A STUDY ON THE CONCENTRATION AND DISPERSION OF PM_{10} IN UTHM BY USING SIMPLE MODELLING AND METEOROLOGICAL FACTORS

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ABSTRACT

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment, into the atmosphere. Air pollution can also be known as degradation of air quality resulting from unwanted chemicals or other materials occurring in the air. The simple way to know how polluted the air is to calculate the amounts of foreign and/or natural substances occurring in the atmosphere that may result in adverse effects to humans, animals, vegetation and/or materials. The objective of this study is to create a simulation of air quality dispersion in UTHM campus by using computer aided design mechanism such as software and calculating tools. Another objective is to compare the concentration obtained from the end result of calculation with past studies. The air pollutant in the scope of study is Particulate Matter (PM_{10}). The highest reading recorded for E-Sampler was 305µg/m^3. It was recorded in Structure Lab sampling point while the highest expected concentration by the Gaussian Dispersion Model was 184µg/m^3 for UTHM Stadium. The recommended value for permissible exposure to particulate matter in 24 hours time is 150µg/m^3 according to the Recommended Malaysian Air Quality Guidelines.

ABSTRAK

Pencemaran udara adalah pengenalan bahan kimia, bahan zarahan atau bahan biologi yang boleh menyebabkan mudarat atau ketidakselesaan kepada manusia atau organisma hidup lain, atau menyebabkan kerosakan kepada persekitaran semulajadi atau alam bina, ke atmosfera.Pencemaran udara juga boleh dikenali sebagai degradasi kualiti udara yang terhasil dari bahan kimia yang tidak diingini atau bahan-bahan lain yang berlaku di udara. Cara mudah untuk mengetahui bagaimana tercemar udara untuk mengira jumlah bahan-bahan asing dan / atau semula jadi yang berlaku dalam suasana yang mungkin menyebabkan kesan buruk kepada manusia, haiwan, tumbuh-tumbuhan dan / atau bahan-bahan. Objektif kajian ini adalah untuk mewujudkan simulasi penyebaran kualiti udara di kampus UTHM dengan menggunakan bantuan model komputer seperti perisian dan alat pengiraan. Objektif lain adalah untuk membandingkan kepekatan yang diperolehi daripada hasil akhir pengiraan dengan kajian lepas. Pencemar udara di dalam skop kajian ini adalah Zarah Halus 10 micron (PM_{10}). Nilai bacaan tertinggi yang dicatatkan untuk E-Sampler adalah 305µg/m3. Ia telah direkodkan di dalam kawasan Makmal Struktur manakala nilai kepekatan tertinggi yang dijana oleh Model Serakan Gaussian adalah 184µg/m3 untuk UTHM Stadium. Nilai yang disyorkan untuk pendedahan yang dibenarkan untuk zarah halus dalam tempoh masa 24 jam adalah 150µg/m3 mengikut kepada Garis Panduan Saranan Kualiti Udara Malaysia.

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CHAPTER I

INTRODUCTION

1.1 Introduction

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural environment or built environment, into the atmosphere. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems. Indoor air pollution and urban air quality are listed as two of the world’s worst pollution problems in the 2008 Blacksmith Institute World's Worst Polluted Places report. (Blacksmith Institute, 2011)

The air we breathe contains particles and composition of particles, including mineral dust, metals, metalloids, sea salt, nitrate and ammonium sulphate, organic compounds, elemental carbon and organic and inorganic pollutants that live almost entirely in the gas phase. Some of them are directly emitted into the atmosphere either by natural sources and anthropogenic (primary particles), while others are the result of homogeneous or heterogeneous nucleation and condensation of gases (secondary particles) (Dongarrà, Manno et al. 2010).

Air quality is defined as a measure of the condition of air relative to the requirements of one or more biotic species or to any human need or purpose. (Johnson et al, 1997) while air quality indices (AQI) are numbers used by government agencies to characterize the quality of the air at a given location. As the AQI increases, an increasingly large percentage of the population is likely to experience increasingly severe adverse health effects. To compute the AQI, it requires an air pollutant concentration from a monitor or model. The function used to convert from air pollutant concentration to AQI varies by pollutant, and is different in different countries.

1.2 Research Objective

The objective of this research is to predict the dispersion of PM_{10} by means of meteorological factor mainly wind using a simple modelling and also to compare the difference between concentrations of PM_{10} gained by using E-Sampler to the Recommended Malaysian Air Quality Guidelines. A simple modelling system was chosen which is name as Gaussian Dispersion Model is and it will be used to provide a more detail on the results of concentration and dispersion. The model is use to provide some basis for discussion whether meteorological factor remains as the source for concentration dispersion throughout UTHM campus.

1.3 Research Scopes

The scope in this research is to use the collective data from past research and current research on particulate matter size 10 µm (PM_{10}) and then use it to predict the possible future dispersion patterns. Apart from that, the data collected will also be used to compare with any Malaysian regulations regarding air quality.

The sampling locations are limited to 3 places and those are Structure Laboratory, Tun Syed Nasir Residential College and UTHM Stadium. These places are selected because of the distance factor and also the impact it may cause for a highly concentrated area.

