13 Environmental Chemistry

Chapter Outline

Introduction. Environmental pollution, causes of pollution. Types of pollution, air pollution, source of air pollution. Nature of pollution sources, impacts of air pollution. Classification of air pollutants, sources, ill effects and remedies of air pollutants, sulphur dioxide, carbon monoxide, organic vapours, oxides of nitrogen. Particulate matter, control of particulate matter. Acid rain, harmful effects of acid rain, conservation of resources to minimize acid rain. Ozone depletion, causes of ozone depletion, protecting the stratospheric ozone layer. Global warming, greenhouse effect, greenhouse gases, global climate trend, control measures. Water pollution—classification of water pollution, sources of water pollution, ill effects of heavy metals on water. Sewage and its characteristics, sewage treatment. Land pollution, sources and methods. Waste disposal. Toxic chemicals—List of dangerous chemicals. Thermal pollution, sources and methods. Nuclear pollution, sources and methods. Noise pollution, sources and methods.

13.1 Introduction

Environment is the surrounding in which we live. Environmental chemistry is a science that deals with the chemical constitution and composition of the environment, the inter and intra interactions between different species in the environment and the cause and effect of changes in the environment on the life cycle of the species.

Our environment is a dynamic wonderful life-sustaining system. Various forms of life, which are independent and interdependent and the large numbers of natural processes, are in equilibrium. Many of the needs of man are met by nature. Nature has provided him with good drinking water, pure air to breath and ozone layer to protect him from harmful UV and cosmic rays. The green vegetation around him absorbs the carbon dioxide he breathes out and converts it to oxygen required to sustain life.

Man is always greedy. In his attempt to keep his comfort he has exploited nature too much, disobeyed natural laws and is in the act of destroying the wonderful environmental equilibrium. Rapid increase in population and industrialization are the two main reasons of environmental pollution. Man has overtaken natural causes of pollution like volcanic eruption, forest fire, etc. His polluting capacity has reached a level of more than a thousand times that of natural causes. Maximum danger is produced by highly industrialized countries. Automobiles which use fossil fuel are another highly polluting device man has invented. Automobiles have become automatic mobile polluting stations. Environmental Pollution is multidisciplinary subject involving chemistry, physics, life science, medical science, engineering and agricultural science.

Environmental pollution causes various problems to the living systems. Some of the water pollutants endanger fauna and flora and also aquatic life. Atmospheric and water pollution produces lung problems, reduces visibility, impair health and even causes death. Pollution also destroys historical monuments and other manmade and natural materials. Hence, it has become mandatory on each individual human being to help adopting pollution control methods. It is already late but not too late to repent.

Vertical section of air may be divided into three layers: (1) troposphere which extends up to 18 km, (2) stratosphere extending from 18 to 150 km and (3) ionosphere—above 150 km. Air pollutants concern mainly with troposphere. The densest part of air is troposphere and it contains approximately 78.09 percent N_2, 20.94 percent oxygen, 0.93 percent noble gases, CO_2, CH_4, NO, CO, ozone, water vapour and dust as minor components.

13.2 Environmental Pollution

Environmental pollution is defined as *the excessive discharge or addition of undesirable foreign substances into the environment, which adversely affect the natural quality of the environment causing damages to the living conditions of human beings, animals and plants.*

13.2.1 Causes of Pollution

Before industrialization started, most of the pollutions were from natural causes like volcanic eruption, forest fire, dust storm, etc. Pollution was caused by human beings, and other living organisms through their excreta, death and decay. Most of these pollutants are biodegradable. Now desire of man to have comforts in life has increased the extent of pollution by leaps and bounds. Most of the plastics commonly used in various forms, automobile exhaust, industrial waste, pesticides and herbicides from farm land are some of the main sources of pollution as shown in Fig. 13.1. The causes of pollution may be listed as follows.

1. Rapid growth in population
2. Rapid industrialization involving pollution of earth, water and air
3. Rapid urbanization
4. Misuse of natural resources
5. Natural phenomena like volcanic eruption
6. All transportation mechanisms that use fossil fuels

13.3 Types of Pollutions

The major types of pollutions are as follows:

- Air pollution
- Water pollution

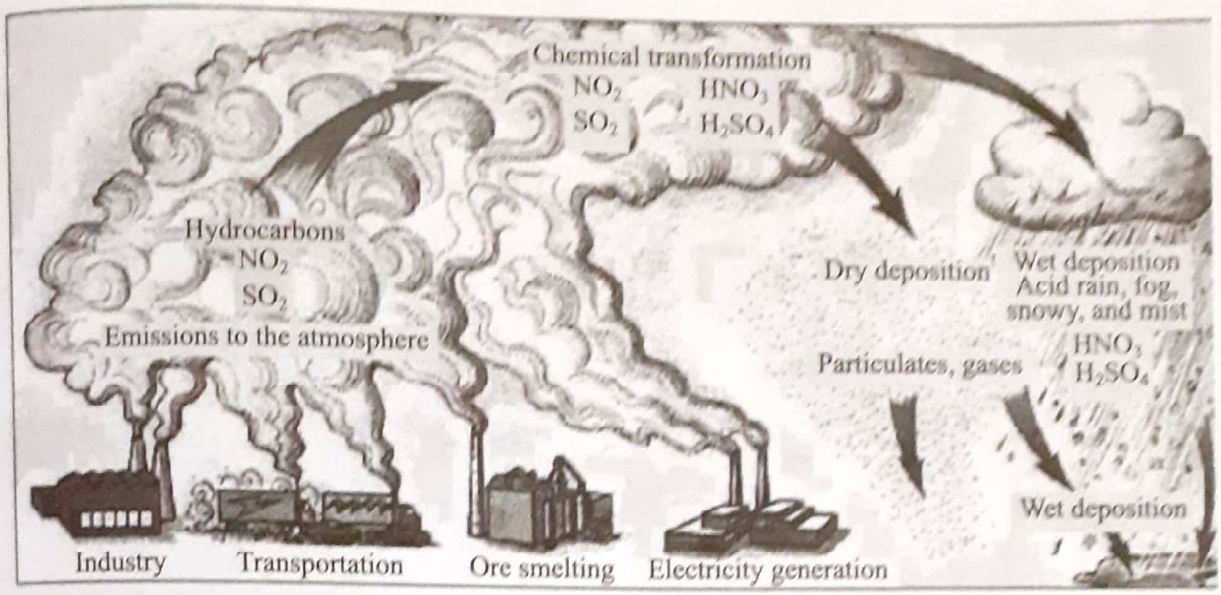


Figure 13.1 *An illustration of polluting environment of various forms.*

- Land/soil pollution
- Nuclear pollution
- Thermal pollution
- Noise pollution

13.3.1 Air Pollution

Air pollution can be defined as *the extensive discharge of undesirable foreign substances into air that adversely affect living conditions of human beings, animals and plants and also cause damages to property.*

Air pollution is an atmospheric phenomenon that has no natural cause. The largest sources of pollution are found in the industrialized countries, because the polluting substances can spread themselves easily in the atmosphere. The industry consists of a large number of processes where several substances are released that causes air pollution as shown in Fig. 13.1.

Air pollution is an indication of disturbances to the composition of compounds in the atmosphere and it may be summarized as follows:

- Excess emission of gases/vapours into the atmosphere
- Saturation of chemical compounds/particulates
- Emergence of new chemical reactions of reactive and nonbiodegradable compounds
- Global warming, acid rain, smog and ozone depletion are some effects of air pollution

13.3.2 The Sources of Air Pollution

Air pollution may be personal, occupational or community pollution.

- *Personal pollution* is due to individuals exposing themselves to pollution, e.g. cigarette smoking (Fig. 13.2).

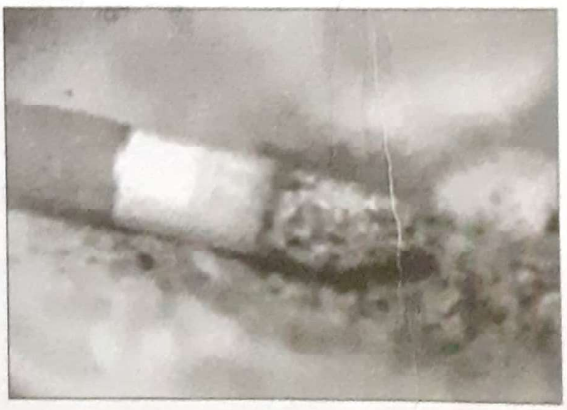


Figure 13.2 *Smoking of cigarette by humans.*

- *Occupational pollution* is due to the pollution in the work place, e.g. coal dust and cement dust in cement factories accumulates as polluted cloud as shown in Fig. 13.3.
- Community pollution involves a variety of pollutants from the chimney exhausts from factory gases, effluents from automobile exhausts, etc. (Fig. 13.4).

Figure 13.3 *Cloud of smoke and dust.*

The major sources to air pollution are due to the following categories:

- Motor vehicle exhaust
- Heat and power generation facilities
- Industrial processes
- Auto manufacturing
- Fertilizer plants
- Building demolition
- Solid waste disposal
- Volcanic eruption
- Fuel production
- Roadway construction
- Electrical components manufacturing
- Solvent evaporation
- Forest fires

Figure 13.4 *Chimney exhausts.*

Air pollution is the accumulation in the atmosphere of substances that, in sufficient concentrations, endanger human health or produce other measured effects on living matter and other materials. The six major common types of pollutants are carbon monoxide, hydrocarbons, nitrogen oxides, particulates, sulphur dioxide, and photochemical oxidants. Among the major sources of pollution are power and heat generation, the burning of solid wastes, industrial processes, and, especially, transportation, etc.

Air pollution is the presence of substances in air that on itself or with other substances has disadvantageous effects on the health of people, animals or plants. If the change of composition of air damages the environment, it is called air pollution. Because of a large mixture of processes in the industry, therefore a large number of air pollutants are released in the atmosphere as shown in Fig. 13.5. Air pollution caused by air pollutants has bad consequences on the health and the environment. Some polluting substances having similar functioning (NO_x and SO_2) contributes to acidification. The small number of polluted substances are carbon dioxide (CO_2), nitrous-oxide (N_2O), carbon monoxide (CO), sulphur dioxide (SO_2), methane (CH_4), volatile organic compounds (VOC), hydrogen disulphide (H_2S) and ammonia (NH_3).

The chemicals that cause air pollution and are bad for the environment and people are as follows:

- *Ozone*: Ozone is produced when other pollutant chemicals combine. It is the basic element of smog. It causes many different kinds of health issues dealing with the lungs. It can damage plants and limit sight. It can also cause a lot of property damage.
- *VOCs* (volatile organic compounds, smog formers): VOCs are let into the air when fuel is burned. This chemical can cause cancer. It can also harm plants.

