CHAPTER - III

CONCEPTS AND DEFINITIONS
CHAPTER 3 - CONCEPTS AND DEFINITIONS

The chapter contains an outline of concepts and definitions of terms used in the thesis. A discussion on major vehicular pollutants and their impacts on human health is ensued here. Understanding of the conceptual dimensions of various terms relevant to the present study like health, illness, morbidity, environment etc., are aimed at in this chapter.

3.1 Environment

To put it simply, ‘Environment’ means our surroundings. It is the sum total of all the external conditions and influences on us. To be more specific, the natural environment is broadly composed of two components- the biotic and the abiotic. The biotic component constitutes of all living organisms, while the abiotic component of the environment constitutes of all inorganic or non-living elements and compounds. The abiotic component consists of elements and compounds like oxygen, carbon-dioxide, water, calcium, various carbonates and phosphates etc., which influence plants, animals, human beings and micro-organisms. According to the definition put forward by Khopkar (2004), “Environment is composed of atmosphere, earth, water and space”. Hussen (2004) states that “The natural environment could be defined as the physical, chemical and biological surroundings that humans and other living species depend on for life support”.

The scope of environmental studies is very broad and essentially follows a multidisciplinary approach. It includes components of biology, geology, chemistry, physics, economics, philosophy and a multitude of other subjects.
Man is inextricably related to the environment and depends on renewable and non-renewable resources of the environment for life-support. Increase in economic activities and technological advancements have triggered massive alterations in natural environment and endangered its restorative and absorptive functions. One of the key reasons that environmental studies have taken centre-stage today is because of rampant environmental pollution from various sources and the unconditional need for protecting the environment.

3.2 Environmental Pollution

Environmental pollution is defined as "An unfavourable alteration of the environment from the effects of changes in energy patterns, radiation level; chemical or physical constitution as well as by human activity" (Khopkar, 2004).

Pollution has been explained as the impact of increased volumes of wastes intensified by continued human efforts to simplify the natural ecosystem, which have the undesirable effect of reducing the numbers of decomposers. Furthermore, beyond certain thresholds, increased wastes could cause the total collapse or irreversible damage to an ecosystem (Hussen, 2004).

The effects of pollution manifest itself in all mediums of the environment viz., air, water and land causing unfavourable alterations to our surroundings that affect human beings, plants and animals adversely. Although pollution is generated from both natural and anthropogenic sources, it is the enormous amount of pollution generated by relentless economic activities carried on by human beings that continues to be of utmost concern. The current trend of pollution, if unchecked, could spell disaster for the whole planet and make life uninhabitable.
The present study requires an understanding of how air pollution caused by vehicles endangers human health.

3.3 Air Pollution

The atmosphere contains a number of gases and particulates which if higher than usual concentrations are harmful to human health and damaging to plants and animals. These gases primarily include Ozone (O₃), Sulphur-dioxide (SO₂), Oxides of Nitrogen (NO, NO₂), Carbon monoxide (CO), and a wide range of Volatile Organic Compounds (VOC) like benzene and butadiene. Particulate matter consists of both solid and liquid particles which include dust, fume, mist, spray, smoke etc. These toxic gases and particulates in the air are referred to as air pollutants and their presence in the air causes air pollution.

3.4 Sources of Air Pollution

Sources of air pollution can be categorized into natural and anthropogenic sources.

Air pollution from natural sources are caused by wind blown dust and volcanic eruptions whose effect are more or less minimized by the self purification ability of the natural environment. But pollution from anthropogenic sources or human activities is increasing at such a rate that has surpassed or is in the verge of surpassing the natural assimilative capacity of the environment.

Air pollution generated by human activities is classified into three broad categories viz., stationary or point sources, mobile sources and indoor sources (Kathuria, 2005).

Stationery Sources: include factories, power-plants, smelters, Natural gas compressor stations, petroleum refineries and in a smaller scale –dry cleaners and degreasing operations.
Mobile Sources: include cars, trucks, buses, motorcycles, tractors, planes, trains etc.

Indoor Sources: include oil, gas, coal, wood and open fires used for cooking, heating and air conditioning systems and poor air ventilation.

The present study is concerned with the on-road mobile sources of air pollution emitted from cars, trucks, buses, motorcycles etc. In general combustion is the chief contributor to outdoor air pollution and motorized transport being the key source of combustion. Fuel and lubricating oil quality have contributed significantly to transport air pollution in India. These facts coupled with India’s high ambient temperatures increases the potential for evaporating emissions rich in reactive hydrocarbons with the potential to generate ground-level ozone (CPCB, 2008). Albeit, outdoor air pollution in India not only contains combustion products but also high amounts of particulate matter which is potentially damaging to human health.