1.4 Problem Statements.

In Malaysia, there are no ambient air quality standards but the Malaysian government however established ambient air quality guidelines in 1988 (Department of Environment, 2012). Pollutants addressed in the guidelines include ozone, carbon monoxide, nitrogen dioxide, sulphur dioxide, total suspended particles, particulate matter under 10 microns, lead and dust fall. The averaging time which varies from 1 to 24 hours for different air pollutants in the Recommended Malaysian Air Quality Guidelines represents the period of time over which measurements is monitored and reported for the assessments of human health impacts of specific air pollutants.

Universiti Tun Hussein Onn Malaysia (UTHM) is located in a unique area because it is surrounded by industrial area which emits pollutants directly into the air. There have been cases; but it is not reported as formal reports, more on visual reports; where particulate matters released from the industrials area goes up in the air and then for some reason fall down back to earth like snow and it accumulate on the ground surface. For this reason, people in the UTHM compound are always in questions with their health when they encounter any sickness whether it is caused by the long exposure to pollutants emitted by the factories or because of some other factors.

1.5 Research Significant

This thesis will provide knowledge about the dispersion of pollutant mainly particulate matters fewer than 10 microns by looking further into the meteorological factors. Furthermore, this research is hopefully to help others in their search for the best system to use in the future.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Air pollution can also be known as degradation of air quality resulting from unwanted chemicals or other materials occurring in the air. The simple way to know how polluted the air is to calculate the amounts of foreign and/or natural substances occurring in the atmosphere that may result in adverse effects to humans, animals, vegetation and/or materials. Urban air pollution with its long and short term impacts on human health, well – being and the environment has been a widely recognized problem over the last 50 years (Gurjar et al. 2008; Ozden et al. 2008). In addition to population growth, the rapid growth of urbanization and industrialization; where the progressive expansion of suburbs into closer proximity with industrial facilities in certain areas has led to the problem of air pollution becoming an increasingly important issue (Ferger 1999; Molina and Molina 2004). Besides deleterious effects on human health, air pollution can negatively impact ecosystems, materials, buildings and works of art, vegetations and visibility (Ilyas et al. 2009; Mage et al. 1996; Riga-Karandinos and Saitanis, 2005).

2.2 Meteorological Aspect for Air Pollution

The transport and dispersion of air pollutants in the ambient air are influenced by many complex factors. Global and regional weather patterns and local topographical conditions affect the way that pollutants are transported and dispersed. The amount and kind of pollutants that are released into the air play a major role in determining the degree of air pollution in a specific area. However, other factors are involved, mainly:

1. Atmospheric pressure;
2. Topography or earth surfaces;
3. Temperature inversion;
4. Wind speed and wind direction

2.2.1 Effects of Atmospheric Pressure in Air Pollution

Atmospheric pressure is the force per unit area exerted into a surface by the weight of air above that surface in the atmosphere of Earth. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the mass of air above the measurement point. Low-pressure areas have less atmospheric mass above their location, whereas high-pressure areas have more atmospheric mass above their location. Likewise, as elevation increases, there is less overlying atmospheric mass, so that pressure decreases with increasing elevation. On average, a column of air one square centimetre in cross-section, measured from sea level to the top of the atmosphere, has a mass of about 1.03 kg and weight of about 10.1 N. The difference in atmospheric pressure and density varies widely on Earth as can be clearly seen in Figure 2.1 while Figure 2.2 will show the atmospheric composition from the ground surface.

