Chapter-I

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The existence of human life on this earth is very seriously threatened by some problems, such as environmental pollution and population growth. India is facing both these problems. Since independence, India has made great technical and technological advancement, all these have meant extensive release of harmful chemicals and other toxic materials including radioactive elements into the environment, toxic gases into the air, chemicals and detergents into the rivers and seas and pesticides into the soils. In India, today, major urban areas and even the country side are exposed to air, water, soil, noise and radioactive pollution, leading to health hazards and extinction of plants and animals (Kotpal and Bali, 1988). Ecological factors also harm the vegetation and affect the leaves in various ways and causes injuries to them.

A more informative definition of pollution has been adapted by Environmental pollution panel, of United States President’s Science Advisory Committee in November 1965 in its report “Restoring the quality of our environment”. This definition is as follows: “Environmental pollution is unfavourable alteration of our surroundings, wholly or largely as a by-product of man’s actions, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundance of organisms. These changes may affect man directly, or through his supplies of water and of agricultural and their biological products, his physical objects or his opportunities for recreation and appreciation of nature.”

Broadly speaking, the pollution refers to any change in the natural quality of the environment brought about by chemical, physical or biological factors. At
United Nation conference on environment on June 14, 1972 at Stockholm (Sweden), the late Prime Minister of the country, Smt. Indira Gandhi had said “Modern man must reestablish an unbroken link with nature and with life. He must again learn to invoke the energy for growing things and to recognise, as did the ancients in India centuries ago. That one can take from the earth and the atmosphere only so much as one put back into them.”

Pollution is an undesirable change in the physical, chemical or biological characteristics of air, water and soil that may harmfully affect the life or create a potential health hazard of any living organism. Pollution is thus direct or indirect change in any component of the biosphere that is harmful to the living components and in particular undesirable for man, affecting adversely the industrial progress, cultural and natural assets or general environment.

With the advancement of science and technology, rapid growth and their requirements, increasing industrialisation is the order of the day. Different industrial effluents are the main source of environmental pollution in all over the world. Rapid growth of population, rapid industrialization with the wide sphere of human activities have resulted into the greater exploitation of the environment. Air, water and soil are the most important components of the environment on which the survival of living beings is dependent. For healthy human life, purity of the environment is of great importance and with any disturbance or alternation in its optimal composition, the state of human life is adversely affected. Water sustains life, it is indispensable for the welfare of human beings and their natural environment. But the misuse and scarcity of this-life-supporting response pose a serious and growing threat to food scarcity, human health and well beings. The very first attempt of man against environment was invention of the fire (Zwiers and Weaver, 2000). From here starts the history of pollution. With the pace of civilization, man succeeded in conquering nature, and in developing social structure which could respond to his desire.
It adversely affects the food supply, human health and world economy. Especially, air pollution is a matter of immediate concern, because to assess its damage to economic, ecologic and aesthetic cost of vegetation, is extremely difficult. The toxicity of a pollutant to plants, small mammals, fishes or wildlife can be evaluated simply by exposing a small group of them under controlled laboratory conditions to various levels of the pollutants in question, such an evaluation cannot ethically be performed in human beings. Instead, the toxicity of chemical pollutants to human should be estimated by some other means.

All chemicals are harmful, even the most innocuous of the substances when taken into the body in sufficient quantities, may lead to undesirable, if not distinctly, harmful effects. It follows, therefore, that the degree/intensity of the injurious effects produced by a toxicant, is determined by two factors:

1. Concentration of the toxicant at the site of action
2. Length of exposure of a susceptible site to the toxicant

The former has given rise to the concept of 'dose' in experimental toxicology and the latter to the classification of exposures to toxicants as acute, subacute/subchronic and chronic types.

The selection of the most sensitive, suitable and acceptable species of animal has always been and still is a big problem. Although, the tendency has always been to use an organism that most closely is related to man on a phylogenetic basis, the truth is that none 'resembles' man in all respect. All one can then do, is to evaluate the extent of comparative relationship that exists between a given species and humans. A good degree of physiological and metabolic similarities would be highly pertinent in safety evaluation.
The meaning of air pollution is the presence of one or more contaminants such as dust, fumes, gases, mist, smoke or any other undesirable foreign material in atmosphere which is hazardous and injurious to natural ecosystem. When, the concentration of these contaminants crosses the limit and creates a situation in which life is difficult to man and plants by damaging the quality of air, so that a comfortable enjoyment of life property becomes impossible, then it becomes a serious problem for mankind. In highly industrialised countries, the level of pollution has reached to terrible limits. Ways are constantly devised to reduce or minimize it. We, in India are also confronted with this problem in certain industrial and urbanized areas. The anthropogenic activities, including urbanization and industrialization, generate a variety of gaseous and particulate pollutants, such as sulphur dioxide (SO$_2$), hydrogen fluoride (HF), nitrogen oxide (NOx), cement kiln dust, soot lead particles, foundry dust, sulphuric acid aerosols, etc. (Subrahmanyam et al. 1985, Uhlirova et al. 1993, Chattopadhyay 1996). These pollutants cause injurious effects on plants, animals and human beings (Uhlirova et al. 1993, Yarmshko et al. 1998, Donoghue et al. 1999, Farooq 2000, Sharma et al. 2002). In India, due to large scale fossil fuel combustion, SO$_2$ is the most common gaseous pollutant. The SO$_2$ problem is of increasing concern than any other effluent because of increasing sources, due to urbanization and the current widespread development of high capacity power plants using sulphur containing fossil fuels like coal and oil; manufacturing of sulphuric acid, paper and pulp products and smelting and refining of sulphur containing ores. Robinson et al. (1978) estimated around 80% of the anthropogenic SO$_2$ originates from the combustion of fossil fuels.
On the earth, air is the real supporter of life. Physical addition of material that turn the air impure or unclean is called air pollution. Air pollution results from gaseous emissions mainly from industries, thermal power stations, automobiles, domestic combustion etc. Main air pollutants are CO, CO₂, SO₂, NO₂, O₃, fluoro carbons, particulate matter toxicants, smog and brick kiln etc. Fuel and wood burning are increasing the air pollution upto measurable extent (Ambasht and Ambasht, 1999) A person can live for five days without water; for five weeks without food, but his existence will cease within five minutes without air (Raju, 1997). Food and water are required intermittently by a living organism but air is required continuously for the survival of all kind of life. Air is elastic, invisible and tasteless mixture of gases that surround the earth, and the thick cover of air mantle that envelops the earth is called atmosphere.

