Determination and Assessment of Suspended Particulate Matters In Relation To Health and Environment

by

Syahenaz Bin Kamaroll Zaman

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Chemical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Chemical Engineering Programme
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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.

SYAHENAZ BIN KAMAROLL ZAMAN

ABSTRACT

This report basically discusses the study conducted and the basic understanding in ambient air quality monitoring of particulate matter. Particulate matter (PM) was measured in two different locations; residential area and industrial area in Ipoh, Perak. Three set of sampling were collected during working days and weekend using a device called MicroVol-1100. In addition, the samplings are conducted on a three-hour basis. The particulate matter concentrations were found in the range of 41 $\mu g/m^3$ and 91 $\mu g/m^3$. The particulate matter concentrations were all below the guidelines which are provided by Department of Environment, Malaysia (DOE). Furthermore, this study includes the effects of particulate matter in relation health and environment. In terms of health, exposure to particulate matter regardless short or long period can cause respiratory and cardiovascular illness and even death. Meanwhile, in terms of effects on the environment, the particulate matter can cause a significant effect to the vegetation, animals and visibility.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Air pollution has been around as long as man has walked the earth. Indeed, in the earliest extant writings, air emission from forging operation of iron and other implements well known such as the emissions from smoking fires and blazing torches. The usual response was to let nature take its course and blow air contaminants away or else to immigrate to areas with breathable air.

It has been known for decades that people with certain occupations incurred diseases of the lungs and respiratory system. Today we know that many of these effects were not only induced by carbon monoxide and toxic metals but also fine particles.

Man-made air emissions were generated in early twentieth century from two general sources which are industrial operations and the generation of electrical power. Most of these operations were driven by the combustion of solid fuels. Air emissions were without controls and were directly released into the atmosphere through a chimney or stack. Early control efforts were aimed at either recovery of materials emitted from the plant or abating smoke emissions. Enormous efforts were made at understanding not only emissions but also their dispersion pattern. It results from a combination of weather patterns, meteorological conditions, sunlight and specific emissions interacting to form ground-level ozone (Roger, 2007).

1.2 PROBLEM STATEMENT

Pollution is the introduction of contaminants into an environment, where these contaminants cause instability, disorder, harm or discomfort to the physical systems or living organisms. Pollution control is a term used in environmental management. It means the control of emissions into air, water or soil. Many of these harmful materials, such as particulate matters, enter the atmosphere from sources currently beyond human control. However, in the most densely inhabited parts of the globe, the principles sources of these pollutants are human activities.

These activities are closely associated with our material standard of living and to eliminate such activities, it would cause such a drastic decrease in the standard of living that this action is seldom considered. So, echoing to this, the remedy proposed in most industrial countries is to continue the activities, yet controlling the air pollutant emissions. Therefore, a determination and assessment of the particulate matter need to be conducted in relation to the effects towards health and environment.

1.3 OBJECTIVES

The main objectives of this study are:

- To measure and analyze the particulate matters using MicroVol-1100 at a specific site selection.
- Acquire data for comparison to regulated standards or guidelines.
- To determine the impact of a single source or a concentrated group of sources of emissions on the surrounding area.

1.4 SCOPES OF STUDY

The scopes of study for this project in order to achieve the objectives are:

- To conduct the measurement data at areas where there are large volumes of human activities.
- Determine the Air Quality Index (API) of the data collected.
- Assessment of the effect of particulate matters to health and environment.

CHAPTER 2
LITERATURE REVIEW

2.1 EMERGENCE OF QUANTIFICATION OF PARTICULATE MATTER

Historical accounts of air pollutant exposures in cities and workplaces prior to the mid-1900s typically were not accompanied by quantitative air concentration data. One can read about the "unbearable stench" in twelfth-century London, the "horrid smoke" of fifteenth-century London (Wilson, 1996), and the "air pollution disaster" in Belgium's Meuse Valley in 1930 (Clayton, 1978). Similarly, Drinker and Hatch (1936) describe the particle levels in the workplace in terms of dust fall (the amount of material falling into a bucket on the floor) or millions of particles per cubic foot (using limited optical particle counting methods). Even today, the British Smoke (BS) method for measuring particulate air pollution is used. In this method, air is drawn through a filter, and the color shade of the filter compared to painted standard surfaces, making true mass estimates difficult.

In the United States, filter-weighing methods (the high-volume of total suspended particulate, TSP) increased in use since the mid-1950s until supplemented by finer mass fractions (EPA, 1982, 1996). It is fair to say that the relevant measures of contaminants in the air that relate to human health effects have not been perfected. Future developments in devising proper air-concentration measures will most likely integrate knowledge of internal dosimetry, toxicology, and atmospheric chemistry.

The late 1950s and early 1960s marked the period in which relatively reproducible measurements of particulate concentrations began to accompany epidemiological studies of human health effects of air pollutants. Several useful summaries of this early epidemiological data can be found, but the air-quality criteria documents, published by the U.S. EPA, are among the most complete and authoritative (EPA, 1982, 1996).

All of this historic researches and studies lead to more refined and stringent Air Quality Standards and Guidelines been produced. The awareness of the community towards air pollution had risen thus creating more opportunities for researchers to conduct more studies on particulate matters. For example, one of the recent studies which had been conducted was to measure the concentration of the particulate matters at the intercity bus station in Surabaya, Indonesia. The outcome of this particular study was that no correlation between number of vehicles as well as vehicle type and particulate matter concentration was found. In addition, wind parameters appeared no significant contribution to the particulate matter dispersion (Razif and Adib, 2006).

Another recent study was measuring the concentration of particulate matters at several locations in Gujranwala City, Pakistan. It was noted that the major problem faced by Pakistan on air pollution was the particulate matter. The result of the study was that it reveals that fact that the particulate matter concentration in Gujranwala, Pakistan (724 $\mu g/m^3$) was five times higher than in Jakarta (140 $\mu g/m^3$), which is suppose to be the most polluted city in Asia (Punjab-EPD, 2007)

Several other significant studies on particulate matter are Fromme *et al.*, (2008) studied the chemical and morphological properties of PM (PM_{10} und $PM_{2.5}$) in classrooms and in corresponding outdoor air. Then it was followed by the study of identifying the major sources of high particulate matter (PM) days in Hong Kong (Huang *et al.*, 2009). At the same period of time, another study was carried out where positive matrix factorization (PMF) model was used to identify the source of particulate matter in Bandung city in Indonesia (Lestari and Mauliadi, 2009).

2.2 INTRODUCTION OF SUSPENDED PARTICULATE MATTERS (PM)

This section provides a discussion of the sources and nature of ambient PM and the solid or gas phase reactions that occur throughout the life of PM particles. A basic understanding of PM characteristics provides improved insight into critical factors that should be considered in the design of a PM monitoring program.

Particles or particulate matter may be either directly emitted into the atmosphere (primary particulate) or formed there by chemical reactions (secondary particulate). The relative importance of primary and secondary particles depends mainly on the geographical location, with its particular mix of emissions, and on the atmospheric chemistry. For example, in areas where wood is burned as heating fuel during the wintertime, most of the particles are primary in nature, whereas during summertime photochemical episodes, a substantial fraction of the particulate matter is attributed to secondary reactions in the atmosphere (Grosjean and Friedlander, 1975). These secondary reactions typically involve secondary PM precursor gases such as sulphur dioxide (SO_2), nitrogen oxides (NOx), ammonia (NH_3), and a wide variety of organic compounds. The resulting secondary PM compounds include sulphates, nitrates, and condensed organic compounds.

Particulate matter can be separated from atmospheric gases by drawing air through a filter fine enough to retain the particles, or by accelerating air through a jet that fires them at a fixed plate, onto which the particles impact and are collected. Particulate air pollutants have very diverse chemical compositions that are highly dependent on their source. They are also diverse in terms of particle size. Figure 1 illustrates the range of sizes (on a logarithmic scale) together with the ranges where certain important components are typically encountered. It shows also the PM_{10}, $PM_{2.5}$ and ultrafine particle fractions, typically those which are measured within the atmosphere for the purposes of health effects studies.