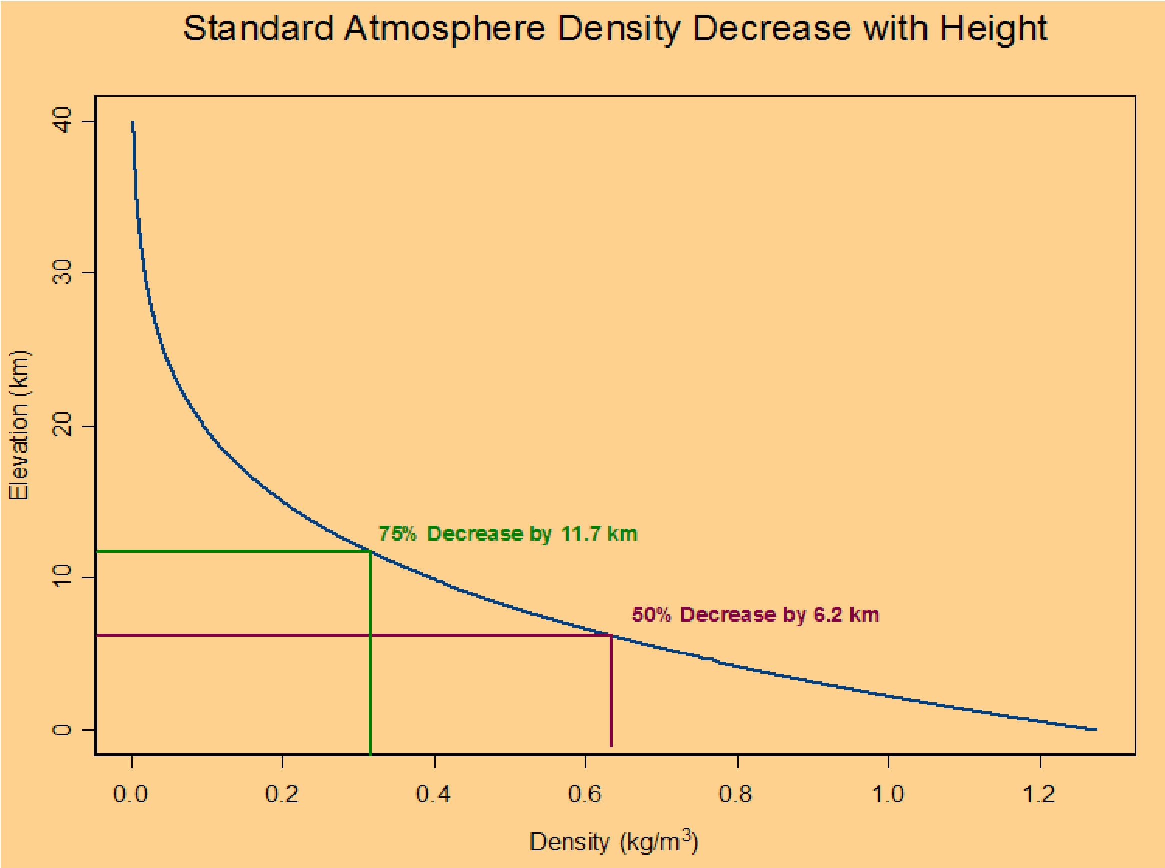


Figure 2.1: Standard Atmospheric Density Based on Elevation. (Source: University of California Santa Barbara.)

As the elevation decreases, the density is increasing. It clearly shows that the higher we go up into the atmosphere, the air around us will get thinner and the density of the atmosphere will also decrease. The height and temperature of a column of air determines the atmospheric weight. Because cool air weighs more than warm air, a high pressure mass of air is made up of cool and heavy air. Conversely, a low pressure mass of air is made up of warmer and lighter air. Differences in pressure cause air to move from high pressure areas to low pressure areas.

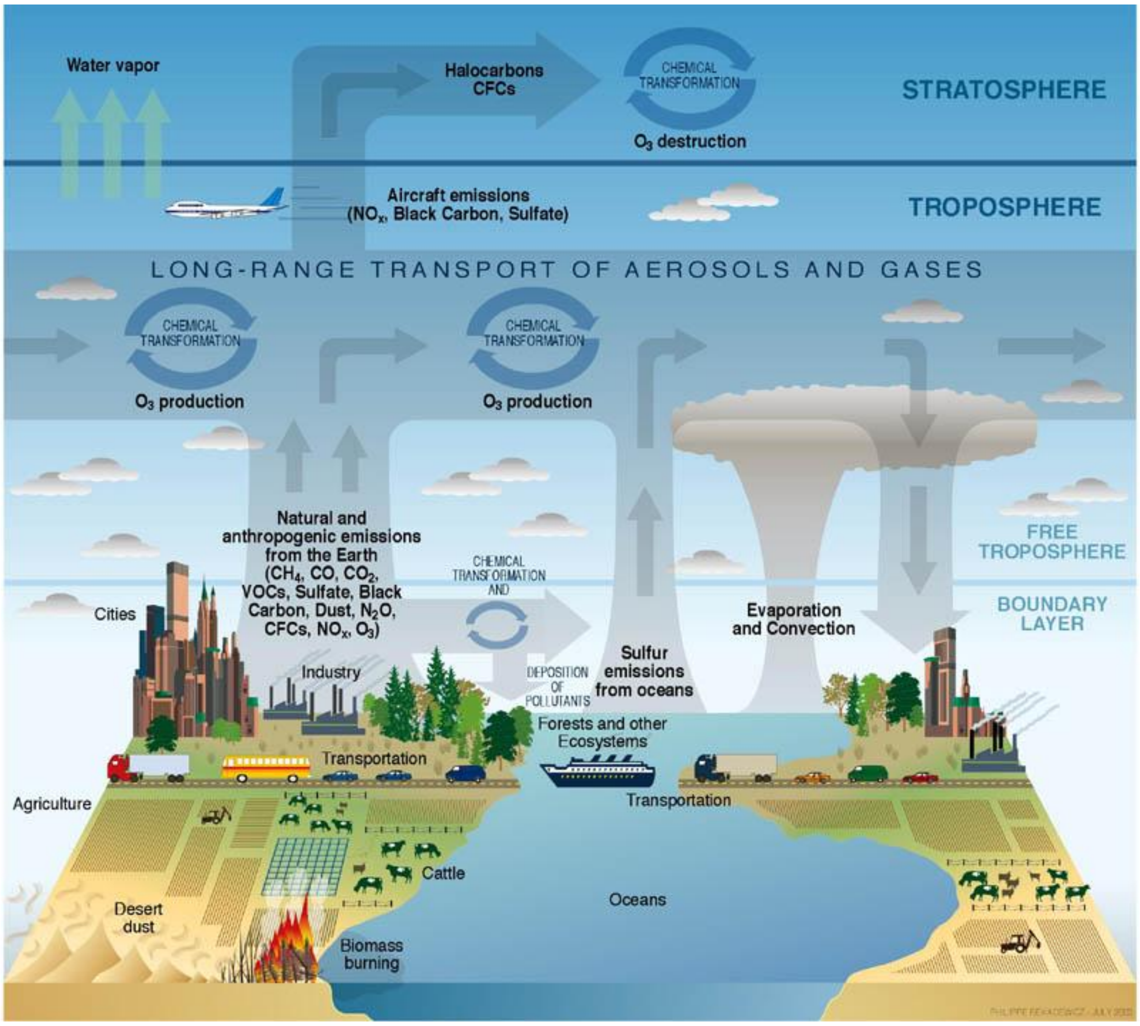


Figure 2.2: Air Pollution Sources and Means of Dispersion. (Source: US Strategic Plan for the Climate Change Science Program, Final Report July 2003)

Another point to remember is that the warm air is heavier than the cool air so the air cycle in the atmosphere will always be in an order of the warm air that have lost its heat goes up to replace the cool air that has gain heat from atmospheric interaction.

