung function. • Increased in respiratory symptoms.	• Visibility impairment. • Environmental damage. • Aesthetic damage.

2.3 Effect Meteorological Parameters toward PM_{10} Variation

Meteorological is the atmospheric phenomena related to the weather. There are many meteorological factors such as humidity, rainfall intensity and temperature. For this study, only four meteorological factors such as wind speed, monsoonal changes, humidity, rainfall intensity and temperature were chosen to determine the effect of meteorological factors to concentration of PM_{10}. This study can prove whether the meteorological factor do effect on concentration of PM_{10} which a type of pollutant that can cause air pollution. From this, which factors affect the most in concentration of PM_{10} and their result in air pollution can be seen. The concentration of air pollutants can be varies depending on meteorological factors, sources of the pollutants and the local topography. Meteorological factors are strongly influenced the concentration because it is a natural phenomenon that experience complex interaction with many type of processes for example, emissions of dust, transportation and chemical transformation.

Study made by Wendell on 1956 which is on Meteorological Factors Affecting Causes and Controls of Air Pollution reported that particulate matter and gaseous can be disperse by wind. Atmospheric pressure also contributes in air pollution when the ground is controlled by low pressure. The high pressure air mass became counter-

clockwise around the center of the flow. The updraft will formed in the center and the wind increase which help the pollutants to move upwards and the concentration of particulate matter will became lower (Li et al., 2015). Both of the studies are made from other countries, where the result might be different with the study made in Malaysia. This is due to the climate in Malaysia that is different from the studied countries.

In Malaysia, Dominick et al, (2012) stated that meteorology plays a crucial role in ambient distributions of air pollution. This is because, the formation of pollutants is influenced not only by the emission of the pollutants but also by the meteorological factors around the area where, Malaysia is a country that has a tropical climate which experiences uniform temperatures and continuous high relative humidity as the country located near the equator. Moreover, periodic changes in wind flow patterns determining the country's four monsoonal changes which are Northeast Monsoon (November to March), transitional period (April to May), Southwest Monsoon (June to September) and second transitional period (October to November). Southwest Monsoon always signifies drier weather while Northeast Monsoon brings heavy rainfall and particularly on East Coast state of Peninsular Malaysia and west state of Sarawak (Dominick et al., 2012).

2.3.1 Wind Speed

The wind direction will bring the pollutant away from their sources and making it less concentrated at the sources and higher in other area. The wind speed specifies how fast the contaminant will increase in the area (Hewson, 1956). The concentration of PM_{10} can be low because it has been diluted by dispersion and this happen when the

wind speed is high (Dominick et al., 2012). Disperse means that the gas and particles are scattered in the atmosphere. The wind will transport the air pollutants to other region. This type of transportation can cause the concentration of PM_{10} become lower from their sources but higher in other places. If the area is surrounded by tall buildings or placed in a hilly area, all of this factor can prevent a strong wind where the pollutants cannot be transport to other region or area easily and might result in higher concentration of pollutants at the area itself (Payus et al., 2013).

2.3.2 Humidity and Rainfall Depth

Higher humidity can be affected in higher rainfall amount. Both of these factors can be related to each other where the higher humidity can cause the increase amount of water vapour and rain will wash away the atmospheric pollutants. This is because, the deposition occurs by precipitation or wet removal is one of the mechanisms for removal of aerosols from the atmosphere. This can give a negative correlation between humidity or rainfall amount with the concentration of PM_{10} (Dominick et al., 2012). The rate of absorption of particulate matter can be increase with the increasing humidity on surrounding area. Their influence can be high during the monsoon and it can bring down the concentration of PM_{10} where the rain acts as their natural scrubber (Jayamurugan et al., 2013). That is why rain was needed during the haze period because it is the natural way to reduce the concentration of particulate matter or other pollutants in the atmosphere.

2.3.3 Temperature

Many studies show that the concentration of PM_{10} has positive correlation with temperature. Temperature can be different due to the different season such as summer, winter, spring and autumn. In Malaysia, the seasonal variation denote as drier and wet season where during the wet season, heavy rainfall might occur as well. The higher the temperature, the higher the concentration of PM_{10} in the area (Dominick et al., 2012). This is because it can increase the quantity of biomass burning and the evaporation of materials. The temperature also can give an affect by causing variation in wind circulation and diluting the concentration of air pollutants (Payus et al., 2013). The different temperature can give a different effect in concentration of PM_{10} where low temperature will give a high relative humidity. Result of temperature and humidity are always reversible because, the higher temperature gives the mean of lower humidity and vice versa.

2.3.4 Correlation between Meteorological Factors and Concentration of PM_{10}

Correlation between two variables which is concentration of PM_{10} and meteorological factors has been identified by other studies (Dominick et al., 2012; Payus et al., 2013; Romina et al., 2014; Amil et al., 2015). This is because meteorological factor plays an important role in the ambient distribution of air pollutants (Dominick et al., 2012). Basically, all the studies that have been carried out proved that the variable does correlate each other but some factors correlate in reversible manner or give negative results. There also some factors that correlates with other factors. For example,

increase in temperature and UV can result in higher concentration of PM_{10}. Same result also can be achieve when the temperature and wind speed are high. But it will affect in reversible manner if the UV and wind speed are increasing (Payus et al., 2013). The result also can be affected due to other factor such as industrialization, development, economic and population.

2.4 Health Effects of PM_{10} to Children

PM_{10} cannot be visibly seen, made it easily to be inhaled by human. This type of particulate matter can contain harmful contaminants that could effect on human health. Mostly the vulnerable people that can be affected by this are elderly people and children. Expose to PM_{10} can affects in lung development in children and decrease in lung function where it also can reduce lung growth rate and decrease in long-term lung function (World Health Organization, 2013). The issue that has been concerning in recent years is the effect of air pollution on health. This is because, it can effect on cardiorespiratory health where from minor respiratory symptoms to increased hospital admissions and mortality (Kjellstrom et al., 2002).

There is little reason why the environmental exposures in childhood are important to understand the pathogenesis of chronic obstructive pulmonary disease (COPD). Firstly, the decreasing of lung growth due to air pollution in childhood is a factor for adult-onset respiratory disease. Second, there might has common cellular and molecular mechanisms underlying impaired pulmonary innate host defenses in children that exposed to air pollution and also the susceptibility to infection in COPD. Third, lung

damage in childhood may contribute to an emerging global health issue. The exposure to PM_{10} can increase the vulnerability to bacterial infection. There a report states that there is an increase in hospital admissions for doctor-diagnosed pneumonia or bronchitis in children less than 5 years of age (Grigg, 2009).

The proof that COPD is a PM-mediated disease is provided by the presence of widespread multiple black pigmented areas in the bronchial wall, alveolar septae and within alveolar macrophages. If the exposure to PM_{10} during childhood is high, the symptoms suggestive COPD will develop early as well (Grigg, 2009).

CHAPTER 3

METHODOLOGY

3.1 Study Area

The samples are collected from two different areas which is an urban (Kota Bharu) and rural (Jeli) area. For urban area, SMK Kubang Kerian 1 is chosen because the population in Kubang Kerian is 12,563 where it is more than 10,000 that has been gazette (Kota Bharu Municipal Council, 2016). For rural, SK Batu Melintang is chosen because the population there is less than the value that has been gazette which is 9,690 (Jeli Land and District Office, 2016).The apparatus will be placed at a school near this area. The station is separate into two because the concentration of particulate matter can be different due to their activities. The development and population in each location also can give different result for this study. From that, the results can be compared together. The school that has been chosen for this study is SK Batu Melintang for rural area (Figure 3.1) and SMK Kubang Kerian 1 for urban area (Figure 3.2).