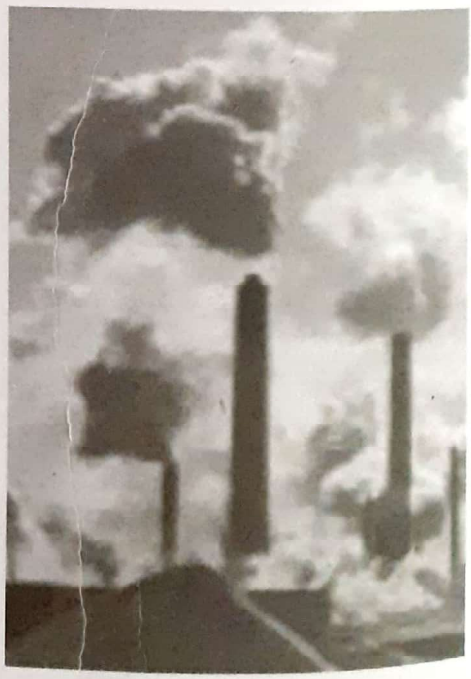


Figure 13.5 *Industrial gaseous waste.*

- NO_x (nitrogen dioxide): This chemical forms smog. It is also formed by burning sources of energy, such as gas, coal and oil, and by cars. This chemical causes problems in the respiratory system (including the lungs). It causes acid rain, and it can damage trees. This chemical can eat away buildings and statues.
- *CO* (carbon monoxide): The source of this chemical is burning sources of energy. It causes blood vessel problems and respiratory failures.
- *PM-10* (particulate matter): The source of this chemical is ploughing and burning down of fields. It can cause death and lung damage. It can make it hard for people to breathe. The smoke, soot, ash and dust formed by this chemical can make many cities dirty.
- *Sulphur dioxide*: This chemical is produced by making paper and metals. This chemical can cause permanent lung damage. It can cause acid rain which kills trees and damages building and statues.
- *Lead*: This chemical is in paint, leaded gasoline, smelters and in lead storage batteries. It can cause many brain and nerve damages and digestive problems.

13.3.3 Nature of Pollution Sources

Air pollution can be manmade or naturally occurring. The main sources of air pollution are as follows:

- Stationary and area sources
- Mobile sources
- Agricultural sources
- Natural sources

(i) Stationary and area sources

A stationary source of air pollution refers to an emission source that does not move (i.e. utilities, chemical and manufacturing industries). Often stationary sources are defined as large emitters who release relatively consistent qualities and quantities of pollutants (Fig. 13.6). The term area source is used to describe the many smaller stationary sources located together whose individual emissions may be low but whose collective emissions can be significant.

Figure 13.6 *Accumulation of air pollutant as cloud.*

(ii) Mobile sources

A mobile source of air pollution refers to a source that is capable of moving under its own power. In general, mobile sources imply to on-road transportation (Fig. 13.7). In addition, there is also a non road or off-road category that includes gas-powered lawn tools and mowers, farm and construction equipment, recreational vehicles, boats, planes and trains.

(iii) Agricultural sources

A wide range of contaminants can reach the river either via groundwater or through drainage ditches, including artificial fertilizer residues, insecticides, herbicides, pesticides and farmyard waste, all of which are potentially very harmful. Accidental milk spillage from dairies is a serious contaminant.

Undiluted animal manure (slurry) is one hundred times more concentrated than domestic sewage, and can carry a parasite, cryptosporidium, which is difficult to detect. Silage liquor (from fermented wet grass) is even stronger than slurry, with a low

Figure 13.7 *Atmospheric pollution from moving vehicles.*

pH and very high BOD (biological oxygen demand). With a low pH, silage liquor can be highly corrosive; it can attack synthetic materials, causing damage to storage equipment and leading to accidental spillage.

Agricultural operations, those that raise animals and grow crops, can generate emissions of gases, particulate matter and chemical compounds (Fig. 13.8). For example, animals confined to a barn or area (rather than field grazing), produce large amounts of manure. Manure emits various gases, particularly ammonia into the air. This ammonia can be emitted from the animal houses, manure storage areas or from the land after the manure is applied. In crop production, the misapplication of fertilizers, herbicides and pesticides can potentially result in aerial drift of these materials.

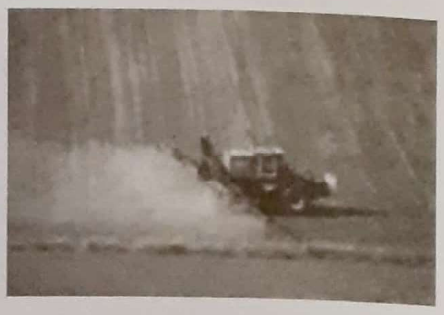


Figure 13.8 *Spraying insecticide, pesticide or fertilizer during agricultural operations.*

(iv) Natural sources

Natural sources of air pollution are sources not caused by people or their activities. An erupting volcano (Fig. 13.9) emits particulate matter and forest fires (Fig. 13.10) can emit large quantities of pollutants, plants and trees emit hydrocarbons and dust storms can create large amounts of particulate matter. Wild animals in their natural habitat are also considered natural sources of pollution given that there is a certain amount of natural pollution, it is very important to control the 'excess' pollution caused by man's activities.

Figure 13.9 *Volcano pollution.*

Figure 13.10 *Forest fire pollution.*

13.3.4 Impacts of Air Pollution

Pollutions are due to atmospheric deposition of nitrogen (NO_x) and other chemical contaminants. These pollutants dramatically impact the watershed as shown in Fig. 13.1.

The effects of nitrogen can be seen in the following:

(i) *Acid rain*: Nitrogen oxide (NO_x) is one of the key air pollutants which causes acid deposition, and results in adverse effects on aquatic and terrestrial ecosystems (Fig. 13.11). Acid deposition increases the acidity of water and soils. Increases in water acidity can impair the ability of certain fish and aquatic life to grow, reproduce and survive. Increases in soil acidity can impair the ability of some types of trees to grow and resist disease.

