TEMPORAL RELATIONSHIP BETWEEN PARTICULATE MATTER (PM_{10}) AND CARBON MONOXIDE (CO) IN KUALA LUMPUR

By

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ABSTRACT

Air pollution is now becoming a common feature in Kuala Lumpur city. It has assumed an important level to the proportion that the city populace recognises its presence. The future of air pollution in the city seems to be bleak. From one stand point, air pollution although dangerous and threatening to the quality of life and environment, it is a luxurious problem and relatively remote in priority to the general public. This research is carried out to understand the changes in trend of particulate matter (PM_{10}) and carbon monoxide (CO) concentration within a set time frame or limit in the selected monitoring sites which is located in heavily trafficked urban area of Malaysia which is Kuala Lumpur. Hourly and daily concentration of particulate matter and carbon monoxide are collected over an 8-month period from January to August. By using the statistical and graphical analysis, the data will be analysed and as the results, the variation of concentration for both particulate matter (PM_{10}) and carbon monoxide (CO) will be define from the analysis. From the research, the results shows that the ambient level of carbon monoxide was relatively low as compared to the particulate matter. Based on the analysis, it was found that the annual average CO value is 2.52 $\mu g/m^3$ while the annual average PM_{10} value is 77.64 $\mu g/m^3$. It was shows that average PM_{10} levels in Kuala Lumpur network are generally higher than average CO levels. The concentrations levels of CO were far below the maximum limit of 30 ppm for one hour averaging time set by the Malaysian Guidelines. On the other hand, the PM_{10} mean concentration was higher but still not exceed the maximum limit 150 $\mu g/m^3$ for the 24 hour averaging time which also set by the Malaysian Guidelines.

ABSTRAK

Pencemaran udara pada masa kini sudah menjadi satu fenomena yang tidak asing lagi di bandar raya Kuala Lumpur. Sebagaimana yang diketahui, pencemaran udara merupakan fenomena yang merbahaya dan mengancam kualiti kehidupan serta alam sekitar. Tujuan kajian ini dijalankan ialah untuk memahami corak perubahan kepekatan PM_{10} dan CO di dalam lingkungan rangkaian set masa di stesen permonitoran terpilih. Stesen ini terletak di salah sebuah bandar di Malaysia iaitu Kuala Lumpur dan mempunyai jaringan lalulintas yang sibuk. Data kepekatan bagi PM_{10} dan CO dicerap setiap jam dan setiap hari selama 8 bulan bermula dari bulan Januari sehingga bulan Ogos. Data yang dicerap ini akan di manipulasikan ke dalam bentuk set data berkala. Dengan membuat analisis secara statistik dan analisis menggunakan graf, data-data tersebut akan dianalisis dan akhirnya variasi kepekatan bagi PM_{10} dan CO akan dapat di takrifkan. Daripada kajian yang telah dijalankan, didapati paras persekitaran ambien CO adalah rendah berbanding paras persekitaran ambien bagi PM_{10}. Berdasarkan analisis yang dibuat didapati nilai purata kepekatan CO sepanjang 8 bulan ialah 2.52 ppm sementara nilai purata bagi PM_{10} pula ialah 77.64 $\mu g/m^3$. Paras kepekatan CO adalah jauh lebih rendah berbanding dengan nilai had standard maksimum yang dibenarkan untuk persekitaran ambien iaitu 30 ppm untuk tempoh purata satu jam seperti yang telah ditetapkan dalam 'Malaysian Guidelines'. Sementara itu, kepekatan purata bagi PM_{10} pula adalah tinggi tetapi masih berada dalam lingkungan had standard yang dibenarkan seperti tertakhluk dalam 'Malaysian Guidelines' iaitu tidak melebihi had standard maksimum 150 $\mu g/m^3$ untuk tempoh purata 24 jam.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The atmosphere is a mixture of different gases, particles and aerosols collectively known as air, which envelops the earth. The atmosphere protects creature by filtering out deadly cosmic rays, powerful ultraviolet (UV) radiation from the sun.