Figure 3.1: Location of SK Batu Melintang for data collected in rural area (Google, 2016).

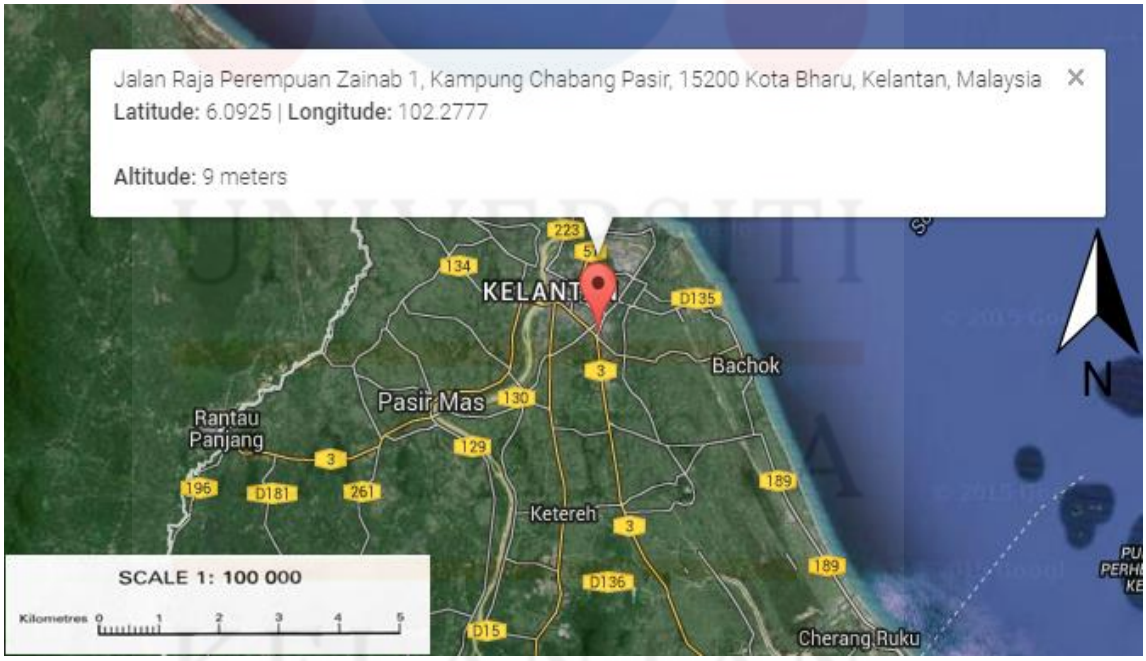

Figure 3.2: Location of SMK Kubang Kerian 1 for data collected in urban area (Google, 2016).

3.2 Preparation of PM_{10} Sampling

Before sampling the filter must be baked in a furnace with temperature of 300^0C for 5 hours. After that, weight the filter paper and record the tare weight as W_1. Then, the filter paper will be placed in the air sampler for 24 hours. Then, to ensure the quality of the results and avoid any contaminant, the filter paper will be folded in aluminium foils and placed in desiccator or seal bag. The equipment use for this study is Sibata low volume air sampler (Figure 3.3), glass fiber filter paper, Sartorius microbalance, forceps, furnace and desiccator.

Figure 3.3: Sibata low volume air sampler

3.3 Sampling of PM_{10}

The data are collected six times in a week which is three times for each area. Due to the 24 hours the filter paper has to be in the sampler, get four data collected in a week all together where two data from each location. The data collection consume three month only. Minimum total data that will be needed are 15 samples for each area; urban and rural, respectively.

Figure 3.4: The air sampler layout at SK Batu Melintang

Figure 3.5: The air sampler layout at SMK Kubang Kerian 1

3.4 PM_{10} Concentration Determination Using Gravimetric Method

Gravimetric method is conducted after the filter paper is taken out from the air sampler. By using forceps, slowly move the filter paper to avoid loss of dust. The microbalance must be in zero condition before all weighing process and the weighing process should use the same microbalance for initial and after sampling. Record the post-sampling weight of sample as W_2. After get both data, initial and final, the concentration of the PM_{10} can be measured by using an equation. The equation is provided as below:

$$C = \frac{(W_2 - W_1)}{V}$$ Equation 3.1

W_1 = tare weight of filter before sampling (µg)

W_2 = post-sampling weight of sample-containing filter (µg)

V = air volume sample (m^3)

3.5 Data Analysis

3.5.1 Primary and Secondary Data

Primary data was the PM_{10} concentrations which were sampled from school environment at SMKKK1 and SKBM. Basically, it is based on the calculation that mention earlier. For secondary data, it was obtained from the Malaysian Meteorology Department for a few meteorology parameters such as wind speed, temperature, rainfall intensity, relative humidity and monsoon. The data was collected by using different instrument for each type of data. Electronic temperature sensor was used to measure the temperature of surrounding area. Anemometer is an instrument use to measure wind speed and wind direction. The common anemometer used is windmill anemometer. Instrument used to measure relative humidity are called hygrometer and example of hygrometer are psychrometer. To measure rainfall, rain gauge are used which basically only a can that collects the rain water. Requested data are daily data collected from 24 April until 26 June 2016. For this study, the data are collected from the Kota Bharu stations for urban area and Jeli stations for rural area.

3.5.2 Correlation and Regression

After the calculation is done, we can start to correlate our data from the sample that we got and the secondary data we got from the Malaysian Meteorological Department. The data are correlated using software called SPSS Software version 21. From this software, we can get the correlation and regression between meteorological factor and the concentration of particulate matter. The correlation formula use for this study is Pearson Correlation Coefficient where we can get the value in positive or negative value (Crawford, 2006). The formula is as follows:

$$r = \frac{\sum xy - \frac{(\sum x)(\sum y)}{n}}{\sqrt{\left(x^2 - \frac{(\sum x)^2}{n}\right)\left(y^2 - \frac{(\sum y)^2}{n}\right)}}$$ Equation 3.2

This formula used to calculate the r, which is to measure the strength and direction of the linear relationship between the two variables. It also referred as Pearson product moment correlation coefficient in honor of its developer whom is Karl Pearson (Bernard, 1978).

