A STUDY ON PM10 ON HEALTH IMPACT OF AIR POLUTION IN ENGINEERING CAMPUS, UNIVERSITI SAINS MALAYSIA

By

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CONTENTS

ABSTRAK

Pencemaran udara merupakan suatu fenomena yang mana ianya telah berdekad lamanya wujud di muka bumi dan ini termasuklah di Malaysia. Pelbagai kajian rancak dijalankan sejak dari dahulu lagi yang mana tujuannya untuk mengenalpasti bentuk pencemaran yang wujud, punca dan sumber berlakunya sesuatu pencemaran tersebut serta langkah-langkah untuk mengatasi masalah tersebut daripada berlarutan. Kajian mengenai kualiti udara di dalam bangunan merupakan senario baru dalam penjanaan kajian partikel terampai. Keadaan yang dianggap mempunyai kemungkinan untuk mengalami masalah kehadiran partikel terampai dalam kuantiti yang melebihi had yang dibenarkan menjadi salah satu sebab mengapa kajian ini dijalankan di Kampus Kejuruteraan, Universiti Sains Malaysia ini. Kehadiran partikel terampai khususnya dengan kepekatan yang tinggi dan jika ianya melebihi had yang telah ditetapkan boleh memberi kesan kepada kesihatan manusia. Pelbagai jenis penyakit terutama sekali yang melibatkan sistem pernafasan boleh dipengaruhi oleh kehadiran bahan terampai ini. Oleh itu, kajian ini adalah melibatkan pengukuran terhadap kepekatan partikel terampai yang terdapat di dalam bangunan di mana 5 lokasi di sekitar kampus telah dipilih sebagai lokasi pengukuran. Proses pengumpulan data daripada alat dipanggil Microdust *pro* dan penganalisaan merumuskan bahawa kehadiran partikel terampai di dalam bangunan di sekitar kampus ini ada di bawah had yang telah ditetapkan oleh pihak berwajib. Hasil keputusan daripada kajian yang dijalankan menunjukkan purata kepekatan tertinggi yang dicapai adalah sebanyak 49.4μg/m^3 yang mana ianya direkodkan di Rumah Kesatuan, manakala purata kepekatan terendah adalah sekitar 2.8μg/m^3 yang mana ianya pula dicatatkan di Kafe Jaya. Bacaan-bacaan ini masih di dalam had piawai yang dinyatakan iaitu sebanyak 150μg/m^3 untuk bacaan purata dalam jangka masa 24 jam untuk partikel terampai. Pelbagai cara telah dicadangkan untuk mengurangkan jumlah kepekatan partikel terampai ini walaupun ianya masih di bawah kawalan. Ini adalah langkah untuk mengelakkan daripada berlakunya penularan tahap kesihatan yang rendah di kalangan para pelajar yang disebabkan oleh partikel terampai biarpun tahap kualiti udara di kampus ini boleh dikatakan bersih daripada masalah pencemaran udara yang disebabkan oleh partikel terampai.

ABSTRACT

Air pollution is a phenomenon that occurs on the earth and it includes Malaysia. It has always been happening ago. Many researches have measured types of pollutant including their sources and how they are distributed in the atmosphere and also the ways to reduce the problems. Research about particulate matter that assembles in the air especially in buildings is a new scenario. The situation where the possibility of the particulate matter is present in the building at this campus is the main cause of this research. As known, high concentration of particles in the air can affect the human health. There are varieties of illnesses caused by particulate matter such as asthma, respiratory problems, Chronic Obstructive Pulmonary Disease (COPD) and cancer. So, this research emphasized on monitoring indoor air pollution at 5 monitoring locations around the Engineering Campus, Universiti Sains Malaysia. The results of the concentration level of PM_{10} which are taken from the equipment called Microdust *pro* have been analyzed and it concludes that the concentration level of PM_{10} is under the limit that is fixed by the authorities. The highest average of the concentration reading is 49.4μg/m^3 where it recorded at Rumah Kesatuan and the lowest reading is 2.8μg/m^3 at Jaya Cafeteria. All of the data are less than the limit of the particulate matter which is 150μg/m^3 for average concentration in 24 hours. There are some of the solutions that proposed in this research to reduce the concentration level before it gets worse in the future. The techniques are suggested to avoid the effect of the particulate matter especially to the human health at this campus.

TABLE LISTS

FIGURE LISTS

ACKNOWLEDGEMENT

Alhamdulillah, thankful to Allah because with His blessing I have done my final year project. First of all I would like to thank to my supervisor, Mr. Nor Azam bin Ramli who had give me a chance and always give his support for me to handle this research in a such right way. Also for his helpful comments during the preparation of the manuscript, it is such a meaningful of experiences.