(ii) *Smog*: It is a collection of pollutants. It is formed by NO_x, particulate matter and humidity, all mixed together. Smog reduces how far and how clearly we can see through the air, an effect called visibility reduction or regional haze. General atmospheric conditions are that haze and ozone occur at the same time and the mix of the two is called smog (Fig. 13.12).

Figure 13.11 *Formation of acid rain cloud due to the presence of CO_2, SO_2, NO_x, etc. with moisture.*

(iii) *Eutrophication*: Reduced levels of dissolved oxygen in water due to increased mineral and organic nutrient deposits produce algae and other water plants that choke other forms of life in the oxygen competition. Soil erosion, phosphorous and direct runoff from feedlot operations and intensive agriculture are the main cause.
When excess nitrogen causes accelerated growth of algae, the algae blocks sunlight, needed for submerged aquatic vegetation to grow, when the algae dies it sinks to the bottom and decomposes in a process which depletes the water of oxygen.

Figure 13.12 *Smog formation in the atmosphere.*

(iv) *Accumulation*: Nitrogen compounds percolate through soil and reach drinking water sources, and these nitrate contaminants pollute the water.
The effects of chemical contaminants can be seen in the following:

(v) *Bioaccumulation*: Chemical contaminants increase with concentration as it moves through the food chain. Example: an invertebrate eats contaminated algae, a small fish eats many contaminate invertebrates, a large fish eats many small fish, and humans eat the big fish which is now loaded with the chemical. Chemical contaminant can accumulate and bind to the sediments they deposit on. When this happens, the chemical contaminants are moved wherever the sediments are moved. Chemical contaminants can change a plant species composition, and make species more susceptible to disease, weather and insect damage. Changes such as these challenge a species ability to reproduce and develop.

(vi) *Persistent*: Chemical contaminants do not break down or diminish over time.

13.3.5 Classification of Air Pollutants

Air pollutants are classified into two types according to their origin.

(i) *Primary pollutants* which are directly injected into air, e.g. SO_2, CO, oxides of nitrogen, dust particles, etc.

(ii) *Secondary pollutants* which are not directly introduced into air but are found in the atmosphere by chemical or photochemical reactions among the constituent of air, e.g. ozone, PAN, etc.

Another method of classification of air pollutants is based on their physical state.

(i) *Gases*, e.g. CO, NO, hydrocarbon vapours, SO_2, etc.

(ii) *Aerosol particulates* which involve solids such as smoke and dust and liquids like fog, sprays, etc.

A third type of classification is based on the chemical composition of the pollutant.

(i) *Inorganic pollutants:* Oxides of N_2, CO, SO_2, H_2S, etc.

(ii) *Organic pollutants:* Hydrocarbons, aldehydes, ketones, etc.

13.3.6 Sources, Ill Effects and Remedies of Air Pollutants

There are six primary pollutants of air. They are (a) SO_2, (b) CO, (c) oxides of nitrogen, (d) volatile organic vapours, (e) particulate matter and (f) ozone.

Their natural and anthropogenic (manmade) sources, ill effects and remedial measures are given below.

13.3.6.1 Sulphur Dioxide

(a) *Natural source*: Volcanic eruptions produce gases containing SO_2. When plants decay they produce H_2S, which gets oxidised in air by ozone to form SO_2.

$$H_2S + O_3 \rightarrow H_2O + SO_4^{2-}$$

(b) *Anthropogenic sources:* Combustion of sulphur containing fossil fuels is the main manmade source. Roasting of sulphide ores of metals also produce SO_2.

$$2FeS + 3O_2 \rightarrow 2FeO + 2SO_2$$

The concentration of SO_2 in air always remained below the permissible level. The concentration of SO_2 is high only in low altitude regions due to anthropogenic forces.

(c) *Ill effects of SO_2*:

(i) *On human beings:* Concentration of SO_2 to about 20 ppm may cause eye irritation and affect digestive systems. Concentration above 400 ppm may be fatal.

(ii) *On plants:* Plants are damaged even at 1 ppm and for some plants yellowing of leaves takes place due to the presence of sulphur dioxide content in air.

(iii) *On materials:* Yellowing of paper, loss of strength due to corrosion of metals and loss of strength of buildings may be caused by SO_2. Acid rain is also caused by SO_2.

(d) *Control of SO_2 pollution*: The main source of SO_2 is the burning of coal. Control of SO_2 pollution may be done by passing the emitted gases through a slurry of limestone when SO_2 is absorbed. Air is blown through the slurry to convert calcium sulphite to calcium sulphate.

$$CaCO_3 + SO_2 \rightarrow CaSO_3 + CO_2$$

$$CaSO_3 + \tfrac{1}{2} O_2 \rightarrow CaSO_4$$

In fluidized bed combustion finely powdered coal and limestone is fed into the chamber and fluidized by blowing air at about 1000°C. All the above changes take place in the chamber.

13.3.6.2 Carbon Monoxide

(a) *Natural source* by the oxidation of methane from marshy places by O_2.

$$CH_4 + \frac{1}{2} O_2 \rightarrow CO + 2H_2O$$

(b) *Anthropogenic source:*

(i) Incomplete combustion of carbon and carbon-containing fuels. CO is one of the major pollutants present in automobile exhaust gases.

(ii) Reaction of CO_2 with carbon at high temperature.

$$CO_2 + C \rightarrow 2CO$$

(c) *Ill effects on human beings:* 10 ppm is the admissible level of CO in air. Concentration above 110 ppm affects the respiratory system. At higher concentration it leads to headache, fatigue, unconsciousness and finally to death. This is caused because CO forms a stable complex carboxyhaemoglobin with haemoglobin of the blood. Haemoglobin loses its capacity to carry oxygen to the cells.