3.5 Vehicular Pollution and Impact on Health

The major vehicular pollutants and their impacts on human health are discussed below.

3.5.1 Particulate Pollutants

Particulate pollutants are harmful substances present in particulate matter which consist of both solid and liquid particles that are distributed in the ambient air. Particulate matter (PM) is a complex mixture of suspended solid and liquid particle in semi equilibrium with surrounding gases (Brook et al., 2003). The term particulate refers to particles- dust, mist, fumes and smoke that become air borne in the surrounding air. These particles are emitted in the air from fuel consumption of motor vehicles, power generation, industrial activity etc., which remain suspended in the air.
for a long time. PM may be classified as primary (particles emitted directly by emission sources) and secondary (particles formed through the atmospheric reaction of gases). The size distributions of airborne particles are important for human health (CPCB, 2008). Studies reveal that smaller the diameter of the particulates, greater the health damaging potential.

Based on size distribution, particulate matter may be classified as:

(i) **Total Suspended Particulates (TSP):** SPM having particle diameter between less than 100µm and remain suspended in the air for a long time. TSPs are generated from burning of fossil fuel and industrial process. Secondary sources of TSPs include conversion of gaseous substances like Sulphur dioxide, Nitrogen oxide and hydrocarbons.

(ii) **Respirable Suspended Particulate Matter (RSPM or PM₁₀):** RSPM or PM₁₀ are particulates having diameter less than 10µm and are small enough to be inhaled. These enter the respiratory tract and pulmonary system of human beings and cause considerable damage to human health. PM₁₀ deposit relatively quickly with a lifetime of less than 2 days, and exposure may lead to adverse responses in the lungs triggering an array of cardio-pulmonary problems (Brunekreef and Forsberg, 2005; Harrabi et al., 2006). PM₁₀ has also been associated with emergency hospital admission for asthma, bronchitis, and pneumonia in older people (Ye et al., 2001). These generally arise due to incomplete combustion of fuel in automobiles and from other pollutants SO₂, NO₂ etc. Besides, road dust, wind blown dust and construction areas are also sources of PM₁₀.

(iii) **Fine Particulate Matter (PM₂.₅):** PM₂.₅ are aerosols having diameter less than 2.5 µm. These are emitted from fuel combustion in motor vehicles, process combustion
and from industrial sources, residential and agricultural burning. PM$_{2.5}$ is also formed from reactions of other pollutants. These particulates are small enough to bypass the screening of the nose and can penetrate alveoli being deposited in the upper respiratory tract. These particles may penetrate deep inside the airways and are more strongly linked to adverse health effects (USEPA, 1996).

(iv) **Nuclei mode or ultra fine particles (UFP).** The particles in this category are smaller than 0.1 μm. They are also known as ultra fine particle (UFP). “UFP are present in great number in polluted urban air” (Jaques and Kim, 2000). “UFPs cause health effects like cardiovascular problems, pulmonary disease, and development of cancer” (Vinzents et al., 2005).

Summing up, particulate pollutants are remarkably detrimental to human health and are responsible for a host of health problems and diseases ranging from visual impairments to decreased lung function to aggravation of asthma to other respiratory and heart diseases and even lung cancer and premature death in case of persistent exposure.

In addition to particulate pollutants, other harmful emittants from vehicles are discussed below.

### 3.5.2 Other Pollutants

(i) **Lead (Pb)**

Particulate contaminants also contain a number of metallic elements like lead, zinc, copper, aluminium etc. The proportion of lead increases as vehicular traffic increases since lead is used as petrol additives. Now a days, though, unleaded petrol is used though its use is not ubiquitous. Lead is the most serious pollutant released from automobile exhausts which causes brain damage primarily in children. It interferes with the development of red blood cells and also causes hypertension.
(ii) Carbon monoxide (CO)

Carbon monoxide is a colourless, odourless poisonous gas which is formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust which contributes nearly 60% of all carbon monoxide emissions nationwide. The largest contributors of CO are petrol-fuelled vehicles. High concentrations of carbon monoxide generally occur in areas with heavy traffic congestion. Peak CO concentrations typically occur during colder months of the year. Other anthropogenic sources of CO emissions include industrial processes and non transportation combustion fuel.

CO binds strongly to hemoglobin in red blood corpuscles resulting in the production of carboxyhemoglobin (COHb). It is an asphyxiant which enters the blood stream through the lungs and reduces the delivery of oxygen to different organs of the body and may be responsible for causing suffocation, unconsciousness and even death in extreme cases. The ill effects of CO are most serious for persons suffering from cardio vascular diseases. At very high levels of exposure, the effects of CO may be fatal even for healthy individuals. Visual impairment, reduced manual dexterity, poor learning ability and difficulty in performing complex tasks are all associated with exposure to elevated CO levels.