The cosmic rays from outer space and the harmful proportion of the electromagnetic radiations from the Sun are arrested and rebuffed by the atmosphere in favour of the biotic components of the earth. Only the near ultraviolet, visible, near infrared radiations and the radio waves are transmitted. The atmosphere plays an important role in maintaining the heat-budget of the earth (Scott et al., 1999). Present scenario divides the biosphere into various life blocks, depending upon temperature, being affective at biochemical and enzymatic level or ecosystem level (Bebiya, 2000; Sykes et al., 1999). The heat balance is maintained by the atmosphere through absorption of infrared radiation emitted by the Sun and insulation of re-emitted rays from the earth’s surface (Dowlatabadi, 2000; Stocker, 2001; Yu and Qiao 2004; Janhau et al., 2005; Samet, et al., 2005).
Atmosphere also supplies nitrogen, through nitrogen-fixing bacteria and ammonia-manufacturing plants which utilize it to yield chemically bound nitrogen essential for life. It is also a vital carrier of water from oceans to land as a part of the hydrological cycle. Atmosphere is a reservoir of several elements essential for life and it serves many purposes and functions. It contains life saving gases like oxygen, which is used in respiration for the liberation of biochemical energy which is essential for metabolic processes in human beings, animals as well as in plants. It also contains carbon dioxide gas which is an essential component required in photosynthesis by the plants, which is the vital process of plant and essential to feed the globe and provide fresh air to breath all kind of life. Operation of various biogeochemical cycles which relate to the movement of matter between an organism and its environment has also been possible only due to the presence of atmosphere (Malhi et al., 2000; Ma et al., 2004; Tomarevic et al., 2005; Saier et al., 2005; Lee et al., 2005; Kurniawan and Schmidt, 2006; Jou and Ju, 2006).

There is no demarcation between the atmosphere and the void of outer space, yet the air remains condensed near the earth surface. 75% of the earth's atmosphere lies within 10 miles of the surface and 99% of the atmosphere lies below an altitude of 19 miles (Murray et al., 1975; Nrusimha et al., 2005; Qin Min et al., 2006). The density of atmosphere shows a sharp decrease with increasing altitude. The total mass of atmosphere is approximately $5 \times 10^{15}$ tonnes, which is roughly one millionth of the Earth's total mass. The composition of normal dry air is given in Table 1.1.
Table 1.1: Chemical composition of normal dry air

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Symbols</th>
<th>% by volume (molecular fraction)</th>
<th>ppm (by volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>78.09</td>
<td>7,80,900.00</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>20.94</td>
<td>2,09,400.00</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>0.93</td>
<td>9,300.00</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO₂</td>
<td>0.032</td>
<td>320.00</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>18 ppm</td>
<td>18.00</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>5.2 ppm</td>
<td>5.20</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>1.3 ppm</td>
<td>1.40</td>
</tr>
<tr>
<td>Krypton</td>
<td>Kr</td>
<td>1 ppm</td>
<td>1.00</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>0.5 ppm</td>
<td>0.50</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O</td>
<td>0.25 ppm</td>
<td>0.25</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>CO</td>
<td>0.1 ppm</td>
<td>0.10</td>
</tr>
<tr>
<td>Xenon</td>
<td>Xe</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>Ozone</td>
<td>O₃</td>
<td>0.02 ppm</td>
<td>0.02</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>NO₂</td>
<td>0.001 ppm</td>
<td>0.001</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>SO₂</td>
<td>0.001 ppm</td>
<td>0.0002</td>
</tr>
<tr>
<td>Radon</td>
<td>Rn</td>
<td>-</td>
<td>0.06×10⁻¹²</td>
</tr>
</tbody>
</table>

Atmosphere has been divided into four concentric layers which vary in their chemical composition, temperature, density and altitude. At the altitude between 85 to 500 km is the outer most region, the ionosphere, the chemical composition of which comprises of electrically charged ions such as O₂⁺, O⁺, NO⁺ etc.
Air composition also varies from place to place and time to time, and it is the composition of constituents in the particular microenvironment which affects growth and development of the biota present in it (Edwards et al., 1998; Jonnalagadda and Baloji, 1991; Cheng et al., 2005). CO\textsubscript{2}, SO\textsubscript{x} and NO\textsubscript{x} may be present in higher proportion in the place where fuel combustion is taking place (Li et al., 1999) in proportion of sulphur containing gases are reported to be relatively high in the paddy growing areas also (Yang et al., 1998; Taylar et al., 2003; Mueller et al. 2004; Ratanam and Kumar, 2005).