(d) *Control of CO Pollution:* The main source of CO pollution is automobile exhaust. These emissions are controlled by using a catalytic converter where CO is oxidised to CO_2.

$$CO + \frac{1}{2}O_2 \rightarrow CO_2$$

13.3.6.3 Organic Vapours

(a) *Natural source:* From marsh gas and from gases from petroleum wells.

(b) *Anthropogenic source:* The major source is from the unburnt gases of automobile exhaust from various industrial processes, perfumes we use in day-to-day life.

(c) *Ill effects:* On their own hydrocarbons do not produce any pollution. They are however converted to photochemical oxidants called PAN (peroxyacyl nitrate) by a series of reactions. PAN is the cause of photochemical smog.

(d) *Control of hydrocarbon pollution*: The main source of anthropogenic hydrocarbon pollution is exhaust gases of automobiles. Control can be done by having a catalytic converter which helps in the oxidation of hydrocarbons to CO_2 and water.

$$C_x\frac{H}{y} + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

13.3.6.4 Oxides of Nitrogen

The three oxides of nitrogen found in the atmosphere are (N_2O) nitrous oxide, (NO) nitric oxide and (NO_2) nitrogen dioxide.

(a) *Natural source:*

(i) By biological oxidation of nitrogenous compounds in the soil N_2O and NO are formed. This easily gets oxidized to NO_2, in air.

(ii) During lightning N_2 and O_2 of air combine to form NO which then gets oxidized to NO_2.

(b) *Anthropogenic source:* Internal combustion engines operate at high temperatures. N_2 and O_2 of the air in the engine form NO and then NO_2. Thus, the exhaust gases from IC engine contain NO and NO_2.

(c) *Ill effects of oxides of nitrogen*

On human beings: Causes eye irritation and respiratory problems, produces acid-induced irritation and lung cancer.

On plants: Nil

On materials: (i) Causes acid rain which damages old monuments and buildings. (ii) Causes formation of photochemical smog which leads to poor visibility of roads and landing difficulties to aircrafts.

(d) *Control of the oxides of nitrogen:* In the IC engines catalytic converter is used for the decomposition of the oxides of nitrogen to N_2 and O_2.

$$\underset{\text{(exhaust gas)}}{2NO_2} \xrightarrow{\text{Pt/Rh. catalyst}} N_2 + O_2$$

13.3.6.5 *Particulate Matter*

Particles (both solids and liquids) with a size around 10 μm form particulate pollution in air. They are also called aerosol. Dust and soot are solid sols while fog and mist form liquid aerosol.

(a) *Natural source* by dust storms, forest fire, etc.

(b) *Anthropogenic source:*

(i) Soot is produced during the combustion of coal, wood, fuel oil, house and municipal garbage and tobacco smoking.

(ii) Dust is produced during material handling and crushing, grinding of ores, etc. Dust is also produced during mixing and packaging of powdered substances like chemicals, flours, starches, etc. Construction of houses, roads, dams and mining also cause formation of dust. House cleaning, body sprays, spraying of crops, engine exhaust also produce aerosols. Flyash from thermal power plants and cement industries is another major source.

(c) *Ill effects of particulate pollution:* Smoke causes respiratory problems and may lead to TB. Silica dust causes asbestosis. Lead dust produces lead poisoning and mercury dust produces kidney problems.

13.3.6.5.1 Control of Particulate Matter

Various methods for the control of particulate matter in air are available depending on the size of particles, their physical nature and the economy involved.

(a) Fabric filter

Dust particles from dry gases can be removed using fabric filters. It consists of fibrous materials with fine pores suspended in a chamber (Fig. 13.13). The gas is allowed to pass through the filters when particulate matter is filtered at the bags. When the mechanical shaker is operated the collected dust particles fall down. Blowing air in the opposite direction can also be done to remove dust particles from the bags.

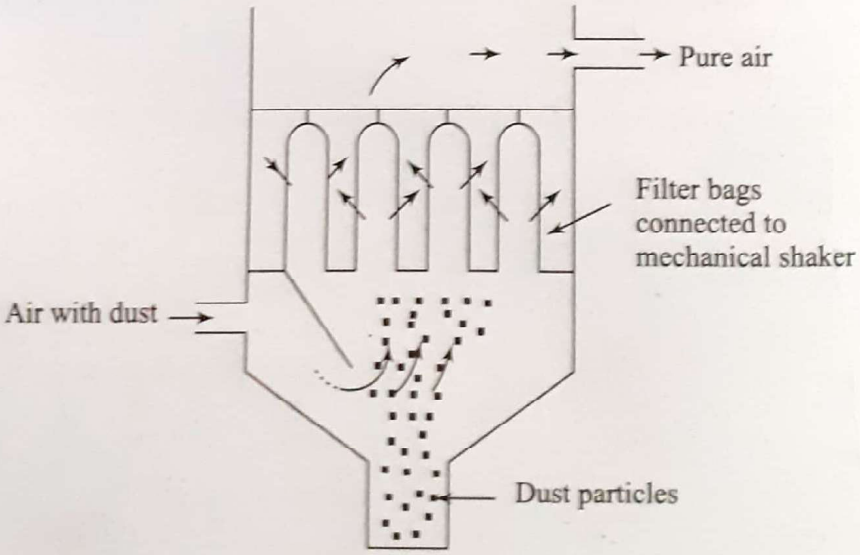


Figure 13.13 *Fabric filter.*

Fabric filters are simple to operate, and have high collection efficiency. But it can be used only for dry gases, requires maintenance and replacement of costly fabrics.

