Chapter-I

INTRODUCTION

The physical, chemical and biological presence of living and non-living things outside an individual species is called as environment. It serves source of all raw materials, source of all energy, receiving and reprocessing plant for all wastes and buffer from harsh conditions. Environmental study is based upon a comprehensive view of various environmental systems. It aims to make the citizens competent to do scientific work and to find out practical solutions to meet current environmental problems.

The citizen acquires the ability to analyze the environmental parameters like the aquatic, terrestrial and atmospheric systems and their interactions with the biosphere. The atmosphere which makes up the largest fraction of the biosphere is a dynamic system that continuously absorbs a wide range of solids, liquids and gases from both natural and man-made sources. These substances travel through air, disperse and react with one another and with other substances both physically and chemically.

Clean air contains 78.09% nitrogen by volume and 20.94% oxygen. The remaining 0.97% is composed of a gaseous mixture of carbon dioxide, helium, argon, krypton, nitrous oxide and xenon as well as very small amounts of some other organic and inorganic gases whose amount in the atmosphere vary with time and place. Various amounts of contaminants continuously enter the atmosphere through both natural and man-made processes that exist upon the earth. The portion of these substances which interacts with the environment to cause toxicity, disease, aesthetic distress, physiological effects or environmental decay, has been labeled by man as a ‘pollutant’.

1.1 Definition of Environmental Pollution

Environmental pollution is one of the most serious ecological crises in the modern world. The three basic amenities for living organisms are air, land or soil and water. In
the past, these amenities were pure, virgin, undisturbed, uncontaminated and basically most hospitable for living organisms. But the situation is just the reverse today, because progress in science and technology is also leading to pollution of environment and serious ecological imbalance which in the long run may prove disastrous for mankind.

1.2 Origin of Pollution

The origin of pollution crisis on the planet earth are given below in different views,

1. Pollution is the wasteful aspects of the science and technology which strive always to produce more disposable items that are responsible for the pollution of environment.

2. There are various factors pointed out the human population explosion, rapid industrialization, deforestation, unplanned urbanization, scientific and technological advancement which are mainly responsible for the pollution crisis on earth. Pollution occurs in countries where there have been the greatest scientific and technological advances.

3. Rapid population growth combined with modern technology has caused a serious environmental crisis. This is because of the fact that in well developed countries, citizens consume more food use more fertilizers and pesticides, fuel, minerals, automobiles and other manufactured products of all kinds. Almost all of these products are manufactured in one or other kinds of industries. These industries are responsible for adding pollutants in environment and hence cause pollution.

1.2.1 Types of Pollution

Pollution is a broad term that includes the accumulation of matter due to unknown activities in the environment, rates of flow which exceed the capacity of the ecosystem to either neutralize or disperse them below harmful levels. An undesirable change in the physical, chemical and biological characteristics of air, water and land that is likely to affect human life or the lives of desirable species adversely is also termed as pollution.
According to environment, pollution can be categorized as (i) Air pollution, (ii) Water pollution (iii) Soil pollution, (iv) Thermal pollution and (v) Noise pollution.

1.3 Pollutants

Pollution is usually brought about by the addition of waste products of human activity to the environment. When the waste products are not efficiently assimilated, decomposed or otherwise removed by the natural, biological and physical processes of the biosphere an adverse effect may result as the pollutants accumulate or get converted into more toxic substances. Thus the materials which cause pollution of environment are called pollutants.

1.3.1 Classification of Pollutants

On the basis of Pollutants formation and exist in the environment it can be classified as primary pollutants, secondary pollutants, biodegradable and non biodegradable pollutants.

(i) Primary Pollutants

The substance emitted directly from an identifiable source it exist as such after being added or released into the environment is called as primary pollutants. Examples are sulphur dioxide (SO$_2$) and oxides of nitrogen (NO$_X$).

(ii) Secondary Pollutants

These are the substances derived from primary pollutants by chemical reactions. For example, primary pollutants such as hydrocarbons and oxides of nitrogen, particularly in the environment react in presence of sunlight to form a group of nitrogen compounds like Peroxy Acetyl Nitrate (PAN) as the secondary pollutant.

(iii) Biodegradable Pollutants

Biodegradable pollutants are the pollutants which can be decomposed easily by the biological process in natural environment. In an engineered system the plant debris
and domestic sewage which on decomposition give out nutrients like carbonates and phosphates that are released in the biosphere.

Heat or thermal pollution also belongs to biodegradable pollutants because heat can be dispersed by natural means. If organic wastes drained out from residential buildings are easily degraded completely by micro-organisms these become useful for the ecosystem.