Sources of Air Pollution

In order to study the nature, intensity and dispersion behavior of pollutants, knowledge of pollution sources becomes primary need of the investigation.

Combustion is a chemical process involving the union of carbon and oxygen, resulting in the production of heat and frequently the light energy as well. A typical example of this could be the burning of coal and coke. Other processes involving a similar phenomenon are: domestic burning, agricultural refuse, firewood and dry dung burning. The energy survey committee of India reported that about 120 million tonnes of wood, 50 million tonnes of dry dung and 30 million tonnes of vegetable wastes are burnt every year in India, largely in villages but also in urban areas.

Energy is a crucial factor in technological development. Per capita energy consumption is considered as an index of the economical status of a country. The world energy consumption is increasing by about 1-3% annually. About 80% of mankind’s energy requirements are met by the use of fossil fuels (coal, petroleum oil and natural gas). Energy is needed for all human activities, from agriculture to aviation. For example, electricity is an absolute necessity for the industrial development; consumption of electricity has been increasing in India at the rate of about 10% per annum.
Electricity consumed was only 2,300 mega watts in 1950, but it was 32,000 mega watts in 1980. As of early seventies about 70% of electricity was consumed by the industrial sector, 9% for irrigation purposes, and 3-4% by electric trains. India relies primarily on coal and oil, for its energy production. About 57% of all electric power produced in India is obtained from thermal power stations, which use coal as fuel (Manjeet Kumar et al., 1986; Sasaki et al., 2006). To meet the increasing energy demand, India will have to raise her coal production from 100 million tonnes/year in 1982 to 400 million tonnes by the turn of this century (Shorter et al., 2005; Wang et al., 2006).

The following sectors are the major consumers of coal in the early 1970’s: Indian railways (16 million tonnes), thermal power plants (16 million tonnes), iron and steel industry (14.5 million tonnes) and coke ovens (3 million tonnes). India has a total coal reserve of 120 billion tonnes. India and Columbia are two of the developing countries with substantial coal reserves, and in India there is already a trend of increasing consumption of coal for electricity generation. It is the process of coal combustion that tends to be the main source of air pollution. Problems of air pollution date back to 14th century, when coal was first introduced as a source of heat. Whereas, a complete combustion would result only in carbon dioxide, an incomplete process, as it occurs in most cases, results in the production of carbon monooxide and carbon particles alongwith carbon dioxide. Also most fuels contain sulphur and nitrogen as minor contaminants and this results in the release of oxides of sulphur and nitrogen during the combustion processes.
Apart from these, coal may contain certain trace elements at various concentrations. This provides an additional source of heavy metal pollution. These trace elements present in coal get into volatile state in the gasifiers under reducing conditions. Most of the metals especially --Hg, As, Cd and Zn-- are evaporable under 900°C. These trace elements are toxic to humans, animals and plants at high concentrations.

Bricks are baked from clay blocks of uniform size, which are of prime importance in the construction of houses and buildings along with the cement. Bricks occupy a good rank among the highly demanded tools for the rapid urbanization and modernization of a developing nation like India. Evidences have proved the use of bricks ever since Indus Valley civilization i.e. even about 5 thousand years back (Maithel et al., 2000; Karnavisdar et al., 2005; Perez et al., 2006). According to Maithel et al. (2000), in India, there are about 1 lakh small or large brick producing units which produce about 10,000 crore bricks per annum and about 50 lakh workers are employed in this industry.

Indian brick industry with an estimated coal consumption of about 20 million tons per year is the third largest consumer of coal in the country after power plants and steel industries (Maithel et al., 1999; Almeida et al., 2006). Brick kilns are provided with the most inferior quality of coal (Grade III/IV) which has very high ash and volatile matter content i.e. about 45 to 70% (Aslam, 1993). The coal shows large variation in calorific value, ash content, volatiles, sulphur content, moisture and fixed carbon content. Few kilns use wooden chips or saw dust for raising the initial ignition temperature which results in incomplete and improper combustion, causing wastage of fuel and enormous dust emission (Jain and Singh, 2000; Charron and Harrison, 2005; Park and Kim, 2006). Major air pollutants released from the brick industries include particulate matters, SO₂, NO₂, CO₂, CO etc. (Maithel et al., 1999; Srivastva and Sarkar, 2006).
Other potentially important fuel, used in the energy-protection sectors is petroleum (or oil). In recent years, petroleum derivatives have replaced coal as the principal source of energy in many places: the use of fuel oil for heating and electric power generation, gasoline for automobiles, kerosene in jet airplanes and diesel oil for automobiles and various appliances are typical examples. Oils are the primary sources of the highly dangerous hydrocarbons in the environment. Moreover, they have led to new type of air pollution problems in which photochemical reactions play an important role. Refining of oil, its combustion during use and losses during transportation are the major points, where the oil tends to pollute the environment. Natural sources of hydrocarbons are for more significant than man-made sources. The natural processes such as bacterial decomposition of organic matter, forest and vegetation are important contributors of hydrocarbons in the environment.