The two most abundant gases in air are nitrogen (78% by volume) and oxygen (21% by volume), and together they make up over 99% of the lower atmosphere. (*Encyclopedia of the Atmospheric Environment*, *http://www.ace.mmu.ac.uk/eae/english.html*, *Jan 16, 2005).* There is no evidence that the relative levels of these two gases are changing significantly over time. In addition to nitrogen and oxygen, air contains a number of trace gases, including the noble gases argon, neon, helium, krypton and xenon, the greenhouse gases and ozone.

Air pollution is a major problem that has been recognized throughout the world since 1952, which is the first episode of air pollution recorded in London. In more recent times pollution from motor vehicles has become the most recognized air quality issue. The number of cars, both in Malaysia and in most countries around the world, is now steadily increasing and a speed up in technological development is required to try and combat the pollution problem. People need to be encouraged to use public transport or share cars whenever possible to reduce the level of pollution.

Poor air quality has negative effects on the environment in which we live. Air pollution from transport includes emissions of carbon monoxide, particulates, nitrogen oxides and hydrocarbons. Ozone is a secondary pollutant produced when many of these primary chemicals react in sunlight in the atmosphere. Such primary and secondary pollutants can effect wildlife vegetation and human health.

The major threat to clean air is now posed by the traffic emissions. Petrol and diesel-engined motor vehicles emit a wide variety of pollutants, principally carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and particulates (PM_{10}), which have an increasing impact on urban air quality. In addition, photochemical reactions resulting from the action of sunlight on nitrogen dioxide (NO_2) and VOCs from vehicles leads to the formation of ozone, a secondary long-range pollutant, which impacts in rural areas often far from the original emission site. In all except worst-case situations, industrial and domestic pollutant sources, together with their impact on air quality, tend to be steady-state or improving over time. However, traffic pollution problems are worsening world-wide.

Amongst the many pollutants highlighted for adverse health effects, particular attention has been focused on fine particulates recently *(Schwartz, 1994; Dockery and Pope, 1994; Pope et al., 1995)*. *Dockery and Pope (1994)* reported that for each 10 $\mu g/m^3$ increase in concentration of particulate matter, less than 10 μm in diameter, there is an estimate of increase in mortality of 0.6-1.6%.

Air pollution can effect our health in many ways with both short-term and long-term effects. Health impact of air pollution depends on the pollutant type, its concentration in the air, length of exposure, other pollutants in the air, and individual susceptibility. Different groups of individuals are affected by air pollution in different ways. Some individuals are much more sensitive to pollutants than are others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted. The extent to which an individual is harmed by air pollution usually depends on the total exposure to the damaging chemicals, i.e., the duration of exposure and the concentration of the chemicals must be taken into account.

Examples of short-term effects include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Other symptoms can include headaches, nausea, and allergic reactions. Short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema. Long-term health effects can include chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys. Continual exposure to air pollution affects the lungs of growing children and may aggravate or complicate medical conditions in the elderly.

1.2 OBJECTIVES

The aim of this study is to understand the changes in trend of particulate matter (PM_{10}) and carbon monoxide (CO) concentration within a set time frame or limit. Besides that, the other objectives of this project are :-

1. To determine the temporal relationship between particulate matter and carbon monoxide in Kuala Lumpur.

2. To study the temporal trend of particulate matter in Kuala Lumpur

3. To study the temporal trend of carbon monoxide in Kuala Lumpur

1.3 LOCATION

The selected monitoring sites are located in an urban environment which is Kuala Lumpur. Hourly and daily data of particulate matter concentration and carbon monoxide concentration are collected from an air quality-monitoring network in Kuala Lumpur. The task of this study is to look into the variation of concentration for both particulate matter (PM_{10}) and carbon monoxide (CO). This data will be analysed to find the temporal relationship between these 2 pollutants.

