Chapter 11

Water Pollution

There is no need for telling about the importance of water in the biosphere. Like air, it is very essential for human existence and also for all living organisms. It is necessary for the survival of any form of life. Water accounts for about 70 per cent of the weight of human body. About 80 per cent of earth's surface is covered by water. Regular supply of plentiful pure water is very essential for healthy living. But due to rapid increase in population and fast industrialisation, most of the rivers, lakes, streams and other water resources are being increasingly polluted.

What is water pollution ?

"Water is regarded as *polluted* when it is changed in its quality or composition, directly or indirectly as a result of human activities, so that it becomes useless or less suitable for drinking, domestic, agricultural, fisheries or other purposes for which it would otherwise be quite suitable in its natural or unpolluted state." Any human activity that impairs the use of water as a resource may be called water pollution. Water is a universal solvent, and as such it gets readily contaminated by the materials with which it comes into physical contact. But, we are not much concerned with several natural phenomena that would make water polluted. For instance, during rainy season, water gathers silt and other impurities on the surface of the earth and makes it polluted in its natural course. Similarly, when there is drought condition, water level goes down and it may get contaminated through seepage of saline water. Pollution in a natural way is not very serious, as the pollutants get assimilated by water in a natural way.

The real menace of water pollution arises from sewage, industrial wastes and a wide array of synthetic chemicals being discharged into the water sources like rivers, streams or lakes. Many industrial effluents usually join rivers and lakes which are main sources of water supply and are biologically degraded by the flora and fauna presented in the river. When pollution load in river exceeds its assimilating capacity, the additional pollution load adversely affects the health of the river and ultimately leads to further reduction in assimilating capacity. Finally

a state is reached when the content of the river becomes toxic, unfit for any use. It is really a sorrowful state of affairs, when the available pure drinking water is becoming very scarce, pollution of rivers is continued by industries making availability of pure water still more scarce.

Polluted water, if used for drinking, transmits various diseases such as cholera, typhoid, jaundice, dysentry, intestinal infections and also viral diseases. Highly polluted water will not be useful for any purposes, either swimming or bathing or for agriculture, as they may contain chemical pollutants like mercury, cadmium, nitrates, chlorinated hydrocarbons and biocides which are highly dangerous and the sea food, fish, clams and other invertebrates become toxic.

According to a study conducted by National Institute of Oceanography, Goa, the people of Bombay discharge about 2,000 million cubic metres of sewage into the sea every year. In Delhi, river Yamuna takes every day about 2,000 million litres of untreated human wastes. Almost all rivers in India are polluted. An analysis conducted in 1982 revealed that about 70 per cent of all available water in our country is polluted.

Even the federal government of USA faces the problem of water pollution. According to Environmental Protection Agency (EPA) industrial discharges remain another serious contributor to surface water degradation. Many billion gallons of industrial waste, often containing many hazardous and toxic wastes are still discharged daily into American surface waters through municipal waste-water systems. Further, according to EPA estimates, "only about 15 per cent of the 3,00,000 industrial discharges are regulated by federal or state discharge permits."

In India, except a few municipalities of urban areas, all other places have only polluted water. The rural population is left without any pure drinking water. They have only contaminated water. The International Institute of Applied System Analysis in Austria has warned that water pollution will be India's major problem in 25 years, rather than any other problems, unless sewerage and sanitaiton facilities are improved.

CLASSIFICATION OF WATER POLLUTION

Water pollutants can be classified into five broad categories, viz., 1. Organic pollutants 2. Inorganic pollutants 3. Suspended solids and sediments 4. Radioactive materials and 5. Health effluents.

1. Organic Pollutants

Organic pollutants can be further classified as (a) Oxyge demanding wastes; (b) Disease-causing wastes; (c) Synthetic orga compounds; (d) Sewage and agricultural run-off; and (e) Oil pollutio

(a) *Oxygen-demanding wastes*: These include domestic waste sewage, industrial wastes from food processing, meat-packing and slaughter houses, paper and pulp mills and tanneries etc., and also agricultural run-off. Most of them are bio-degradable organic compounds which are putresible, creating rotten and foul smell. They decompose by bacterial activity with the help of dissolved oxygen in water. This results in depletion of oxygen in water which is harmful to acquatic animals. The requirement of optimum dissolved oxygen in natural water is estimated to be around 4-6 ppm, which is essential for supporting aquatic life. Decrease of oxygen from this level is an index of pollution and aquatic organisms cannot survive.