Another major source of air-borne pollutants, through the combustion processes is the automobile. Pollution occurs each time a motorist presses his brake pedal. Thus vehicles on road serve as mobile sources of air pollution, contributing such pollutants as carbon monoxide, nitrogen dioxide, smoke, organic vapours and incompletely-burnt hydrocarbons. Their contribution to air pollution is minimum, and the combustion process is nearly complete when vehicles are driven at constant speeds, with minimum stops and starts.

Leaded gasoline is by far the most significant source of lead in the environment. Lead is added to gasoline to increase its octane rating and facilitate better combustion by preventing pre-ignition losses. Recently there has begun a worldwide drive to get lead, out of gasoline. Nickel may be emitted from the Ni added to gasoline and Ni-containing parts of automobiles. Zinc and cadmium come from the lubricating motor oils, tires and galvanized parts of the vehicles. Cadmium concentrations range from 0.07 to 0.10 ppm in diesel oils and 0.20-0.26 ppm in lubricating oils; cadmium in automobile tires ranges from 20 to 90 ppm. It
is amazing to know of the various chemicals and materials involved in the manufacture of automobiles and keeping them on road.

Diesel vehicles are important sources of nitrogen oxides, hydrocarbons and particulates. Regulations proposed in the early eighties called for a reduction in particulate emission from 0.35 g/km to 0.12 g/km, and restricted the nitrogen oxide emissions from 1.2 g/km to 0.6 g/km. It had been a problem to achieve the simultaneous control of particulate and NOx emissions efficiently.

The world’s population is increasing relentlessly and so are people’s needs and clearly, this is putting all sectors of the global economy, power generation, transportation, agriculture production etc. under the increasing pressure (Verma, 2000). All the above processes are the mother of pollution. Thus, anthropogenic sources that contribute to air pollution can be divided mainly into two categories, i.e. mobile sources and stationary sources. Certain activities of human such as deforestation (Potter, 1999), dead body cremation (Tripathi et al., 1984; Mishra and Tripathi, 1999) also contribute to environmental pollution considerably. Mobile sources mainly include the heavy vehicles (Luria et al., 1984; Thompson et al., 1984; Tyagi, 1988-89; Vouitsis et al., 2005; Jayanthi and Krishnamoorty, 2006) or light vehicles (Oluwande, 1979) and traffic congestion (Newman and Kenworthy, 1987; Lee Cheng et al., 2006) which mainly pollutes the urban atmosphere (Mansfield and Freer-Smith, 1981; Janhau and Hallquist, 2005).

Various heavy metals are released in the atmosphere through a variety of agency (Azad et al., 1982), the prominent are, lead by gasoline combustion (Snakin and Prisyazhnaya, 2000; and Tuba and Csintalan, 1993). Coal combustion releases cadmium and zinc (Jaworowski and Grzybowska, 1980) as well as mercury. Nickel and copper by industrial source (Kashulin et al., 2001; Cruz et al., 2006) and many more. Presence of atmospheric halide i.e. fluorides have been reported in Tibet by Cao et al. (2000). The fine particles of atmosphere which include particulates of diameter less than 100 μm, such as carbon particles
aerosols, dust, tars, metallic dust etc. are mostly released through various automobiles (Tripathi et al., 1991) and industrial processes (Shu et al., 2000).

Several rules and regulations have been formulated from time to time to control the pollution (Khitoliya and Khitoliya, 1996). Central Pollution Control Board (CPCB) has prescribed the National Ambient Air Quality Standards for industrial, residential and the sensitive areas (Table 1.2). The Government of India has fixed National Emission Standards for brick kiln by a gazette notification number 141 dated 3rd April 1996. In addition to above, formation of 10 mm of top soil takes nearly 100 to 400 years but the conventional type of manufacturing clay bricks in the country is destroying fertile top soil to the extent of 3050 hectare per year.