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Thank you.

CHAPTER 1
INTRODUCTION

1.0 BACKGROUND

The number of studies related to air pollution conducted in Malaysia has been far less than in European countries. It is already 27 years since the Environmental Quality (Clean Air) Regulations 1978 were introduced in the country. The trend indicated that short-term exposure to high levels of PM_{10} was detrimental to human health. Since the onset of the industrial revolution, there has been a steady change in the composition of the atmosphere mainly due to the combustion of fossil fuels used for the generation of energy and transportation. The most harmful of the gases and agents that are emitted are particulate matter, carbon dioxide, polycyclic organic matter, and formaldehyde.

Air pollution is a major environmental health problem affecting the developing and the developed countries alike. The effects of air pollution on health are very complex as there are many different sources and their individual effects vary from one to the other. It is not only the ambient air quality in the cities but also the indoor air quality in the rural and the urban areas that are causing concern. In fact in the developing world the highest air pollution exposures occur in the indoor environment. Air pollutants that are inhaled have serious impact on human health affecting the lungs and the respiratory system; they are also taken up by the blood and pumped all round the body. These pollutants are also deposited on soil, plants, and in the water, further contributing to human exposure.

Effects were found to be greatest in children, the elderly, and people with pre-existing respiratory problem; youngsters are among the most resistant. The health effects include cases of asthma attacks; chronic bronchitis in children and adults, respiratory hospital admission, emergency room visits and restricted activity days. This research will try to gather the data from the students in Engineering Campus at Universiti Sains Malaysia who are exposed to air pollution.

1.1 OBJECTIVES

1. To collect data on and study on ambient air quality in Engineering Campus, Universiti Sains Malaysia where it is shows that PM_{10} is increasing with time.
2. To find the solutions to reduce air pollution that can affect the health of the students.
3. To study the relationship between the air quality, human health and nuisance.
4. To get the level of concentration in Engineering Campus, Universiti Sains Malaysia and to recognize the relation between the concentration and health effects on the students.

1.2 THE IMPORTANCE AND BENEFITS OF THE RESEARCH

1. This research reviews the results of ambient air quality monitoring and studies related to air pollution in Engineering Campus, Universiti Sains Malaysia and its impact on human health.
2. It also determines the health impacts to the students which are exposed to the sources of the air pollution.
3. Assist to find the solution for the problems that were involved in this research.
4. Ambient air quality standards identify individual pollutants and the concentrations at which they become harmful to the public health and the environment.

1.3 STATEMENTS OF PROBLEM

As known from the title of this research; "A Study on PM_{10} of Air Pollution in Engineering Campus, Universiti Sains Malaysia", it considers the level of the concentration of PM_{10} in Engineering Campus, Universiti Sains Malaysia which affects the health of the students here.

The data from the monitoring locations around this campus are used to analyze and then to make a conclusion about the air in this campus depending to the range that given by the API and Malaysian Air Quality Guidelines (Ambient Standards) diagnosis.

1.4 RESEARCH CHAPTERS

This research reviews current information on levels and the risks to health and well-being of PM_{10} as an air pollutant around the Engineering Campus, Universiti Sains Malaysia. Therefore, this research concentrates particularly on the campus situation. Whilst acknowledging and drawing information from important studies and developments elsewhere.

This research consists of five important parts:

- Chapter 1 presents an introduction about the research and it provide the objectives and benefits when doing this research.
- For those not familiar with the basic concepts of Particulate matter and its health effects, Chapter 2 presents a brief explanation in order to facilities understanding of the rest of this research. It presents a summary of the most recent information on the health effects of particulate matter, in which the available epidemiological, toxicological and human information will be treated jointly.
- In Chapter 3, the information currently available on the processes of sampling, measuring and monitoring the data from the selection locations around this campus.
- Chapter 4 presents the results of the monitoring processes and it also discusses the results of the data which are complying with the graphs. It also discusses the sources of air pollutant and the effects of the results on the health in Engineering Campus, Universiti Sains Malaysia.
- The results and discussions that presents before have been concluded in Chapter 5.

CHAPTER 2
LITERATURE REVIEW

2.0 GENERAL

The atmosphere that surrounds the planet earth is one of the factors that make our planet hospitable toward life. The average human makes use of about 30 pounds of air each day, using it to oxidize food for energy and warmth. Implicit in the very concept of air pollution is the assumption that there is something basically 'right' or 'good' about certain constituents of the atmospheric mixture. Within the scale of human life on the earth, the atmosphere's composition (Table 2.1) has been stable and has in fact been 'good' in the sense that it was suited to human (Lynn, 1976).