(b) Gravity separation

Air is allowed to flow through dust-settling tanks slowly in one direction. The suspended heavier particles settle down and collect at the conical portions of the tank. Purified air flows out (Fig. 13.14).

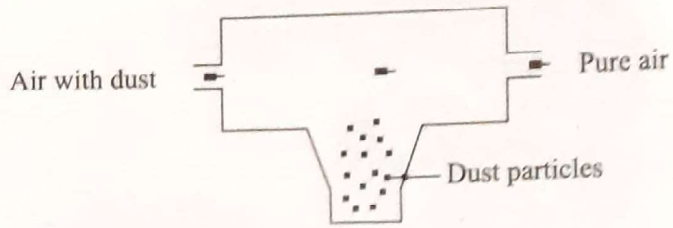


Figure 13.14 *Gravity Separator.*

(c) Cyclone separator (centrifugal separator)

The principle of operation of a cyclone separator is based on centrifugal force to separate dust particles from gas streams. The principle is shown in Fig. 13.15.

A cyclone separator consists of a cylindrical centrifugal chamber, inner tube, conical base and dust collector. The impure air containing dust particles is admitted into the chamber tangent to the surface. It is made to move in a spherical manner down the chamber and pass up in smaller spirals through the inner tube. Under the influence of the centrifugal force dust particles get separated and collect in the conical base. Purified air leaves the chamber through the top of the inner tube.

This method is simple, maintenance free and is economical. But it has low efficiency to smaller particles.

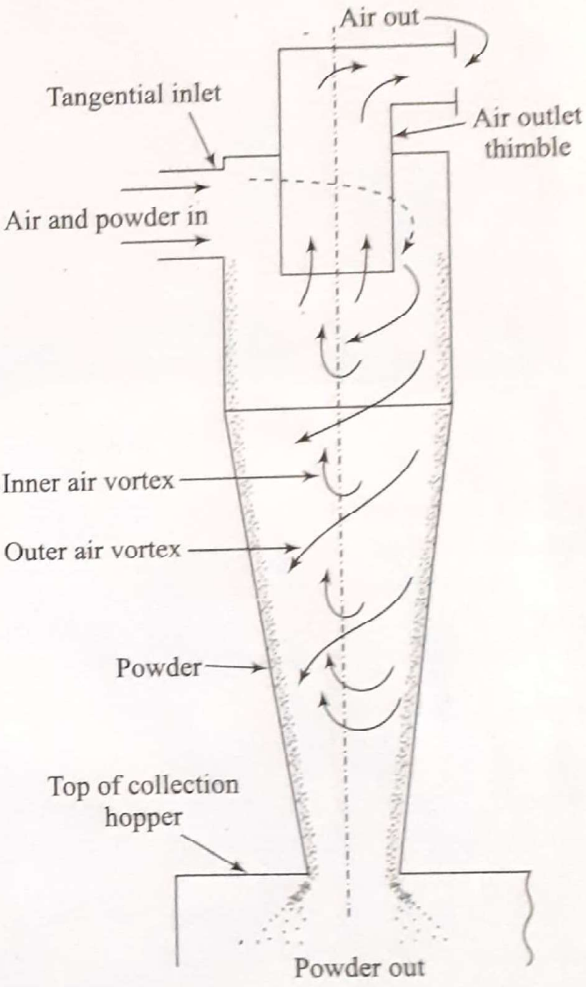


Figure 13.15 *A typical cyclone separator.*

(d) Wet scrubber

Impure air is allowed to ascend a tower and water is sprayed from the top (Fig. 13.16).

Descending water wets the dust particles and settles the particle at the bottom of the chamber as sludge. Scrubber also removes water-soluble gaseous impurities.

This method is also simple and removes both dust particles and water-soluble gases. It is highly efficient. But disposal of sludge becomes costly, large quantities of water is required and air pollution now becomes water pollution.

(e) Electrostatic precipitator

Cottrell electrostatic precipitators are widely used in industries to remove particulate matter from gaseous effluents. They are connected to the exhaust outlets of chimneys Fig. 13.17. The exhaust gas stream of industrial plant is allowed to pass between metal electrodes maintained at a high potential of 50,000 volts.

The pointed electrodes develop high intensity current and produce coronas in which the gas molecules get ionized releasing electrons from the gases. The electrons so generated collide with the suspended particles present in the gas and the particles become negatively charged. These negative particles are attracted by the collection electrode. The discharged