(b) *Disease-causing wastes*: Sewage and other wastes would create pathogenic micro organisms and these would cause tremendous damage to public health. These microbes contain viruses and bacteria and they cause water-borne diseases such as typhoid, dysentry, cholera and polio, as well as other infectious diseases. Hence, the preliminary step in controlling water pollution is to disinfect the water sources liable for pollution.

(c) *Synthetic organic compounds*: These are the waste materials arising out of man-made synthetic materials, such as pesticides, insecticides, detergents, pharmaceuticals, food additives, synthetic fibers, plastics, paints and industrial chemicals etc., which may enter the water course either by discharge or by spillage during transport. Most of these chemicals are toxic to plants, animals and also humans. Besides, some of these may cause offensive odours and colours in water even in small quantities. Non-degradable chemicals from synthetic detergents often lead to persistent foams in water; besides volatile substances like alcohol, ether, gasoline etc., may cause explosion in sewers.

(d) *Sewage and agricultural run-off*: Generally, sewage and run-off from agricultural land contains plant nutrients. This may stimulate growth of plenty of algae and similar aquatic weeds in the receiving water body. This results in degradation of the value of water and it loses its dissolved oxygen in the long run, and finally the water body becomes dead through *eutriphication* process.

(e) *Oil pollution*: We are familiar with the reports of oil slick during the Gulf war between Iraq and US - led allied forces in 1991.

Oil pollution in ocean and rivers cause serious damage to aquatic plants, birds and animals. Oil pollution results in reduction of light transmission through surfaces water, thereby reducing photosynthesis by marine plants. It reduces the dissolved oxygen in water endangering water birds and coastal plants. In recent years, oil pollution in seas has been increasing due to spills from cargo oil tankers, leakage from oil pipes, accidental fires in ships and oil tankers, besides oil-based technologies and massive shipment. Oil pollution causes deleterious effects on marine life and sea-food.

2. **Inorganic Pollutants**

Finely divided metals, metal compounds, cyanides, sulphates, nitrates, mineral acids, inorganic salts etc., form inorganic pollutants in water. A great variety of metal forms can exist in a natural water at low concentrations. Metalliferous mining, smelting and refining release metals to the atmosphere, water and sediments, as do electricity generating plants, incinerators, sewage sludge and residues from leaded gasoline.

Various metals and metallic compounds released from anthropogenic activities add up to their natural background levels in water. Some of these trace metals play essential roles in biological processes, but at higher concentration, they prove toxic to biota.

3. **Suspended solids and sediments**

Suspended solids and sediments in water are mainly due to soil erosion. Sediments are mostly contributed by natural process of erosion, agricultural development, mining and construction activities. Suspended solids in water mainly comprise of silt, sand and minerals eroded from the land. Tropical countries are subject to soil erosion by water, wind and other natural forces.

Soil erosion has become one of the major problems in India. It is estimated that 175 million hectares of land are susceptible to degradation by soil erosion. According to Landsat Imagery 1980- 82 about 16.2 per cent lands have become waste lands. Deforestation and soil erosion go hand-in-hand in our country; the former the cause and the latter, the result. It is found that 6,000 million tonnes of soil are washed away into the sea, every year. This means NPK (Nitrogen, Phosphorous and Pottasium) fertilizers applied to the soil are washed away to the extent of 5.37 million tonnes into the sea every year. Fertile soils are slowly removed from agricultural land to areas where it is not required, such as water reservoirs, rivers and seas. This is called *siltation*. Apart from the soil losing its fertility and productivity, the siltation

results in reducing the storage capacity of reservoirs due to silta... This type of problem is faced with many reservoirs in our coun... Ramganga, Hirakud, Bhakra, Nizamsagar etc., face problems of silta... reduction in storage capacity and loss of irrigation potential.

The suspended solids present in water may block the sun ligh... required for photosynthesis by the vegetation at the bottom of the wat... bodies. This will in turn damage the shell fish, corals and other form... of life at the bottom. Further, sludge blankets containing organic solid... decompose resulting in obnoxious gases.

These problems can be controlled only by proper cultivation... practices, efficient management of soil and also preservation of fores... which would reduce soil erosion.

4. Radioactive Materials

We have studied already under 'Nuclear Pollution' the problem... created by radioactive waste materials.

The radioactive water pollutants may arise from mining processing... of ores, e.g., uranium tailings; use of radioactive isotopes in agricultural... industrial, medical research and applications; radioactive materials due... to testing and also use of nuclear weaponry.