Table 2.1: Composition of dry air

Gases	Percent of volume
Nitrogen	78.03
Oxygen	20.99
Argon	0.94
Carbon dioxide	0.03
Balance*	0.01
Total	**100.00**

* Includes hydrogen, helium, neon, krypton, xenon and the various pollutants
Source: Lynn, (1976)

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 terms of industrial pollution and the degradation of urban environment. Among them, air pollution is the major issue that has been affecting human health, agricultural crops, forest species and ecosystems. Since the onset of the industrial revolution, there has been a steady change in the composition of the atmosphere mainly due to the combustion of fossil fuels used for the generation of energy and transportation (Afroz et al., 2003).

Air pollution is a major environmental health problem affecting the developing and the developed countries alike. The effects of air pollution on health are very complex as there are many different sources and their individual effects vary from one to the other. It is not only the ambient air quality in the cities but also the indoor air quality in the rural and the urban areas that are causing concern. In fact in the developing world the highest air pollution exposures occur in the indoor environment. Air pollutants that are inhaled have serious impact on human health affecting the lungs and the respiratory system. They are also taken up by the blood and pumped all round the body. These pollutants are also deposited on soil, plants and in the water, further contributing to human exposure (Afroz et al., 2003).

Monitoring data and studies on ambient air quality show that some of the air pollutants in several large cities are increasing with time and are not always at acceptable levels according to the national ambient air quality standards. Data on air pollution and case studies are very limited in Malaysia (Afroz et al., 2003). This research reviews the results of ambient air quality monitoring and studies related to air pollution in Engineering Campus, Universiti Sains Malaysia and its impacts on human health.

2.1 AIR POLLUTION

The natural problems would have qualified as "air pollution" under this generally accepted definition of pollution of ambient, or outdoor, air:

'*Air pollution is the presence in the outdoor atmosphere of one or more air contaminants such as dust, fumes, gas or smoke, in sufficient quantities, of such characteristics, and of such duration as to be or to threaten to be injurious to human, plant, or animal life or to property, or which reasonably interferes with the comfortable enjoyment of life and property'* (Chobanoglous et al., 1993).

The number of air pollutants is large and growing. Some, such as sulfur and nitrogen oxides and carbon monoxide, are widely distributed, exposing much of the population to their effects. Others, such as dusts causing silicosis among quarry workers and black lung among coal miners, affect small and clearly identifiable new threats to human health, as new chemicals whose consequences are unknown are produced. Most of them are occupational hazards that do not endanger the general population (Stewart Jr., 1979).

National ambient air quality standards have been established that may require draconian measures in some urban areas, including severe restrictions on the use of cars and temporary cutbacks in industrial production and generation of electricity. Yet standards were established on the basis of uncertain and contradictory evidence. Many instruments relied upon for pollution readings were inaccurate; the monitoring system was inadequate. The resulting measures of air pollution were not measures of exposure to pollution. Studies of excess illness and mortality associated with air pollution report inconsistent findings (Stewart Jr., 1979).

Modernization and progress have led to air getting more and more polluted over the years. Industries, vehicles, increase in the population and urbanization are some of the major factors responsible for air pollution. The following industries are among those that emit a great deal of pollutants into the air:

i. Thermal power plants
ii. Cement
iii. Steel
iv. Refineries
v. Petrochemicals
vi. Mines

Source: http://edugreen.teri.res.in/explore/air/major.htm (27th September 2004)

2.2 INDOOR AIR POLLUTION

Much attention is paid to outdoor air quality and its impact on health, but individuals may spend 90% or more of their time indoors. This research reviews current information on levels of particulate matter as an air pollutant and the risks for health and well-being around the Engineering Campus, Universiti Sains Malaysia. Therefore, this research concentrates particularly on the campus situation, whilst acknowledging and drawing information from important studies and developments elsewhere.

For a number of pollutants found indoors, the main sources are outside. Where significant indoor sources exist, these will tend to dominate personal exposure. Certainly it is known that the behaviour of individuals and their activity patterns (reflecting the time spent in various different 'micro-environments') can markedly affect their exposure to a range of air pollutants. Increasingly, therefore, the need is being recognized to take much better account of indoor exposures and to understand the importance of personal behaviour patterns. Only in this way can adequate assessments be made of the true impact of air pollution on health (Harrison, 1996).

2.3 MAJOR AIR POLLUTANTS

Air pollution results from a variety of causes, not all of which are within human control. Dust storms in desert areas and smoke from forest fires and grass fires contribute to chemical and particulate pollution of the air. The source of pollution may be in one country but the impact of the pollution may be felt elsewhere. Listed below are the major air pollutants and their sources.