The domestic sewage can be readily decomposed by natural process or by engineered systems (such as municipal sewage treatment plant) which enhance capacity of the nature to decompose and recycle. However, if these pollutants enter the environment in such large quantities that complete degradation cannot take place. It becomes biodegradable pollutant and thus pollutes the environment.

(iv) Non Biodegradable Pollutants

Non-biodegradable pollutants are those which either do not degrade or degrade very slowly in the natural environment. Such pollutants are mostly inorganic compounds like mercury and lead salts, aluminium, iron and phenolic compounds. Such pollutants are harmful even in low concentration.

These pollutants not only accumulate but are often biologically magnified as they move in biochemical cycles and along food chains. It may also react with other compounds present in the environment to produce even more toxic additional products and high concentration may even prove fatal.

1.4 Air Pollution

Air pollution is one of the most dangerous forms of environmental pollution in current times. Rates of increase in air pollutant concentrations in developing countries such as India are higher than those in developed countries and hence atmospheric pollution is often severe in cities of developing countries all over the world (Mage, D et al., 1996)¹.
1.4.1 Definition of Air Pollution

Air pollution may be defined as any atmospheric condition in which certain gaseous and particulate matters are present in such concentrations that may produce undesirable effects on man and ecosystem. Air pollution may have harmful effects on living things and materials. It may interfere with biochemical and physiological process of plants to an extent which ultimately leads to yield losses (Heck, W.W et al., 1988)².

1.4.2 Sources of Air Pollution

Air pollution from automobiles, industrial plants, coals burning power plants, incinerators and furnaces have created serious environmental pollution problems. Apart from local effects air pollutants can travel long distances and cause impacts far from its source (Agarwal M, 2005)³. However, sources of air pollution can be broadly classified into (a) natural sources and (b) man-made or anthropogenic sources.

1.4.2a. Natural Sources

The natural sources of air pollution are volcano eruption releasing poisonous gases (such as SO₂, H₂S and CO), forest fires, natural organic and inorganic decay or vegetative decay, marsh gases, deflation of sands and dust extra terrestrial bodies, cosmic dust, pollen grain of flowers, soil debris, comets and fungal spores. All these are naturally produced and released in air making it foul and injurious to health.

1.4.2b. Anthropogenic or Man-made Sources

Man-made sources include population explosion, burning of fossil fuels, vehicular discharges, rapid industrialization, agricultural activities, modern warfare and smoking lead to global warming.

1.5 Types of Air Pollutants

Air pollutants are generally categorized into two types. (1) Particulate Pollutants and (2) Gaseous Pollutants.
1.5.1 Particulate Pollutants

In general the term ‘particulate’ refers to all atmospheric substances that are not gases and it can be suspended droplets or solid particles or mixtures that can be composed of materials ranging in size from 100µm to 0.1µm and less. The chemical composition of particulate pollutants is very much dependent upon the origin of the particulate. The high concentration of particulate matter in the environment has become a problem for many countries (Elbir, T *et al.*, 2000). Particulate matter consists of primary aerosols such as sulfate, nitrate, sulphur dioxide (SO$_2$) and oxides of nitrogen (NO$_x$), if present in excess in ambient air affect the respiratory tract causing irritation and increasing airway resistance (Tsai.Y and Cheng,M.T. 2001). Dust, fumes, smoke, mist, fog and aerosol are the classification of particulates. Suspended Particulate Matter (SPM) is a complex mixture of small and large particles with size less than 100µ varying origin and chemical composition.

The largest source of particulate matter is coal-fired power plants. Along busy transportation areas exhaust of automobiles is also a prime contributor of this pollutant. The particulate matters generated by natural sources are much greater than that from anthropogenic sources. Health effects associated with particulate matter are linked to respiratory, cardiovascular problems and premature mortality (Callen, M.S *et al.*, 2009).

1.5.2 Gaseous Pollutants

Gaseous Pollutants are toxic and poisonous gases which have oxides of carbon, nitrogen and sulphur, chlorine, ammonia, hydrogen sulphide are formed from various industrial operations. These gases are toxic especially in high concentrations. Acute or chronic exposure to these pollutants can occur when they inhaled, ingested or absorbed from skin. They give rise to local or systemic effects. Occupational diseases such as silicosis and asbestosis are due to the gaseous pollutants. It causes sight and respiratory problems.
(i) Carbon Monoxide (CO)

Carbon Monoxide is a colourless, odourless, invisible, and poisonous gas. It is produced by the incomplete burning of carbon in fuels, cigarette smoke and domestic heat appliances. Major sources include automobile exhaust, wood stoves, incinerators, other industrial sources.