2.2.2 Effects of Topography in Air Pollution

Topography is a field of planetary science comprising the study of surface shape and features of the Earth. It is also the description of such surface shapes and features (especially their depiction in maps). The topography of an area can also mean the surface shape and features. Topography also means the arrangement of the natural and artificial physical features of an area. Topography specifically involves the recording of relief or terrain, the three-dimensional quality of the surface, and the identification of specific landforms.

Terrain, or land relief, is the vertical and horizontal dimension of land surface. Terrain is used as a general term in physical geography, referring to the lay of the land. This is usually expressed in terms of the elevation, slope, and orientation of terrain features. Terrain affects surface water flow and distribution. Over a large area, it can affect weather and climate patterns.

In terms of terrain, mountain areas are generally colder than surrounding land due to higher altitudes. Mountainous regions block the flow of air masses, which rise to pass over the higher terrain. The rising air is cooled, which causes condensation of water vapour, and precipitation. These being the case, one side of a mountain, the windward side, will often have more precipitation and vegetation; the leeward side is often drier.

In terms of proximity to the ocean, land and water retain different amounts of heat. Land heats more quickly than water, but water holds heat longer. Proximity to water moderates the climate, while inland climates are harsher. Those living near the water will experience breezy, moist weather, when the warm air from the land meets the cooler air from the water and rises, making for a windy climate with precipitation. The further inland one goes, the drier the climate in most regions.

Concentrations of pollutants can be greater in valleys than for areas of higher ground. This is because, under certain weather conditions, pollutants can become trapped in low lying areas such as valleys. This happens for example, on still sunny days when pollution levels can build up due to a lack of wind to disperse the pollution. This can also happen on cold calm and foggy days during winter. If towns and cities are surrounded by hills, wintertime smog's may also occur. Pollution from vehicles, homes and other sources may become trapped in the valley, often following a clear cloudless night. Cold air then becomes trapped by a layer of warmer air above the valley (USEPA, 2011).

2.2.3 Effects of Temperature Inversion

The situation of having warm air on top of cooler air is referred to as a temperature inversion, because the temperature profile of the atmosphere is "inverted" from its usual state. Inversions layers can occur anywhere from close to ground level up to thousands of feet into the atmosphere and because of that, there are two types of temperature inversions:

1. Surface inversions that occur near the Earth's surface;
2. Aloft inversions that occur higher above the ground.

2.2.3.1 Causes of Temperature Inversions

The most common manner in which surface inversions form is through the cooling of the air near the ground at night. Once the sun goes down, the ground loses heat very quickly, and this cools the air that is in contact with the ground. However, since air is a very poor conductor of heat, the air just above the surface remains warm.

Conditions that favour the development of a strong surface inversion are calm winds, clear skies, and long nights. Calm winds prevent warmer air above the surface from mixing down to the ground, and clear skies increase the rate of cooling at the Earth's surface. Long nights allow for the cooling of the ground to continue over a longer period of time, resulting in a greater temperature decrease at the surface. Since the nights in the wintertime are much longer than nights during the summertime, surface inversions are stronger and more common during the winter months. A strong inversion implies a substantial temperature difference exists between the cool surface air and the warmer air aloft. During the daylight hours, surface inversions normally weaken and disappear as the sun warms the Earth's surface. However, under certain meteorological conditions, such as strong high pressure over the area, these inversions can persist as long as several days. In addition, local topographical features can enhance the formation of inversions, especially in valley locations.

Surface temperature inversions play a major role in air quality, especially during the winter when these inversions are the strongest. The warmer air above the cooler air acts like a lid where it suppress, vertical mixing and trapping the cooler air at the surface along with the pollutants because as pollutants from vehicles, fireplaces, and industry are emitted into the air, the inversion traps these pollutants near the ground, leading to poor air quality. Graphical ways of understanding temperature inversion can be clearly seen in Figure 2.3.

Figure 2.3: Temperature Inversion and the Effects. (US Environmental Protection Agency, 2011)

2.2.3.2 Consequences of Temperature Inversions

Some of the most significant consequences of temperature inversions are the extreme weather conditions they can sometimes create. Although freezing rain, thunderstorms, and tornadoes are significant weather events, one of the most important things impacted by an inversion layer is smog. This is the brownish gray haze that covers many of the world's largest cities and is a result of dust, auto exhaust, and industrial manufacturing.

Smog is impacted by the inversion layer because it is in essence, capped, when the warm air mass moves over an area. This happens because the warmer air layer sits over a city and prevents the normal mixing of cooler, denser air. The air instead becomes still and over time the lack of mixing causes pollutants to become trapped under the inversion, developing significant amounts of smog.