### Table 1.2: National Ambient Air Quality Standards

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Time-weighted Average</th>
<th>Concentration in ambient air</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Industrial Area</td>
<td>Residential, Rural &amp; Other Areas</td>
<td>Sensitive Areas</td>
<td></td>
</tr>
<tr>
<td>Sulphur Dioxide (SO₂)</td>
<td>Annual*</td>
<td>80 μgm⁻³</td>
<td>60 μgm⁻³</td>
<td>15 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 hours**</td>
<td>120 μgm⁻³</td>
<td>80 μgm⁻³</td>
<td>30 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO₂)</td>
<td>Annual*</td>
<td>80 μgm⁻³</td>
<td>60 μgm⁻³</td>
<td>15 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 hours**</td>
<td>120 μgm⁻³</td>
<td>80 μgm⁻³</td>
<td>30 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>Suspended Particulate Matter</td>
<td>Annual*</td>
<td>360 μgm⁻³</td>
<td>140 μgm⁻³</td>
<td>70 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>SPM</td>
<td>24 hours**</td>
<td>500 μgm⁻³</td>
<td>200 μgm⁻³</td>
<td>100 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>Respirable Particulate Matter</td>
<td>Annual*</td>
<td>120 μgm⁻³</td>
<td>60 μgm⁻³</td>
<td>50 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>RPM (size less than 10 nm)</td>
<td>24 hours**</td>
<td>150 μgm⁻³</td>
<td>100 μgm⁻³</td>
<td>75 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Annual*</td>
<td>1.0 μgm⁻³</td>
<td>0.75 μgm⁻³</td>
<td>0.50 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 hours**</td>
<td>1.5 μgm⁻³</td>
<td>1.0 μgm⁻³</td>
<td>0.75 μgm⁻³</td>
<td></td>
</tr>
<tr>
<td>Carbon Monoxide (Co)</td>
<td>8 hours*</td>
<td>5.0 mgm⁻³</td>
<td>2.0 mgm⁻³</td>
<td>1.0 mgm⁻³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 hours**</td>
<td>10.0 mgm⁻³</td>
<td>4.0 mgm⁻³</td>
<td>2.0 mgm⁻³</td>
<td></td>
</tr>
</tbody>
</table>

* Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at a uniform interval.

** 24 hourly/8 hourly values should met 98% at the time in an year. However, 2% of the time it may exceed but not on two consecutive days.
Changing Air Quality and its Impact

Initially during evolution of the earth, the atmosphere was reducing due to complete absence of free oxygen. In due course, the quality of atmosphere changed gradually by the evolution of photosynthetic green plants, and now the environment became healthy due to release of free oxygen during photosynthesis (Veizer et al., 2000). It was the very same period when the stratospheric ozone layer was formed due to photodissociation of oxygen (Chapman, 1930). Duration of the healthy environment could not proceed longer after the appearance of man on the earth (Van Ardenne et al., 1999). Last two centuries have degraded the quality of air even more than that in the last two thousand years, due to extensive combustion of coal in industrial revolution. By advancement in science and technology, the variety of pollutants is also increasing (Cacac et al., 2001; Lin et al., 2005; Shah et al., 2006). The rate of contamination of the environment during the last three decades have been much more than that during the last two centuries. This geometrical increase in the rate of pollution has ruined the quality of air (Schmidt, 2000; Cooper and Jenkins, 2003; Elbir et al., 2004; Hien et al., 2005; Yakovleva et al., 2005).

Man is the only species on the earth which can alter the micro-environmental conditions according to his will (Landsberg, 1970) but his immunity response has declined owing to pollution (Smith, 2000), and is being expressed as various primary symptoms, such as allergies (Ormstad, 2000), pulmonary problems (Cho et al., 2000; Ganguly et al., 2000; Yong Zhi et al., 2004), inhomogeneity (Roemer et al., 1999), hypercholesterolaemia (Kotseva, 2001), male infertility (Sharpe, 2000), ageing (Holliday, 2000), neurogenic effect (Molhave et al., 2000), cancer (Argo, 2000; Zhou et al., 2005) and also increase in the rate of mortality (Lee et al., 2000(b); Moolgavakar, 2000; Powe and Keneth, 2004).
Pani (2000) in the millennium article of *Molecular Psychiatry* has compared the change in physiology of persons residing in normal and industrialized area. Respiratory allergies are controlled much by climatic changes along with the air pollutants (D'Amato *et al.*, 2000). Hygenic aspects of air pollution have been studied by Boev *et al.* (1998); Heisterkamp *et al.* (2000); Zhao *et al.* (2003) and Morawska *et al.* (2005). Impact of noise pollution on Guinea Pig by Emmerich *et al.* (2000) shows the loss of cochleal hair. Study of the impact of indoor and outdoor air pollutants by personal exposure was done by Monn (2001). Susceptibility also depends upon the age of the concerned person (Mauderly, 2000). Children are more sensitive to air pollution (Abzalilova and Setko, 1998 and Gouveira and Fletcher 2000). Air pollution also affects the antenatal development in human (Ekimora and Vozynuk, 1999; Prahlad *et al.*, 1999; Elminir, 2005).

Atmospheric deposition of particulates and pollutants transform the chemicals properly into the water bodies, as studied in Bulgaria by Ignatova and Dombrine (1996) and in Subarctic region by Kashulin *et al.* (2001). He had reported the deposition of Ni and Cu in snow and lake sediments which is ultimately taken by the fishes, was recorded at the rate of 0.9 mg m\(^{-2}\) per year at the distance of 100 km away from the source. Various damages of air pollution and their respective costs have been investigated by Rabl and Spadaro (1999) and Sant *et al.* (2006).