(iii) Hydrocarbons (HC)

Hydrocarbons are organic compounds consisting in majority of carbon and hydrogen. Liquid geologically extracted hydrocarbons are referred to as petroleum or mineral oil while gaseous geologic hydrocarbons are referred to as natural gas.

Incomplete combustion of fossil fuels like petroleum, natural gas etc., in vehicles is a major source of air pollutants having highly damaging properties. These cause
irritation to the eyes, nose, throat often leading to constriction of the bronchus and aggravation of asthma. Hydrocarbons also have carcinogenic properties and may be the cause of lung cancer. Hydrocarbons react with other chemicals to form a variety of compounds like aldehydes, Ketones, Volatile Organic Compounds (VOC) which are known to have remarkably harmful effects on human health.

(iv) Benzene

Benzene, a VOC, is a minor constituent of petrol. Benzene is an aromatic, sweet-smelling, colourless, inflammable liquid which is used as additive in gasoline or petrol. It is produced from combustion and evaporation of both petrol and diesel. Benzene falls within the category of non-methane volatile organic compounds which is also used as an important industrial solvent and a precursor in the production of drugs, plastics, synthetic rubber and dyes. "Benzene has been found very harmful for human health for its hematotoxic, neurotoxic, leukemogenic and carcinogenic effects" (Farris et al., 1993).

(v) Sulphur dioxide (SO2)

Sulphur dioxide belongs to the family of sulphur oxide gases which are formed when fuel containing sulphur (mainly coal and oil) are burnt. It is present in appreciable quantities where diesel is used as fuel. Sulphur dioxide is also generated during metal smelting and other industrial processes. SO2 affects the major air passages to the lungs and induces increased production of mucous. Exposure to high levels of SO2 are accompanied by symptoms of wheezing, cough, chest tightness, shortness of breath and may lead to asthma, bronchitis in the long run and also aggravation of existing cardio vascular diseases. Children, the elderly and individuals active outdoors are more prone to the ill effects of SO2.
(vi) Nitrogen oxides (NO)

Nitrogen oxides are highly reactive gases formed in the ambient air through oxidation of Nitric oxide (NO) and Nitrogen dioxide (NO$_2$). The major sources of NO are high temperature combustion process, such as those occurring in automobiles and power plants. Heat convectors used in residences and gas stoves also produce substantial amounts of NO$_2$. In addition, Nitrogen oxides play a major role in the formation of ozone and acid rain.

Exposures to NO$_2$ may lead to increased respiratory infections in individuals with pre-existing respiratory illness and cause alterations in the lung. It causes changes in airway responsiveness and lung functions and aggravates respiratory illness in children and adults and may also be responsible for visual impairments in some cases.

(vii) Polycyclic aromatic hydrocarbons (PAHs)

PAHs a constituent of hydrocarbons, are emitted from combustion of petrol and diesel have been found to contain highly carcinogenic potential. PAHs are usually adsorbed on the particulate pollutants. They enter the body through inhalation of these respirable particles. “Several PAHs like benzo(a)pyrene [B(a)P] are highly carcinogenic” (Hrudkova et al., 2004).

Below are discussed some concepts related to health which have been often used in the thesis.

3.6 Health

The most widely accepted definition of health is put forward by WHO (1948) in the preamble of its constitution as ‘Health is a state of complete physical, mental and social wellbeing and not merely a disease or infirmity’ In the recent years, the
definition of health has been further broadened to include the ability to lead a 'socially and economically productive life' (Adapted from Park, 2002).

Though the definition of WHO has been criticized on the ground that it is too broad and not an operational one, but it highlights the multidimensional aspect of health and recognizes the fact that perception of well-being is as important to an individual as presence or absence of disease.

The wellbeing of an individual or a group of individuals has objective and subjective components. The objective component of wellbeing relate to standard of living and levels of living – income, occupation, housing conditions, sanitation, nutrition while the subjective component of wellbeing generally refers to quality of life. The quality of life includes a combination of the effects of the factors that determine health, happiness, education, social and intellectual attainments, justice etc.

3.6.1 Disease, Illness and Sickness

Health and disease lie along a continuum and it very difficult to define disease. In the simplest of senses, disease is just the opposite of health – which is any deviation from the normal functioning or state of complete physical or mental wellbeing, since health and disease are mutually exclusive (Park, 2002).