Kuala Lumpur as the capital and largest city of Malaysia was founded by tin miners in 1857, it is the commercial and industrial hub of the country. Kuala Lumpur is situated midway along the west coast of Peninsular Malaysia, at the confluence of the Klang and Gombak rivers. It is approximately 35 km from the coast and sits at the centre of the Peninsula's extensive and modern transportation network. Kuala Lumpur is easily the largest city in the nation, possessing a population of over one and a half million people drawn from all of Malaysia's many ethnic groups. (*http://www.geographia.com/malaysia/kualalumpur.html; Jan 16, 2005)*

By referring to the website *http://www.myfareast.org/Malaysia/kualalumpur; Jan 16,2005,* the statistics of Kuala Lumpur were determined. This can be seen in Table 1.1 ;

Table 1.1 Statistics of Kuala Lumpur

Area (km)	Population (year 2000)	Breakdown of Races				
		Malay	Chinese	Indian	Non-Bumiputera	Other
243	1297526	579994	498250	153108	54401	16868

The growth of Kuala Lumpur as urban-industrial centre has generated a number of problems. Some are common to cities the world over, but others are more typical of cities in tropical or developing countries. One of these problems is air pollution, which results from vehicular congestion and industrial activities.

Traffic congestion in Kuala Lumpur is a product of the rapid increase in the number of road vehicles. Congestion is most pronounced in the older areas of Kuala Lumpur, which have narrow streets and inadequate parking facilities.

The development of industrial activities in Kuala Lumpur for the last 10 years represents another area of concern which is directly related to the present study. It has been estimated that both transport and industries produce about 99% of the major pollutant emissions in the study area.

Table 1.2 shows major sources of air pollutant emission in Kuala Lumpur area in tonnes which is estimated from supply of fuels.

Table 1.2 Major Sources of Air Pollutant Emission in Kuala Lumpur area (tonnes) as estimated from Supply of Fuels

Source	Carbon Monoxide	Hydrocarbons	Oxides of nitrogen	Oxides of Sulphur	Particulates	Total	% of total
Transport	82504.8	17599.3	6752	898.3	2085	109839.4	91.9
Industry	71.3	71.3	2564.1	5698.5	427.3	8832.5	7.4
Domestic		20.6	635.8	27.5	130.5	814.4	0.7
Total	82576.1	17691.9	9951.9	6624.3	2642.8	119486.3	100

(Sources : Sham, 1979)

Computation of total emissions and comparison of these figures with those obtained from other cities suggest that pollution in the study area is still relatively low. However, for certain types of pollutants, these have nearly equalled and in certain cases exceeded those of some city area in mid-latitude regions. *(Sham, 1979).*

The map of Kuala Lumpur city is shown in Figure 1.1.