(i) <u>Carbon monoxide (CO)</u>

- Carbon monoxide (CO) is a colorless, odorless gas that is produced by the incomplete burning of carbon – based fuels including petrol, diesel and wood. It is also produced from the combustion of natural and synthetic

products such as cigarettes. It lowers the amount of oxygen that enters our blood. It can slow our reflexes and make us confused and sleepy (Greenstone, 2002).

(ii) Carbon dioxide (CO_2)

- It is the principle greenhouse gas emitted as a result of human activities such as the burning of coal, oil and natural gases (Greenstone, 2002).

(iii) Chlorofluorocarbons (CFC)

- CFC gases that are released mainly from air-conditioning systems and refrigeration. When released into the air, CFC_s rise to the stratosphere, where they come in contact with few other gases, which lead to a reduction of the ozone layer that protects the earth from the harmful ultraviolet radiations of the sun (Greenstone, 2002).

(iv) Lead

- Lead is present in petrol, lead batteries, paints, hair dye products, and etc. Lead affects children in particular. It can cause nervous system damage and digestive problems and in some cases, cause cancer (Greenstone, 2002).

(v) Ozone

- Ozone occurs naturally in the upper layers of the atmosphere. This important gas shields the earth from the harmful ultraviolet rays of the sun. However, at the ground level, it is a pollutant with highly toxic effects. Vehicles and industries are the major source of ground-level ozone emissions. Ozone makes our eyes itch, burn and water. It lowers our resistance to colds and pneumonia (Greenstone, 2002).

(vi) Oxides of nitrogen (NO_x)

- ❖ It causes smog and acid rain. It is produced from burning fuels including petrol, diesel and coal. Nitrogen oxides can make children susceptible to respiratory diseases in winters (Greenstone, 2002).

(vii) Particulate matter (PM)

- ❖ It consists of solids in the air in the form of smoke, dust and vapour that can remain suspended for extended periods and is also the main source of haze, which reduces visibility. The finer of these particles, when breathed in can lodge in our lungs and cause lung damage and respiratory problems (Greenstone, 2002).

(viii) Sulfur dioxide (SO_2)

- ❖ It is gas produced from burning coal, mainly in thermal power plants. Some industrial processes, such as production of paper and smelting of metals, produce sulfur dioxide. It is a major contributor to smog and acid rain. Sulfur dioxide can lead to lung diseases (Greenstone, 2002).

2.4 AIR QUALITY IN MALAYSIA

Malaysia experiences good to moderate air quality status most of the time. However, several unhealthy air quality statuses were also recorded at several parts of the countries especially in major cities (DoE, 2003).

Ambient air quality standards identify individual pollutants and the concentrations at which they become harmful to the 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, crops, vegetation, aquatic resources and buildings (Afroz et al., 2003).

The Malaysian Air Pollution Index (API) is obtained from the measurement of fine particles (below 10μm) and several gases. Table 2.2 shows the API for Malaysia. Based on API readings throughout the country, the air quality has been considered generally good. In the urban environment of the Klang Valley, the index also has generally been between good and moderate, except for serious haze events in September and October. The bad air days of 1997 combined with the hosting of the Commonwealth Games in September 1998 provided as incentive for the installation of eight more air quality monitoring stations, bringing the new total to 39 (Afroz et al., 2003).

Table 2.2: The Malaysia Air Pollution Index

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

Source: DoE (1996)

Table 2.3 lists the recommended Malaysian Air Quality Guidelines (Ambient Standards) and compares them with the National Ambient Air Quality Standards currently enforced in the United States and WHO guidelines. The Malaysian guidelines are fairly consistent with standards of the United States (Afroz et al., 2003).

Table 2.3: Ambient Air Quality Standards – Malaysia and the United States

Air Pollutants	Malaysia (µg/m^3)	USA (µg/m^3)	WHO (µg/m^3)
Carbon monoxide (CO)			
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 (PM)			
Annual	90	50	-
24 – h average	150	150	-
Sulfur dioxide (SO_2)			
Annual	-	80	-
24 – h	105	365	-

Source: DoE (1996)

2.4.1 Main sources of air pollution in Malaysia

The major sources of air pollution in Malaysia are:

- Mobile sources
- Stationary sources
- Area sources
- Transboundary haze

Source: DoE (1996)

For the past 5 years, emissions from mobile sources (i.e., motor vehicles) have been the major source of air pollution, contributing to at least 70–75% of the total air pollution. Emissions from stationary sources generally have contributed to 20–25% of

the air pollution, while open burning and forest fires have contributed approximately 3–5%. According to the (DoE, 1996) Malaysia, in 1996, the percentages, of the air emission load by type were motor vehicles, 82%; power stations, 9%; industrial fuel burning, 5%; industrial production processes, 3%; domestic and commercial furnaces, 0.2%; and open burning at solid waste disposal sites, 0.8% (Figure 2.1).