The radioactive isotopes are toxic to any form of life if they exceed... tolerance limit. The adverse consequences on living organisms including... human beings may be "somatic" and also "genetic" as we studied earlier.

5. Heated Effluents

We have studied under 'Thermal Pollution' the problems relating... to discharge of heated effluents into the water bodies by industrial... establishments. Many industries using water as a coolant, dispose off... the waste hot water by returning it into the original water bodies.

We studied that this would lead to depletion of oxygen in water... leading to damages to aquatic life. By this, the ecological balance of... water bodies would be upset or aggravated and alter the spectrum of... organisms that can adopt to live at that temperature and dissolved... oxygen level. This may also promote conditions favourable for growth... of pathogenic bacteria.

WATER POLLUTION IN INDIA

Water is basic to life and scarce too. But unfortunately, we prefer... to ignore this simple fact and use it wastefully. Our careless attitudes... lack of responsibility on the part of industrialists and lack of ethics on...

TABLE 11.1
Water supply in metropolitan cities in India (1980)

City	Water Supply (in 10 lakh litre)	Per capita water supply (Litre per day)
Bombay	2143.0	207.8
Delhi	1848.0	258.0
Calcutta	976.1	226.7
Hyderabad	652.5	241.6
Ahmedabad	477.0	113.9
Bangalore	435.0	200.1
Kanpur	407.0	307.0
Lucknow	277.0	262.3
Madras	250.0	75.8
Nagpur	240.0	206.5
Pune	202.3	169.8
Jaipur	168.0	155.5
Total	8075.9	Average 189.4

In the absence of pure drinking water, people resort to unclean wells, ponds and lakes for water supply. Most of the rivers and water bodies in India are repositories of sludge worms, blood worms, blood-suckers, pests and pathogenic bacteria.

Pollution of River Ganga

Ganga, one of the sacred rivers of India, flowing a distance of 2525 Kms from Gangotri to the sea, covering most of the States in north India, forming nearly one-third of nation's water resources, is a highly polluted river. There are six major segments of the river which are heavily polluted. Kanpur and Calcutta segments of the river are highly polluted and segments covering Varanasi, Kannauj, Allahabad and Patna are comparatively less polluted. Studies made by West Bengal Water Pollution Control Board revealed that Ganga water

between Uluberia in Howrah district and Diamond harbour contains high bacterial counts. The water in this segment is considered to be unsafe even for irrigation. The biggest source of pollution is the industrial effluents from nearly 135 large and medium industries on its banks. The next serious source is the raw untreated sewage discharged into the river by nearly 100 townships on the banks in its course. Another significant source is the dumping of dead bodies into this river. Some, 30,000 bodies are burnt and thrown every year. Besides, carcasses, human excreta, washing of dirty things, discharge of waste from dairy farms add to the pollution.

In the year 1968, the *river Ganga caught fire* near Monghyr in Bihar. This sounds rather fantastic; but it is true. The reason being that the oily effluent discharged into the river from Barauni Oil Refinery caught fire while floating on the surface of the river. It has been estimated the quantity of effluents flow into the river is around 500 million litres per day from paper, jute, and chemical mills near Calcutta, besides animal and domestic wastes.

Though Ganga water is well known for its self-purifying capacity, its self-cleansing power is gradually declining due to massive discharge of pollutants.

In June 1990, *Ganga Action Plan (GAP) WAS LAUNCHED TO CONTROL THE POLLUTION* of the river by insisting on establishment of treatment plants for sewage, sludge and effluents. Some pilot projects were also started towards cleaning of the river. It has not made much headway.

Pollution in the River Yamuna

The river Yamuna, one of the chief tributaries of Ganga, is the primary source of water supply to Delhi and is highly polluted due to the discharge of city effluents and wastes from urban population and industrial establishments located along its banks. Of the total volume of water supplied to Delhi, about 20 per cent is consumed and 80 per cent flows back into Yamuna through about 20 open drains. Drains in Tughlaquabad, Maharani Bagh, Najafgarh, Kalkaji etc, carry heavy pollution load. Besides, thermal stations municipal sewerage add to pollution levels. The industries adding to the pollution of the river are electroplating, soap manufacture, printing, rubber, plastics, food processing, chemicals and leather tanning.