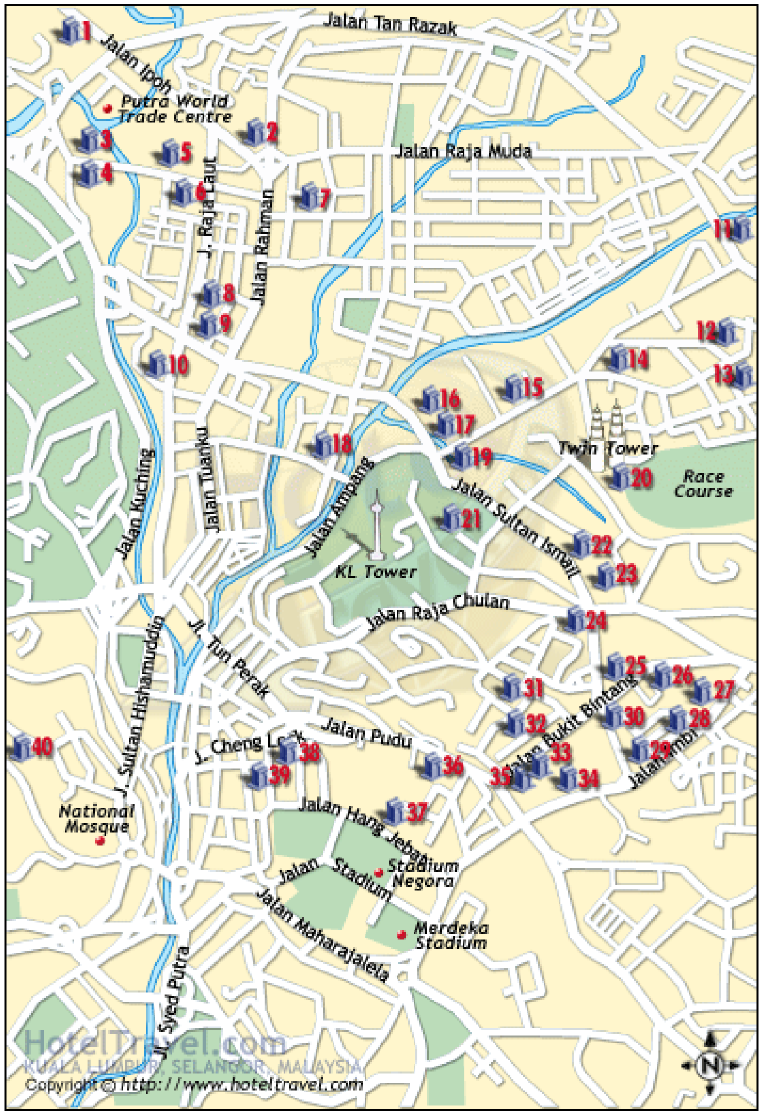

Figure 1.1 Kuala Lumpur Map

(Sources : *Kuala Lumpur Hotel Travel Guideline, http://www.kuala-lumpur-hotel.com/kualalumpur_maps/kualalumpur_map.htm; Jan 16, 2005)*

Climatically, Kuala Lumpur represents a typical tropical city characterized by uniformly high temperatures, heavy annual precipitation well distributed throughout the year and relatively low wind speed. *Sham (1976b and 1979)* has shown that although comparisons between tropical and mid-latitude cities may be prejudiced by the different characteristics of weather conditions and emission climate of Kuala Lumpur has a high potential for pollution. It was also pointed out that following an abundant supply of radiation and sunshine, conditions in the study area appear to be suitable for the formation of photochemical smog. This, coupled with marked increases in energy use which have occured in recent years, is certainly a cause for concern.

1.4 SCOPE OF STUDY

In this project, the hourly and daily data of particulate matter and carbon monoxide concentration was monitored from air monitoring station in heavily trafficked urban area of Malaysia which is Kuala Lumpur. Samples of particulate matter and carbon monoxide were collected by using the PM_{10} analyzer and CO analyzer. This monitoring were conducted by Alam Sekitar Malaysia Sdn. Bhd. on behalf of The Department Of Environment Kuala Lumpur.

The collected data will be manipulated into periodical data set and then by using the statistical and graphical analysis, the data will be analyzed. Data will be plotted using the line graph. From the analysis, the variations of concentration for both particulate matter (PM_{10}) and carbon monoxide (CO) will be define. From the variation, the relationship between PM_{10} and CO can be determined as an outcome for this project.

Theoretically, particulate matter (PM_{10}) and carbon monoxide (CO) must have the same variation as both PM_{10} and CO comes from the same major sources which is from vehicles. Most of the vehicles in Kuala Lumpur especially passenger car are using petrol. The emission from petrol engine produces carbon monoxide (CO), particles (fine) and nitrogen dioxide (NO_2).

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The quality of the air is very important component to the human being, animals and plants. But, nowadays air becomes polluted seriously and the composition of the air pollutants increasing in the air.

Air pollution is not new, nor has it been getting worse. But many more people are concentrated in large city today than ever before. Even if cities have no more air pollution than in the past, the exposure to air pollution has increased greatly.