During severe inversions that last over long periods, smog can cover entire metropolitan areas and cause respiratory problems for the inhabitants of those areas. London's Great Smog of 1952 and Mexico's similar problems are extreme examples of smog being impacted by the presence of an inversion layer.

In December 1952, such an inversion occurred in London. Because of the cold December weather at the time, Londoners began to burn more coal, which increased air pollution in the city. Since the inversion was present over the city at the same time, these pollutants became trapped and increased London's air pollution. The result was the Great Smog of 1952 that was blamed for thousands of deaths. Like London, Mexico City has also experienced problems with smog that have been exacerbated by the presence of an inversion layer. This city is infamous for its poor air quality but these conditions are worsened when warm sub-tropical high pressure systems move over the city and trap air in the Valley of Mexico. When these pressure systems trap the valley's air, pollutants are also trapped and intense smog develops. Since 2000, Mexico's government has developed a ten year plan aimed at reducing ozone and particulates released into the air over the city (USEPA, 2011).

2.2.4 Effects of Wind Speed and Wind Direction in Air Pollution

Wind is simply air in motion. On global or macro scale wind patterns are set up due to unequal heating of earth surface by solar radiation at the equator and the Polar Regions, rotation of the earth and the difference between conductive capacities of land and ocean masses. Secondary or mesoscale circulation patterns develop because of the regional or local topography. Mountain ranges, cloud cover, water bodies, deserts, forestation, etc., influence wind patterns on scales of a few hundred kilometres. Accordingly a pattern of wind is setup, some seasonal and some permanent.

Micro scale phenomenon occurs over areas of less than 10 kilometres extent. Standard wind patterns may deviate markedly due to varying frictional effects of the earth surface, such as, rural open land, irregular topography and urban development, effect of radiant heat from deserts and cities, effect of lakes, etc.

The movement of air at the mesoscale and micro scale levels is of concern in control of air pollution. A study of air movement over relatively small geographical regions can help in understanding the movement of pollutants.

The dispersion of air pollutants mainly depends on physical processes is air; those of wind and weather. How far air pollutants are transported mainly depends upon particle size of the compounds and at which height the pollution was emitted into the air. Fumes that are emitted into air through high smoke stacks will mix with air so that local concentrations are not very high. However, wind will transport the particle compounds and the pollution will be spread and disperse where else, rain can remove pollutants from air (USEPA, 2011).

2.3 Characteristics of Air Quality in Malaysia

In the early days of Malaysia, development and growth were not planned; they were initiated according to the needs and pressures of the time. Consequently, this haphazard development has resulted in negative impacts on the environment as a whole and on air quality in particular (Sham, 1994). Earlier, Sham (1979) pointed out that atmospheric pollution problem is becoming more serious as there is always a potential for the occurrence of inversion in the valley. In anticipation of the potential severity and magnitude of the problem, the government enacted into law the Environmental Quality Act in 1974; subsequently, the Division of the Environment was established and the Clean Air Regulations were formerly gazette in 1978.

The first “long-term” air quality monitoring project emphasizing suspended particulate and sulphur dioxide was carried out by the Department of Environment

(DOE) and the Meteorological Service Department (MMS) at the industrial and residential zones in Petaling Jaya in 1978. Results of the study suggested that the suspended particulates exceeded 93% of the time in industrial area in which the previously proposed standard was a 24-h average of 100 $\mu g/m^3$ and 95% of the time in the residential zone which the previously proposed standard was a 24-h average of $50\mu g/m^3$ (DOE, 1997).

Ambient air quality standards identify individual pollutants and the concentrations at which they become harmful to the public health and environment. The standards are typically set without regard to economic feasibility for attainment. Instead, they focus on public health including the health of “sensitive” populations such as asthmatics, children and the elderly and public welfare including protection against decreased visibility and damage to animals, crop, vegetation, aquatic resources and buildings. The Malaysian air pollution index (API) is obtained from the measurement of fine particles (below 10 µm) and several gases: carbon monoxide, sulphur dioxide and nitrogen dioxide. Table 2.1 shows the API for Malaysia.

Table 2.1: The Malaysia Air Pollution Index

API	Diagnosis
0 -50	Good
50 – 100	Moderate
101 – 200	Unhealthy
201 – 300	Very unhealthy
301 - 500	Hazardous

(Source: Department of Environment (2010)

Apart from API, Malaysia has also list out some recommended air quality guidelines which is compared with National Ambient Air Quality Standards currently enforced in the United States and WHO Guidelines. Table 2.2 lists the recommended

Malaysian Air Quality Guidelines (Ambient Standards). The Malaysian guidelines are fairly consistent with the standards of the United States.

Table 2.2: The ambient air quality standards for Malaysia and the United States

Air pollutants	Malaysia ($\mu g/m^3$)	USA ($\mu g/m^3$)	WHO ($\mu g/m^3$)
Carbon monoxide			
8-h average	10 000	10 000	10 000
1-h average	35 000	40 000	30 000
Nitrogen dioxide (NO_2)			
Annual	-	100	-
1-h average	320	-	400
Ozone (O_3)			
8-h average	120	-	100
1-h average	200	240	150
Particulate matter			
Annual	90	50	-
24-h average	150	150	-
Sulphur dioxide (SO_2)			
Annual	-	80	-
24-h average	105	365	-

(Source: Department of Environment (2010))

2.4 Air Pollution Studies in Malaysia

In Malaysia, few studies have been conducted on air pollution. Most of them are related to the 1997 haze episode. In most years, the Malaysian air quality was dominated by the occurrence of dense haze episodes. From July to October 1997, Malaysia was badly affected by smoke haze caused by land and forest fires. Previous incidents of severe haze in the country were reported in April 1983 (Chow and Lim, 1983), August 1990 (Cheang, 1991; Sham, 1991), June and October 1994 (Yap, 1995). The severity and extent of the 1997 smoke haze pollution were unprecedented affecting some 300 million people across the region. The actual amount of economic losses suffered by countries in the region during this environmental disaster were enormous and yet to be fully determined.