Earlier anthropogenic sources were not considered to be main source of it in the atmosphere. But now, it has been established that about 95% to 98% of carbon monoxide pollution comes from man-made sources. Around the world about 4000 million tons of carbon monoxide is emitted from natural sources. It has a strong affinity for combining with the hemoglobin of the blood to form carboxy hemoglobin (COHb). This reduces the ability of hemoglobin to carry oxygen to the body tissues. It is also responsible for heart attacks and a high mortality rate.

(ii) Sulphur dioxide (SO$_2$)

Coals contain a significant amount of sulphur. Sulphur dioxide is emitted largely from burning of coal, high-sulphur oil, diesel fuel in industries like steel mills, refineries, and paper pulp mills. It is not possible to remove sulphur from the coal, oil and diesel before burning. Hence the process of combustion results in the formation of SO$_2$. Approximately about 200 million tons of SO$_2$ are generated annually from natural sources. This gas is usually found in association with particulate matter. Sulphur dioxide and particulates together make up a major portion of pollutant load in many cities, acting both separately and in concert to damage health.

Thermal power plants and other industrial sources are responsible for most of the SO$_2$ emissions in Delhi. Increase in Sulphur dioxide emissions are also linked with increase in motor vehicle population (Gurjar, R. et al., 2004)$^{10}$.

(iii) Oxides of Nitrogen (NO$_X$)

Nitric oxide is a colourless, odourless gas but nitrogen dioxide is reddish brown and has suffocating odour. It reacts with other gases to form ozone and smog. The combustion of fossil fuel in automobiles or industry is the major source of nitrogen
oxides. Various compounds, such as NO and NO₂, exist, so these are designated in total as NOₓ. Oxides of nitrogen are originated from both natural and anthropogenic sources. Among the nitrogen oxides, nitrogen dioxide pollution is contributed by anthropogenic sources. Among the sources, about 65 percent of NOₓ is emitted from automobiles, 25 percent is from burning of coal and 10% is from the use of natural gas. Among the seven oxides of nitrogen are known to exist in the ambient air, only two are thought to affect human health. These are nitric oxide (NO) and nitrogen dioxide (NO₂).

Studies confirmed the number of vehicles has increased by six fold since 1980 in China (Liu, J.G and Diamond.J. 2005) resulting in rise of NOₓ concentrations to 12 Tg N yr⁻¹ and is predicted to double during the year 2020 (Streets. D.G and Waldhoff. S.T 2000). Oxides of nitrogen emissions are growing at an annual rate of 5.5% per year have been monitored over the Indian region (Garg. A, et al., 2001). Annual average NOₓ concentrations varied from 4.3 to 42.9 ppb in various parts of the country has been discussed (CPCB, 2009).

(iv) Hydrogen Sulphide and Mercaptans

Hydrogen sulphide is a foul smelling gas. It is well known for its odour like rotten egg. Exposure to hydrogen sulphide for short periods can result in fatigue of the sense of smell. Other sulphur compounds that are of interest in air pollution mainly because of their strong odours are methyl mercaptan (CH₃SH) and ethyl mercaptan (C₂H₅SH).

(v) Ozone

Ozone is a gas that has an irritant action in the respiratory tract, reaching much deeper into the lungs that the oxides of sulphur.

(vi) Fluorides

Fluorides present in air, range from those which are extremely irritating and corrosive like hydrogen fluoride to relatively non-reactive compounds. But, fluoride is a cumulative poison even under condition of prolonged exposure and in sub-acute concentrations.
(vii) Lead

The main source of lead in urban atmosphere is the atmosphere. It creates urban concentration of inorganic lead 1-3 µg/m$^3$, with high values in areas of heavy traffic. Inorganic lead acts as an agent which causes a variety of human health disorders. The effects include gastro-intestinal damage, liver and kidney damage, abnormalities in fertility and pregnancy, mental development of children gets affected.

The primary source of lead in the atmosphere is the additive tetraethyl lead which is used as a catalyst to help gasoline burn in automobile engines. Lead was easily left out of gasoline and more easily gasoline was developed. Lead pollution has been reduced significantly since leaded gasoline was banned several years ago. But it still exists caused by the lead smelters, burning of lead batteries, and burning of lead-contaminated waste oil.