Air-borne sulphur oxides (SO\(_2\), SO\(_3\)) produced naturally or from human activities (such as the combustion of fossil fuels etc.) can be absorbed by rainwater and snow, forming H\(_2\)SO\(_3\) and H\(_2\)SO\(_4\) respectively. These acids tend to lower the pH of the precipitation. When the pH of rainwater or snow is less than 5.7, it is called Acid Rain. The acid concentration of such rain waters may range upto 60-
70 μg/L. The acidity of the rainfall is largely a reflection of the amount of sulphurous materials (SO₂, SO₃, SO₄⁻) leached from the atmosphere.

Currently, about 60-70% of acidic rainfall is caused by sulphur compounds and about 30-40% by nitrates. The oxidation processes (i.e., Nitrogen, sulphur oxides → Nitric, sulphuric acids) occur only at higher relative humidities (>70%). Oxides of nitrogen and sulphur in atmosphere are the cause of acid rain (Larssen and Carmichael, 2000). The pH value of rain was correlated with the concentration of atmospheric oxides of nitrogen and sulphur in Indonesia by Gillett et al. (2000). The impact of acid rain on calcium nutrition and forest health has been studied by Dehayes et al. (1999) and Sant et al. (2006). Impact of acid rain on limestone and dolomite has been studied by Parvez and Pandey (1990). Pollution level at Agra was studied by Parmar et al. (2001). Damage to Taj Mahal of India due to atmospheric sulphur dioxide has been studied by Goyal (1980). Gojstad (2000) reported that the acidity in rain checks the biodiversity and controls the biotic composition of that area.

In the plants, the rate of photosynthesis is inhibited in the presence of SO₂ and NO₂ (Bennett et al., 1990). Gaseous exchange and permeability is also affected by SO₂ as reported in maize by Gerinio et al. (1990), in Abelmoscus esculentus L. by Katiyar (2000), in cucumber, radish and soyabean by Beckerson and Hofstra (1979). The response of air pollutants on fruit crop i.e. mango has been studied by Singh et al. (1990), Singh (1992) and Farooq (2000). Changes in leaf structures in response to air pollutants have been reported by Paul et al. (2000) and Brej and Fabiszewski (2006), injuries induced by the photochemical oxidants especially ozone have been reported by Cape (1997), though the extent of symptoms vary from plant to plant.

Air pollutants reduce the pigment development in foliar region of the plants growing in polluted area (Panigrahi et al. 1992 and Piepho, 2000). Due to
reduction in photosynthetic pigments in response to air pollution, the photosynthetic yield has also been reported to fall (Pande and Mansfield, 1985; Bucker and Ballach, 1992 and Kainulainen et al., 1995), thus affecting the growth of the plants (Clarke and Murray, 1990 and Gavali et al., 1997), this ultimately decides the vegetation characteristics of a community (Farrar, et al., 1977; Mooney et al., 1991 and Reiling and Davison, 1992). The same has been reported around an aluminium factory (Narayan et al., 1994) and thermal power plants (Rosenberg et al., 1979 and Singh et al., 1994).

In general, the apparent concentration of Pb in aerial parts of the plant decreases as the distance from the root increases. This occurs due to greater localization of Pb in cell walls of the root than in other parts of the plant. Further, binding of Pb occurs more in lignified tissues rather than non-lignified tissues. It is found that in barley, much of the applied Pb was retained in the root epidermis while a small amount could be detected in the vascular tissues. This suggests that the extent of localization of Pb in different tissues of the plant is also dependent on the plant species. In seeds, the testa prevents entry of Pb into the internal tissues until it is ruptured by the developing radicle. Once the testa is ruptured, Pb is taken up very rapidly, with notable exceptions occurring in the meristematic regions of the radicle and hypocotyls. In the cotyledons, Pb moves through the vascular tissues and tends to accumulate in discrete areas in the distal parts (Baker, 1981).

The content of Pb in various plant organs tends to decrease in the following order: roots > leaves > stem > inflorescence > seeds. However, this order can vary with plant species (Antosiewicz, 1992). In onion (Allium cepa) plants, absorbed Pb is localized in highest concentration in the root tips followed by proximal parts of the root, while its lowest concentration is found in the root base (Sharma and Dubey, 2002). Leaves differ in their abilities to accumulate Pb depending on age.
Maximum Pb content is found in senescing leaves and least in young leaves. Ultrastructural studies have revealed that, variable amounts of Pb deposits are present mainly in the intercellular space, cell wall and vacuoles, whereas small deposits of this metal are seen in the ER, dictyosomes and dictyosome derived vesicles. The cell wall and vacuole together account for about 96% of absorbed Pb (Ahmed and TajMir, 1993). The fact that Pb is found in the ER and dictyosome is apparently related to metal secretion of the cell surface into the vacuole. A small quantity of Pb reaches nuclei, chloroplasts and mitochondria and exerts its toxic effects on these organelles. In leaf cells of *Potamogeton* spp. it was shown that the electrochemical potential gradients between cell vacuoles and the outside bathing solution ranged from -150 to -240 mV which could favour a passive influx of Pb into vacuoles during Pb treatment. Of particular interest is the invagination of the plasmalemma to form pinocytotic vacuoles in many plant species. In *Stigeoclonium* the formation of such vacuoles is important for the sequestration of excess metal ions, as these vacuoles could protect the cell contents from toxic effects of Pb. Sometimes, particularly in close proximity to the plasmodesmata, the larger Pb particles appear to occupy much of the volume of the cell wall. In the other regions where the cell wall is much thicker and more substantial, smaller Pb particles accumulate within the cell wall towards its periphery. The deposition of these smaller Pb particles occurs possibly through the action of pinocytotic vesicles (Sharma and Dubey, 2002).