The primary air pollutants found in most urban areas are carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), hydrocarbon (HC) and particulate matter (PM). These air pollutants are contributed by many sources such as transportation (motor vehicles), industry and open burning

2.2 AIR POLLUTION

2.2.1 Definition

The term air pollution is restricted to those conditions in which the general atmosphere contains substances in concentrations, which are harmful or likely to be harmful people and environment. *(Gilpin,1971)*

Air pollution is the presence in the outdoor atmosphere of any dust, fumes, mist, smoke, other particulate matter, vapor, gas, odorous substances, or a combination thereof, in sufficient quantities and of such characteristics and duration as to be, or likely to be, injurious to health or welfare, animal or plant life, or property, or as to interfere with the enjoyment of life or property. *(www.sra.org/glossary.htm; October 1, 2004)*

The list of pollutants which is produced by industrial, domestic and traffic sources are :

i. Particulate matter (PM_{10})
ii. Carbon monoxide (CO)
iii. Sulphur dioxide (SO_2)
iv. Nitrogen dioxide (NO_2)
v. Ozone (O_3)

Table 2.1 below shows a list of the most prevalent pollutants and also their sources which is most significant.

Table 2.1 : A List of the most Prevalent Pollutants and Sources

POLLUTANT	SOURCE (MOST SIGNIFICANT)
Particulate matter (PM_{10})	Vehicle exhausts; many industrial processes; incineration; power generation etc.
Carbon Monoxide (CO)	Motor engine exhausts; some industrial processes.
Sulphur dioxide (SO_2)	Power generators using coal or oil etc., that contain sulphurous elements.
Nitrogen oxides (NO_x)	Vehicle exhausts. power generators. Fertiliser plants
Photochemical oxidants Including Ozone (O3)	Reaction of NO_x and unburnt hydrocarbons (from vehicle exhausts) to sunlight.
Carbon dioxide (CO_2)	All sources that involve combustion.
Others	Solvents (vapour), fuel combustion vapours etc.

Sources : *http://homepage.ntlworld.com/booty.weather/metinfo/ozone.htm; January 16, 2005)*

2.2.2 Air Quality

The quality of the air is very important to all creatures in this world. Over the last two decades, there has been increased public awareness about issues such as urban smog, acid rain and global warming. Also, there have been many advances in air pollution reduction technology that have led to a decline in emissions of a number of pollutants since the 1970s. *(http://www.casadata.org; October 1, 2004)*

As technology improves, there are able to better track quantity of emissions released into the atmosphere and the quality of the air. The more learning about the environment and the impact on it, the better able are to make informed choices about how to improve air quality both from a society and individual basis.

The quality of the air we breathe is dependent on the rate that pollutants are emitted into the atmosphere and the ability of the atmosphere to disperse these pollutants. The movement and dispersion of air pollutants is controlled by wind, temperature, turbulence and the changes in these elements caused by local topography (mountains and valleys).

2.2.3 Air Pollution Index (API)

An air pollution index system normally includes the major air pollutants which could cause potential harm to human health should they reach unsafe levels. There are 5 pollutants included in Malaysia's Air Pollution Index (API) which is : -

- Ozone (O_3)
- Carbon Monoxide (CO)
- Nitrogen Dioxide (NO_2)
- Sulphur Dioxide (SO_2)
- Suspended Particulate Matter less than 10 microns in size (PM_{10})

The index values may also be categorized according to episode or action criteria, such as air pollutant levels within stipulated standards, or levels signifying conditions for alert, warning, emergency and significant harm. The key reference point in these air pollution index systems is the index value of 50 (the "safe" limit), which is based on the *National Air Quality Standards or Guidelines* for the specific air pollutants concerned. *(Department of Environment,2003)*

Table 2.2 shows the significant harm level to air pollution index value of 500.

Table 2.2 : Significant Harm Level to API value of 500

Pollutant and Averaging Time	Concentration	
	μg/m^3	ppm
Carbon monoxide (CO) 8 hour	57500	50
Nitrogen dioxide (NO_2) 1 hour	3700	2
Ozone (O_3) 1 hour	1200	0.6
Particulate matter (PM_{10}) 24 hour	600	0
Sulphur dioxide (SO_3) 24 hour	2620	1

(Source : Department of Environment, 2003)

The recommended Malaysia air quality guidelines adopted in air pollutant index calculation is shown in Figure 2.3.