Multiple linear regressions are a technique that allows us to predict the percentage or degree of association between the independent and dependent variable. The formula is written as:

$$Y_i = \beta_0 + \beta_1 x_{1i} + \cdots + \beta_k x_{ki} + \varepsilon_i \text{ with i= 1, ... , N}$$ Equation 3. 3

The root mean square error (RMSE) and the coefficient of determination (R^2) are important values. The value usually used to measure the reliability or fit of a linear model. It also termed as the regression coefficient of determination. The model with the smallest RMSE will take as the best linear model (Dominick et al., 2012)

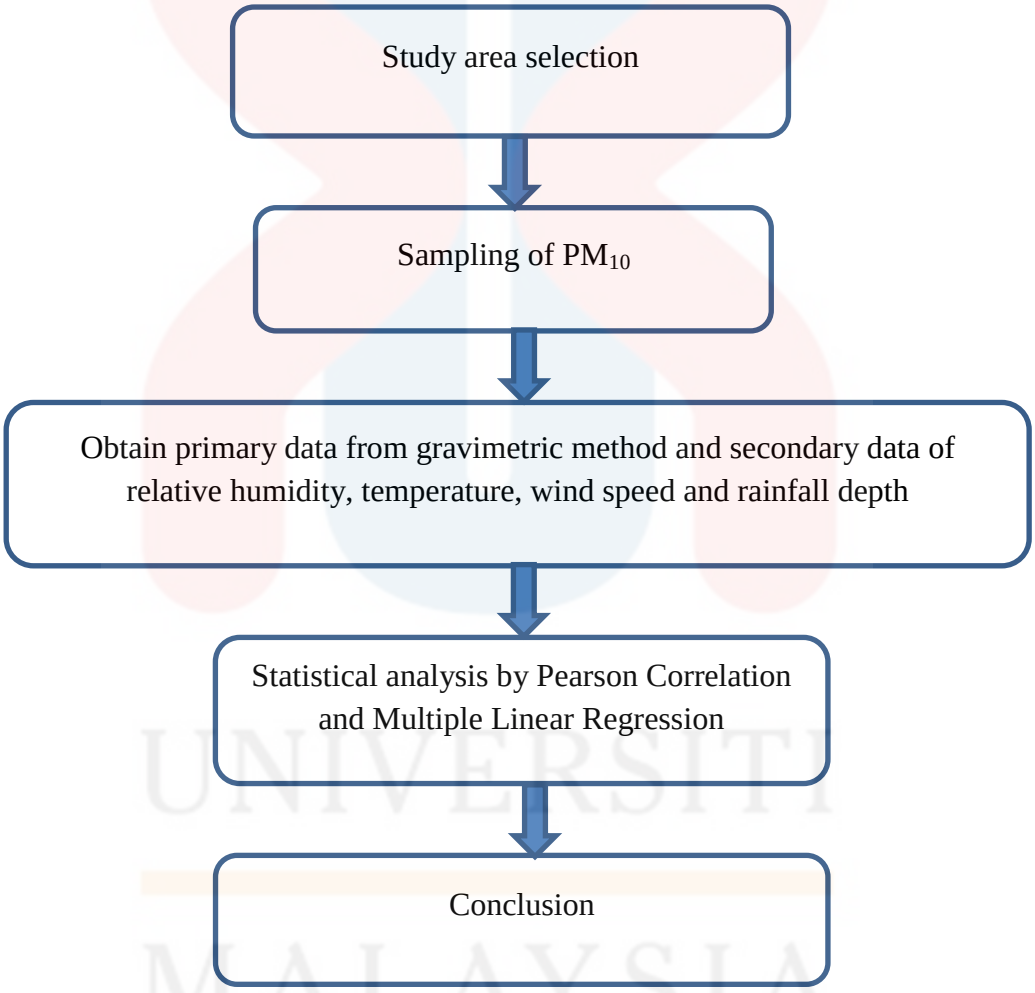

Figure 3.6: Research flowchart for the study

CHAPTER 4

RESULTS & DISCUSSION

4.1 Descriptive Statistics of PM_{10} at Two Different Study Areas

This study was conducted in April, May and June located at SMK Kubang Kerian 1/urban and SK Batu Melintang/rural. The concentration of the PM_{10} was calculated using Equation 3.1 which is a Gravimetric Method used to measure the concentration of PM_{10}. The results show a different concentration of PM_{10} was collected at both study area for the three months of sampling duration. On April, the mean concentration of PM_{10} recorded was 75.0 ± 18.7 µg/m^3 for Kubang Kerian and 36.3 ± 3.0 µg/m^3 for Batu Melintang. For May, the concentration recorded was 49.5 ± 7.9 µg/m^3 for Kubang Kerian and 41.3 ± 19.6 µg/m^3 for Batu Melintang (Table 4.1 and Table 4.2).

Table 4.1: Descriptive statistics of PM_{10} concentration (µg/m^3) at Kubang Kerian

Month	Min	Max	Mean	Standard Deviation
April	51.0	99.6	75.0	18.7
May	37.5	56.1	49.5	7.9
June	24.9	37.9	33.2	5.1

These two months shows that the concentration of PM_{10} in Kubang Kerian was higher than Batu Melintang which proved that the concentration of PM_{10} was higher at

urban area. Meanwhile on June, the results show that the concentration of PM_{10} in Batu Melintang was slightly higher than Kubang Kerian with the difference of 4.8µg/m^3.

Table 4.2: Descriptive statistics of PM10 concentration (µg/m^3) at Batu Melintang

Month	Min	Max	Mean	Standard Deviation
April	32.8	38.4	36.3	3.0
May	18.0	76.6	41.3	19.6
June	19.4	86.1	38.0	27.4

The lowest concentration recorded during this study in Kubang Kerian was in June with mean 33.2 ± 5.1 µg/m^3 and in April at Batu Melintang with mean 36.3 ± 3.0 µg/m^3. From the graph (Figure 4.1), it clearly shows that the concentration of PM_{10} was the highest in April at Kubang Kerian with mean 75.0 ± 18.7 µg/m^3 and for Batu Melintang, it was in May with mean 41.3 ± 7.9 µg/m^3. The concentration of PM_{10} recorded can be caused from the same sources which are motor vehicles which is the causes of air pollution in Malaysia (Dominick et al., 2012). At Kubang Kerian, the area was frequently exposed to the traffic congestion while Batu Melintang was rarely experience the traffic congestion. During the traffic, many particles are released due to the combustion of fossil fuels from the motor vehicles which make the concentration of PM_{10} are higher at Kubang Kerian because of the traffic congestion.

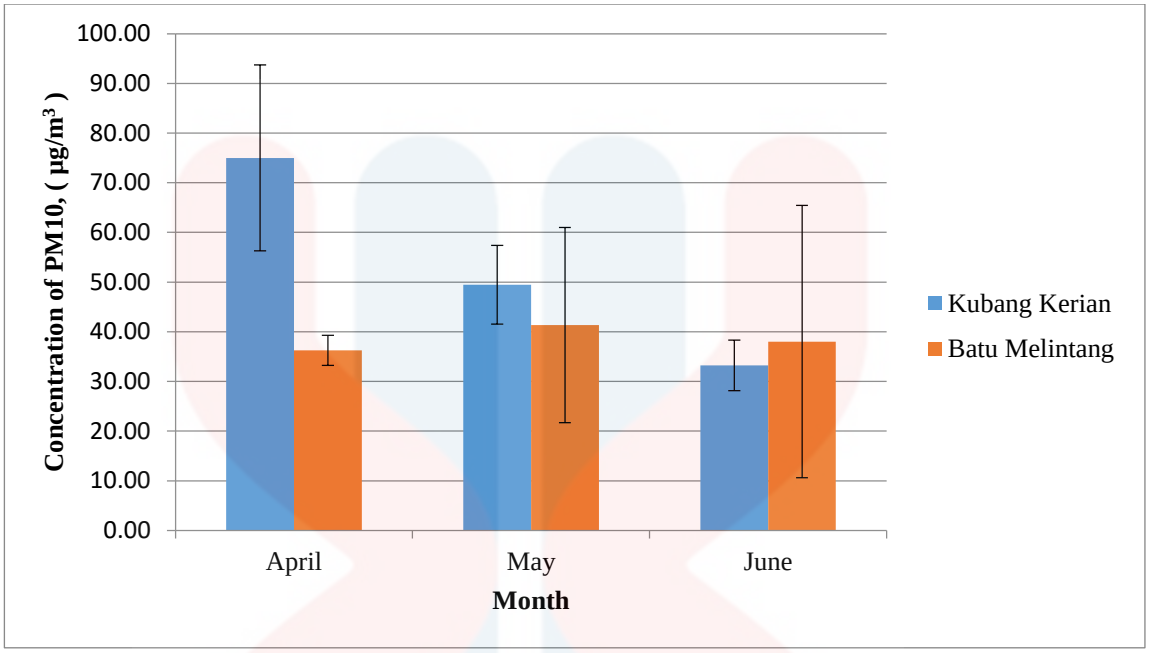

Figure 4.1: Graph for monthly concentration of PM_{10} between Kubang Kerian and Batu Melintang