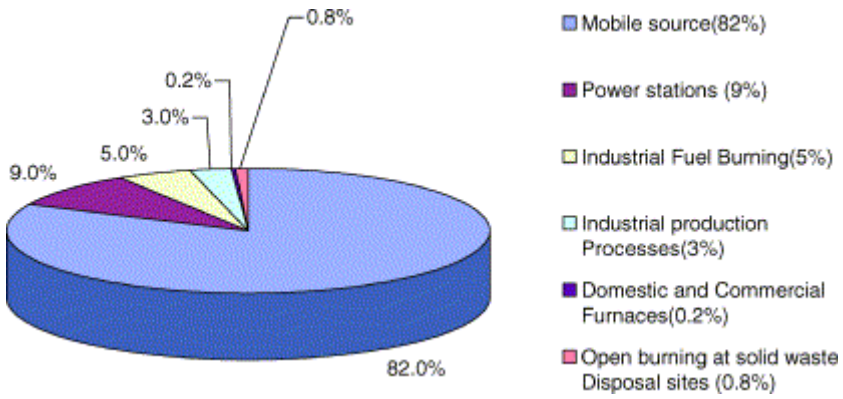

Figure 2.1: Sources of air pollution in Malaysia, 1996

Source: DoE (1997)

2.4.2 Health impacts of air pollution in Malaysia

There are possible short-term and long-term health effects of exposure to air pollution. In the short term, high levels of air pollution lead to an acute condition. In addition, blockage of sunlight may promote the spread of harmful bacteria and viruses that would otherwise be killed by ultraviolet B (Beardsley et al., 1997). The possible long-term health effects of exposure to air pollution are unknown and difficult to detect. Components of smoke haze, including polycyclic aromatic hydrocarbons, are known carcinogens the effects of which may not be apparent for years. The consequences may be more severe for children, for whom the particulates inhaled are high relative to body size (Afroz et al., 2003).

There is a very limited number of studies that relate air pollution to its health impact in Malaysia. The lack of data gathering for environmental epidemiological analysis makes it difficult to estimate the health impact of air pollution. Recent studies in this country have examined possible health effects of the 1997 forest fires (World Health Organization, 1998).

2.4.3 Health impacts of specific air pollutants

The most harmful of the gases and agents that are emitted are particulate matter, carbon dioxide, polycyclic organic matter and formaldehyde. Some of these gases can seriously and adversely affect the health of the population and should be given due attention by the concerned authority. The gases mentioned below (Table 2.4) are mainly outdoor air pollutants but some of them can and do occur indoor depending on the source and the circumstances (http://edugreen.teri.res.in/explore/air/health.htm , 27th September 2004).

Table 2.4: Relationship between air pollutants, the symptoms and consequences

Pollutant	Symptoms	Consequences
Carbon monoxide	Reduced visual acuity and sensory discrimination	Traffic accidents
	Reduced respiratory function	Asthma, bronchitis, other of angina, arteriosclerotic disease
Sulphur dioxide, sulphates	Irritation of respiratory system	Excess mortality
	Reduced respiratory function	Emphysema, bronchitis, other respiratory disease
Nitrogen dioxide, nitrates	Irritation of respiratory tract	Bronchitis, other respiratory illnesses
	Reduced respiratory function; reduced resistance to infection	Excess mortality; hypertensive heart disease suspected
Hydrocarbons	A few are irritating to eyes, respiratory tract	Cancer
Oxidants	Irritation of eyes, respiratory tract	Bronchitis, asthma, emphysema, difficulty in breathing
Particulates	Irritation of eyes, respiratory tract	Excess infant mortality; respiratory disease; some types of cancer

Source: Stewart Jr. (1979)

2.5 BASIC CONCEPTS

In this section, it is provided on some basic concepts of particulate matter or PM. These basic concepts that are presented in this section are about air quality and health effects.