Motor exhaust and soil-derived dust were the most important sources of particulate. Chan *et al.* (1999) investigated the source apportionment of PM$_{2.5}$ and PM$_{10}$ in Brisbane with a receptor model. Results indicated that the major contributors of PM$_{10}$ aerosol mass included soil/road dusts (25%), motor vehicle exhaust (13%), sea salt (12%), Ca-rich and Ti-rich compounds (11%, from cement or mineral processing industry), biomass burning (7%), and elemental carbon
Secondary aerosol contributed 15%. The major sources of PM$_{2.5}$ in the suburban area were EC (24%), secondary organics (21%), biomass burning (15%), and secondary sulfate (6%). Wahlin and Palmgren (2001) measured the relationship between ultrafine particles and traffic in streets. Results showed that “petrol + diesel” and “diesel” were the major ultrafine particle contributors in the streets. Jaecker-Voirol and Pelt (2000) investigated the source of PM$_{10}$ in Ile de France. Their article indicated that the contribution of paved-road surface dust seemed to be several times higher than vehicle exhaust gas in the resuspension of PM$_{10}$, and the road traffic was a significant source of PM$_{10}$. Molnar et al. (2002) measured the fine and ultrafine particles from the roadside and indicated that the particle size between 10 and 368 nm showed a great dependency on wind speed and wind direction.

Many particulate source profiles have been compiled representing emissions from fugitive dust (e.g., paved and unpaved road dust, soil dust, storage pile dust, etc.), motor vehicle exhaust, vegetative burning, marine aerosol, industrial emissions, and other aerosol sources (Watson et al., 1994; Wetson and Chow, 2001; Chen et al., 2001; Vega et al., 2001). These profiles differ with respect to location and time; additional profiles are always needed for contemporary inventories and source apportionment studies. Data revealed that diesel particulates were the major source of ambient PM$_{10}$. Industrial oil burning also had a significant contribution.

Qin et al. (1997) investigated particulate composition in Hong Kong; results indicated that carbon (C), SO$_4^{2-}$, ammonium ion (NH$_4^+$), nitrite (NO$_3^-$), chlorine (Cl$^-$), Ca, potassium (K$^+$), aluminium (Al), Cu, Zn, and Pb were the major components in the aerosols. Sternbeck and Szadin (2002) analysed metal emissions from road traffic in two tunnels. The vehicle-derived metals (Cu, Zn,
Cd, Sb, Ba and Pb) were derived mainly from wear and tear. The metals and large particles were resuspended in the air close to the roads. Kupiainen and Terrahattu (2003) pointed out that increased traffic enhanced the PM$_{10}$ resuspension, especially during spring, in the United States, Japan, Norway, Sweden, and Finland, among other countries. The springtime PM$_{10}$ sources consisted primarily of mineral matter from tire-induced, paved-road surface wear and traction.

A factor analysis gave four sources for the street dust, which included a mixture of metallic dust and crustaceous materials, vehicles, road pavement materials, and a mixture marine aerosols and crustaceous material.

Plants are the best indicator of pollution (Bonatti, 1997 and Singh, 1998). The pollutants have been noticed to be absorbed and translocated in various other parts such as fruits (Dickson et al., 2000; Stewart et al., 2001 and Pathak 2002). Nutrient translocation is also affected by the deficiency of certain minerals such as phosphorus, potassium and magnesium as reported by Cakmak et al. (1994). Changes in stomatal regulation in response to pollution have been studied by Shah et al. (2000). Elevation in gaseous CO$_2$ concentration in atmosphere is beneficial for plants (Allen, 1990). Overall nature tries to establish balance between sources and sinks of CO$_2$ (Riviere, 1999; Son et al., 2000). SO$_2$ has been reported to be absorbed by bark of the plants (Joshi et al., 1993). The same is reported in tobacco and maize by Murchie et al. (2000), in *Abelmoscus esculentus* L. by Dwivedi (1999) and in tomatoes by Khan et al. (1998). Phytotoxicity of SO$_2$ have been shown by Puckett et al. (1973) and Polle et al. (1994). Impact of regular pollution on different plants have been studied by Angold (1997), Tripathi et al. (1999) and Ratcliffe and Beeby (1984). Outbreak of insects along motorways have been reported by Port and Thompson (1980). UV rays affect the biochemical
properties of the plants has been reported by Tevini (1994), Rao et al. (1996), Lice et al. (2003), Nu Xian et al. (2003), Domange and Gregoire (2006).

Cement industry is one of the most important industries with the present installed capacity of 36.5 million tonnes. Cement dust is one of the most important air pollutants, which is believed to affect vegetation in vicinity of cement factories. This dust is a mixture of calcium, potassium, aluminium, silver and sodium oxides. Its particle size ranges from 1 to 100. It is actually heterogeneous substance constituents and concentration of which vary with time and location.