4.2 Time Series Plot of PM_{10} Concentration

There was an increase of concentration in the early of the study which is in April until early May. After that, the result shows only a slight increase and inconsistent until the end of the study (Figure 4.2). The mean recorded for the concentration of PM_{10} at the area is 52.6 µg/m^3 and below the Recommended Malaysian Air Quality Guidelines (RMAQG) said that 150 µg/m^3 is the recommended concentration of PM_{10} adopted in Air Pollution Index calculation. The highest concentration recorded in the study also remain below the value proposed by RMAQG, which means the area still safe from a serious air pollution problem because of PM_{10} (Department of Environment, 2000).

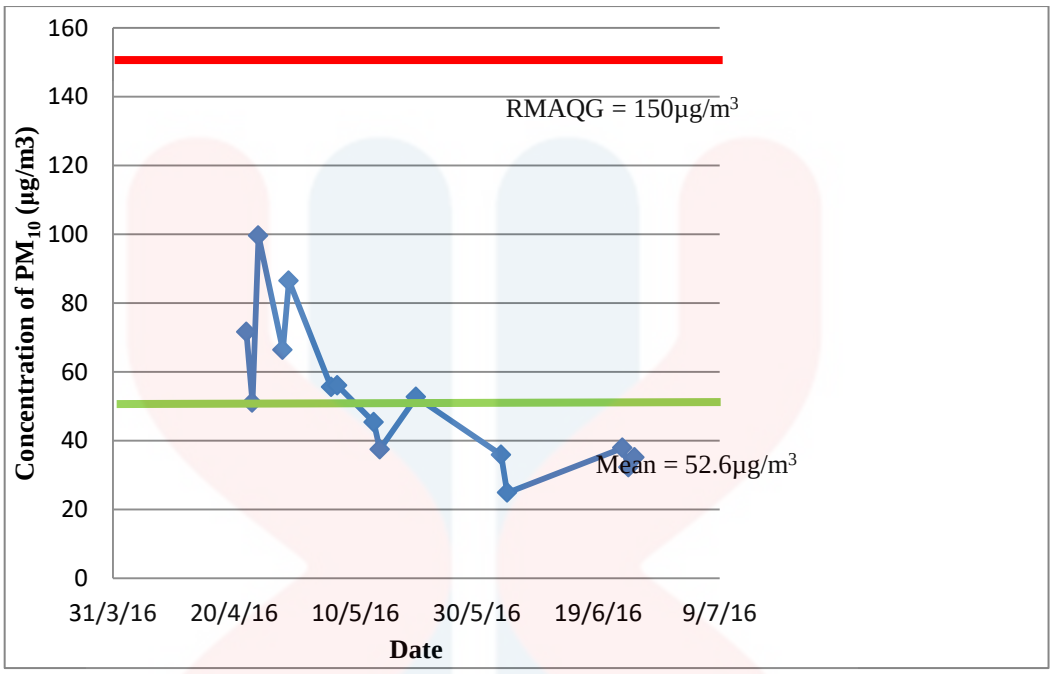

Figure 4.2: Time series plot of PM_{10} concentration at Kubang Kerian

The concentration increase drastically on the early May and slowly decrease along the month (Figure 4.3). On the early of June, the concentration went up again and goes down drastically until it rise a little before the end of the study. The mean recorded was 39.2 µg/m^3. This area also can be said free from air pollution that caused from the concentration of PM_{10}. This is due to the concentration of PM_{10} that been recorded during the study still under what has the RMAQG been recommended.

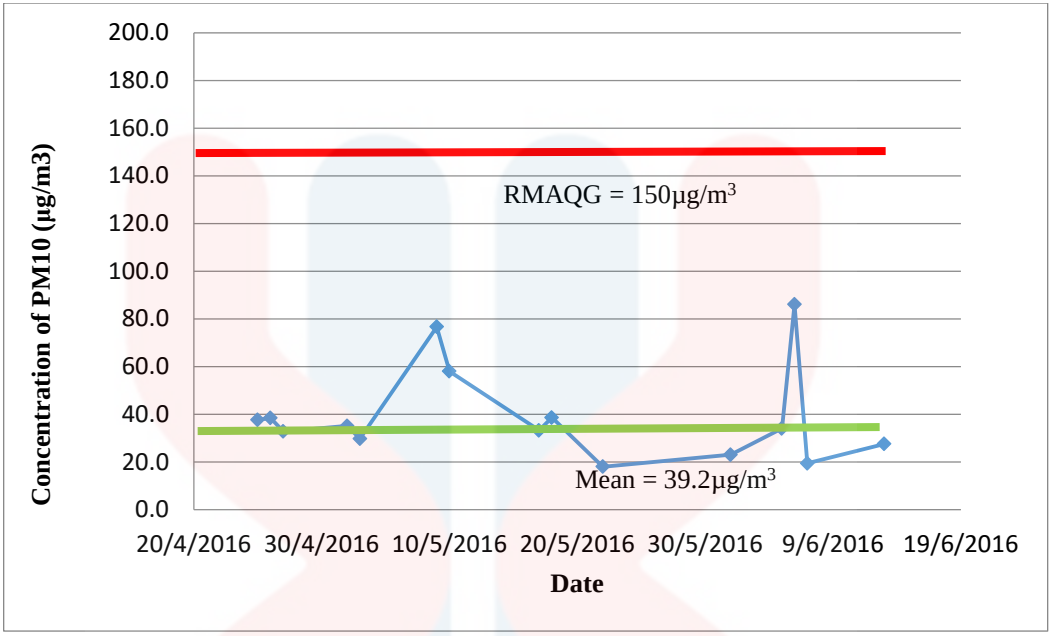

Figure 4.3: Time series plot of PM_{10} concentration at Batu Melintang

4.3 The Influence of Meteorological Factors on Concentration of PM_{10}

Both figure Figure 4.4 and Figure 4.5 shows a high relative humidity value which is at the range of 70% to 80% for both study area. At Batu Melintang there was two times where the concentration becomes the higher which was on early May and at the end of the study in June. Meanwhile in Kubang Kerian, the highest concentration of PM_{10} was on April. A high value of relative humidity, can result in a low concentration of PM_{10} because relative humidity is the ratio of the amount of water vapour in atmosphere. But based from the result, there was time that we get a high concentration of PM_{10}. The explanation for this phenomenon is because the relative humidity did not reach its dew point where it changes from air to liquid phase due to the cold air in the surrounding area. The phase transformation can affect the value of PM_{10} concentration

where the water molecules can act as natural washout of the pollutant and result in lower concentration of PM_{10} (Kenneth, 1999).