2.5.1 Basic concepts concerning air quality

2.5.1.1 Particulate Matter

Particulate Matter (PM) or particles with aerodynamic diameter of 10μm or less are called inhalable. This is the fraction that is naturally inhaled by humans, while larger particles are less likely to enter the human respiratory tract. To mimic human respiration and correctly estimate the inhaled dose, ambient PM is sampled through a size-selective inlet with a 50% efficiency cut-off at 10μm aerodynamic diameter. This PM fraction is called PM_{10}. In the alveolar region (deep in the lungs) peak deposition for particles above 0.1μm occurs near a diameter of 4μm. Particles that are smaller still are categorized as $PM_{2.5}$ (50% cut-off 2.5μm), PM, or even $PM_{0.1}$ (Aben et al., 2002).

This is a general term for a mixture of solid and liquid particles in the air, usually produced by stationary fuel combustion and industrial processes. Particulates include small bits of soot and ashes that emanate from incinerators and smokestacks (Martin, 1999).

2.5.1.2 Sources and composition of PM

PM has both a primary component, which is emitted directly by sources such as traffic and industry, or indirectly as wind-blown soil particles and sea spray, and a secondary component which is formed in the atmosphere by chemical reactions of gases, most notably sulphur dioxide, oxides of nitrogen, ammonia and volatile organic

compounds. PM can be emitted, and exist in the atmosphere, in a wide range of particle sizes. Both primary and secondary PM may be the result of natural or anthropogenic sources. Heterogeneous PM in the atmosphere can lead to new and sometimes highly reactive components. A high ambient relative humidity can also cause PM to exist in a droplet from beside a more solid particulate form (Aben et al., 2002).

Apart of its size range and emission sources PM can also be characterized by its chemical composition. The chemical composition of PM in ambient air depends on the contribution made by both anthropogenic and natural sources. The former includes primary emissions from industry, power production and traffic, and secondary emissions of gases precursors. The natural sources mainly consist of primary emissions of sea salt, wind-driven soil dust and secondary organic particulate matter (Aben et al., 2002).

Heterogeneous atmospheric reactions of ambient PM with gases can in the right circumstances result in highly reactive products like radicals and peroxides. Due to their high reactivity these components are hard to measure, particularly using conventional particle sampling techniques. Other lesser known factors are particle charge and radiation. These considerations of PM_{10} or $PM_{2.5}$ are compared with health effects (Aben et al., 2002).

There are sources of PM_{10} in both urban and rural as are, major sources include:-

1. Motor vehicles
2. Dust from construction, landfills and agriculture
3. Wildfires and brush or waste burning
4. Industrial sources
5. Windblown dust from open lands

Source: http://www.arb.ca.gov/html/brochure/pm10.htm (27th September 2004)

2.5.1.3 Transport of PM

The atmospheric residence times and hence ranges of travel of these different size fractions vary considerably. They range from more than 60 hours for sub-micron particles larger than 0.1 μm in diameter to less than two hours for size class above 20 μm. Residence times are also equivalent to a mean transport distance (Aben et al., 2002).

2.5.2 Basic concepts concerning health effects

2.5.2.1 Research on health effect of PM

The obvious route of exposure of air pollution is through the respiratory tract, and it is biologically more plausible that air-pollution-related health effect will cause deaths from, for instance, respirable causes, pneumonia, chronic obstructive pulmonary disease (COPD) or cardiovascular diseases than from unrelated causes of death such as digestive diseases. As a number of deaths for respiratory diseases and for cardiovascular diseases is lower than that for all-cause mortality, the ensuing Relative Risk or RR per specific increase in PM should be higher for those specific causes of death than that for all-cause mortality (Aben et al., 2002).

A measure for health effects that is being used frequently in the full report is the epidemiological concept of Relative Risk or RR. By definition a RR is the ratio of the risk of disease in an exposed cohort over a defined time interval compared to the risk of disease in an unexposed cohort over this same interval. Because everybody is exposed to ambient air pollution to some extent, in environmental epidemiology this RR is quite often expressed as a relative increase in mortality, e.g. for a specific increase in PM concentrations (Aben et al., 2002).

2.5.2.2 Mechanisms of PM-related health effects

One approach for identifying biological mechanism is to break down the complex mixture into smaller fractions based on the physical, chemical or biological characteristics of PM. Physical characteristics are further divided into size (coarse, fine, ultra fine), surface area, number, charge or radiation of particles. Chemical classification is roughly done between organic and inorganic or between a water-soluble or non-soluble fraction, and often also by specific groups such as transition metals, salts, hydrocarbons, crystal-like material, etc. Biological characterization is based on content of moulds, fungi, bacteria (or components produced by bacteria, e.g. endotoxins) pollen, etc. Apart from knowing that what is causing the health effects, it is also important to know how these effects are induced in order to link the epidemiological observations with an underlying biological mechanism (Aben et al., 2002).