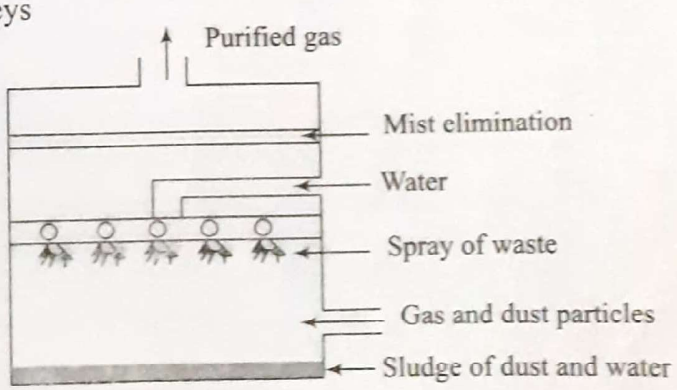


Figure 13.16 *Wet scrubber.*

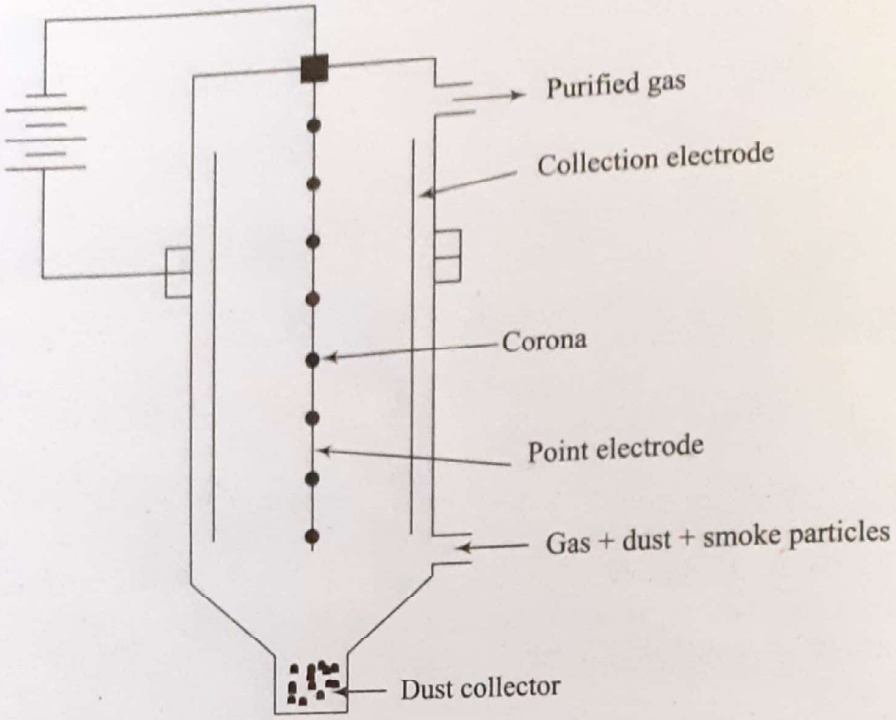


Figure 13.17 *An electrolytic precipitator.*

particles are removed by tapping or vibrations of the electrode. The particles collect in the conical collector. Dust-free gas flows out at the top.

The method has low maintenance cost with high collection efficiency, large quantities of gas can be cleaned. Initial cost is very high. It can be used only for particulate impurities, and gaseous impurities cannot be removed.

13.3.7 Acid Rain

Acid rain is a result of air pollution. When any type of fuel is burnt, a large number of different chemicals are produced. The smoke that comes from a fire or the fumes that come out of a car exhaust do not just contain the sooty grey particles that you can see—they also containa lot of invisible gases that can be even more harmful to our environment.

Power stations, factories and cars all burn fuels and therefore they all produce polluting gases. Some of these gases (especially nitrogen oxides and sulphur dioxide) react with the tiny droplets of water in clouds to form sulphuric and nitric acids. The rain from these clouds then falls as very weak acid—which is why it is known as 'acid rain'.

Rainwater is slightly acidic since it dissolves varying amounts of CO_2 from air. The lowest pH of rainwater is 5.6.

$$H_2O + CO_2 \rightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

In some places in western countries sometimes the pH of rainwater comes down to 4.5 and even up to 2.4. Such a rain is called acid rain (Fig. 13.18). Two main sources of acidity in rain are sulphur dioxide and oxides of nitrogen. When sulphur containing fossil fuels are burnt they produce SO_2 which in presence of rainwater and air forms H_2SO_4.