(viii) Hydrocarbon Vapours

Some of the hydrocarbon vapours in the atmosphere have health implications. The effect of formaldehyde is primarily irritating. It is a major contributor to eye and respiratory irritation caused by photochemical smog.

(ix) Carcinogenic Agents

Carcinogenic agents like poly-cyclic organic compound, 3, 4-benzpyrene are responsible for cancer. The origin of these compounds is in the incomplete combustion of hydrocarbons and other carbonaceous materials. They are also reported to be present in exhaust discharge from internal combustion engines.

The airborne particulates and related trace metals have been linked with both acute and chronic adverse health effects which mostly include respiratory diseases, lung cancer, heart diseases and damage to other organs (Prieditis, H., Adamson, I.Y.R., 2002$^{15}$, Magas, O.K et al., 2007$^{16}$, Wild, P et al., 2009$^{17}$). Numerous epidemiological studies have shown a correlation between elevated levels of airborne particulates and increased rate of morbidity and mortality (Pope, C.A. 2000$^{18}$). In addition to poly-cyclic organic compounds, it has been found that some aliphatic hydrocarbons are also carcinogenic.
(x) **Radioactive Isotopes**

The major sources of radioactive air pollutants are nuclear reactors, environmental accelerators, scientific and medical use of radioactive isotopes, agricultural and industrial use of radioactive isotopes as tracers, and testing of nuclear bombs in the atmosphere. The serious health effects are anemia, leukemia and cancer. Radioactive isotopes also cause genetic effects and sterility as well as embryo defects and congenital malformations.

1.6 **Air Pollution due to Industries**

Air pollutants are responsible for vegetation injury and crop yield losses are causing increased concern (Fuji S, 1973). The emitted air pollutants from various industries are shown in the table 1.1.

### Table 1.1

**Air Pollutants emitted from various industries**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Type of Industry</th>
<th>Origin of Emission</th>
<th>Pollutants Emitted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Chemical and metallurgical industry</td>
<td>Roasting and heating of lead, zinc and copper ores</td>
<td>SO(_X), NO(_X), CO, dusts, fumes, and trace metals.</td>
</tr>
<tr>
<td>2.</td>
<td>Iron and steel industry</td>
<td>High temperature processing of coal and iron ore.</td>
<td>CO, CO(_2), PM, dust, fumes, hydrocarbons, H(_2)S and SO(_2).</td>
</tr>
<tr>
<td>3.</td>
<td>Chemical process industries</td>
<td>Raw material processing, reaction products and their purification.</td>
<td>SO(_2), NH(_3), NO(_2), Hydrogen fluoride, HCl, H(_2)S, variety of hydrocarbon compounds and solvents.</td>
</tr>
<tr>
<td>6.</td>
<td>Food and agricultural industries</td>
<td>Food processing, crop spraying and dusting, use of fertilizers and field burning.</td>
<td>Vapours, odours, dust, chlorinated hydrocarbons, lead, arsenic, phosphate, smoke, fly ash and soot.</td>
</tr>
</tbody>
</table>
Air pollution becomes a major threat to the survival of plants in the industrial areas (Gupta AK and Mishra RM, 1994). Rapid industrialization and addition of the toxic substances to the environment are responsible for altering the ecosystem (Mudd JB and Kozlowski TT, 1975; Clayton G.D and Clayton F.E. 1982, Nriagu J.O and Davidson C. 1986). The cement industries also play a vital role in the imbalances of the environment and produces air pollution hazards (Stern A.C, 1976).

1.7 Air Pollution due to Vehicles

In the developing and developed countries automobiles become an unavoidable part of the modern life. The automobiles are one of the major sources of air pollution and they produce almost one-third of all air pollutants. One of the main causes is exhaust fumes from automobiles that run on gasoline and diesel.

The principal pollutants emitted from burning of fuel from automobiles are volatile organic compounds, suspended particulate matter, carbon monoxide, oxides of nitrogen, sulphur dioxide and hydrocarbons which are known to be toxic to human health and damaging to the environment.

The petrol and diesel engines emit similar type of pollutants but their proportions are varied due to difference in the mode of operation of these two types of engine. In petrol engines, the fuel and air is mixed homogeneously and combusted in high temperature, the exhaust gas is almost colourless. The improper mixing and combustion in lower temperature produces more smoke with white, blue or black. Diesel engines can also contribute significant amounts of particulate matter to the atmosphere as the diesel combustion process results in soot.