2.5.2.3 The human respiratory system

Several diseases of the respiratory tract are common, everyday words – the flu, the common cold, pneumonia and most of these infectious maladies, caused by either bacteria or viruses. Bacterially caused diseases, principally tuberculosis and pneumonia, have been greatly reduced in prevalence and seriousness by modern drugs, sanitation and public health efforts. In striking contrast to these successes of modern medicine, three respiratory conditions are not decreasing in prevalence. They are chronic bronchitis, pulmonary emphysema and cancer of the lung. They are all epidemiologically associated with air pollution (Lynn, 1976).

Some of the smallest particles (Figure 2.2), called respirable particulates may tend to be deposited in the alveoli (tiny air sacs in the lungs). In the lungs, particulates slow down the exchange of oxygen with carbon dioxide in the blood, causing shortness of breath. The heart gets strained, because it works harder to compensate for oxygen loss. Usually, people most sensitive to these conditions have respiratory diseases like emphysema, bronchitis, asthma or heart problems. Particles themselves may be

poisonous if inhaled, damaging remote organs like the kidneys or liver. Swallowed mucous that is laden with hazardous particulate matter may damage the stomach (http://www.cpcb.delhi.nic.in/htm, 21st January 2005).

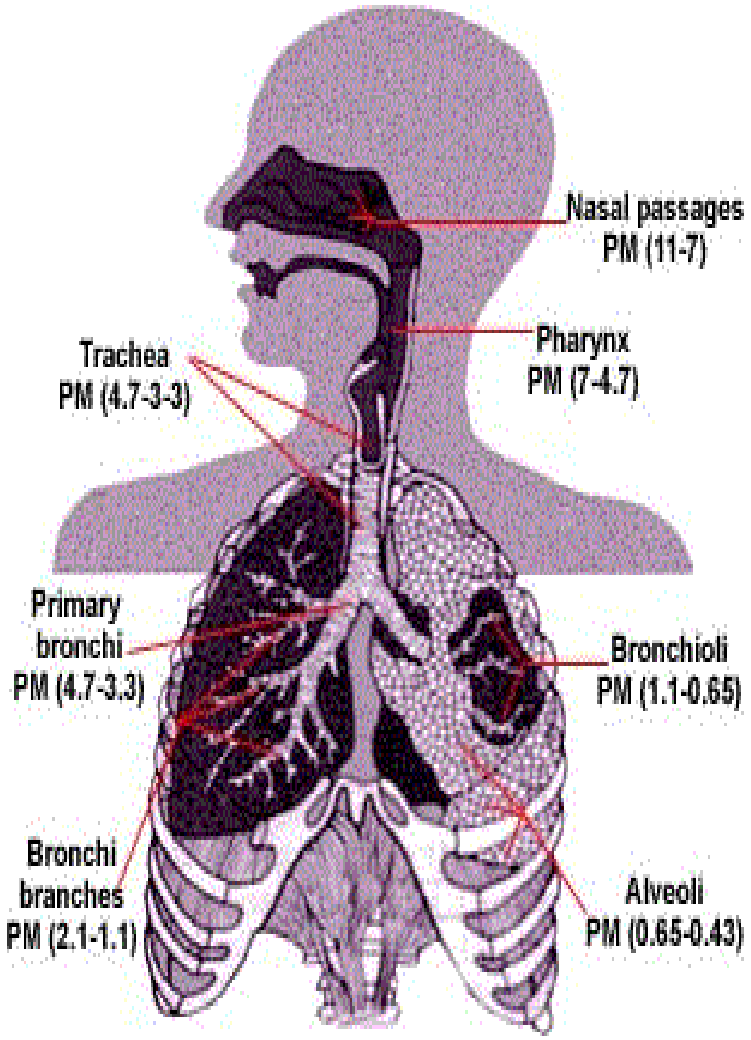

Figure 2.2: Depositions of particulate matter (PM) in respiratory system

Source: http://www.cpcb.delhi.nic.in/htm (21st September 2004)

i. Chronic bronchitis

This chronic condition is one of the most significant cripplers of the middle-aged, though it is not generally directly fatal. The condition results from the over secretion of mucus in the bronchial lining and is characterized by a chronic cough to get rid of the excess. Frequently, if the pollutant exposure continues, emphysema is gradually superimposed and becomes the dominant cause of death (Lynn, 1976).