Some time ago, the Delhi administration requested the World Health Organisation to study the environmental problem of the capital. It pointed out that the unequal distribution of basic amenities

river. It has been abused as a convenient dumping ground for wastes and effluents of all kinds, particularly at Bokaro. River Godavari is also polluted at Rajamundry; river Tungabhadra at Harihar and Chaliyar at Mavoor in Kerala.

Apart from rivers, most of the lakes, canals and other water bodies are polluted and the problem of pollution is not confined either to one river or one State. Satellite photography near Bombay shows that the Arabian Sea is contaminated for a hundred kilometers northward.

Government of India, realising the ever-increasing problem of water pollution, enacted the Water (Prevention and Control of Pollution) Act in 1974. A Central Board was formed for implementing the different clauses of the Act. As any other Act, this is also in the statute books.

Control of Water Pollution

Control of water pollution depends on effective sewage system and treating the effluents properly so as to make them free from pollutants. For this, sewage treatment plants are essentially required in all municipal towns and other urban areas.

The complete treatment of waste water in the sewage consisted of three important stages, viz., Primary treatment, Secondary treatment; and Tertiary treatment. We shall study about these in detail:

1. Primary Treatment

Sewage water will contain large quantities of solid matter, grit, oil, grease and floating rubbish such as cloth, wool, cans etc. First, all large objects present in waste water are removed by metal bars as strainers in the open channel. Then the velocity of water is reduced in a grit-settling chamber of a large size, and grit is removed so that they may not cause any physical damage to pipes and the parts of plants for further treatment. Then the water will contain only oil and grease and other soluble impurities. Oil and grease will be removed by skimming tanks through aeration, chlorination or vacuum flotation. If necessary, chemical reagents may be used to remove oil and grease in emulsified form. Now, the water is free from suspended solids and impurities and also oil and grease. The primary treatment is mainly *sedimentation*. This process could be made more effective by means of *Mechanical Flocculation* and *Chemical coagulation*.

Finely divided suspended solids and colloidal particles cannot be efficiently removed by mere sedimentation by gravity. To remove fine particles, *mechanical flocculation* is used in which the waste water is passed through a tank fitted with paddles rotating at an optimum speed.

The waste water will be detained in this for about 30 minutes. finely divided suspended solids coalesce into larger particles and out. Specialised equipment such as *Clariflocculator* is also used wher flocculating chamber is a part of sedimentation tank.

In *Chemical Coagulation*, the waste water is treated with cer chemicals which form a floc (flocculent precipitate) that absorbs a entrains the suspended and colloidal particles present. Many chemica may be used as coagulants. The most common are (i) Alum; and (Hydrated lime. Alum is the most popular coagulant used both in wat and waste water treatment. Coagulation is the most effective an economical way of removing impurities in the waste water.

2. Secondary Treatment

In the secondary treatment, the dissolved and colloidal organ matter present in waste water is removed by biological process involving bacteria and other micro organisms. These processes may b aerobic or anaerobic. In *aerobic processes*, bacteria and other micr organisms consume organic matter as food. They bring abou coagulation and flocculation of colloidal matter; oxidation of dissolve organic matter to carbondioxide; and degradation of nitrogenou organic matter to ammonia, which is then converted into nitrite and eventually to nitrate. Thus, the secondary treatment reduce BOD (i.e. biological Oxygen Demand). It also removes appreciable amounts of oil and phenol. However, commissioning and maintaining of secondary treatment are a little expensive. *Anaerobic treatment* is employed for the digestion of sludges. The efficiency of the process depends upon waste loading, absence of oxygen and toxic material and P^H temperature. (P^H denotes a scale to find out the acidity or alkalinity of solution or soil). The plants used in the secondary treatment are *"Trickling Filters"* and *"Activated Sludge Process"* depending upon the type of waste to be treated. The former are used for the treatment of industrial wastes from dairy, distillery, brewery, cannery, food processing, pulp and paper mills, pharmaceuticals, petro chemicals, slaughter house and poultry processing industries. Activated sludge process could be used for effluents from food processing, textile processing, antibiotic manufacturing industries etc. *Oxidation Ditch* is an improved method of activated sludge process.

Oxidation method can be used for all types of wastes and any gree of purification can be obtained. The process can withstand ganic and hydraulic shock loads. The heavy metal ions present in waste water are precipitated as hydroxides which settle as sludge wever, oxidation requires larger space.