Diesel and petrol fuelled vehicles are responsible for the generation of a wide range of pollutants with concentrations and relative proportions of pollutants depending on vehicle technology and operating conditions (Colville, R.N et al., 2001).
automobiles the gases emitted during deceleration and acceleration are more harmful than those produced during constant speed. Until a few years ago, lead was added to most gasoline to get better performance of the engine. The lead passes through the engine and out of the exhaust system into the air. Lead is poisonous to the living beings.

1.8 Effects of Air Pollution

The effects of air pollution are classified as,

1) Effects of air pollution on human health 2) Effects of air pollution on plants species 3) Effects of air pollution on animals 4) Effects of air pollution on economics and 5) Effects of air pollution on properties of atmosphere.

1.8.1 Effects of Air Pollution on Human Health

Air pollution is one of the greatest environmental crises. The air we breathe has not only life-supporting properties but also life-damaging properties. Under ideal conditions the air we inhale has a qualitative and quantitative balance that maintains the well-being of man. But the balance among the air components is disturbed, or in other words, if it is polluted, it may affect human health. CO is a very dangerous asphyxiant and its high levels are fatal to human life.

The increase in cardiovascular deaths has been suggested to result from an increase in the risk of blood clotting (Seaton, A. et al., 1995)\textsuperscript{26}. The duration of exposure of the body to polluted air is also an important factor.

1.8.1a. Effect of Radioactive Fallout

The biological effect of radiation may be somatic or genetic damage. In somatic damage, the exposed individual is affected, while in genetic damage the future generations become the victims. The causes of radioactive fallout from testing of nuclear weapons are cancer, shortening of life span and genetic effects or mutation. One significant point is noted that the effect of radioactive fallout causes long range effects affecting the future of man and hence the future of our civilization.
1.8.2 Effect of Air Pollution on Plants

Air pollution has long been known to have an adverse effect on plants. At first, it was only sulphur dioxide that was considered a dangerous pollutant. Now with the advent of various pesticides and new industrial processes, the range of harmful pollutants has multiplied tremendously. Sometimes, vegetation over 150km away from the source of the pollutants has been found to be affected.

Plants response to air pollution can be used to assess the quality of air that may provide early warning signals of air pollution trends. Impingement, absorption and accumulation of air pollutants on the plants leaf area and it is used to reduce the pollution level in the air environment (Escobedo F.J et al., 2008)\textsuperscript{27} with a various extent for different species (Hove L.W.A, et al., 1999)\textsuperscript{28}.

Industrial pollution particularly from smelters has caused complete destruction of vegetation economics of the damage caused to crops and plants. There are many reports of the effect of pollutants like cement dust on plants. Cement factories are major source of pollutants for the surrounding areas (Stratmann, V.H et al., 1966)\textsuperscript{29}.

Air pollutants are responsible for reduction of biological and physiological responses of various plants and crops grown at polluted areas (Joshi PC and Chauhan A. 2008)\textsuperscript{30}. The effects of air pollutants on vegetation are shown in the table 1.2.

Table 1.2
Effects of Air Pollutants on Vegetation

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Effects on Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2}</td>
<td>Chlorosis (Disappearance of chlorophyll and yellowing of leaves)</td>
</tr>
<tr>
<td>NO\textsubscript{2}</td>
<td>Premature fall of leaves and suppressed growth of plants and reduced yield</td>
</tr>
<tr>
<td>Ozone</td>
<td>Necrosis (Dead areas on leaves), leaf damages and reduced yield</td>
</tr>
<tr>
<td>PAN (Peroxy Acetyl Nitrate)</td>
<td>premature fall of leaves, discoloration and Epinasty (downward curvature of leaves due to higher growth rate on the upper surface)</td>
</tr>
</tbody>
</table>
1.8.2a. Structure of a Normal Leaf

The structure of a leaf will help us to understand why damage occurs on plant species on account of air pollutants. It has been seen a network of denser structures, the veins, all interconnected to the base or stem of the leaf. The leaf veins act as the transport system for water and food just like blood vessels in animals.

The leaf tissue is in layers with a skin or epidermis layers on top and bottom and the photosynthetic cells in between. The stomata are the entrances in the leaf bottom (and in some leaves in the top) through which CO$_2$ enters to play its role in photosynthesis. These openings are protected by pairs of specialized guard cells which open and close to allow gases to enter or leave the leaf. Such gases of course include pollutants like sulphur dioxide.