Table 2.3 : Recommended Malaysia Air Quality Guidelines adopted in Air Pollutant Index calculation

Pollutants	Averaging Time	Malaysia Guidelines	
		(ppm)	$\mu g/m^3$
Ozone (O_3)	1 Hour	0.1	200
	8 Hour	0.06	120
Carbon Monoxide (CO)	1 Hour	30	35
	8 Hour	9	10
Nitrogen Dioxide (NO_2)	1 Hour	0.17	320
Sulphur Dioxide (SO_2)	10 Minute	0.19	500
	1 Hour	0.13	350
	24 Hour	0.04	105
Particulate Matter (PM_{10})	24 Hour		150
	1 Year		50

(Sources : Azman and Lai 1996)

Location of Continous Air Quality Monitoring Stations in Peninsular Malaysia is shown in Figure 2.1

Figure 2.1 : Location of Continous Air Quality Monitoring Stations

(Source : Department of Environment, 2003)

2.3 PARTICULATE MATTER (PM_{10})

2.3.1 Definition

The word “particulate” derives from “particle” and is used to include all solid or liquid substances in the air. There is a tremendous variety of such material in the air, primarily solid rather than liquid. It comes from a wide variety of sources in all sizes, shapes, colours, textures and chemical compositions and can remain suspended in the air for periods ranging from a few seconds to a few years. *(Lynn, 1976)*

Particulate matter consists of solid or liquid substances that are visible as well as invisible. The particles affect visibility and can be transported over long distances by winds. *(Roberts, 1998)*

According to website *http://www.arb.ca.gov (October 1, 2004),* PM may be divided into many size fractions, measured in microns (*a micron is one-millionth of a meter)*. ARB regulates two size classes of particles - particles up to 10 microns (PM10) and particles up to 2.5 microns in size (PM2.5). PM2.5 particles are a subset of PM10.

Figure 2.2 shows actual size for both PM_{10} and $PM_{2.5}$ which are each measured and expressed as the amount (in micrograms) of particles contained in a cubic meter of air, expressed as micrograms per cubic meter ($\mu g/m^3$).

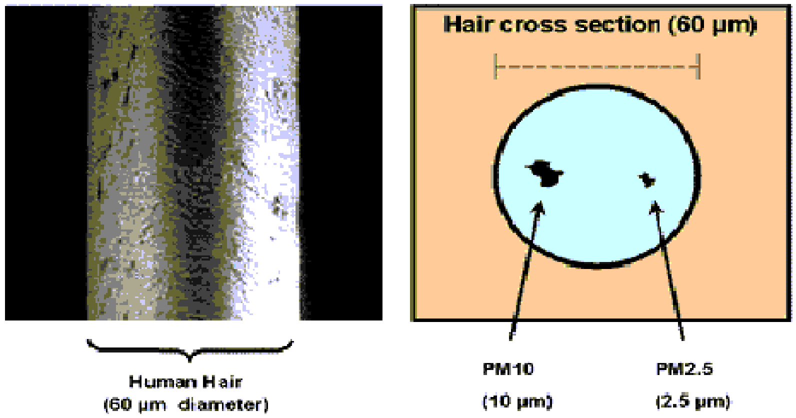

Figure 2.2 : Size of Particulate Matter

(Sources : *http://www.arb.ca.gov, October 1, 2004)*

2.3.2 Sources of Particulate Matter (PM_{10})

Generally, the majority of anthropogenic (man-made) particulates are in the 0.1 to 10 micrometer diameter range. Particles larger than 10 micrometers are usually due to "fugitive dust" (sand and dirt blown by winds from roadways, fields, and construction sites) and contain large amounts of silica (sand like) materials. PM_{10} particulates, on the other hand, are generally created during a burning process and include fly ash (from power plants), carbon black (from automobiles and diesel engines), and soot (from fireplaces and wood stoves). The other sources of PM_{10} are crushers, mills, grinders, dryers, furnaces, boilers, incinerators, conveyors, textiles finishing, mixers and hoppers, chemical processing equipment, spray booths, forest fires. *(Roberts, 1998)*

2.3.3 Standards and Regulations for Particulate Matter (PM_{10})

The primary particulate standard was changed by the EPA in July, 1987. The standard now applies only to those particles with an aerometric diameter of 10 microns or less (PM_{10}). Where as the old standard applied to the entire range of suspended particulates without regard to size or chemical composition. The new PM_{10} standard recognizes that particles of this size can be inhaled deeply into the lungs where they can remain for years. In addition the following changes were made to the form of the standard:

- PM_{10} makes up a portion of the total suspended particulates (TSP). Therefore, the levels of the standard for PM_{10} were reduced. They are now 150 $\mu g/m^3$ and 50 $\mu g/m^3$ for the 24-hour and annual arithmetic mean concentrations respectively. *(http://www.airmonitoring.utah.gov/PM10.htm; October 2, 2004)*

Concentrations of PM_{10} are expressed in the weight of particulate matter found in a cubic meter of air. The current *Environmental Protection Agency (EPA)* standard for PM_{10} is actually composed of both an acute (24 hour allowable average) and chronic component (annual allowable average):

- A 24 hour average not to exceed 150 micrograms per cubic meter of air ($\mu g/m^3$) more than three times in three years.
- An annual arithmetic average not to exceed 50 $\mu g/m^3$.

2.3.4 Health Effects of Particulate Matter (PM_{10})

Particles inhaled by humans are segregated by size during deposition within the respiratory system. The major regions of the respiratory system differ widely in structure, size, function, sensitivity, or reactivity to deposited particles and to the mechanism of particle elimination from the system. Larger particles deposit in the upper respiratory tract, while smaller inhalable particulates travel deeper into the lungs and are retained for longer periods of time. This is why PM_{10} is of primary concern to health agencies today. Not only does it penetrate deeper and remain longer in the lungs than larger particles, but PM_{10} also contains large quantities of organic materials that may have significant long-term health effects. The route of toxicity due to particulate exposure also may not be directly through the respiratory system, but may allow for the collection of materials and subsequent entrance to the stomach in swallowed mucous. Such a mechanism is the primary route for lead exposures due to atmospheric lead. *(http://www.airmonitoring.utah.gov/PM10.htm; October 2, 2004)*

Based on the *'Air Quality Control Handbook'* written by *E. Roberts Alley, 1998* the health effects of PM_{10} are decreased visibility; smoke and dust effect on human health; chronic diseases of the respiratory tract; lead poisoning, soiling of homes and clothing; destruction of plant life and agriculture; effects on climate.

2.3.5 Common Measurement Method for Particulate Matter (PM_{10})

"BAM1020 automatically measures and records dust concentration. It uses the principle of beta (β) adsorption to provide a simple determination of mass concentration. A known amount of electron scattering and attenuation through a clean filter is compared with that of a dust-sampled filter. To calculate mass concentration, a ratio of the number of detected beta particles passing through the filter and the sample volume is used."

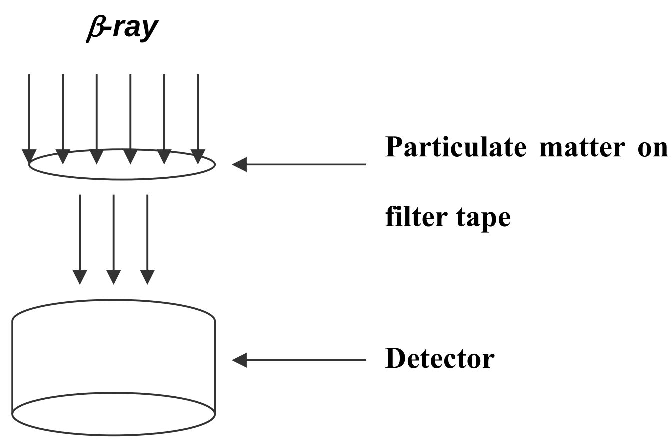

Figure 2.3 : BAM1020 – Particulate Matter (PM_{10}) Analyzer

(Source : Department of Environment, 2003 - http://www.jas.sains.my; October 1, 2004)

2.3.6 Principle Operation of The Equipment

"The BAM1020 measures and records hourly particulate mass concentrations in ambient air. It uses beta ray attenuation to calculate collected particle mass concentrations in units of µg/m^3. A ^{14}C element emits a constant source of high-energy electrons, also known as beta particles. The beta rays are attenuated as they collide with particles collected on a filter tape. The decrease in signal detected by the BAM1020 scintillation counter is inversely proportional to the mass loading on the filter tape."