3 Tertiary Treatment

This final treatment is intended to remove the dissolved materials which had escaped during the first two processes and also to enhance the quality of water treated. The major objectives of tertiary treatment are removal of fine suspended solids; bacteria; dissolved organic solids and fine traces of organics, if it is necessary. Removal of dissolved inorganic solids is a major problem with waste waters from industries like fertilizer, textile processing, tannery and electroplating. Depending upon the quality and cost, any of the following treatment methods can be employed:-

(a) **Evaporation:** This is an energy intensive and expensive method. However, this method can be used only when the recovered solids or the concentrated solutions are reused. This method is suited when the waste water to be treated is less.

(b) **Ion-Exchange:** The use of ion-exchange for de- mineralisation of water is well known. It is widely used for obtaining de-ionised water for use in high-pressure boilers. Now this process is extended to waste water treatment for the removal of and recovery of toxic materials from waste water. Ion- exchange process is economical only when the removed salts are reused in the process, as in electro-plating industry. Special ion-exchangers are available for retrieval of toxic metal ions from industrial waste water. By ion-exchange processes all toxic materials including cyanides can be removed from waste water.

(c) **Adsorption:** This is a method by activated carbon to remove small quantities of organic contaminants from waste water. This is particularly useful for the removal of pesticides (e.g. DDT) and insecticides and other toxic heavy metal ions from industrial waste water.

(d) **Reverse Osmosis:** This is a method by which a semipermeable membrane allows water molecules through and retains ions. A thin cellophane sheet, supported on a filter cloth can be used as a successful membrane. High pressures are required for useful flow rates and recovery can be achieved by back flushing. This method is used for recovery of valuable components from effluents, for reuse, pollution control and recycling of waste water.

(e) **Electro Dialysis:** By this process, dissolved species are exchanged between two liquids through selective ion-exchange membranes. An electro motive force brings out the separation of the species according to their charge. The semi-permeable membrane allow the passage of certain charged species, while rejecting the passage of oppositely charged species. This method is used in desalination of

Chapter 12

Air Pollution

We studied about some basic features of atmosphere in an earlier chapter, while dealing with environmental segments. Some knowledge of the structure of the atmosphere is essential to understand the concepts behind air pollution; as air is the part of atmosphere at lower levels.

Atmospheric Structure

The atmosphere extends upto 500 km above the earth's surface and it consists of four major regions, called *Troposphere*, *Stratosphere*, *Mesosphere* and *Thermosphere*.

Troposphere is the region nearest to the earth's surface, extending from the surface of the earth to about 11 to 12 Km altitude. This is the region of the atmosphere which is closely connected with the activities on the earth and this accounts for nearly 70 per cent of the atmospheric mass. In the absence of any significant pollution, the composition of the air remains more or less constant. This region contains water, cloud and particulate matter. In this region the temperature of air decreases with increasing altitude from the ground temperature. This is the main reason for places situated at the top of hills having cool weather, due to low temperature. In the troposphere, near ground level the temperature will be around 25 degrees centigrade and at the end of the region it will be –55 degree centigrade. The change of temperature with height is called the "*Lapse Rate*". The decreasing temperature with increasing altitude is called positive lapse rate.

Stratosphere is the nearest region beyond troposphere, extending to a height of about 40 Km from troposphere. The significant point in this region is its negative lapse rate of temperature. That is to say, in stratosphere the temperature increases with increase in altitude. From –55 degree centigrade, the temperature increases to –2 degree centigrade at the end of stratosphere. This warming up tendency in the stratosphere is due to the absorption of solar ultra violet radiation by ozone. The concentration of ozone in this region is in the range

of 1 to 5 ppm by volume and this is responsible for negative lapse rate. The air in this region is very dry and the clouds and convection currents from the lower troposphere do not penetrate into this region. The stratosphere is quiet compared to turbulent troposphere. This is very significant from the view point of pollution. The presence of ozone in stratosphere is very vital, as it serves a protecting shield from the harmful effects of ultra violet rays coming from solar radiation. The life on earth is protected only by the presence of ozone in stratosphere. *Depletion of ozone would lead to harmful effect, as the ultra- violet rays could reach the earth easily.* Further, because of the quite nature of stratosphere, the molecules and particles in this have long residence time, being undisturbed. Any pollutant reaching this region would result in global hazard, as compared to their impact in the troposphere which is denser, turbulent and capable of more adjustments.