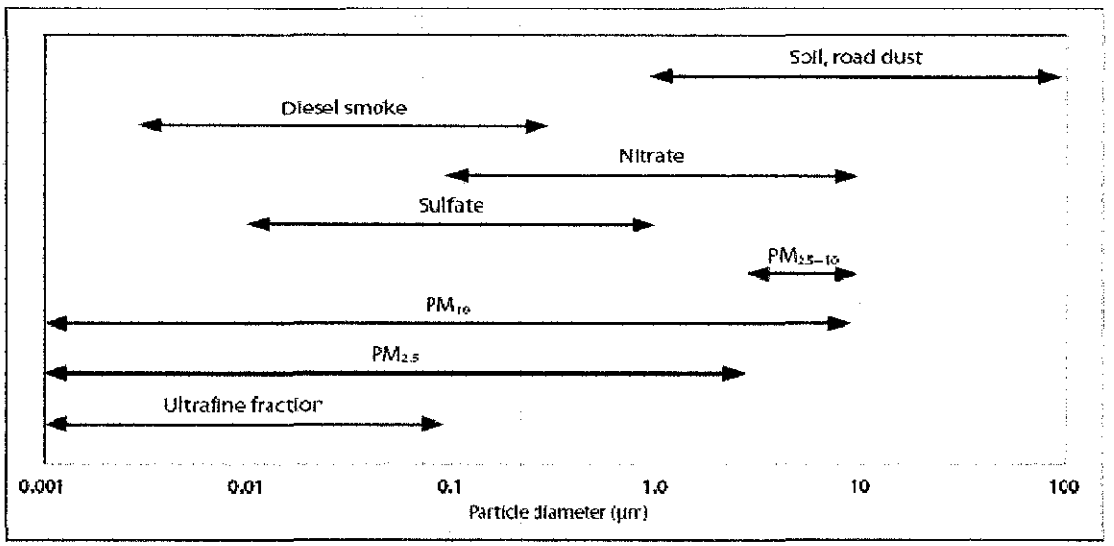


FIGURE 1: Size range of airborne particles, showing the health-related ultrafine, $PM_{2.5}$ and PM_{10} fractions and the typical size range of some major components

Six major components account for nearly all of the PM_{10} mass in most urban areas are:

i. Geological material (oxides of aluminum, silicon, calcium, titanium, and iron);
ii. Organic carbon (consisting of hundreds of compounds);
iii. Elemental carbon;
iv. Sulphate;
v. Nitrate; and
vi. Ammonium.

Liquid water absorbed by soluble species is also a major component when the relative humidity exceeds approximately 70 percent, but much of this evaporates when filters are equilibrated prior to weighing. Water-soluble sodium and chloride are often found in coastal areas, and certain trace elements are found in areas greatly influenced by industrial sources.

2.3 DEFINITION OF PM_{10} AND $PM_{2.5}$

PM_{10} stands for "Particulate Matter of less than 10 millionths of a meter (10 micrometers or 10 μm) in diameter". These particles have the greatest potential of reaching the furthest parts of the lungs. It is worth remembering that the majority of inhaled particles never reach the lungs, an estimated 70-80% of particles with diameters between 1 and 7 μm are deposited in the nose and throat. Particles over 2.5 μm only remain suspended in air for short periods.

$PM_{2.5}$ stands for "Particulate Matter of less than 2.5 μm in diameter". $PM_{2.5}$ is covered by the PM_{10} heading. That is why $PM_{2.5}$ is responsible for much of the health affects attributable to $PM_{2.5}$ and PM_{10} particles can remain suspended in air for long periods and can be transported by winds over long distances. Rain can be said to play the role of removing the particles from air, yet the PM above PM_{10} will be removed in the rain leaving only the PM_{10} remains in the air.

2.4 PRIMARY AND SECONDARY PARTICULATE MATTER

2.4.1 Primary Particulate

Atmospheric concentrations of primary particles are, on average, proportional to the quantities that are emitted. Primary particles are emitted in several size ranges, the most common being less than 1 μm in aerodynamic diameter from combustion sources and larger than 1 μm in aerodynamic diameter from dust sources. Particles larger than 10 μm in aerodynamic diameter usually deposit to the surface within a few hours after being emitted and do not have a large effect on light scattering, unless high winds and turbulence re-suspend the particles.

Emission source categories include (Schnell, 2001):

- Major stationary (point) sources (e.g., boilers, process heaters, incinerators, and steam generators);
- Area sources (e.g., fires, windblown dust, petroleum extraction operations, meat cooking operations, and residential fuel combustion);
- Mobile sources (e.g., automobiles, buses, trucks, trains, and aircraft);
- Agricultural and ranching activities (e.g., fertilizers, herbicides, tilling operations, and ammonia emissions from livestock); and
- Biogenic sources (e.g., pollen fragments and particulate abrasion products from leaf surfaces).

Combustion processes (e.g., power plants, incinerators, diesel engines) may produce particles not only in the nucleation range (less than approximately 0.08 μm) but also in the accumulation range (approximately 0.08 – 2 μm). The relative numbers of particles produced in the nucleation range compared to the accumulation range depend on the nature of the combustion process (e.g., fuel, operating conditions) and air emission controls, as well as the conditions of cooling and dilution (Finlayson-Pitts and Pitts, 1986). Partitioning of particulate mass to the condensation and nucleation fractions is affected by the rate of cooling, the relative humidity of the diluting air, and the presence of other particles.

2.4.2 Secondary Particulate

Once released into the atmosphere, primary particle emissions are subjected to dispersion and transport and, at the same time, to various physical and chemical processes that determine their ultimate environmental fate. The role of the atmosphere may be compared in some ways to that of a giant chemical reactor in which materials of varying reactivities are mixed together, subjected to chemical or physical processes and finally removed. Primary emissions from various sources such as motor vehicles, residential wood combustion, meat cooking, etc., are very complex mixtures containing thousands of organic and inorganic constituents in the gas and particulate phases.

These compounds have different chemical reactivities and are removed by dry and wet deposition processes at varying rates. Some of the gaseous species, by a series of chemical transformations, are converted into particles, forming secondary aerosols. Sulphates and nitrates are the most common secondary particles, though a fraction of organic carbon can also result from volatile organic compounds (VOC) via atmospheric reactions.

Atmospheric gases can also become suspended particles by absorption, solution, or condensation. Several of these mechanisms may operate in series in the process of secondary particle formation. In absorption, gas molecules are attracted to and adhere to existing particles. Sulphur dioxide and many organic gases have an affinity for graphitic carbon (e.g., activated charcoal is often used as a scrubbing agent for these gases), and most graphitic carbon particles in the atmosphere are usually found in association with an organic component. Most gases are somewhat soluble in water, and liquid particles will rapidly become saturated in the presence of sulphur dioxide, nitrogen dioxide, and certain organic gases.

Many hydrocarbons are emitted at elevated temperatures as a result of incomplete combustion and condense rapidly upon cooling to ambient temperatures. These are usually considered to be primary emissions if the condensation takes place rapidly, within approximately 1 minute of exiting the stack, but the particles formed can be sensitive to changes in temperature and the surrounding gas concentrations.

2.5 CHARACTERISTICS OF PARTICULATE MATTER

Air quality parameters fall into categories such as liquid, solid and gaseous matter. Federal criteria documents identify particulates as any dispersed matter, regardless solid or liquid, in which the individual aggregates are larger than a single small molecule (about 0.002 μm in diameter) but smaller than about 500 μm (AQCPM, 1970).

PM may be classified and discussed according to their physical, chemical and biological characteristics. Physical characteristics include size, mode of formation, settling properties and optical qualities. Meanwhile, chemical characteristics include organic or inorganic composition and lastly, the biological characteristics relate to their classification as bacteria, viruses, spores and pollen.

2.5.1 Physical Characteristics

2.5.1.1 Size

Size is one of the most important physical properties of PM. Particulate sized are measured in micrometers (μm), with one micrometer equal to 10^{-6} meters. Particles larger than 50 μm can be seen with unaided eye, while those smaller than 0.005 μm may only be observed through an electron microscope.

Human hair ranges from 5 to 600 μm in diameter, while the particles of major interest in air pollution studies range from 0.01 to 100 μm in size. Particles smaller than 1 μm do not tend to settle out rapidly. For example, metallurgical fumes, cement dust and fly ash carbon black into the range of 0.01 to 100 μm.

2.5.1.2 Mode of Formation

Particles could be classified according to their mode of formation as dust, smoke, fumes, fly ash, mist or spray. The first four are solid particles, while the last two are liquid respectively.

Dust (small), are solid particles created by the breakup of larger masses through processes such as crushing, grinding or blasting. This could potentially come directly from the processes or handling of materials such as coal, cement or grains. It may be a by-product of a mechanical process such as the sawing of wood or made up of residue from a mechanical operation such as sandblasting.

Smoke (fine), are solid particles resulting from the incomplete combustion of organic particles such as coal, wood or tobacco. It mainly consists of carbon and other combustible materials. Smoke particles have diameters range from 0.5 to 1 μm. Fumes (fine) are also solid particles which are formed by the condensation of solid material vapours. Fumes may be from sublimation, distillation, calcinations or molten metal processes, and they range in size from 0.03 to 0.3 μm.

Fly ashes are solid particles which consist of finely divided, noncombustible particles contained in flue gases arising from the combustion of coal. Inherent in all coal, these mineral or metallic substances are released when the organic portion of particulates discussed.