Natural history refers to the usual or expected course of a disease. For chronic bronchitis, as with so many lung diseases except perhaps lung cancer, the natural history is highly variable. One can have mild, moderate, or severe disease. Generally, the longer the symptoms have been present and the longer the exposure to cigarettes (or whatever cause), the more severe will be the disease. However, there is great individual variation. For this reason physicians frequently order breathing tests (pulmonary function tests) on patients with suspected COPD. These tests of lung function require the patient to exhale quickly and forcefully through a tube attached to a measuring device. Another test, blood gas analysis, is performed on a sample of arterial blood and determines if the patient's lungs are bringing in enough oxygen and getting rid of enough carbon dioxide. These tests (pulmonary function and arterial blood gas) give the best idea of disease severity and what the long term outlook may be (Martin, 1999).

Increased particulate exposure enhances the incidence of bronchitis in exposed population. Acute bronchitis and bronchiolitis may be misdiagnosed as odema, which may get further complicated in the people with myocardial damage and increased left arterial pressure. Bronchiolitis or pneumonia induced by air pollution in the presence of pre-existing heart problems might precipitate congestive heart failure and cardiovascular mortality (http://www.cpcb.delhi.nic.in/htm, 21st January 2005).

ii. Pulmonary emphysema

A progressive destructive change in the alveoli, pulmonary emphysema ultimately causes the loss of effective use of much of the lung and leads to death by heart failure. With the destruction of some of the walls of the alveoli, many of the small air sacs are combined into one larger volume, with a resultant loss of surface area for capillaries and gas diffusion. Some of the other walls of the alveoli lose their elasticity, which inhabits exhalation, trapping air in the lungs and forcing a much greater part of the work of exhaling onto the chest muscles. The earliest effect of this destruction is shortness of breath, probably first noticed on exertion or on rising in the morning and is usually attributed to smoking or lack of exercise. The shortness of breath, however, progressively worsens until just ordinary breathing is an effort; ultimately, physical activity is impossible and continued overload causes heart failure (Lynn, 1976).

Patients, who develop predominant emphysema, where the lung tissue is destroyed, may have a genetic or constitutional basis. Certainly most smokers don't develop emphysema. Evidence for a genetic tendency comes from the small percentage of emphysema patients who lack a certain enzyme called alphalantitrypsin. This enzyme, normally present, functions to break down another enzyme (trypsin) that tends to destroy lung tissue. If trypsin accumulates, as it might with alphalantitrypsin deficiency, the result can be lung destruction (emphysema). Perhaps they have some other yet-to-be discovered genetic deficiency (Martin, 1999).

Deficiency of alphalantitrypsin is an inherited disorder present in less than two percent of the population. Fortunately, this deficiency itself rarely causes severe lung disease unless the patient smokes. There is a synergistic effect between this inherited deficiency and cigarette smoke, presumably leading to destruction of the lung tissue by the body's enzyme system. Although this helps to explain why some people get emphysema, it does not explain all or even most cases. The vast majority of emphysema patients do not lack alphalantitrypsin (Martin, 1999).

iii. The Difference between Chronic Bronchitis and Emphysema

Although both diseases are caused by cigarette smoke, the damage in the two cases is different. Chronic bronchitis starts with ciliary damage; in the most severe cases the airways themselves are irreversibly damaged, yet the basic architecture of the lungs remains intact. In emphysema not only are the airways damaged, but many of the alveoli and their accompanying blood vessels are destroyed. They are destroyed by the effects of the cigarette smoke, leaving only empty air spaces that cannot effectively transfer oxygen and carbon dioxide. For gas exchange to occur the patient has to literally work harder to bring more air into the remaining normal air spaces. For this reason emphysema is generally a more severe condition than chronic bronchitis, and not usually amenable to any specific treatment (Martin, 1999).

Blood vessels are not shown in this figure. In chronic bronchitis the airways are narrowed but intact. In emphysema the damage is more extensive, involving actual destruction of alveoli and blood vessels; note the coalescence of two alveoli into one larger, ineffectual "space" that no longer functions as a normal alveolus. The end result in chronic bronchitis is thickened air tubes and loss of the ciliary blanket. The end result in emphysema is literally "holes" in the lung (Martin, 1999).

iv. Lung cancer

Cancer of any location is a growth of cells beyond their normal, biological limit, destroying other tissues in their path, as it were, more or less rapidly in various types. Similarly, the lungs are frequently the recipients of carcinomas originating in other parts of the body, as all the body's blood routinely passes through the lungs. Such secondary tumors and the small number (about a tenth) of the primary tumors that are benign are less serious, their effects usually being limited to obstructing the bronchi. Actually, the earliest outward symptoms of primary bronchial carcinoma is also just bronchial obstruction; the reason it is no routinely fatal is that such obstruction rarely occurs in time

to give warning before the tumor has reached metastasis, the stage of rapid spreading throughout the body (Lynn, 1976).