1.8.2b. Environmental Factors on Plants

Environmental factors on plants are the primary factor which controls the gas absorption by the leaves in the degree of opening of the stomata. When the stomata are wide open, absorption is maximum and vice versa. Consequently, the same conditions that enhance the absorption of the gas (CO$_2$ for photosynthesis) predispose the plant to injury (by absorbing a pollutant gas like SO$_2$).

The conditions that cause the stomata to open are high light intensity (especially in the morning hours), high relative humidity and adequate moisture supply to the roots of the plant and moderate temperatures. Most plants close their stomata at night and are therefore much more resistant at night than in the day time. But some plants like potato, which do not close their stomata at night, are as sensitive in the dark as in the light.

The relationship between the diurnal trend of stomatal apertures and susceptibility in alfalfa and other plants also exhibited (Loftfield J.V.G. 1921)\textsuperscript{31}. Oxides of sulphur and nitrogen, Fluoride compounds (like hydrogen fluoride), chlorine, mercury, PAN (Peroxy Acetyl Nitrate) interfere with photosynthetic pigments during photosynthesis and it
retards the plant growth. Smog and dust reduce the amount of light reaching the leaf and also by clogging the stomata may reduce carbon dioxide intake to some extent and thus interfere with photosynthesis.

1.8.2c. Types of damage to Leaves by Air Pollutants

Damage to leaves takes several forms

A. Necrosis: Necrosis is the killing or collapse of tissue

B. Chlorosis: Chlorosis is the loss or reduction of the green plant pigment, chlorophyll. The loss of chlorophyll usually results in a pale green or yellow pattern. Chlorosis generally indicates a deficiency of some nutrient required by the plant. In many respects, it is analogous to anemia in animals.

C. Abscission: Leaf abscission is dropping of leaves.

D. Epinasty: Leaf epinasty is a downward curvature of the leaf due to higher rate of growth on the upper surface.

1.8.2d. Kinds of Injury on Plants

Plant diseases showed the symptoms which are very similar to those caused by air pollution. High temperatures, poor plant care, shortage of nutrients and water may also cause an appearance which is similar to that of a plant damaged by air pollution. It may also be due to insect damage. Therefore, while diagnosing the effects of air pollution one must consider factors such as plant disease, nutrition history, weather damage, insect damage, and the nature of pollutants in the area.

1. Acute Injury

It results from short-time exposure to relatively high concentrations, such as might occur under fumigation conditions. The effects are noted within few hours to a few days and may result in visible markings on the leaves due to a collapse and death of cells. This leads to necrotic patterns that are area of dead tissue.
2. Chronic Injury

It results from long-term low level exposure and usually causes chlorosis or leaf abscission.

3. Growth or Yield Retardation

The injury is in the form of an effect on growth without visible markings (invisible injury). Usually a suppression of growth or yield occurs. While deciding about the type of injury the plant has suffered, one must carefully distinguish between adverse effects caused by air pollution and adverse effects resulting from other factors.

1.8.2e. Effect of Specific Air Pollutants on Photosynthesis and Respiration

1. Effect of Sulphur Dioxide

Sulphur dioxide produces two types of injury on the leaves of plants acute and chronic depending on the concentration and period of exposure. The acute injury is characterized by the killing of marginal areas of the leaf. Immediately after fumigation these areas will get a dull, water-soaked appearance. Subsequently they dry up and usually bleach to an ivory colour through some species finally assumed a brown or reddish-brown colour. Chronic injury is caused by the slow, long-continued absorption of sub lethal amounts of gas or by absorption of an amount of gas somewhat less than that necessary to cause acute injury.

2. Effect of Hydrogen Fluoride

Hydrogen fluoride behaves somewhat similar to sulphur dioxide except that with a few species of plants. It is effective in causing lesions and interfering with photosynthesis in concentrations two or three orders less than in the case of sulphur dioxide. With most species it is up to 10 times as effective as sulphur dioxide. However, recovery of plants from the fluoride effect is much slower than sulphur dioxide. This difference in rate of recovery is probably explained by the fact that sulphite in the leaves is rapidly oxidized to
the relatively non-toxic sulphate. But fluorides can be removed only by the slower process of volatilization or by some obscure chemical reaction. Forage may be rendered unsafe for animal feeding if more than 50 ppm of fluorine is absorbed.

3. Effect of Ozone

Ozone is phytotoxic in exposures of a few hours at about 0.2 ppm. Injury due to ozone is quite different from typical smog injury. The lesions are generally confined to the upper surface on plant leaves as a result necrosis (Dead areas on leaves), leaf damages and reduced yield.