During non-haze episodes, vehicular emissions accounted for more than 70% of the total emission in the urban areas. Air quality studies conducted in the Klang Valley during the non-haze episodes between 1986 and 1989, December 1991 to November 1992 and January 1995 to December 1997 demonstrated two distinct daily peaks in the diurnal variation in the concentrations of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide and particulate matter. The morning hour peak was mainly due to vehicle emissions and the late evening peak was attributed mainly to meteorological conditions including atmospheric stability and wind speed. Total suspended particulate matter was the main pollutant because the concentrations at a few sites in the Klang Valley often exceeded the Recommended Malaysian Air Quality Guidelines.

A comprehensive study conducted by the Department of Environment, Japan International Cooperation Agency, the Malaysian Meteorological Service and Universiti Putra Malaysia between December and August 1993 gave clear indications that air pollution in the Klang Valley has become worse. This study also indicated that if no effective counter – measures were introduced, the emissions of sulphur oxides (SO), nitrogen oxides (NO), particulate matter, hydrocarbons and carbon monoxides (CO) in the year 2005 would increase 1.4, 2.12, 1.47 and 2.7 times respectively to the 1992 levels (Awang et al. 1997).

A separate study of air quality in Kuala Lumpur found that the smoke haze was associated with high levels of suspended microperticulate matter but with relatively low levels of other gaseous pollutants such as carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone (Awang et al. 2000; Noor, 1998). During this period, PM_{10} concentration rose beyond the Malaysian Air Quality Guidelines (MAQG, 1989) level in almost all area monitored. It increased 4-fold higher in the Klang Valley and up to 20-fold in Kuching (Awang et al., 2000).

2.5 Sources of Air Pollution from Certain Industries in Malaysia

Malaysia has enjoyed one of the least polluted urban environments in Asia. The goal of achieving industrial country status by the year 2020 and the associated rapid economic growth have started to impose costs in term of industrial pollution and the degradation of urban environment (Afroz et al. 2003). Malaysia's economic growth depends on the manufacturing industries especially electronics, chemicals and rubber. However, the increasing rate of production has resulted in an emission of organic and inorganic gases, chemicals and dust. The various types of industrial pollutants produce are different. For example, the chemical industry releases pollutants that contain a variety of compounds based on nitrogen and sulphur while the oil refinery smoke contains sulphur dioxide and hydrocarbons. Metal industry is responsible for polluting the air with sulphur dioxide and toxic dust. Table 2.3 will show the stack gas emission standards regarding with the gases release by certain industry.

Table 2.3: Stack Gas Emission Standards

Pollution	Emission sources	Standards
1. Dark smoke	(1.1) Solid Fuel Equipment to Facilities	Ringlemann Chart No.2

	(1.2) Equipment using other types of fuel	Ringlemann Chart No.1
2. Dust	(2.1) Facilities used for the heating of metal other than Cold Blast Foundry Cupola (2.2) Facilities discharging dust containing asbestos and free silica (2.3) Portland Cement Manufacturing: (2.3.1) Kiln (2.3.2) Clinker, cooler, grinder, others	0.2 gm/Nm^3 0.12 gm/Nm^3 0.2 gm/Nm^3 0.1 gm/Nm^3
	(2.4) Asphalt concrete/bituminous mixing plant: (2.4.1) Stationary Plant (2.4.2) Mobile Plant	 0.3 gm/Nm^3 0.4 gm/Nm^3
	(2.5) Other source	0.4 gm/Nm^3
3. Metal and Metallic compound 3.1 Mercury 3.2 Cadmium 3.3 Lead 3.4 Antimony	 Industry Industry Industry Industry	 0.01 gm/Nm^3 0.015 gm/Nm^3 0.025 gm/Nm^3 0.025 gm/Nm^3

3.5 Arsenic 3.6 Zinc 3.7 Copper	Industry Industry Industry	0.025 gm/Nm^3 0.1 gm/Nm^3 0.1 gm/Nm^3
4. Gases		
4.1 Acid gases	Sulphuric Acid manufacturing	3.5 gm of SO_3/Nm^3 and no persistent mist
4.2 Sulphuric acid mist	Any sources other than (4.1)	0.2 gm of SO_3/Nm^3 and no persistent mist
4.3 Chlorine gas		0.2 gm of HCl/ Nm^3
4.4 HCL	Any source	0.2 gm of HCl/ Nm^3
4.5 Fluorine, hydrofluoric acid, inorganic compound	Any source Aluminium manufacturing from alumina	0.2 gm of Hydrofluoric acid / Nm^3
4.6 -do -	Any sources other than (4.5)	0.10 gm of Hydrofluoric acid / Nm^3
4.7 Hydrogen sulphide	Any source	5 ppm (Vol %)
4.8 NO_x	Acid Nitric manufacturing	1.7 gm of SO_3/Nm^3 and Substantially Colourless
4.9 SO_x	Any sources other than (4.8)	2.0 gm SO3/ Nm^3