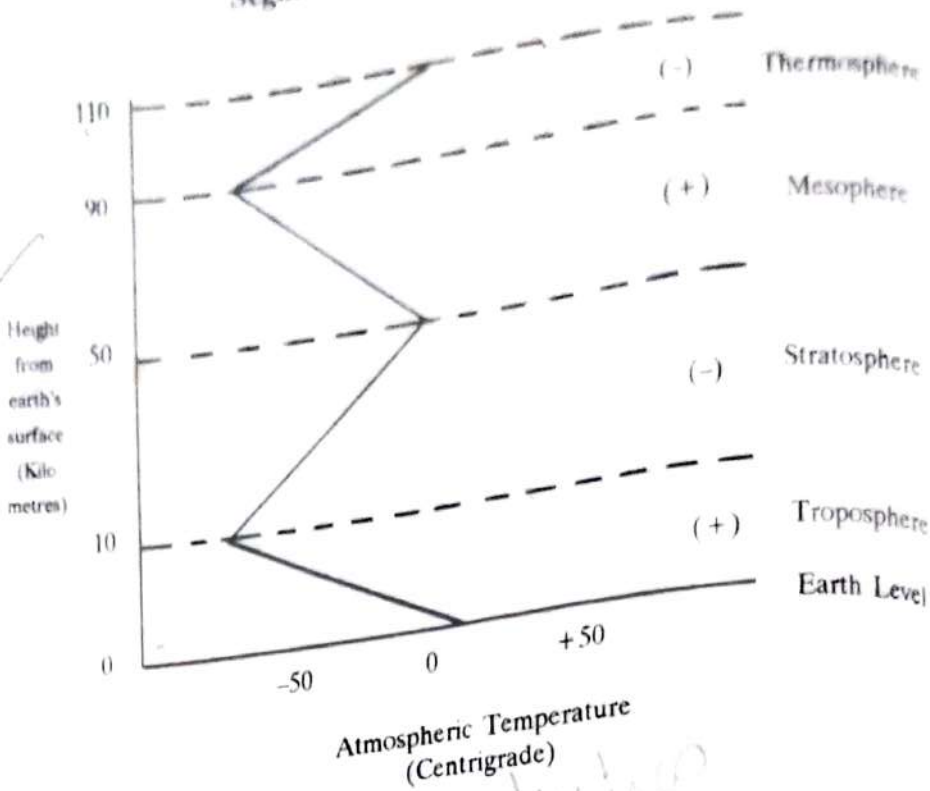
Mesosphere is above stratosphere and extends to a height of about 40 Kms from stratosphere. In this region, again temperature will have positive lapse rate, i.e., decreasing temperature with increasing altitude. This is due to low levels of ozone and other species that can absorb ultra-violet radiation from the sun. The fag end of mesosphere will have temperature about –92 degrees centigrade. Beyond this is a transitional layer called "Mesopauses" having minimum temperature in the atmosphere, i.e., –100 degree centigrade.

The regions beyond mesosphere, i.e., above mesospause is called *Thermosphere*, where again the temperature will have negative lapse rate, i.e., increasing with altitude. The maximum temperature in this region is about 1200 degrees centigrade with low pressure and low densities. Oxygen and nitric acid are present in this region and they absorb the solar radiations in the far ultra-violet region, and in this process they undergo ionisation. The region above the stratosphere in the altitude of 50 to 100 Kms is called "*Ionosphere*", as positive ions, e.g., O_2^+, O^+, NO^+ etc., and electrons exist at significant levels. These charged species persists for a long periods of time, without mutual neutralisation, due to the rarified conditions existing in the region.

From air pollution point of view, troposphere is of particular significance and from global warming point of view stratosphere is significant.

The **Figure** 12.1 roughly indicates the different segments of the atmosphere with altitude and temperature with lapse rate.

Fig. 12.1
Segments of atmospheric regions



What is air pollution ?

Air polfution is defined as "the presence in the outdoor atmosphere of one or more contaminants or combination thereof, in such quantities and of such duration as may be, or may tend to be injurious to human plant or animal life, or property, or which unreasonably interfere with the comfortable enjoyment of life, or property, or the conduct of business." (According to US Public Health Service)

The atmosphere readily absorbs various pollutants released through natural causes, as well as man-made causes and thereby acts as a big natural sink for the biosphere. Any excessive release of air pollutants in the atmosphere by anthrapogenic activities, disturb the dynamic equilibrium in the atmosphere and thereby affect man and his environment.