4. Effects of various Fumigants on plants

i) Chlorine

Apart from the fluorides, halogens and their compounds are relatively unimportant air pollutants which might cause injury to vegetation. However, chlorine is more toxic to vegetation than sulphur dioxide by a factor of two or three. Lesions are generally marginal and interveinal. Damage to vegetation caused by chlorine is rare, and most of the reported cases are due to accidents or excessive use of gas for sterilizing.

ii) Hydrogen Chloride

Hydrogen chloride is considerably less toxic to vegetation than sulphur dioxide. Hydrogen chloride causes first a chlorotic margin in the leaf, which may become necrotic. At higher concentrations, lesions are produced. The threshold concentration is about 10 ppm for a few hours exposure.

iii) Nitric Oxides

Injury to plants due to nitric acid vapours has been observed near factories handling large amounts of this acid. The effects include brown margins and brownish-black spots on the leaves. Concentrations of about 25 ppm will cause these effects. Nitrogen oxides are important in photochemical reaction which causes smog.
iv) **Ammonia**

Ammonia is a gas of intermediate toxicity. It is interesting to note that ammonia and hydrogen chloride almost have about the same toxicity.

v) **Hydrogen Cyanide**

Hydrogen Cyanide is used to fumigate green houses and trees in orchards for pest control. Sometimes this fumigation injures the vegetation.

vi) **Smog**

London type smog is thought to be essentially a sulphur dioxide problem. But the gaseous constituents as well as aerosols need further evaluation. The Los Angeles type smog is now fairly well understood, but the actual components that cause these effects are still unknown. Two types of smog injury to vegetation have been recognized in Los Angeles, one due to gases (smog gas) and the other due to deposition on the leaves of fog droplets (smog fog). The effects of various pollutants like sulphur dioxide, ozone and fluorides on plants is shown in table 1.3.

<table>
<thead>
<tr>
<th><strong>Table 1.3</strong></th>
<th>The Effect of Various Pollutants on Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pollutant</strong></td>
<td><strong>Dose</strong></td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>Mild</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
</tr>
<tr>
<td>Ozone</td>
<td>Mild</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
</tr>
<tr>
<td>Fluorides</td>
<td>Cumulative effect</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Mild</td>
</tr>
<tr>
<td>Ethylene</td>
<td>Mild</td>
</tr>
<tr>
<td>PeroxyAcetylNitrate</td>
<td>Mild</td>
</tr>
</tbody>
</table>
1.8.2f. Sensitivity of Plants to Air Pollutants

The sensitivity of plant to air pollutant is conditioned by many factors.

1. Genetic Factors

Plant response to pollutants varies between species of a given genus and between varieties within a given species. Such variation is simply a function of genetic variability as it affects the plants morphological, physiological, and biochemical characteristics. Plant does not necessarily show similar susceptibility to different pollutants. For example, some plants are sensitive to fluoride but resistant to sulphur dioxide.

2. Climatic Factors

The important climatic factors are affecting the response of vegetation to air pollutants are duration of light, light quality (wave length), light intensity, temperature and humidity.

1.8.2g. Leaf Destruction in Relation to the Yield

Many industries that emit phytotoxic gases are located near valuable agricultural lands. If damage is done to nearby crops the farmer is legally entitled to recover the losses (especially in countries where air pollution control legislation is in force). Therefore an objective method is required for determining the extent of losses. Many studies have shown that for sulphur dioxide, the reduction in the yield of the crop is proportional to the percentage of leaf area destroyed. The response of stomata to SO$_2$ entry is largely dependent on leaf age, concentration and combination of pollutants was examined (Pfanz H, et al., 1987$^{32}$). The leaf destruction in relation to the yield can be represented in the mathematical form

$$Y = A - BX$$  \hspace{1cm} (1)

Where, \(Y\) = yield expressed as the percentage of full yield, \(X\) = percentage of leaf area destroyed, \(A\) = constant (about 100%) and \(B\) = slope of yield-leaf destruction curve.
In general, the leaf destruction yield functions are straight lines, starting with 100% yield ‘y’, at 0% leaf destruction ‘x’ and ending with a definite decrease in yield at 100% leaf destruction. But from the practical point of view, the reduction in the yield is difficult to measure experimentally if leaf destruction is less than about 5%.

1.8.3 Effects of Air Pollution on Animals

The effects of air pollution on animals have generally developed as a corollary to the concern about its influence on human health. Most of the information concerning the natural exposure of animals to air pollution is contained in the reports of some major air pollution disasters. Recently considerable information has been reported from medical research laboratories which describe the results of experimental exposure of small animals to various air pollutants. Animals used for laboratory research work were mice, rabbits, rats, guinea pigs and monkeys.