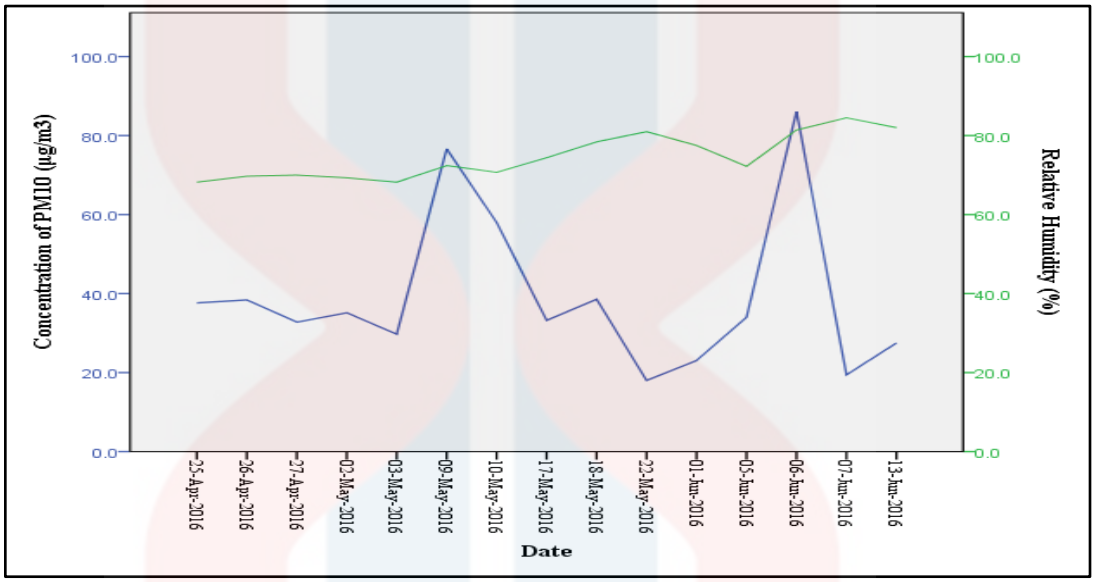

Figure 4.4: Influence of Relative Humidity on Concentration of PM_{10} in Batu Melintang

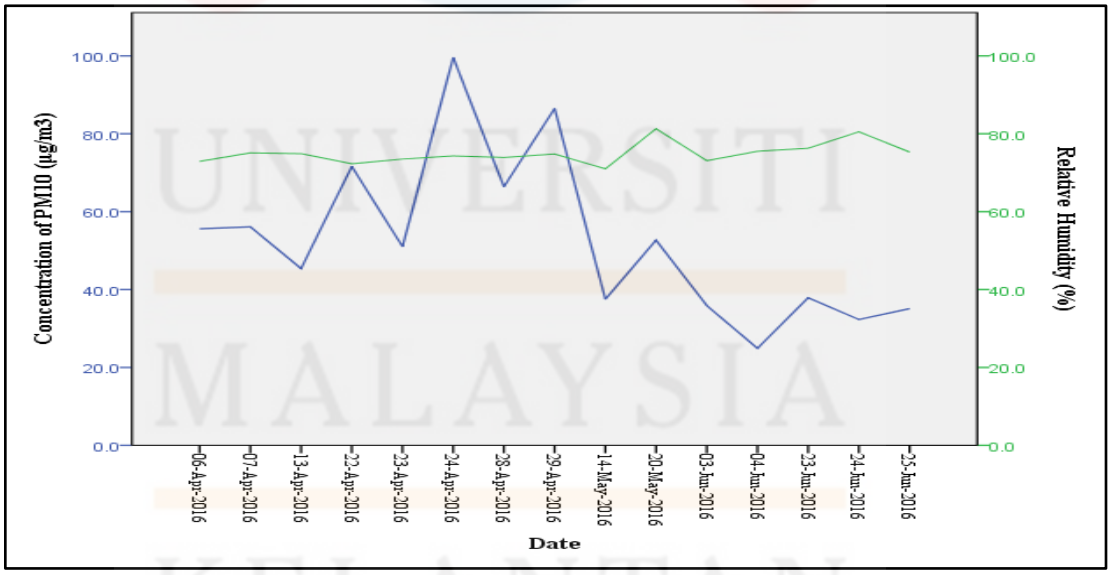

Figure 4.5: Influence of Relative Humidity on Concentration of PM_{10} in Kubang Kerian

There is two highest peak of concentration of PM_{10} at Batu Melintang which is on early May and June at the end of the study. At Kubang Kerian the highest peak was at the end of April. From the figure (Figure 4.6 and Figure 4.7) we can say that the concentration of PM_{10} is high when the rainfall depth value is low. Rain precipitation is the natural mechanisms to remove the pollutant that consist in air for example PM_{10}. These mechanisms will effect on low concentration of PM_{10} and reduce the natural formation of the PM_{10} (Suhyang et al., 2014).

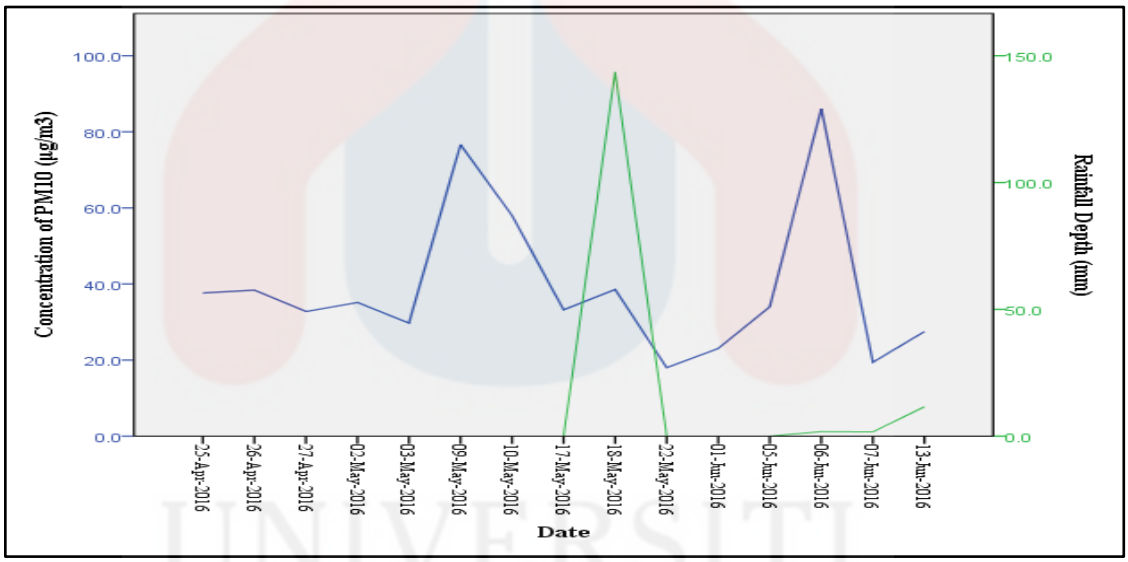

Figure 4.6: Influence of Rainfall Depth on Concentration of PM_{10} in Batu Melintang