In all countries of the world, the magnitude of air pollution is increasing at an alarming rate due to increase in population, urbanisation, industrialisation and other comforts and luxuries of life in which automobiles have greater part. The pollutants travel through air and interact with substances available in the atmosphere before they reach a sink, such as an ocean or a human receptor. If the pollutants released are in greater volume and density, they enter into the

atmosphere at a faster rate and accumulate in the air too much before they are absorbed by the natural sinks; in other words, the quantum of release of pollutants is larger than what could be absorbed by the atmosphere without disturbing its equilibrium. Too much of accumulation i.e., too much of pollution would endanger the environment on earth and also the very life on earth. Further, the absorption of the pollutants in the atmosphere depends upon the meteorological conditions prevailing at a given time and place.

SOURCES OF AIR POLLUTION AND THEIR EFFECTS

There are different types of air pollutants. The classification depends on their origin, or chemical composition or the state of matter of the pollutants. According to origin, pollutants may be primary pollutants and secondary pollutants. The former type of pollutants are directly emitted into the atmosphere and are found as such. They are CO, NO_2, SO_2 and hydrocarbons etc. The latter types are derived from primary pollutants due to chemical or photo-chemical reactions in the atmosphere. Examples:- Ozone, Peroxy-acyl Nitrate (PAN), Photo-chemical Smog etc.

On the basis of chemical composition, pollutants may be classified as organic and inorganic pollutants. Examples of organic pollutants are alcohol, hydrocarbons, aldehydes etc. Under inorganic pollutants, we have carbon compounds, halogen compounds, oxidising agents, inorganic particles like fly ash, silica, asbestos, dust etc.

On the basis of state of matter, pollutants can be classified as gaseous pollutants and particulate pollutants. Gaseous pollutants get mixed with the air and do not normally settle out. (example: CO, NO_x, SO_2) Particulate pollutants are finely divided solids or liquids and often exist in colloidal state as aerosols. (Example: fumes, smoke, dust, mist, fog, smog and sprays)

The commonest source of air pollution are as follows:-

1. *Carbon monoxide* released from motor vehicles, engines powered with petroleum derivates used for transportation and heating.

2. *Hydrocarbons* mostly discharged by motor vehicles and also from exhausts of industrial plants.

3. *Nitrogen oxides* released by motor vehicles, power plants and industrial establishments.

4. *Sulphur oxides* released mostly by motor vehicles, power generating plants and industrial units.

5. *Particulate matter* coming out of power plants, industries an waste disposal.

6. *Natural pollutants* like pollen, volcanic gases, marsh gas etc

Pollution by automobiles

It is evident from the list of sources of air pollutants, automobi contribute major part of pollution. As a matter of fact, nearly 75 p cent of the entire global carbon monoxide emission comes from transp sector, out of which gasoline-fed internal combustion engines contrib nearly 60 per cent. The exhaust of automobiles and diesel-driven he vehicles contain many harmful gases and the problem of air pollut at ground level is very serious. In developed countries, the haza from automobile pollution were recogonised and adequate preven measures were taken to bring the pollution under control. Bu developing countries, this poses a serious problem. The main pollut are carbon monoxide, hydrocarbons, oxides of nitrogen and sulp acetic acid and particulates.

Pollution by motor vehicles is of three types. In the first p the emission of thick smoke from the exhaust of vehicles which poorly maintained. The emission of smoke with bad odour suffocation causes nuisance to all and it is also much irritating. Seco after the spread of this smoke, which is in large quantities during hour traffic, the residents nearby are worst affected and they from chronic heart and lung diseases. Thirdly, as the emission co large quantities of organic compounds and oxides of nitrogen, photo- chemical reactions take place which damage vegetation an impair visibility. Pollutants are exhausted from major parts automobile, viz., exhaust, crank case and fuel tank evaporative A poorly maintained engine in an automobile emits ten times pollutants than an ideally maintained one. Over speeding an loading also create air pollution. The smoke emitted from diesel are still more dangerous. The smoke contains semi-burnt and u hydrocarbons, some of which are proved carcinogens.