The process by which farm animals get poisoned is entirely different from that by which human beings exposed to polluted atmospheres are poisoned. In case of farm animals it is a two-step process that is accumulation of the air-borne contaminant in the vegetation and forage and subsequent poisoning of the animals when they eat the contaminated vegetation.

1.8.4 Effects of Air Pollution on Economics

Air pollution damage to property is a very important economic aspect of pollution. It covers a wide range of corrosion metals, soiling and eroding of building surfaces, fading of dyed materials. It also covers rubber cracking, spoiling or destruction of vegetation, effects on animals as well as interference with production and services and deterioration of works of art. Hence, there is an urgent need to investigate and study this problem and express the damage to property in economic terms has been done in this direction. Crop production is highly dependent upon environmental conditions among which air quality plays a central role. The reduction in yield of wheat cultivar M 234
grown at ambient air pollution level and at rural sites assessment of economic crop loss has been studied (Rai, R et al., 2007).

1.8.5 Effects of Air Pollution on Properties of Atmosphere

The effects of air pollution on the physical properties of atmosphere are decrease in visibility, reduction of solar radiation, effects on weather conditions and effects on atmospheric conditions.

1.9 Control Measure of Air Pollution

Air pollution can be controlled by preventive measures and control of effluents techniques. Air pollution can be controlled by treating the flue gases through scrubbers, dry and wet collectors to remove the pollutants followed by discharging the treated gases (discharges) using higher stacks. Industries should be allowed in places where the effects of pollutants can be minimized naturally and easily. This can be achieved through consideration of topography and wind direction of the area. Better raw materials that will cause less pollution can be used. Automobiles should be provided with catalytic converters. The use of fossil fuels should be reduced with unconventional energy sources such as solar, tidal, wind and biogas. National Ambient Air Quality monitoring should be practiced strictly by the State and Central Pollution Control Board.

1.10 Air Quality

According to the World Health Organization (WHO) air pollution is a situation where the outdoors or the atmosphere contains concentrated materials that are harmful to the biosphere. The quality of air or the extent of pollution can be determined by measurements made either at the source (Chimney) or the air around it (ambient). Now remote measurements can be made at large heights above the ground with sophisticated instruments. There are two method used for ambient air quality measurement such as stock emission and ambient air quality.
1.10.1 Air Quality Monitoring

India’s air quality monitoring network, originally called the National Ambient Air Quality Monitoring (NAAQM) was initiated in 1984 with seven stations in Agra and Ampara. The network was established by Central Pollution Control Board (CPCB) in coordination with the SPCBs under the Air (Pollution and Control) of Pollution Act, 1981 to collect compile and disseminate information on air quality.

The National Ambient Air Quality Standard has been notified for seven parameters such as Suspended Particulate Matter (SPM), PM$_{10}$, NO$_2$, SO$_2$, CO, Ammonia (NH$_3$) and lead. Additional parameters, such as Hydrogen sulfide (H$_2$S) and Polycyclic Aromatic Compounds (PAHs) are also being monitored in selected sites. The NAAQS helps to identify non-attainment cities in order to develop the necessary preventive and corrective measures by taking into account the geographical and climate conditions in order to better understand the natural cleansing process of generated pollutants.

1.10.2 Ambient air Quality Standards

India’s first set of ambient air quality standards was adopted in 1982 under the Air (Prevention and Control of Pollution) Act, 1981. The act mandated the establishment of the central and state boards for the prevention and control of air pollution. It empowered the central board- the CPCB to create and enforce air quality standards. The limiting concentration values for various pollutants were determined considering an adequate margin of safety. The concentration values vary because the NAAQS is based on land-use, health effects, and emission control.

1.10.3 Air Quality Control Techniques

Irrespective of technical advancements, sustenance of all forms of life on earth through the control of gaseous and particulate pollutants in the atmosphere has become of prime importance in the current times.
i) Mass awareness and education of the causes and effects of air pollution and importance of air pollution control.

ii) Establishment of emission standards and ambient air quality standards.

iii) Measurement and control of air pollution from different sources.

iv) Monitoring ambient air quality and maintaining air pollutants below safe level.

v) Developing and adopting new technology to remove gaseous and particulate pollutants from the atmosphere.

The control systems for air pollution depend on the type of pollutants such as settling chambers, electrostatic precipitation, filters, scrubbers and combustion.

1.11 References