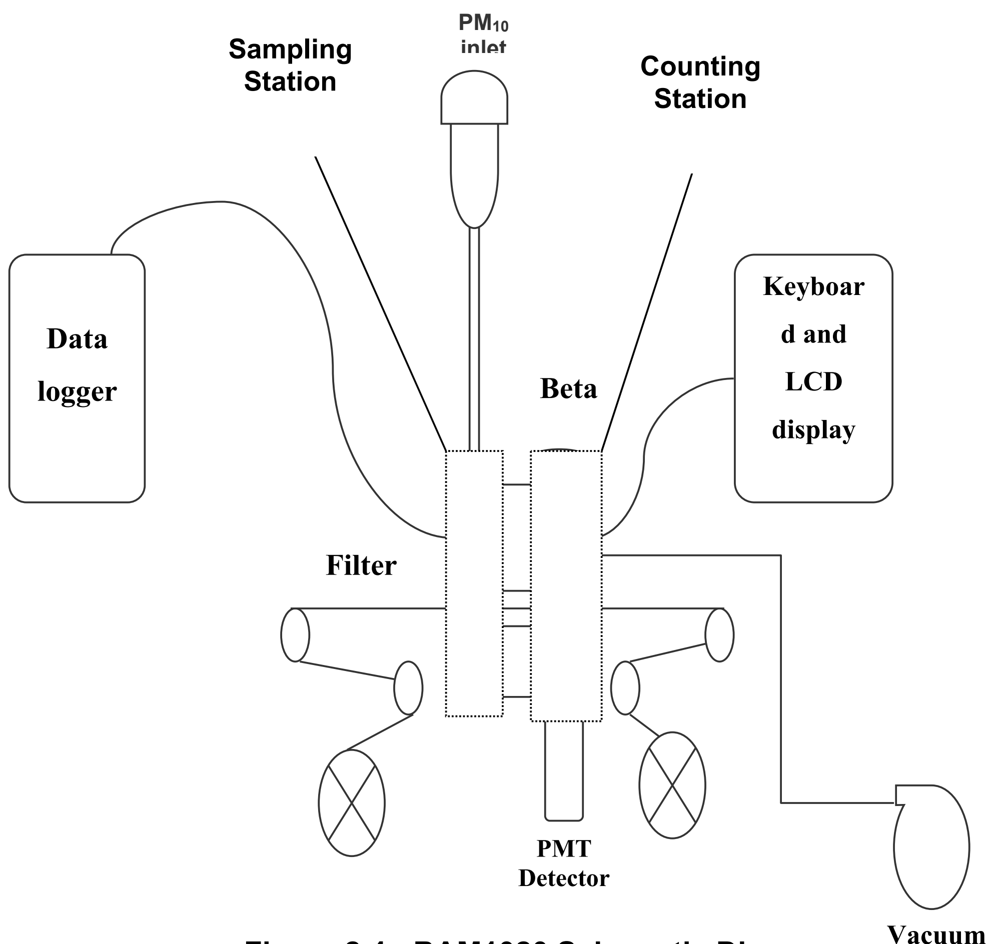

Figure 2.4 : BAM1020 Schematic Diagram
(Source : Department of Environment, 2003)

<u>Method of Operation for BAM1020</u>

1. Move tape to new spot under the counting system.
2. Initial count, 10 – 4 minutes.
3. Move tape from counting station to sampling station. Closed nozzle, pump turns on.
4. Initial count, 11 (membrane).
5. Moves membrane out.
6. Final count, 12 (calculate the mass of the membrane).
7. Re-tracks membrane.
8. Waits for end sampling period (40 minutes).
9. Pumps stops – lifts nozzle – move tape from sampling station to counting station (particulate filter).
10. Final count – 13 (concentration) – calculate concentration (10/13).
11. Wait till 1:00 to begin again.

(Source : Department of Environment, 2003)