Mist consists of liquid particles or droplets that form by the condensation of a vapor, the dispersion of a liquid, or the enactment of a chemical reaction. Mists are usually less than 10 μm in diameter. If the mist concentration is high enough to obscure visibility, the mist is called a fog. Lastly, spray is also consisted of liquid particles which form by the atomization of a parent liquid such as pesticides and herbicides. Spray particles range in size from 10 μm to 100 μm.

2.5.1.3 Settling Properties

Settling characteristics are one of the most important properties of particulates, since settling is the major natural self-cleansing process for removal of particulates from the atmosphere. Particulates can generally be classified as suspended. Suspended particulates vary in size from less than 1 μm to approximately 20 μm. They remain suspended in the atmosphere for long periods of time. However, dust fall are larger and heavier, and settle out close to their sources. Their size is generally greater than 10 μm (Henderson, 1985).

The surface properties of particulates, including adsorption, absorption, chemisorptions and adhesion are particularly the important factors in the settling process of particles less than 1 μm in size. Settling of even smaller particles, those less than 0.1 μm in diameter, tends to be affected by a phenomenon know as the Brownian motion. The random movement, or Brownian motion, as shown in Figure 2 where particles in the submicron range causes them to collide with the surrounding molecules, then to coagulate, flocculate and eventually settle out.

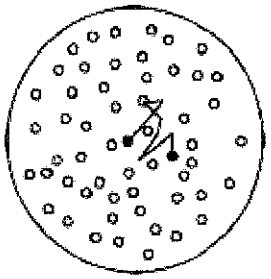


FIGURE 2: The Brownian motion

2.5.1.4 Optical Qualities

Reduction in visibility is one of the most obvious effects of the air pollution and the scattering of light by PM is primarily responsible for the visibility reduction. Particles in the range of 0.38 to 0.76 μm are the distances where visible light are the most effective in visibility reduction.

2.5.2 Chemical Characteristics

There is great variation in the chemical composition of the particulates found in the atmosphere. Atmospheric particulates contain both organic and inorganic components. Some of the more common organics found in particulates include phenols, organic acids and alcohols. Common inorganics found in particulates include nitrates, sulfates and metals such as iron, lead, manganese, zinc and vanadium.

2.5.3 Biological Characteristics

The biological particles in the atmosphere include protozoa, bacteria, viruses, fungi, spores, pollens and algae. Microorganisms generally survive for only a short time in the atmosphere. This is because of the lack of nutrients and ultraviolet radiation from the sun. However, certain bacteria and fungi form spores and these spores can survive for a long periods. Many spores and pollens are adapted for aerial dispersion and are found at elevations above 300 meters. Some, especially the blue green algae, have been found at such attitudes up to 2000 meters (McCrone *et al.*, 1973).

The World Health Organization (WHO) states:

> "Recently a comprehensive report on PM phenomenon in Europe was compiled (Lapple, 1961). Sulfate and organic matter are the two main contributors to the annual average $PM_{2.5}$ or PM_{10} mass concentrations, except at curbside sites where mineral dust is also a main contributor to PM_{10}. On days when PM_{10} is more than $50\mu g/m^3$, nitrate becomes also a main contributor to $PM_{2.5}$ or PM_{10}. Black carbon contributes 5-10% to $PM_{2.5}$ and somewhat less to PM_{10} at all sites. This includes the natural background sites. Its contribution increases to 15-20% at some of the curbside sites. Because of the complexity and the importance of particle size in determining exposure and human dose, numerous terms are used to describe PM."
> (U.S EPA, 1979)

2.6 INDOOR VS. OUTDOOR PARTICULATE MATTER

The average person spends the majority of their time in indoor environments where air contaminant levels can be substantial. Samet and Spengler (1991) summarized the situation as follows:

> Most indoor living or working environments have air pollutant sources. Even people and pets can be sources of fibers, particles, organic vapors, and microbiologic material. Additional pollution comes from heating and cooking, combustion sources, emissions from tobacco, abrasion of surfaces,

out gazing of vapors, intrusion of soil gases, and a plethora of biological sources; thus, it should not be surprising to find indoor environments that are substantially more polluted than nearby outdoor air. High concentrations of pollution in indoor settings can, at times, dominate short- and long-term exposures and may be associated with discomfort, irritation, illness, and even death.

Associations between outdoor PM levels and human health effects are complicated by indoor exposures in several ways. First, outdoor pollutants enter buildings and contribute to indoor exposures; the rate of intrusion is greater for smaller particles and for less reactive chemicals than for those that react with surfaces (such as ozone) and during seasons when buildings are better ventilated (Leaderer *et al.*, 1999; Abt *et al.*, 2000). Furthermore, some factors that modify outdoor pollutant levels, such as the use of heating and air-conditioning systems, modify the characteristics and levels of indoor pollutants.

Valberg and Watson (1998) have explored alternative, albeit untested, hypotheses for linking outdoor PM with human health effects. These authors argue that three pathways, in addition to direct exposure to outdoor PM, should be considered AS:

- Direct effects of weather conditions on health;
- Human behavior patterns that produce excess mortality and morbidity that are coincidentally linked to outdoor PM levels; and
- Weather and behavior patterns linked with outdoor PM that changes exposures to indoor pollutants. As an example of the third pathway, the authors point out that indoor wood-burning increase both indoor and outdoor PM levels.

The relative contributions of indoor sources to PM exposures depend on the characteristics of the indoor environment. When certain sources are present, such as tobacco smokers, standing water, unvented stoves, insect infestations, and wood burning equipment, air quality can be dominated by these pollutant-generators. Also, the rate of intrusion of outdoor air and the combined effect of small sources of pollutants may have a profound effect on indoor air quality. Indoor air quality and

the potential health effects of indoor pollutants is a large subject, and readers are referred to several sources of information (Samet and Spengler, 1991; Gammage and Berven, 1996; Committee on Indoor Pollutants, 1981; World Health Organization, 1990; and EPA, 1991).

2.7 RECOMMENDED MALAYSIAN AIR QUALITY GUIDELINES (RMAQG)

There are no ambient air quality standards in Malaysia. The Malaysian government, however, established ambient air quality guidelines in 1988. Pollutants addressed in the guidelines include ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, total suspended particles, particulate matter under 10 microns, lead and dust fall. The averaging time, which varies from 1 to 24 hours for the different air pollutants in the RMAQG, represents the period of time over which measurements is monitored and reported for the assessment of human health impacts of specific air pollutants.

Table 1 illustrates the table of Recommended Malaysian Air Quality Guidelines. The red box in Table 1 indicates particularly on particulate matter's concentration as according to the guideline for a 24-hour average time sampling is 150μg/m^3.

TABLE 1: The Recommended Malaysian Air Quality Guidelines (RMAQG).

Pollutants	Averaging Time	Malaysia Guidelines	
		ppm	μg/m^3
Ozone	1 Hour	0.1	200
	8 Hour	0.06	120
Carbon Monoxide	1 Hour	30	35
	8 Hour	9	10
Nitrogen Dioxide	1 Hour	0.17	320
	24 Hour	0.04	
Sulphur Dioxide	1 Hour	0.13	350
	24 Hour	0.04	105
Particulate Matter (PM10)	24 Hour		150
	1 Year		50
Total Suspended Particulate (TSP)	24 Hour		260
	1 Year		90
Lead	3 Month		1.5
Dust	1 Year	133 mg/m^2/day	

2.7.1 Air Quality Monitoring

Air quality in the country is monitored continuously and manually to detect any changes in the ambient air quality status that may cause harm to human health and the environment.

2.7.1.1 Continuous Air Quality Monitoring (CAQM)

The Department of Environment (DOE) monitors the country's ambient air quality through a network of 51 stations. These monitoring stations are strategically located in residential, traffic and industrial areas to detect any significant change in the air quality which may be harmful to human health and the environment. The CAQM stations are divided into five categories. Out of 51 stations established in Malaysia, 26% are industrial stations, 57% are residential, 2% traffic, 2% background and 13% PM_{10} stations. The five categories of parameters measured in CAQM stations are:

TABLE 2: Data from all CAQM stations are pooled hourly and telemetrically by DOE to calculate the Air Pollutant Index (API) values.

Category	Sulphur Dioxide	Nitrogen Oxides	Carbon Monoxide	Ozone	Hydrocarbon	PM_{10}	UV
Industrial	X	X	-	-	X	X	-
Residential	X	X	X	X	X	X	X
Traffic	X	X	-	X	X	X	-
Background	X	X	X	X	X	X	X
PM_{10}	-	-	-	-	-	X	-

The CAQM monitoring locations are chosen based on the following criteria:

- Results of past and current monitoring;
- Representativeness;
- Accessibility;
- Availability of support services (power, telephone line etc.);
- Security; and
- Effects of any specific topography

Automatic monitoring is designed to collect and measure data continuously (24 hours a day) during the monitoring period. Automatic Continuous Air Monitoring Stations typically include:

- Measurement instrumentation (for both pollutant gases and meteorological parameters);
- Support instrumentation (support gases, calibration equipment);
- Instrument shelters (temperature controlled enclosures); and
- Data acquisition system (to collect and store data).