Cement dust pollution on vegetation is adverse. The leaves get covered with dust, which in contact with transpiring moisture solidifies to form a thin but hard layer. The alkaline hydroxide passes through a leaf epidermis and stomata. It is present on upper surface. Cement crust preludes light entry and reduces photosynthesis. The tissue also gets hardened by hardened particles.

The crust further checks CO$_2$ uptake by leaves. The total effect of light reduction, injury and reduced CO$_2$ entry in leaves results into reduced primary production. Such reports have been made by various workers on cotton, maize, wheat crops, guava Syzigium cuminii, conifers, Butea monosperma trees.

A number of grass species associated with numerous leguminous and non-leguminous forms constitute the natural herbaceous vegetation. The herb layer which forms the important source of grazing has been arranged in four groups- the grasses, asteraceae, legumes and other forbs. They are also badly affected by the air pollution.

The plant act as pollution sink and they replenish the atmosphere with much needed oxygen. The possibilities of using tree as pollution sink often been
suggested. However, to recognize their potential as pollution sink, one has to know the sensitivity level of plant to specific pollutant in general.

Dust deposition has been observed to increase leaf ash, pH, leaf extract. pH foliar content and leaf damage on contrary concentration of chlorophyll, carotenoids and ascorbic acid as well as the amount of relative water content was observed to decrease.

The surface deposition of dust in per unit leaf surface was found to vary from species to species. The leaves which are pubescent, large, fleshy and rough in texture offer greater chance for dust depositions. The rough and heavy leaves have been reported to collect particulate seven times more efficiently than smooth leaves.

The highest value of leaf as well as leaf extract pH in the plants growing at polluted site may be attributed to the Cement dust deposition. The role of Cement dust deposition in affecting the pigment concentration may be viewed in light that the Cement dust deposited on plants surface tends to form a crust, which upsets the physiology of plants. Cement dust is highly alkaline which can saponify leaf epidermis and disturb leaf physiology in general and chlorophyll content.

The climatic shift or changes in climatic pattern have been also recorded due to increase in pollutant concentration (Easterling et al., 2000; Macilwain, 2000; Zwiers and Weavers, 2000; Sanderson and Farant, 2005). Floral physiology in plants has also been shown to be affected by temperature or global warming (Yoshida et al., 1998; Lee et al., 2000; Robertson et al., 2000; Xiang et al., 2003; Sharma and Jain, 2003 and Brien et al., 2004). Due to the rapid increase in pollution sources and the pollutants release, the ecosystem of the earth is getting disturbed (Postal and Heise, 1988). Increase in gases such as carbon dioxide, sulphur dioxide, etc. result in global warming (Philander, 1998; Richardson, 2000;
Bennett and Willis, 2000; Chaulya, 2003; Bradshaw et al., 2004 and Toda Kei et al., 2004), which would ultimately be responsible for glacial termination (Runnegar, 2000; Monnin et al., 2001 and Schiermeier, 2001). Jacobson (2000) has studied the post glacial changes in the vegetation. Recently impact of air pollutants especially dust, SPM and vehicular emissions with respect to biochemical constituents of plants, leaf area, morphology, anatomy and air quality index has been worked out by Singh (2000), Raina and Sahma (2003), Sirajuddin et al. (2003), Swami et al. (2004), Agrawal et al. (2006), Wagh et al. (2006), Naik et al. (2007, 2008), Agrawal et al. (2008), Chauhan and Joshi (2008), Sultan et al. (2008), Banerjee et al. (2009), Gupta et al. (2009), Gupta et al. (2009), Hemavathi and Jagannath (2009), Pandey et al. (2009), Prashant et al. (2009) and Rao et al. (2009).

Aim of Present Study

During general survey of Varanasi, various sources of pollution have been marked which include industries, locomotives, automobiles (heavy and light vehicles), aircrafts, open refuge burning, various kinds of kitchen stoves which may use LPG or kerosene oil, domestic furnace, electricity generators, dead body cremation etc.

It was revealed that, there are high load of vehicular transportation and about 1588 small scale industries located in and around the city of Varanasi, where crude oils and coal are used as a fuel material for power generation. In Varanasi locomotives and automobiles play a significant role in polluting the atmosphere by the continuous discharge of NO\textsubscript{X}, CO, Hydrocarbons, SPM etc. Huge amount of the above pollutants are released everyday into the ambient air due to the operation of heavy and light vehicles (Tripathi et al., 1995). In Varanasi, the transportation through road can be divided in two types. One is the bussy road, from the area where the vehicles run very slowly and other is open or National high way road. At these roads, the vehicles run very fast. As already
stated, Varanasi is an ancient city so it consists of traditional and narrow roads which ultimately lead to traffic congestion, during which excess amount of pollutants are emitted by incomplete combustion of fuels.

However, scientific study still lacks about the actual impact of dust, SPM and automobile emissions on the surrounding vegetation. Therefore, in order to evaluate the “Hazardous impact of dust and SPM on leaf area and biochemical constituents of road side dominant plants growing along highway at Varanasi” present topic has been selected.