(Source: Department of Environment Malaysia (2010)

Universiti Tun Hussein Onn Malaysia (UTHM) is an educational centre that is located next to industrial area. The aforementioned industrial areas are occupied by numerous industries that vary in production. There are electronic circuits, relays, fibre boards, cardboard boxes and wood based products. All of these things produce some sort of pollutant whether it is chemical gases release from the acid scrubber or even some dust particulate from stack. All of the air pollutant will cross the UTHM air space and without anybody realize, it will contribute to some sort of issues such as haze, unwanted smell, dust particulate, sore throat or even fever.

2.6 Particulate Matter

Particulate matter is the term for solid or liquid particles found in the air. Some particles are large or dark enough to be seen as soot or smoke. Others are so small they can be detected only with an electron microscope. Because particles originate from a variety of mobile and stationary sources (diesel trucks, woodstoves, power plants, etc.), their chemical and physical compositions vary widely. Particulate matter can be directly emitted or can be formed in the atmosphere when gaseous pollutants such as SO_2 and NO_x react to form fine particles. This pollutant can cause eye and throat irritation, and the accumulation of particulate matter in the respiratory system is associated with numerous respiratory problems such as decreased lung function. High levels of particulate matter can also pose health risk to sensitive groups such as children, the elderly and individuals with asthma or cardiopulmonary diseases. Particulate matter (PM_{10}) can also cause undesirable impact on the environment.

The size of particles is directly linked to their potential for causing health problems. United States Environmental Protection Agency (USEPA) is concerned about particles that are 10 micrometers in diameter or smaller because those are the particles that generally pass through the throat and nose and enter the lungs. Figure 2.4 will show the comparison of size between particulates. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. USEPA groups particle pollution into two categories:

- "Inhalable coarse particles," such as those found near roadways and dusty industries, are larger than 2.5 micrometers and smaller than 10 micrometers in diameter.

- "Fine particles," such as those found in smoke and haze, are 2.5 micrometers in diameter and smaller. These particles can be directly emitted from sources such as forest fires, or they can form when gases emitted from power plants, industries and automobiles react in the air.

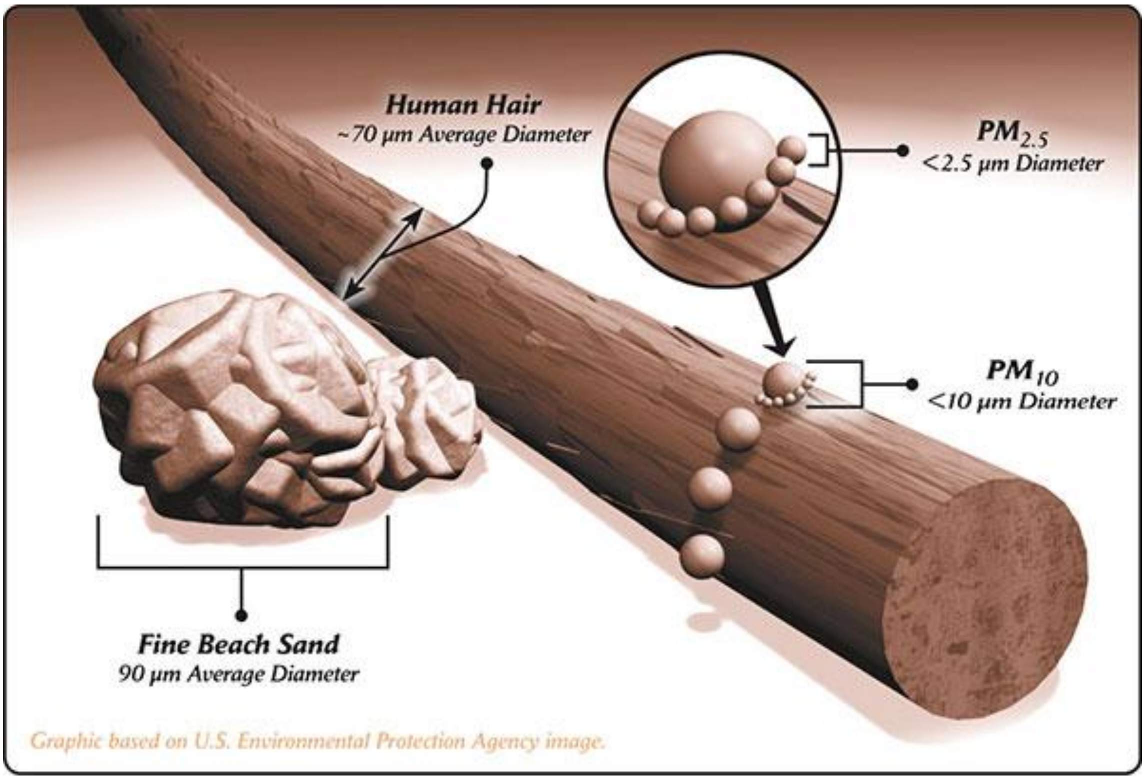


Figure 2.4: Comparison of size between particulates with human hair and sand. (Source: U.S Environmental Protection Agency)

2.6.1 Particulate Matter Impacts

Particulate matter can be emitted directly to the air or may be formed in the air through chemical change of gases. Direct emission sources are vehicle engines, factories, construction sites, tilled fields, unpaved roads, stone crushing and burning of wood. Indirectly formed particulate matter through reactions of gases in the presence of water or sunlight originates from fuel combustion in motor vehicles, power plants and other industrial processes. Particulate matter has great impacts on human health and on the environment (Anderson et al, 2005).