2.7.2 Air Pollutant Index (API)

The air quality in Malaysia is described in terms of Air Pollutant Index (API). The API is an indicator of air quality and was developed based on scientific assessment to indicate in an easily understood manner, the presence of pollutants and its impact on health. The API system of Malaysia closely follows the Pollutant Standard Index (PSI) developed by the United States Environmental Protection Agency (U.S EPA).

The air pollutant index scale and terms used in describing the air quality levels are as follows:

TABLE 3: Air pollutant index scale used in Malaysia

API scale	Air quality
0 – 50	Good
51 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very unhealthy
301 and above	Hazardous

The CAQM stations measure the concentration of five major pollutants in the ambient air, namely, PM_{10}, SO_2, NO_2, CO, and O_3. These concentrations are measured continuously on hourly basis. The hourly value is then averaged over 24-hour running period for PM_{10} and SO_2, 8-hour period for CO, whilst O_3 and NO_x are read hourly. An hourly index is calculated for each pollutant. The highest index value recorded is then taken as the API for the hour (DOE, 2006).

2.7.3 Air Quality Trend

The overall air quality for Malaysia in 2006 decrease quite significantly compared to the previous year. There was a significant increase in the number of unhealthy days recorded at various locations in the Klang Valley, the West and the East Coast of Peninsular Malaysia and the state of Sarawak.

During the dry season between February and March 2005, some areas in the Klang Valley experienced short periods of slight to moderate haze due to peat land fires in several areas in the state of Selangor. Following the prolonged dry season in the region which was coupled with the direct influence of southwesterly wind, several parts of the country experience short-term mild to severe have episodes from mid-May until mid-October 2005.

The last and forest fires in the Riau Province of Central Sumatra, Indonesia as reported by the ASEAN Specialized Meteorological Center (ASMC) were the primary caused of transboundary pollution which was aggravated by the stable atmospheric conditions during the period. Between 1 August 2005 and 15 August 2005, the central, eastern and northern parts of the Peninsular Malaysia experienced severe haze. The hazy conditions in the Klang Valley and surrounding areas were more severe in terms of intensity that that of September 1997 in Peninsular Malaysia. It reached its peak on 11 August 005 when a haze emergency was declared in two areas in the Klang Valley, namely Pelabuhan Klang and Kuala Selangor when the API in both areas exceeded 500. However, the emergency declaration was lifted on 13 August 2005 after the API readings in both areas dropped below the hazardous level and the visibility improved. (DOE, 2005)

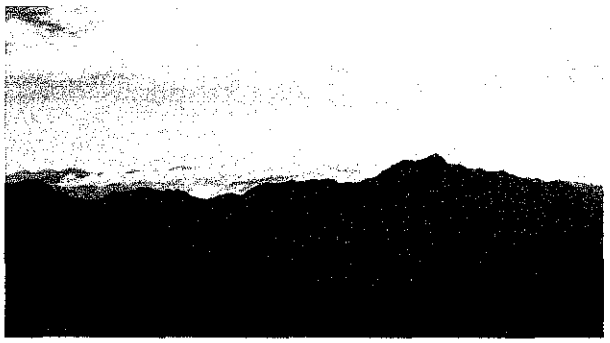


FIGURE 3: An example view of a haze free location (DOE Photo Library, 2009)

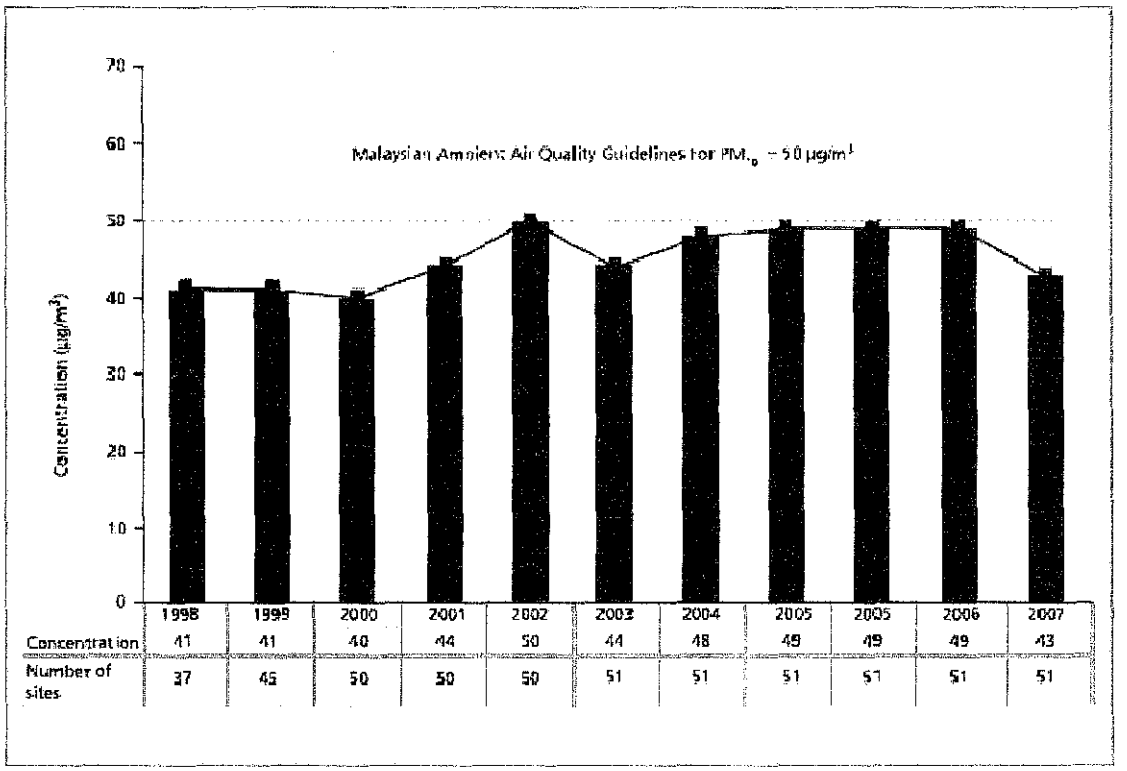


FIGURE 4: The annual average concentration of PM_{10} in Malaysia, 1998-2007 (As according to the RMAQG, the concentration of PM for one year averaging time is 50µg/m^3) (DOE, 2008).

The following graph, Figure 5 illustrates the annual concentration of PM_{10} measured at the CAQM station in Sekolah Kebangsaan Jalan Pegoh, Ipoh, Perak from 2003 to 2007.

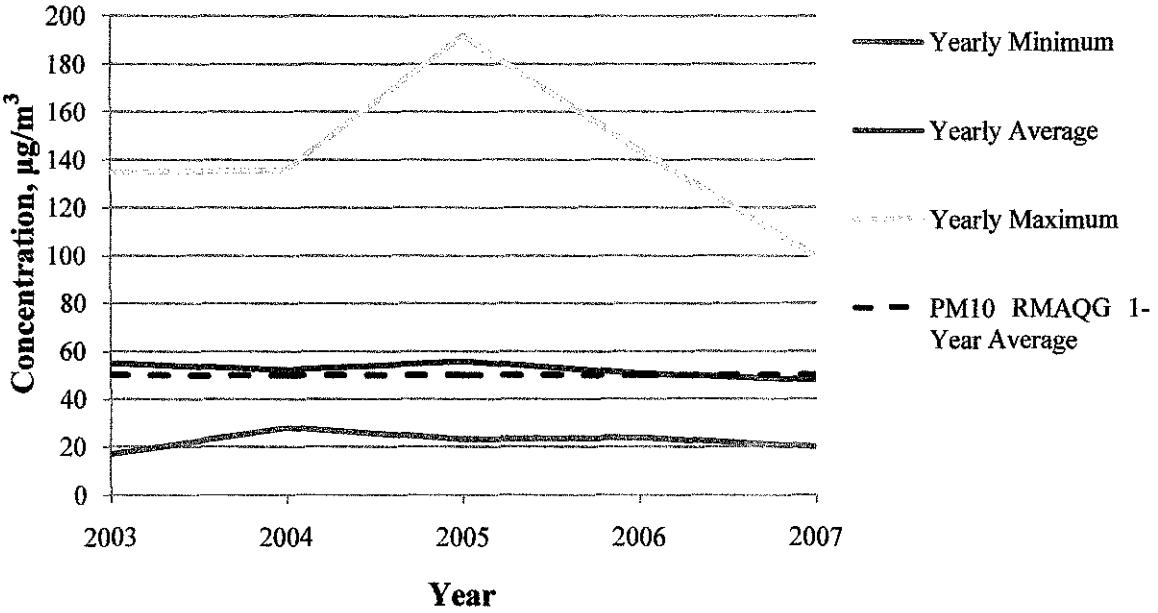


FIGURE 5: The yearly concentration of PM_{10} measured at CAQM station in S.K. Jalan Pegoh, Ipoh, Perak from 2003 to 2007 (DOE, 2008).