Though in its common usage, the terms disease, illness and sickness are apparently synonymous there are subtle distinctions between the three.

(i) **Disease** literally means without ease, or when something is wrong with bodily function.

(ii) **Illness** refers not only to the presence of a specific disease but also to the individual’s perception and behaviour in response to the disease, as well as the impact of that disease on the psychosocial environment (Ouslander and Beck, 1982).
Sickness refers to the state of social dysfunction that is a role the individual assumes when ill. A doctor sees people who are ill, rather than the diseases which he must diagnose and treat (Richie and Milner, 1971).

As mentioned above, health being multidimensional, there are many indicators to measure health. These include mortality indicators, morbidity indicators, disability rates, nutritional status indicators, environmental indicators, socio-economic indicators etc.

3.6.2 Morbidity

As mortality indicators fail to measure ill-health in a community, morbidity indicators supplement these measures and are used to describe the health status of a population. Some of the common morbidity rates are – incidence and prevalence, attendance rates at out-patient departments or health centres, duration of stay in hospital, spells or sickness or absence from work or school (WHO, 1981).

Environment indicators on the other hand, reflect the quality of physical and biological environment in which people live. These include indicators relating to pollution of air and water, solid waste, noise, exposure to toxic substances etc (WHO, 1976).

3.6.3 Cost of Illness

"Cost-of-illness studies measure the economic burden of a disease or diseases and estimate the maximum amount that could potentially be saved or gained if a disease were to be eradicated" (Segel, 2006). In other words, costs of illness (COI) provide monetary measures of the opportunity cost of illness and amounts spent on medical expenses, hospital and diagnostic costs etc.
3.6.4 Restricted Activity Days

Restricted activity days (RAD) are defined by Ostro (1987) as days spent in bed, days missed from work and days when activities are partially restricted due to illness.

3.7 Other concepts

3.7.1 Household

A group of persons normally living together and taking food from a common kitchen constitutes a household. The word 'normally' means that temporary visitors are excluded but temporary stay-aways are included (NSSO).

3.7.2 Household size:

The size of a household is the total number of persons in the household.

3.7.3 Monthly per capita consumer expenditure (MPCE)

For a household, this is the total consumer expenditure over all items divided by its size and expressed on a per month (30 days) basis. A person’s MPCE is understood as that of the household to which he or she belongs.

3.7.4 Reference system with respect to consumption

For estimating the value of consumption of items, a system of mixed reference has been followed. For most of the items, the value of consumption of items was recorded for a period of 30 days (one month). However, the items for which annual consumption value was stated, viz., clothing, footwear etc, the value was converted to a reference period of 30 days by multiplying the recorded figure by the factor 30/365.3

3 Concepts of household, household size, MPCE and Reference follow the standard usage of these concepts as documented in various rounds of NSSO

66
3.7.5 Arithmetic Mean

(i) Simple Arithmetic Mean: Arithmetic Mean (AM) is the most popular and widely used measure of central tendency widely used for obtaining a summary measure for the entire data. AM is defined as the sum of the observations divided by the number of observations.

If \( X_i \); \( i = 1, 2, \ldots, n \) be the number of observations, then Arithmetic mean (\( \bar{X} \)) is given by

\[
\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \quad (i)
\]

(ii) Weighted Arithmetic Mean: One of the limitations of Arithmetic mean is that it gives equal importance to all items. However, the relative importance is not the same for all items. In those cases, Weighted Arithmetic Mean is a more suitable method of averaging as compared to simple Arithmetic Mean.

If \( X_i \); \( i = 1, 2, \ldots, n \) be the number of observations with weights \( W_i ; i= 1,2,\ldots,n \) then Weighted (AM) is computed as

\[
\bar{X}_w = \frac{1}{\sum_{i=1}^{n} W_i} \sum_{i=1}^{n} W_i X_i
\]

Weighted AM has been widely used for averaging both secondary and primary data related to ambient air quality (Ref. Chapter 5) and household data (Ref. Chapter 6) respectively.
3.7.6 Growth Rates

Rate of growth is used to estimate the change in the same variables at different points of time. One way of calculating growth rate could be to consider the values of relevant variables at the initial time period \((t_0)\) and the terminal time period \((T)\). Growth over two points in time is defined as

\[
g = \frac{X_i - X_{i-1}}{X_{i-1}}\]  

\(X_{i}; i = 0, 1, 2, \ldots\), \(t\) refers to observations in the present time period while \(X_{i-1}\) refers to observations in the previous time period.

The formula in equation (i) has been applied for estimating growth rates related to ambient air quality and motor vehicle data (Ref. Chapter 5).

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