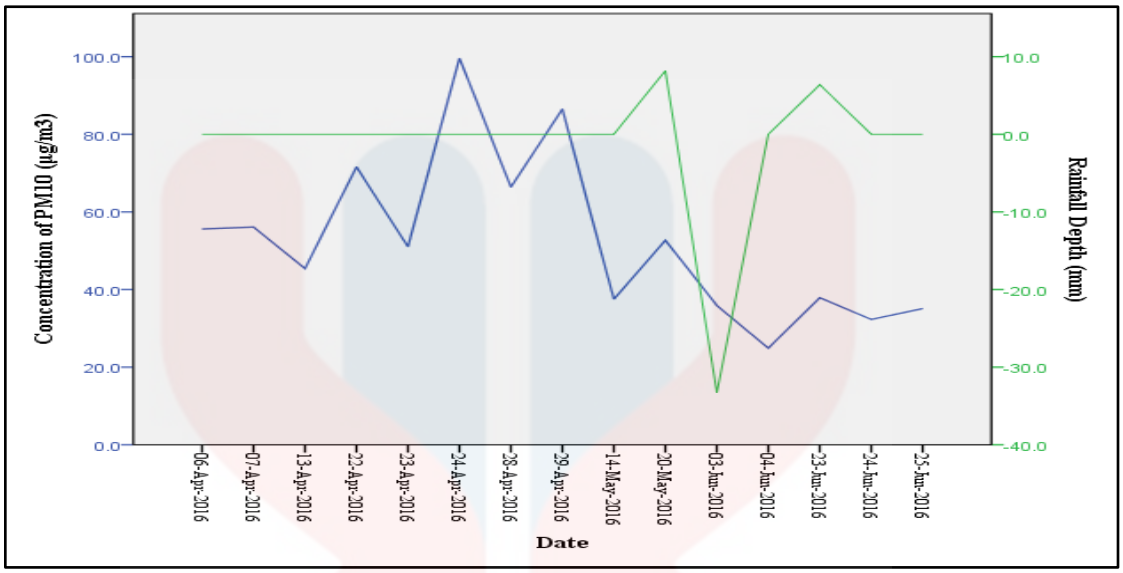

Figure 4.7: Influence of Rainfall Depth on Concentration of PM_{10} in Kubang Kerian

The average ambient temperature in Malaysia is 20ºC to 30ºC because Malaysia is a country that has a hot and humid weather. The result shown at both areas is still in the average value of temperature. The highest peak at Batu Melintang was on June at the end of the study and followed by the second peak on early May (Figure 4.8). At Kubang Kerian, the highest peak was on mid-April and followed by the second peak at the end of April (Figure 4.9). The increase in temperature can effect in the increasing of the concentration of PM_{10}. This phenomenon occur because the temperature made the surrounding become drier than usual and PM_{10} can be produced naturally for example, from the soil. Temperature increase result in low humidity means no moisture in atmosphere that can wash out the pollutant away. Therefore, there is no obstacle in inducing the PM_{10} in the atmosphere (Payus et al, 2013).

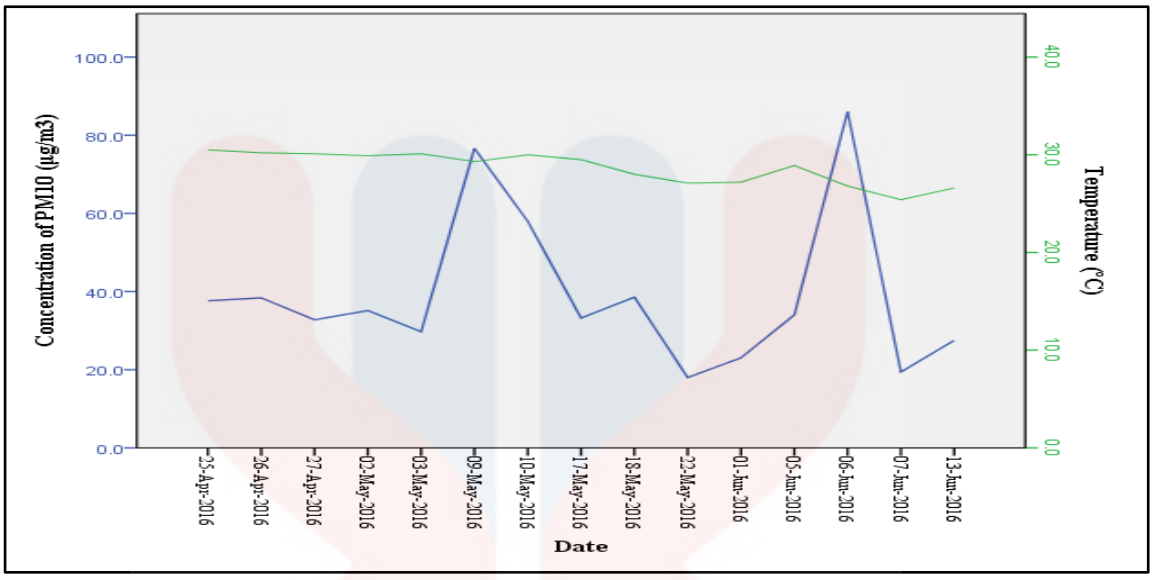

Figure 4.8: Influence of Temperature on Concentration of PM_{10} in Batu Melintang

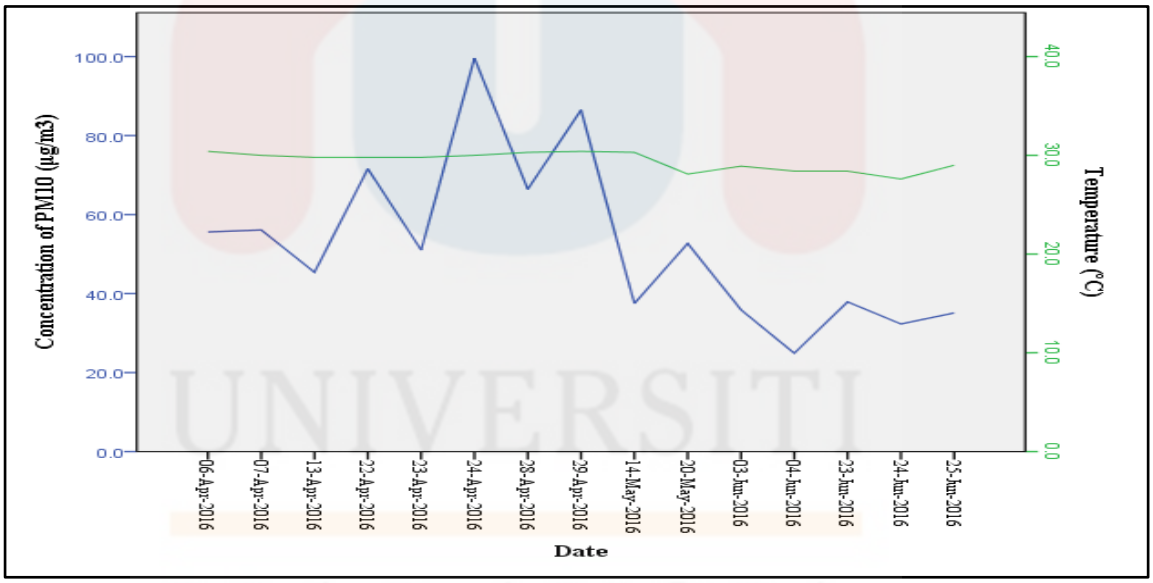

Figure 4.9: Influence of Temperature on Concentration of PM_{10} in Kubang Kerian

At both study area we noticed that the trend of the wind speed is not constant. There are always ups and downs (Figure 4.10 and Figure 4.11). The intensity of wind can be known by using the Beaufort scale. Based on the Beaufort scale, both of the study

areas stay at 0 until 2 which is 0 for calm, 1 for light air and 2 for light breeze. The low intensity of the air could result in high concentration of PM_{10} where wind act as transport for the pollutant from the sources to the other areas. Therefore, the pollutants at the area cannot be transported to the other area.