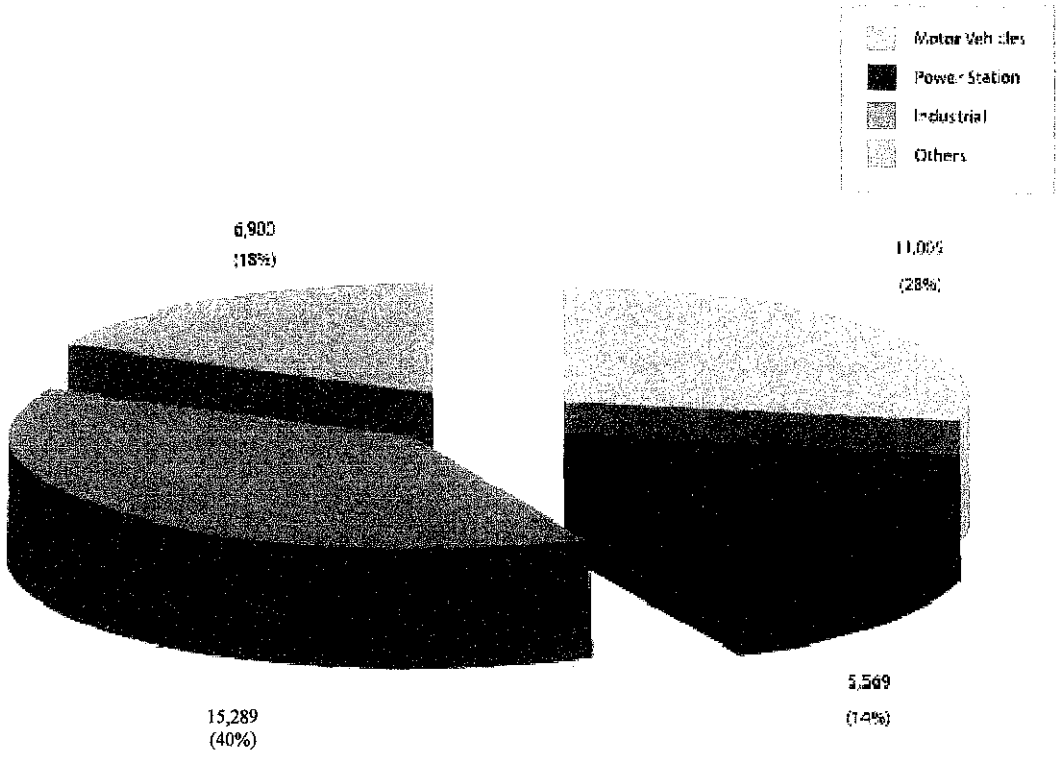


FIGURE 6: Illustration of PM_{10} emission by sources as in metric tonnes, 2007 (DOE, 2008)

CHAPTER 3
METHODOLOGY

3.1 PROJECT IDENTIFICATION

Particulates can be emitted from a considerable range of sources, both natural and anthropogenic. Examples of natural sources of particulates are fungal spores and sea salt while anthropogenic sources or in layman term, human made particulates are agriculture, combustion and construction activities.

PM is described by their diameter. The particulates are a concern to air pollution and typically measured in microns. Large or coarse particles are those considered to be well above 10 microns while very small or fine particles are considered to be those less than one micron or even submicron. Size distributions commonly are expressed in terms of the mass distributions.

Nowadays, there are two sampling approaches that are used to detect the presence of air pollution which are source sampling and ambient sampling. Source sampling obtains the pollutant count of a specific source, whereas ambient sampling collects the pollutant within the total air mass surrounding the earth or generally the site area. For this project purposes, ambient sampling measurement is used.

3.2 PROJECT ACTIVITIES

3.2.1 Sampling Consideration Factor

There are several factors that must be considered before the sampling in order to obtain accurate and reliable data for this project which are site selection, sampling duration and also sampling device.

3.2.1.1 Site Selection

The sampling sites were located within Ipoh, Perak. For this particular study, two specific location been selected as the PM_{10} sampling site. First site is located adjacent to a Continuous Air Quality Monitoring (CAQM) station (Figure 7); located at Sekolah Kebangsaan Jalan Pegoh, Ipoh, representing as the residential area. Second site is at an industrial area known as Tasek Industrial Area (Figure 8). Ipoh has a population exceeding 700,000 inhabitants. Tasek is mostly known by the industrial activities such as cement industry, latex rubber glove factories and many others. Therefore, these industrial activities are allegedly the major cause of air pollution related problems in the area. Though, recent measured data obtained from the CAQM stations shows that the air within the area is still below the Recommended Malaysian Air Quality Guidelines (RMAQG), yet this study is conducted to measure the concentration of PM_{10} at both the source site (industrial area) and also the residential area in relation to health and environment.

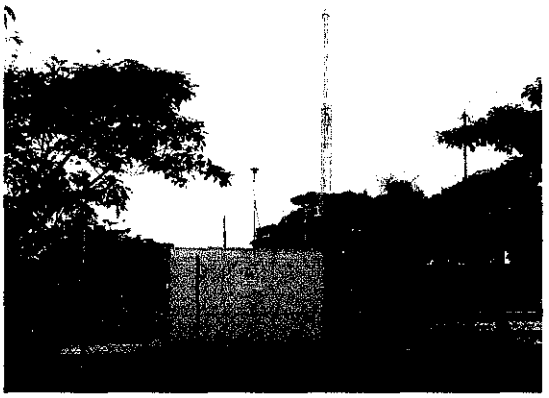


FIGURE 7: The Continuous Air Quality Monitoring (CAQM) station at Sekolah Kebangsaan Jalan Pegoh, Ipoh, Perak.

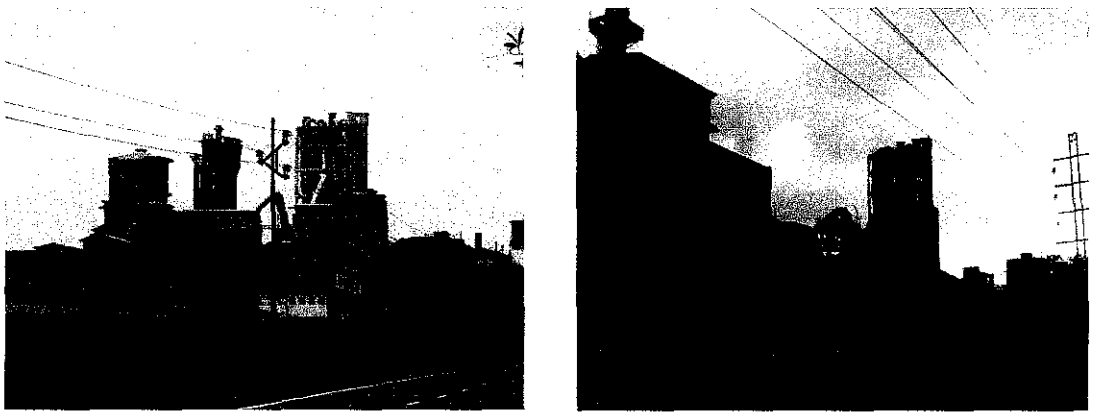


FIGURE 8: Close up view of Tasek Cement Plant, Ipoh, Perak.

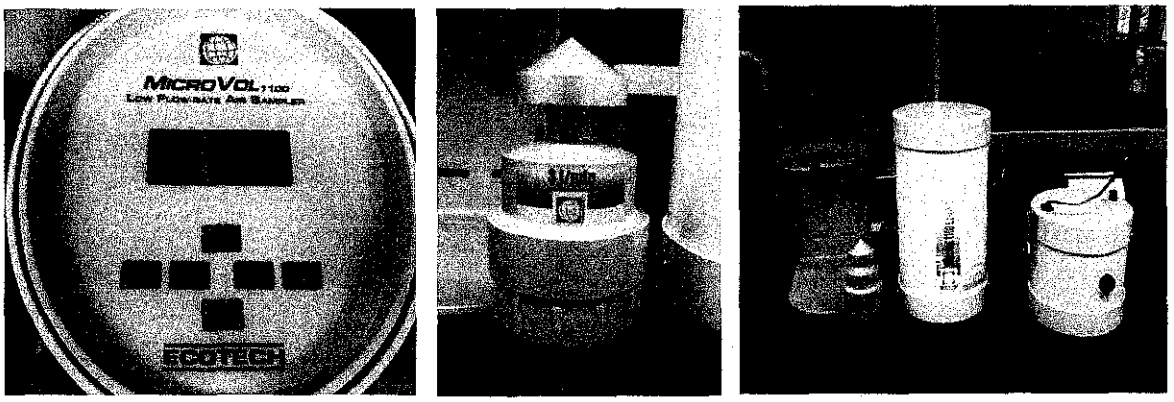
3.2.1.2 Sampling Duration

The length or duration of the sampling is determined to be three hours. The sampling will be taken at two different time intervals, but still on the same day as the sampling is carried out. The time intervals are 9.00 to 12.00 pm and 1.00 to 4.00 pm during weekdays (Wednesday and Friday) and weekend (Sunday). The reasons why the sampling durations are as such is because to compare the concentration of PM during the working days and during the holiday.