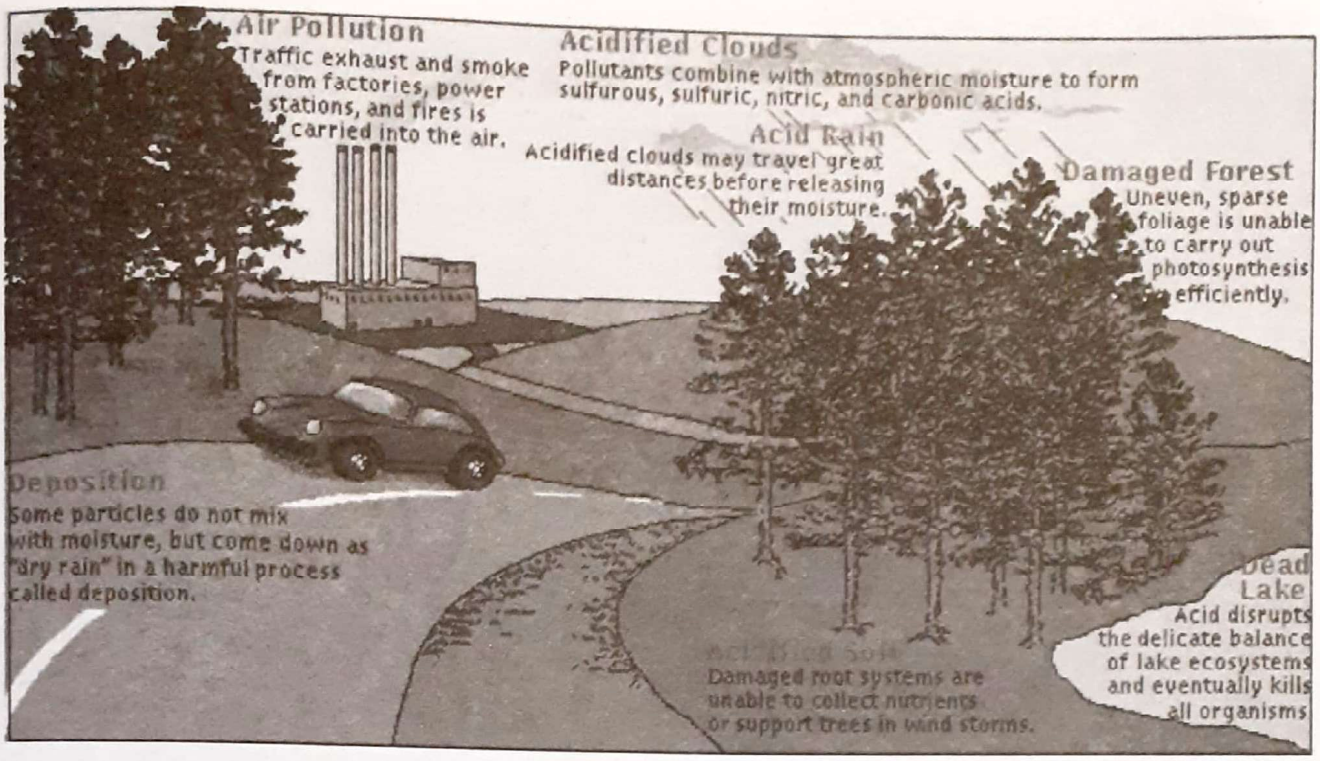


Figure 13.18 *An illustration of formation of acid rain and its ill effects.*

$$S + O_2 \rightarrow SO_2$$

$$H_2O + SO_2 + \frac{1}{2}O_2 \rightarrow H_2SO_4$$

Automobile exhaust contains nitric oxide. In contact with air it forms nitrogen dioxide which dissolves in water to form nitrous and nitric acids.

$$NO + \frac{1}{2}O_2 \rightarrow NO_2$$

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

1. Acid rain results in acidifications of streams and lakes. This endangers the life of aquatic animals and plants. Fishes are killed and their reproductivity is severely reduced. Growth of green algae is impaired. Many useful bacteria are killed and hence decomposition of organic matter in water is reduced making the water useless. Acid dissolves metals like aluminium, lead, zinc, iron, etc. increasing metal ion concentrations in lakes and stream. This again affects life span of aquatic living beings.
2. With decrease in pH, the nutrients like potassium, iron, magnesium, etc., are washed away from the soil. This affects the growth of plants (Fig. 13.19). The nitrifying bacteria present in the roots of leguminous plants are destroyed causing decrease in fertility of the soil.
3. Acid rain causes extensive damage and destruction to buildings as it leaches away the reinforcement.

Figure 13.19 *The growth of trees are affected by acid rain.*

4. Acid rain damages building materials made of marble, limestone, slate, metals, etc. The action of acid on marble or lime-stone makes the surfaces look pitted. This is called *stone leprosy*. The reaction is

$$CaCO_3 + 2H^+ \rightarrow Ca^{+2} + H_2O + CO_2$$

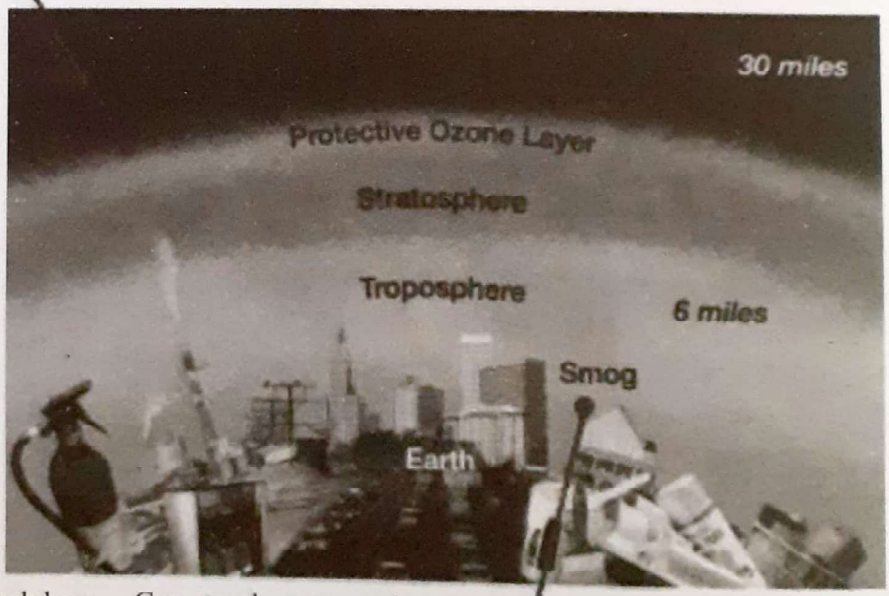
13.3.7.1 *Conserving Resources to Minimize Acid Rain*

- Greater subsidies of public transport by the government to encourage people to use public transport rather than always travelling by car.
- Every individual can make an effort to save energy by switching off lights when they are not being used and using energy-saving appliances—when less electricity is being used, pollution from power plants decreases.
- Walking, cycling and sharing cars all reduce the pollution from vehicles.

13.3.8 Ozone Depletion

Ozone is a gas that occurs both in the earth's upper atmosphere and at ground level (Fig. 13.20). Ozone can be 'good' or 'bad' for your health and the environment, depending on its location in the atmosphere. Ozone occurs in two layers of the atmosphere. The layer closest to the earth's surface is the troposphere. Here, ground-level or 'bad' ozone is an air pollutant that is harmful to breathe and it damages crops, trees and other vegetation. It is a main ingredient of urban smog. The troposphere generally extends to a level about 6 miles up, where it meets the second layer, the stratosphere. The stratosphere or 'good' ozone layer extends upwards from about 6 to 30 miles and protects life on Earth from the sun's harmful ultraviolet (UV) rays.

Too little there…Many popular consumer products like air conditioners and refrigerators involve CFCs or halons during either manufacture or use. Over time, these chemicals damage the earth's protective ozone layer



Too much here… Cars, trucks, power plants and factories all emit air pollution that forms ground-level ozone, a primary component of smog.

Figure 13.20 *An illustration of ozone layers in different strata of atmosphere.*