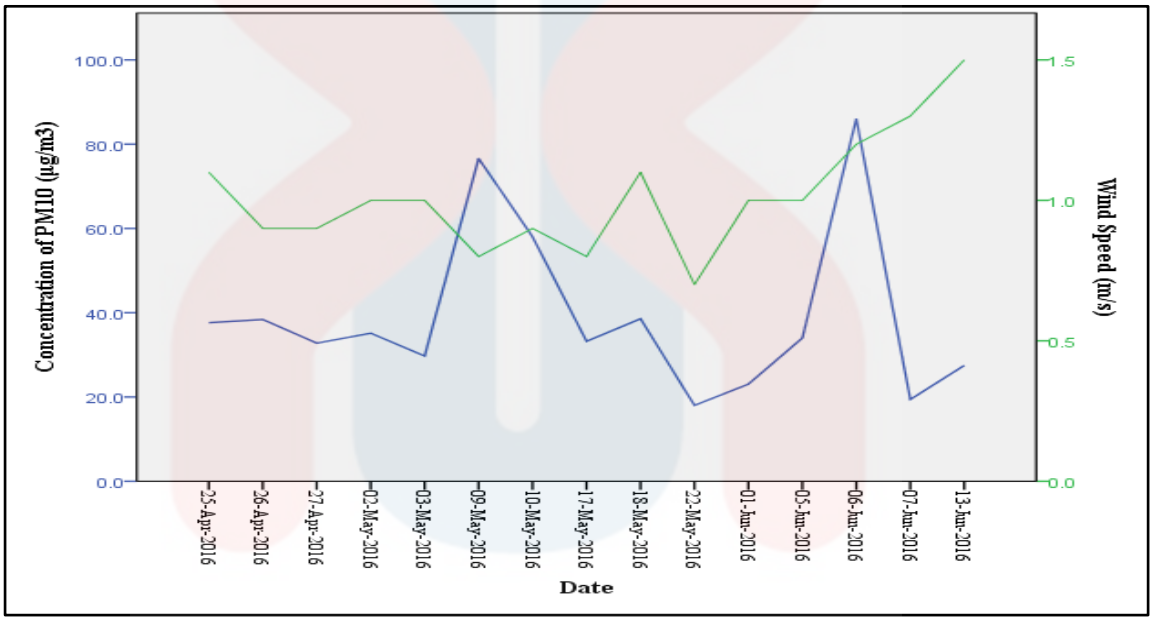

Figure 4.10: Influence of Wind Speed on Concentration of PM_{10} in Batu Melintang

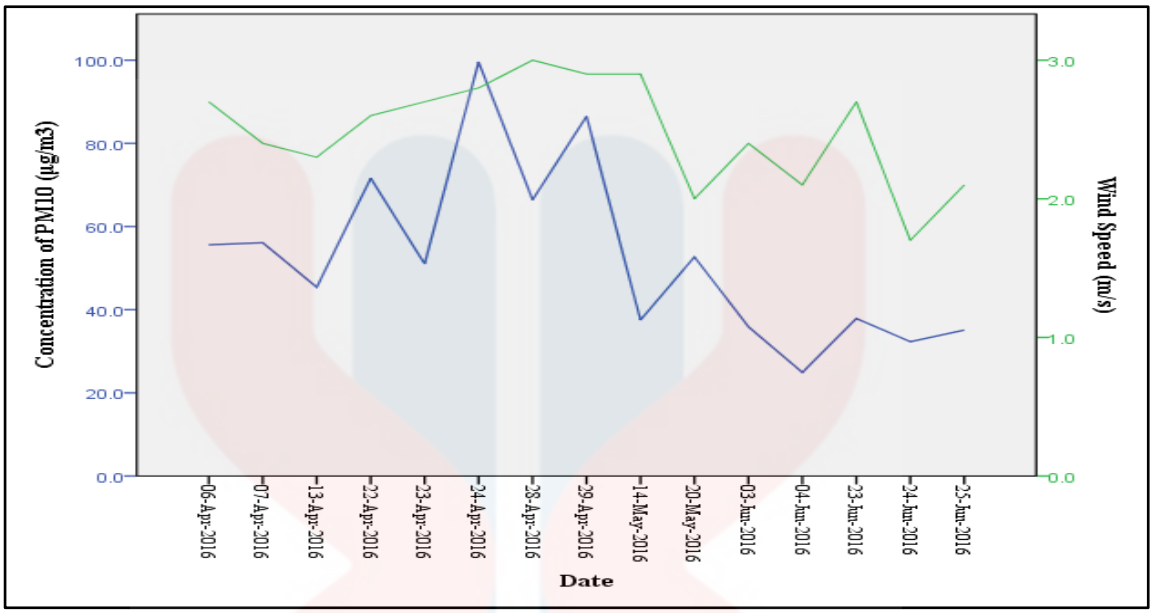

Figure 4.11: Influence of Wind Speed on Concentration of PM_{10} in Kubang Kerian

4.4 Correlation between Concentration of PM_{10} and Meteorological Factors

The correlation between PM_{10} and meteorological factors were examined to know the influence of meteorological factors on PM_{10} concentration. The Pearson correlation of PM_{10} and the meteorological factors such as relative humidity, rainfall depth, temperature and wind speed were presented in Table 4.3 and Table 4.4.

Table 4.3: Correlation between Concentration of PM_{10} and Meteorological Factors in Kubang Kerian

	PM_{10} ($\mu g/m^3$)	**Temperature (°C)**	**Relative Humidity (%)**	**Wind Speed (m/s)**	**Rainfall Depth (mm)**
PM_{10} ($\mu g/m^3$)	1.000	0.599*	-0.204	0.574*	0.170
Temperature (°C)		1.000	-0.776**	0.814**	-0.001
Relative Humidity (%)			1.000	-0.730**	0.343
Wind Speed (m/s)				1.000	0.005
Rainfall Depth (mm)					1.000

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

Table 4.4: Correlation between Concentration of PM_{10} and Meteorological Factors in Batu Melintang

	PM_{10} (µg/m^3)	**Temperature (ºC)**	**Relative Humidity (%)**	**Wind Speed (m/s)**	**Rainfall Depth (mm)**
PM_{10} (µg/m^3)	1.000	0.154	-0.107	-0.066	-0.017
Temperature (ºC)		1.000	-0.974**	-0.530*	-0.147
Relative Humidity (%)			1.000	0.470	0.224
Wind Speed (m/s)				1.000	0.177
Rainfall Depth (mm)					1.000

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

At Kubang Kerian, there is no significant correlation was found at the study area. Relative humidity was negatively correlated with concentration of PM_{10} and temperature. Because of constant temperature, the relative humidity varies directly with the moisture content in the atmosphere. The lower the moisture content, the lower the relative humidity. But the rise of temperature without changing the amount of moisture in the air reduces the relative humidity. It will not change the specific humidity unless the air is cooled below the dew point (Kenneth, 1999). Therefore, it results in the increase of PM_{10} concentration along with the low wind speed that could not act as the transport for the pollutant to disperse to the other areas (Payus et al., 2013).

Meanwhile at Batu Melintang, there also no significant correlation was found at the study area and all the meteorological factors are negatively correlated with concentration of PM_{10} except for temperature. At both study area, temperature shows that it is positively correlated with the concentration of PM_{10}. When the temperature rises, it can affect the pollutant concentrations by causing variations in wind circulation and lift it to the atmosphere (Payus et al., 2013). During the study the temperature are constant at the range of 20ºC to 30ºC which is the average temperature in Malaysia and with the less occurrence of rain, the concentration can be increased easily.