3.2.1.3 Sampling Device

During this study, the sampling device used is MicroVol-1100. The MicroVol-1100 uses a pump module to perform particle size selective measurements. It is compact, lightweight and easy to use. The MicroVol-1100 is approximately one meter in height.

Several pictures shown below illustrate the MicroVol-1100:



(a) (b) (c)

FIGURE 9: (a) The control part of the MicroVol-1100; (b) The particulate sampler which consists of fractionators, filter and a Hi-Vol Blower; (c) The components of the MicroVol-1100.

3.2.3 Sampling Procedures

The complete sampling procedure is based on several characteristics that must be considered, which are the pollutant sampled, the methods used in collecting the pollutants, the device chosen and the method of analysis. Ambient sampling is related to analysis in that a weight of air pollutant is collected. This weight of air pollutant is then analyzed to determine the quantity of air pollutant collected and is measured in micrograms (μg). Then, the total volume of air pollutant passing through the device was measured in cubic meter (m^3). Thus, the pollution concentration of the particulate matters in the air sample is then expressed in micrograms per cubic meter ($\mu g/m^3$).

To conduct the sampling process, several procedures have to be followed such as:

1. The milipores filter was prepared, weighted and was placed in the filter holder.
2. The MicroVol-1100 pump is switched on and followed by the MicroVol-1100 is also switched on.
3. The ambient air enters the MicroVol-1100 via the particulate sampler inlet.
4. The air pollutant contained in the ambient air was collected by the milipores filter that was placed initially in the filter holder.
5. The data is observed and collected for duration of three hours.
6. The milipore filter was quickly removed and weighted.
7. The final and initial masses of milipores filter were recorded to be analyzed.

The sampling procedure is generally follow the flow diagram (Figure 10) provided by Canadian Chemical Producers' Association (CCPA, 2001).

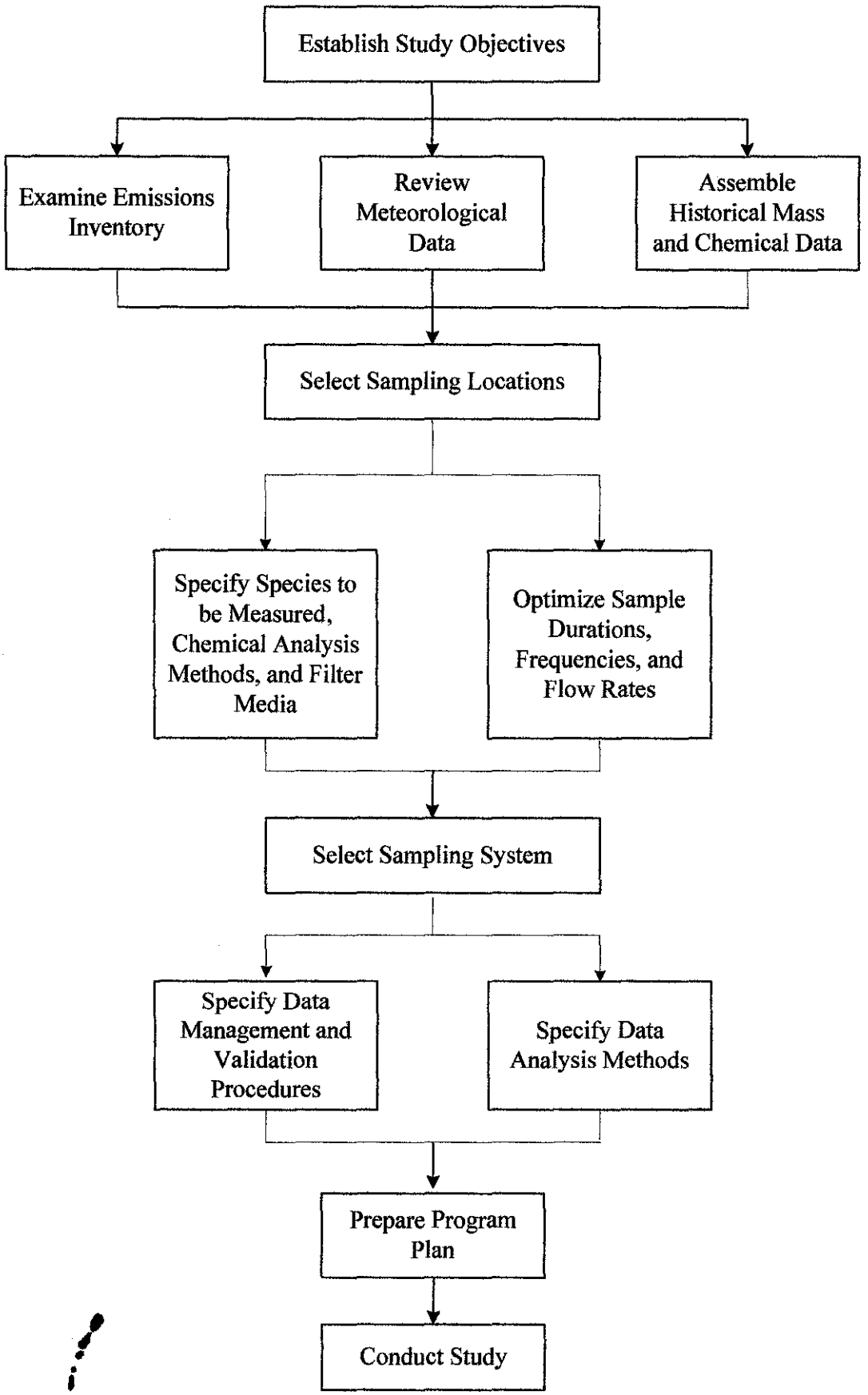


FIGURE 10: Flow diagram for sampling procedures

TABLE 4: Design of sampling results documentation

Sampling Location	Sampling Time (3 Hours)								
	Weekday : Wednesday			Weekday : Friday			Weekend : Sunday		
	Filter's Weight (mg)		Concentration ($\mu g/m^3$)	Filter's Weight (mg)		Concentration ($\mu g/m^3$)	Filter's Weight (mg)		Concentration ($\mu g/m^3$)
	Before	After		Before	After		Before	After	
S.K Jalan Pegoh (9.00 am to 12.00 pm)									
Tasek Industrial Area (1.00 pm to 4.00 pm)									

3.2.4 Calculations

The calculation methodology presented here developed by U.S. Environmental Protection Agency (EPA, 1998). The calculation method covers the calculation of the sample volume, net PM_{10} mass and PM_{10} concentration:

$$M_x = (M_f - M_i) \times 10^3 \qquad \textbf{(4.1)}$$

Where,

M_x = Total mass of particulate matter ($PM_{2.5}$ or PM_{10}) collected during sampling period (μg)

M_f = Final mass of the conditioned filter after sample collection (mg)

M_i = Initial mass of the conditioned filter before sample collection (mg)

10^3 = Unit conversion factor for milligrams (mg) to microgram (μg)

According to the MicroVol-1100 particulate matter sampler measurement of the total volume of ambient air passing through the sampler, V is in cubic meter (m^3):

$$V = Q_{avg} \times t \times 10^{-3} \qquad \textbf{(4.2)}$$

Where,

V = Total sample volume (m^3)

Q_{avg} = Average flow rate over the entire duration of the sampling period (L/min)

t = Duration of sampling period (min)

10^{-3} = Unit conversion factor for liters (L) into cubic meters (m^3)

The equation below can be used to determine particulate matter mass concentration:

$$PM_x = \frac{M_x}{V} \qquad \textbf{(4.3)}$$

Where,

PM_x = Mass concentration of particulate matter ($\mu g/m^3$)

M_x = Total mass of particulate matter collected during sampling period (μg)

V = Total volume of air sampled (m^3)

CHAPTER 4
RESULTS AND DISCUSSION

4.1 INTEGRATED SAMPLING FOR PARTICULATE MATTER

4.1.1 Introduction

This section represents the results and discussion of the ambient air quality monitoring conducted at the selected sampling sites in Ipoh, Perak. The sampling was taken for three hours duration at different time and days. In addition, the results collected will be discussed with respect to the Recommended Malaysian Air Quality Guidelines (RMAQG) and in relation to health and environment.