2.6.1.1 Particulate Matter Impact on Humans Health

Because of its small in size, it can easily pass through our respiratory system very easily. Some of the effects that particulate matter will bring are:

- Aggravated asthma
- Increase in respiratory symptoms like coughing and difficult or painful breathing
- Chronic bronchitis
- Decreased lung function
- Premature death.

2.6.1.2 Particulate Matter Impact on Environments

1. Visibility Impairment

Particulate matter is the major cause of reduced visibility (haze).

2. Atmospheric Deposition

Particulate matter can be carried over long distances and then settle on the ground or in the water. Settling of Particulate matter has the following impacts:

- acidification of lakes and rivers
- change of the nutrient balance in coastal waters and large river basins
- depletion of the nutrients in soil
- damage of sensitive forests and farm crops
- reduction of the diversity of ecosystems

3. Deterioration of Buildings and Monuments

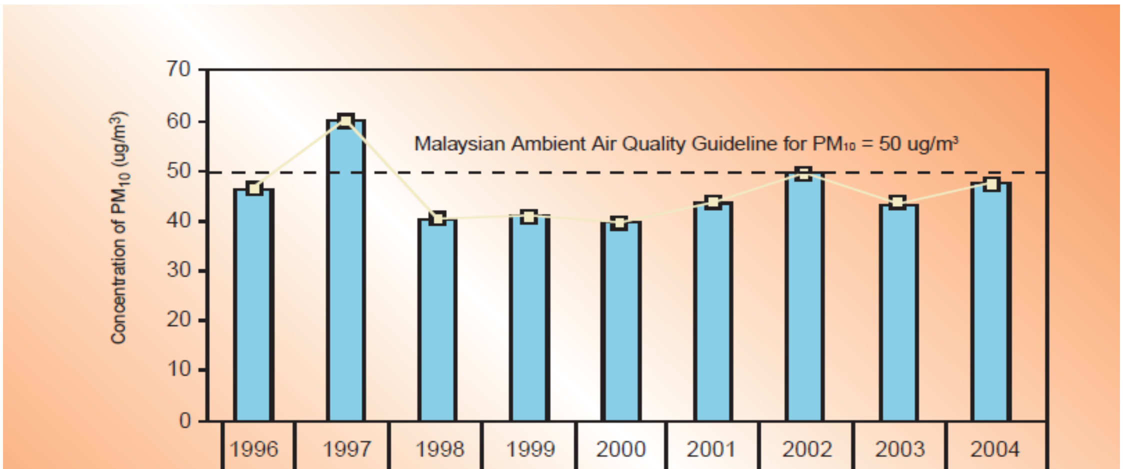
Soot, a type of PM, stains and damages stone and other materials. This leads to deterioration of buildings and culturally important objects such as monuments and statues.

2.6.2 Particulate Matter Studies in Malaysia

The presence of high levels of PM_{10} in the atmosphere is a major cause of reduced visibility, resulting in hazy conditions especially during the dry season. Other environmental impacts can occur when particulate matter is deposited onto soil, plants, water or other materials (Environmental Quality Report, 2004). Depending on the chemical composition of these substances, when particulate matter is deposited in sufficient quantities, it may change the nutrient balance and acidity in soil, interfere with plant metabolism and change the composition of the materials. PM_{10} continues to be the prevalent pollutant in many areas in Malaysia.

Figure 2.5 will show that the annual average levels of PM_{10} concentration in the ambient air between 1996 and 2004 were just slightly below the Malaysian Ambient Air Quality Guideline for PM_{10} except in 1997, when the country experienced severe haze episodes, and in 2002, when the annual average concentration of PM_{10} was equivalent to the Malaysian Ambient Air Quality Guidelines.

The 1997 reading was high above the Malaysian Ambient Air Quality Guidelines because Malaysia was one of the countries affected by 1997 Southeast Asian haze. It was a large-scale air quality disaster which occurred during the second half of 1997 and its after-effects causing widespread atmospheric visibility and health problems within Southeast Asia.



	1996	1997	1998	1999	2000	2001	2002	2003	2004
Concentration (ug/m^3)	46	60	41	41	40	44	50	44	48
No. of sites	13	27	37	45	50	50	50	51	51

Figure 2.5: Annual Average Concentration of Particulate Matter (PM_{10}), 1996 – 2004. (Source: Environmental Quality Report, 2004)

2.7 Air Quality Dispersion Model

Air quality dispersion modelling is used to estimate concentrations of pollutants that new (or existing) emissions sources may emit and air quality dispersion modelling is used to predict ground level concentrations down point of sources. The object of a model is to relate mathematically the effects of source emissions on ground level concentrations, and to establish that permissible levels are, or are not, being exceeded. Models have been developed to meet these objectives for a variety of pollutants and time circumstances. Examples of emissions sources include stack

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