4.5 Multiple Linear Regression (MLR) Analysis

Table 4.5: MLR analysis result

	PM_{10} ($\mu g/m^3$)	T (ºC)	RH (%)	RD (mm)	WS (m/s)	Adjusted R^2	RMSE
Kubang Kerian	-663.17	14.60	3.68	9.73	-0.05	-0.30	22.41
Batu Melintang	-1118.56	19.80	6.90	28.71	-0.33	0.46	15.42

T = Temperature, RH = Relative Humidity, RD = Rainfall Depth, WS = Wind Speed

MLR was conducted to establish the relationship between concentration of PM_{10} and meteorological factors. In this study, the dependent variable is concentration of PM_{10} and the independent variable is meteorological factors. Equation 4.1 is the equation for Batu Melintang and Equation 4.2 is for Kubang Kerian. The influence of meteorological factors on the concentration of PM_{10} was found to be highest at Kubang Kerian 0.30 (-30%) and followed by Batu Melintang 0.46 (46%). Temperature, relative

humidity and rainfall depth showed a positive influence on the concentration of PM_{10}. Average temperature contributes to the production of PM_{10} because it increases the quantity of biomass burning and the evaporation of materials for instance, soil dust from earth's surface (Dominick et al,. 2012). With the help of less rain occurrence, the concentration of PM_{10} can rise easily because the pollutant could not be wash out by the water molecule. Same thing happen with relative humidity because it can act the same with the rain phenomenon where the water vapor absorbs the pollutant and bring the pollutant down to the earth's surface. But in this case, the concentration of PM_{10} still remain normal even though the relative humidity is high because changing in temperature does not change the specific humidity unless the air is cooled down until it reach dew point (Kenneth, 1999). Meanwhile, wind speed indicates a negative influence on the concentration of PM_{10} because the pollutant can be transport away to other areas. Due to the tall building and the hilly area, the wind can be slow down to reach the area.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

The concentration of PM_{10} can be different in different area based on the activity conducted on the area. The population at the area also contribute to the concentration of PM_{10}. From the study, the concentration is higher with 52.6 µg/m^3 in urban area because urban area has a higher number of populations than in rural with 39.2 µg/m^3. The high number of population effect on a high number of motor vehicles which is the major sources of PM_{10} in Malaysia. On top of that, the development at the area also contributes the increasing of concentration of PM_{10}. This study shows that the average concentration is still below the value suggested by the RMAQG of Air Pollutant Index (API) calculation. Meteorological factors also play their roles in contributing the increasing and decreasing the concentration of PM_{10}.

In this study, it focused on a few factors which are wind speed, relative humidity, temperature and rainfall depth. All this factors have their influence on the concentration of PM_{10} because all of it related to each other. But the most influential factors is temperature because based on the Pearson correlation analysis, the r value of both study area shows a positively correlated result in temperature and concentration of PM_{10}. It is the same with the MLR analysis that has been done where it shows that temperature and rainfall depth have a high degree of association with concentration of PM_{10}. These two factors prove that meteorological factors can give an impact towards concentration of

PM_{10} which can result in air pollution when it saturated in the atmosphere. The most influential factor is temperature and followed by the rainfall depth.

5.2 Recommendation

This kind of study should be widen and exposed to the public especially environmental students. With the haze occurrences that repeatedly occur at our country, air pollution should be considered as one of the main issues on environmental issue. The public should be aware about this condition to ensure their health and family. An education or awareness programme should be done for the public to make sure they know the effect of air pollution to their health.

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APPENDICES

Table A1: Gravimetric analysis for PM_{10} concentration at Kubang Kerian

No	Date	Concentration of PM_{10} ($\mu g/m^3$)
1	22 April 16	71.563
2	23 April 16	51.007
3	24 April 16	99.550
4	28 April 16	66.389
5	29 April 16	86.528
6	06 May 16	55.590
7	07 May 16	56.076
8	13 May 16	45.410
9	14 May 16	37.535
10	20 May 16	52.741
11	03 June 16	35.915
12	04 June 16	24.861
13	23 June 16	37.941
14	24 June 16	32.326
15	25 June 16	35.104

Table A2: Gravimetric analysis for PM_{10} concentration at Batu Melintang

No	Date	Concentration of PM_{10} ($\mu g/m^3$)
1	25 April 16	37.639
2	26 April 16	38.389
3	27 April 16	32.778
4	02 May 16	35.139
5	03 May 16	29.722
6	09 May 16	76. 632
7	10 May 16	57.986
8	17 May 16	33.213
9	18 May 16	38.576
10	22 May 16	18.008
11	01 June 16	23.056
12	05 June 16	34.028
13	06 June 16	86.051
14	07 June 16	19.417
15	13 June 16	27.500

Table A3: Secondary data from Meteorology Department for Kubang Kerian (Sources: Malaysian Meteorological Department, 2016)

Date	Concentration of PM_{10} ($\mu g/m^3$)	Temperature (° C)	Relative Humidity (%)	Wind Speed (m/s)	Rainfall Depth (mm)
22/4/2016	71.6	29.8	72.3	2.6	0.0
23/4/2016	51.0	29.8	73.5	2.7	0.0
24/4/2016	99.6	30.0	74.3	2.8	0.0
28/4/2016	66.4	30.3	73.9	3.0	0.0
29/4/2016	86.5	30.4	74.8	2.9	0.0
6/5/2016	55.6	30.4	72.9	2.7	0.0
7/5/2016	56.1	30.0	75.1	2.4	0.0
13/5/2016	45.4	29.8	74.9	2.3	0.0
14/5/2016	37.5	30.3	71.0	2.9	0.0
20/5/2016	52.7	28.1	81.3	2.0	8.2
3/6/2016	35.9	28.9	73.1	2.4	-33.3
4/6/2016	24.9	28.4	75.5	2.1	0.0
23/6/2016	37.9	28.4	76.3	2.7	6.4
24/6/2016	32.3	27.6	80.5	1.7	0.0
25/6/2016	35.1	29.0	75.3	2.1	0.0

Table A4: Secondary data from Meteorology Department for Batu Melintang (Sources: Malaysian Meteorological Department, 2016)

Date	Concentration of PM10 (μg/m3)	Temperature (° C)	Relative Humidity (%)	Wind Speed (m/s)	Rainfall Depth (mm)
25/4/2016	37.6	30.5	68.2	1.1	0.0
26/4/2016	38.4	30.2	69.7	0.9	0.0
27/4/2016	32.8	30.1	70.0	0.9	0.0
2/5/2016	35.1	29.9	69.3	1.0	0.0
3/5/2016	29.7	30.1	68.2	1.0	0.0
9/5/2016	76.6	29.3	72.4	0.8	0.0
10/5/2016	58.0	30.0	70.7	0.9	0.0
17/5/2016	33.2	29.5	74.4	0.8	0.0
18/5/2016	38.6	28.0	78.4	1.1	143.5
22/5/2016	18.0	27.1	81.0	0.7	0.0
1/6/2016	23.1	27.2	77.5	1.0	0.0
5/6/2016	34.0	28.9	72.2	1.0	0.0
6/6/2016	86.1	26.8	81.4	1.2	1.8
7/6/2016	19.4	25.4	84.5	1.3	1.7
13/6/2016	27.5	26.6	82.0	1.5	11.6