4.1.2 Ambient Air Quality Monitoring

Table 4 illustrates the results of the weighted filters and calculated concentration of each sampling. The filters has been weighted before and after as to measure the weight of PM that has been collected on the filters while conducting the sampling using the MicroVol-1100. Sample calculations are shown as in APPENDIX II.

4.2 RESULTS

These sampling are conducted at two separated locations which are:

- Next to Sekolah Kebangsaan Jalan Pegoh, Ipoh (Adjacent to the existing a Continuous Air Quality Monitoring (CAQM) station within the school area).
- At the Tasek Industrial Area (500 meters away from the Tasek Cement Plant's Entrance).

Table 5 shows the results of each integrated sampling concentration which had been conducted.

TABLE 5: Sampling results documentation

Sampling Location	Sampling Time (3 Hours)								
	Weekday : Wednesday			Weekday : Friday			Weekend : Sunday		
	Filter's Weight (mg)		Concentration ($\mu g/m^3$)	Filter's Weight (mg)		Concentration ($\mu g/m^3$)	Filter's Weight (mg)		Concentration ($\mu g/m^3$)
	Before	After		Before	After		Before	After	
S.K Jalan Pegoh (9.00 am to 12.00 pm)	0.1400	0.1428	52	0.1410	0.1718	57	0.1400	0.1622	41
Tasek Industrial Area (1.00 pm to 4.00 pm)	0.1390	0.1880	91	0.1370	0.1802	80	0.1380	0.1726	64

TABLE 6: Simplified representation of the ambient air concentration of each sampling conducted

Sampling Location	Concentration ($\mu g/m^3$)		
	Weekday: Wednesday	**Weekday: Friday**	**Weekend: Sunday**
S.K Jalan Pagoh **(9.00 am to 12.00 pm)**	52	57	41
Tasek Industrial Area **(1.00 pm to 4.00 pm)**	91	80	64

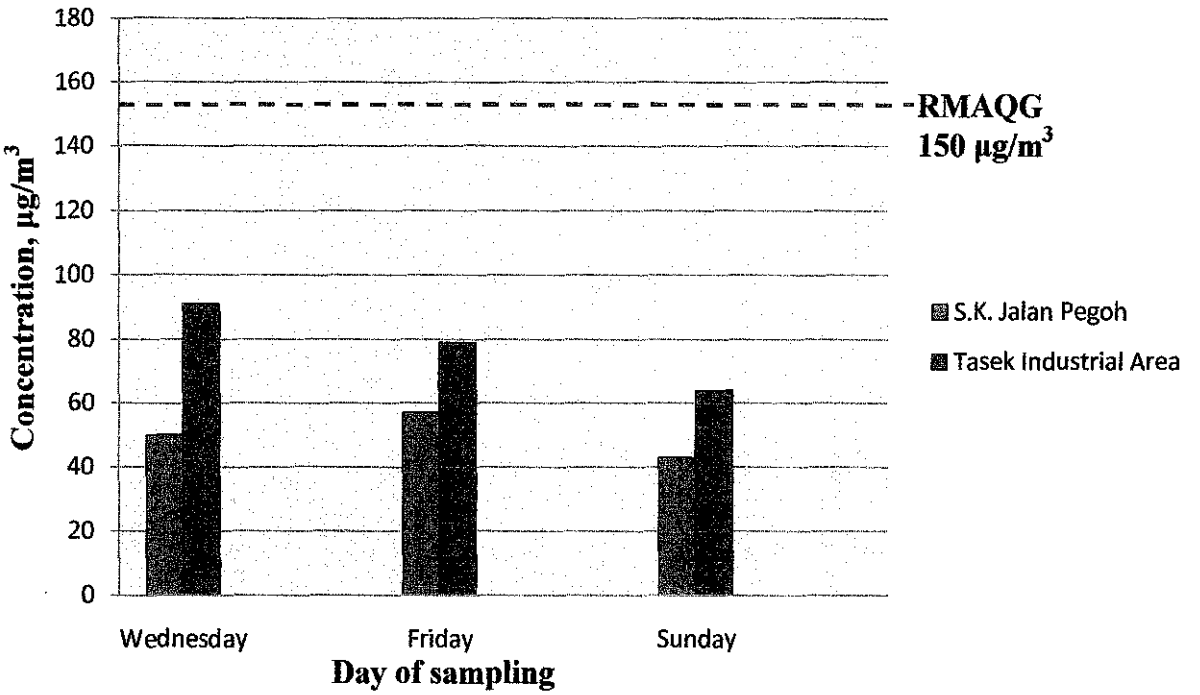
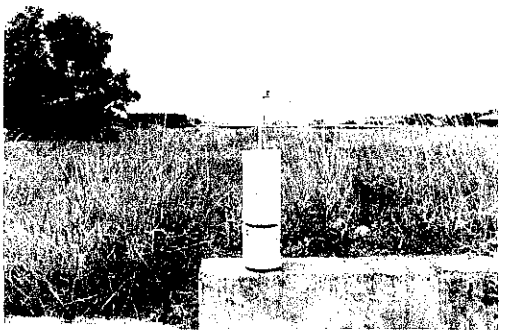


FIGURE 11: Graphical representation of ambient air concentration

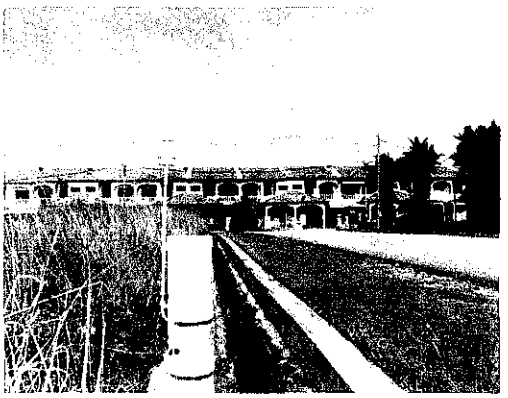
Figure 12 and Figure 13 are the close up views of each sampling locations that were selected for this project:

Sekolah Kebangsaan Jalan Pegoh, Ipoh



(a)

(b)



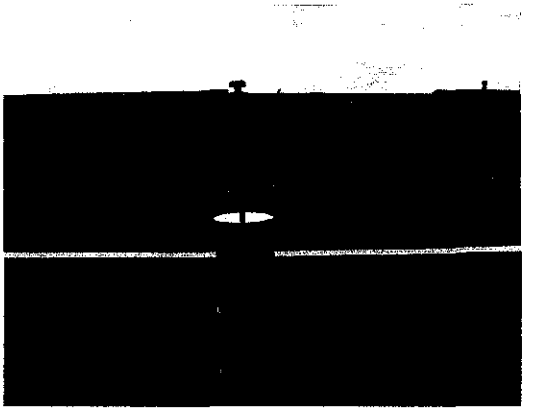
(c)

(d)

FIGURE 12: (a) The North view from the sampling point; (b) The South view from the sampling point; (c) The East view from the sampling point; and (d) The West view from the sampling point.

Tasek Industrial Area

(a)



(b)

(c)

(d)

FIGURE 13: (a) The North view from the sampling point; (b) The South view from the sampling point; (c) The East view from the sampling point; and (d) The West view from the sampling point.

4.3 DISCUSSION

According to Table 5 and Figure 11, the concentrations recorded at the residential area are lower compared to the concentrations recorded at the industrial area. The high concentrations of PM at the industrial area are due to the high number of human activities which as a group, acts as the source of PM emissions. These activities include the Tasek Cement Plant, a latex rubber gloves factory, a tire producing factory and many others. Apart from the fact that in this area, though the number of human activities is high, yet the human activities are not the only contributor to the PM emissions. Emission from mobile, stationary sources and open

Meanwhile, comparing the concentrations in terms of time, during weekdays and weekend, it definitely shows a significant difference. The results show that the concentration of PM is higher during the weekdays (working days) compared to the weekend. During the weekend, the number of human activities and also motorized transportation within then areas are at minimal thus leading to a lower concentration of PM. Movement of people and goods requires energy which relies mostly on the burning of fossil fuels and this leads to emissions and noise caused with adverse local effects.

4.3.1 Effects of Particulate Matter In Relation To Health and Environment

Particulate matters are present in many different sizes. Large particles mainly come from the soils and smaller particles come from the burning of fossil fuels, like gasoline in cars and the coal used at power plants. The smaller particles, the more dangerous it can be. This is because it can travel deeper into the lungs. When particulate matter is inhaled, it can irritate and damage the lungs, causing breathing problems.

People who have asthma or any type of lung or heart disease are directly impacted by high levels of the PM. The elderly and children are also especially vulnerable to the effects of PM. Many studies have shown links between PM and health effects. Increases of PM in terms of mass or even concentration are linked to decreases in lung function, increases in breathing problems, hospitalization and even early death.

Particles of special concern to the protection of lung health are those known as fine particles, less than 2.5 microns in diameter. Fines particles are easily inhaled deeply into the lungs where they can be absorbed into the bloodstream or remain embedded for long periods of time. Both short and long term of exposure to particulate matter can cause respiratory and cardiovascular illness and even death. The most severe effects are likely to be caused by exposure to particles over a long period of time (Vassilakos, 2005).

Particulate matters have significantly marked effects on the environment. These effects are:

- Effect on vegetation;
- Effect on animals; and
- Effect on visibility.

At sufficient concentrations, PM can cause tissue collapse and markings on the upper surface of the leaves known as stipple (pigmented red-brown) and flecking (bleached straw to white). Smog, fog or haze intensified by smoke or other atmospheric pollutants such as PM, can produce a typical smog injury to the vegetations known as bronzing on the underside of the vegetable leaves. In addition, as the effect on grasses, the collapsed tissue shows up as bands bleached tan to yellow. Smog exposure has also been shown to produce early maturity or senescence in plants. One to two hours of exposure at high concentration to the vegetation could cause injury in sensitive species such as tomatoes, tobaccos, beans and potatoes (Pictorial Atlas, 1970).

Air pollutants affect animals much the same as they affect people, lethal or damaging doses to animals depend on the animal's size and respiratory rate. An additional hazard to animals is chronic poisoning from ingesting forage contaminated by the particulate pollutants (DOE, 2007)

In term of visibility, particulate matters are the major cause of visibility reduction. In other words, PM results haze, smoke and dusts. The scattering of light by PM is primarily responsible for the reduction.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The results of the ambient air quality monitoring conducted at Sekolah Kebangsaan Jalan Pegoh and Tasek Industrial Area indicates that the particulate matter concentrations were below the Recommended Malaysian Air Quality Guidelines limits.

The sources of air pollutions are nearly as numerous as grains of sand. In addition, the effects of hazardous air pollutants, such as particulate matter, are too wide in relation to health and environment. Increase in particulate matter in terms of mass could lead to the decrease of lung function and increase in breathing problems and hospitalization. Moreover, the particulate matter imposed significant effects to the environment in terms of vegetation, animal and visibility.

Malaysia is still far away from other advance country in terms of solving the global environmental issues. The major causes of this problem are the attitude and awareness of the Malaysian itself. Therefore, the Malaysian and other authorities, government and non-governmental organizations, should act quickly in order to keep our environment safe and clean not only for the current generation, but as well for the next generation.

5.2 RECOMMENDATIONS

Particulate matter can cause undesirable impact in relation to health and environment. Therefore, there are a few of recommendation can be taken into consideration for further improvement to this study. The recommendations are as below:

1. To be more flexibility in conducting this study in terms of device usage and number of filters provided. By having the appropriate flexibility, a more detail study can be conducted on the ambient air quality monitoring in relation to health and environment.

2. The authorities in Malaysia should start enforcing the importance of air pollution control at the sources and reconsidering to amend the current guidelines to provide a safe and clean environment for the future generations.

3. To co-related the findings of this study with other relevant projects and studies to further improve or even develop a better and new compliance models.

REFERENCES

1. Menczel J., L.A. 1996. *Encyclopedia of Environmental Science and Engineering*, **(1 A-L)**, North Caroline, USA

2. Roger D.G., 2007. *Principles of Air Quality Management*, Second Edition, New York, CRC Taylor & Francis

3. Thomes E.P., N.C. 1992. "Screening Procedures for Air Quality Impacts," *Air Quality Planning and Standards Research* **27711:** 3-57

4. Turner D.B., 1964. *A Diffusion Model for an Urban Area*, Journal of Applied Meteorology, Volume 3, 83-91.

5. Turner, D.B., 1994. *Workbook of atmospheric dispersion estimates: an introduction to dispersion modeling*, 2nd Edition, CRC Press.

6. Beychok, M.R., 2005. *Fundamentals of Stack Gas Dispersion*, 4th Edition, author-published.

7. Vesilind, P.A., Pierce, J. and Weiner, R.F. 1988. *Environmental Engineering*, 2nd Edition Boston: Butterworth Publisher.

8. Talib M.L., Rozali M.O., Norela S., Ahmad Daud M.N. and Permata N.J., 2002, "Air Quality In Several Industrial Areas In Malaysia" in Oman, R., Ali Rahman, Z., Latif, M.T., Lihan, T. and Adam J.H. (Eds) *Proceeding of the Regional Symposium on Environment and Natural Resources*, Kuala Lumpur, Malaysia.

9. Schnell K.B, Jr. and Brown C.A, 2001, *Air Pollution Control Technology Handbook*, New York, CRC Press.

10. D. Owen Harrop, 2002, *Air Quality Assessment and Management. A Practical Guide*, London, SPON Press.

11. Aryes J., Maynard R. and Richards R., 2006, *Air Pollution and Health*, **(3)**, Danvers, Imperial College Press.

12. Phalen R.F, 2002, *The Particulate Air Pollution Controversy. A Case Study and Lessons Learned*, Boston, Kluwer Academic Publishers.

13. Vallero D., 2007, *Fundamentals of Air Pollution,* Boston, Academic Press - Elsevier.

14. WHO, 2006, *Air Quality Guidelines - Global Update 2005,* Germany, Drunkpartner Moser.

15. Arif A.R, 2008, *Integrated Air Sampling For Particulate Matter,* Malaysia, Faculty of Chemical Engineering, UiTM.

16. DOE Malaysia, 2008. "Air Pollution Trend and Status" in *Malaysia Environment Quality Report 2007,* Malaysia.

17. Vassilakos C., Saraga D., 2005. *Temporal variation of $PM_{2.5}$ in the ambient air of a suburban site in Athens*, Greece, Sci Total Environ.

18. U.S Government Printing Office, 1970. *Air Quality Criteria For Particulate Matter (AQCPM)*, Washington D.C, Superintendent of Documents, Published no. **AP-50**

APPENDICES

APPENDIX I : GANTT CHART

Name : Syahenaz Bin Kamaroll Zaman

ID no. : 8477

Title : Determination and Assessment of Suspended Particulate Matters In Relation To Health and Environment (FYP 2)

No	Task/Activity	Academic Week														Exams	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Acquainted with Supervisor										Mid-Semester Break						
2	Proceed with Case Study #3																
	a Understanding of Particulate Matter																
	b Familiarization calculations and methods																
	*Submission of Progress Report 1 (13/2/2009)				o												
3	Integrated Sampling of Particulate Matter																
4	Updates and review with Supervisor																
5	*Submission of Progress Report 2 (3/4/2009)											o					
6	Poster exhibition (8-9/2/2009)												o				
7	Engineering Design Exhibition (EDX)													o			
8	Final Report Preparations																
9	Submission of Final Report															o	
10	FYP 2 Oral presentation																

APPENDIX II : SAMPLE CALCULATIONS

1. Sample calculation at S.K Jalan Pegoh, Friday (1.00 – 4.00 pm) on 25th March 2009

Weight of filter:

Before : 0.1410 mg

After : 0.1718 mg

Mass Particulate Matter

$$M_x = (M_f - M_i) \times 10^3$$

$$M_x = (0.1718 - 0.1410) \times 10^3$$

$$M_x = 30.8\ \mu g$$

Total Sample Volume

$$V = Q_{avg} \times t \times 10^{-3}$$

$$V = 3\ L/min \times 180\ min \times 10^{-3}$$

$$V = 0.54\ m^3$$

Particulate Matter Mass Concentration

$$PM_x = \frac{M_x}{V}$$

$$PM_x = \frac{40.8\ \mu g}{0.54\ m^3}$$

$$PM_x = 57\ \mu g/m^3 << 150\ \mu g/m^3 \text{ (RMAQG)}$$

2. Sample calculation at Tasek Industrial Area, Wednesday (1.00 – 4.00 pm) on 25th March 2009

Weight of filter:

Before : 0.1390 mg

After : 0.1880 mg

Mass Particulate Matter

$$M_x = (M_f - M_i) \times 10^3$$

$$M_x = (0.1880 - 0.1390) \times 10^3$$

$$M_x = 49\ \mu g$$

Total Sample Volume

$$V = Q_{avg} \times t \times 10^{-3}$$

$$V = 3\ L/min \times 180\ min \times 10^{-3}$$

$$V = 0.54\ m^3$$

Particulate Matter Mass Concentration

$$PM_x = \frac{M_x}{V}$$

$$PM_x = \frac{49\ \mu g}{0.54\ m^3}$$

$PM_x = 91\ \mu g/m^3 << 150\ \mu g/m^3$ (RMAQG