Coal Combustion

Another prominent source of air pollution is burning of industrial purposes. Coal is a complex heterogeneous containing both organic and inorganic elements. The im contained in coal can be divided into two categories; those form and those that contribute sulphur. Coal cleaning process it generate millions of tonnes of wastes. Since coal contains when it is burnt, SO_2 (Sulphur dioxide) will be produced.

nitrogen compounds and particulates. Nearly, 40 per cent of global pollution by sulphur oxides are due to combustion of fuels, coal-fired power stations, refineries, metallurgical operations and manufacture of sulphuric acid. Most of man-made sulphur oxide pollution is concentrated in urban and industrial areas. The pollutants released in the form of sulphur and nitrogen compounds with particulates are very injurious to agricultural crops and also human health. Green plants are very sensitive to acute exposure to sulphur dioxide than mammals. Upto 5 ppm of sulphur dioxide in the air will have little effect on animals; but it can inflict massive damage in many plants in the form of necrotic lesions on leaves, causing lesser productivity. Agricultural fields near coal-burning factories are bound to have productivity problems. Besides, sulphur dioxide creates many health problems like head-ache, chest congestion, irritation, vomiting etc. At times, it may prove fatal also by affecting respiratory system.

Industrial Emissions

Industries cause not only water pollution, but also air pollution by their activities. They discharge toxic gases, fumes, vapours and particulate matter into the air causing deterioration of the quality of air we breathe.

Fertilizer industries emit sulphur and nitrogen compounds, urea dust, fertilizer dust, smoke and flourides, besides ammonia and ammonium sulphate.

Thermal power stations discharge fly ash, sulphur and nitrogenous oxides, carbon monoxide, unburnt coal dust etc.

petroleum refineries and petrochemical industries release hydrocarbons SO_x, NO_x, carbon monoxide, aldehydes, particulate matter etc.

Iron and Steel Industries are responsible for the discharge of acid fumes, oil and solvent fumes SO_2, CO, NO_2 particulates etc.

Chemical industries release into the air, pollutants like hydrocarbons, CO, SO_x, NO_x, H_2S, mercury, acid fumes and particulates etc.

Cement dust is a common air pollutant discharged from cement industries. Besides, they discharge flyash, smoke, lime, SO_x, NO_x etc.

Paper industries pollute the air with H_2S and mercaptants.

Besides industries, aeroplanes in these days are polluting the atmosphere in a large way due to the gases emitted into the air. The

fuel in the aeroplanes on combustion produces SO_2 as pollutant in the upper part of the atmosphere which is turned into sulphuric acid. These are poisonous. The rain water containing these acids destroy the fertility of the soil.

From this, it is evident that man is the main culprit in polluting the air due to use of coal, petroleum, fossil materials in various industries and in the transport system. The main pollutants arising out of these activities are hydrocarbons, carbon monoxide, sulphur dioxide, carbon dioxide, hydrogen sulphide, oxides of nitrogen, chlorine, hydrogen flouride, oxidants, ammonia, hydrochloric acid, radioactive gases, arsenic, beryllium, boron, cadmium, chromium, lead, zinc, manganese, nickel,mercury, dust particles etc.

Carbon Monoxide

This is chemically symbolised as CO. The atmospheric air normally contains just 0.1 ppm of carbon monoxide. This gas is contributed to the atmosphere by natural process, such as, volcanic activity, electrical discharge in the atmosphere during storms and rains and seed germination etc. The presence of CO created by natural activity would not pose a harzard; but the excess of CO in the atmosphere caused by automobile exhausts, forest fires, agricultural burning, industrial operations, such as electric and blast furnaces in iron and steel industry, petroleum refining, gas manufacture and coal mining, paper industry etc., would pose threat to the environment and healthy living. The concentration of CO in city air on an average would amount to 55 ppm, as against the natural level of 0.1 ppm. Generally, micro organisms acts as a major sink for CO contained in the atmosphere nearby. It has been estimated that roughly 3 Kgs of soil sample could remove around 120 ppm of CO contained in the surrounding atmosphere in about three hours. But the problem in cities is that in places where there are large concentration of CO in the atmosphere, availability of soil would be least and the CO could not find a sink around them. The relationship between CO emission in cities in crowded localities and the availability of soil to act as natural sinks would be inverse.

Carbon monoxide reduces oxygen-carrying capacity of blood, so that less oxygen is available to body cells. Hence, larger concentration of CO in the air would prove fatal to human beings and animals; or at any rate create breathing trouble.

Oxides of Nitrogen

There are many possible oxides of nitrogen; but the main constituents of the atmosphere are Nitrous Oxide (N_2O); Nitric Oxide

(NO) and Nitrogen dioxide (NO_2). Nitrous oxide is called 'laughing' gas used as anesthetic in dentistry. Nitric oxide is obtained by oxidising ammonia in the making of nitric acid. Nitric oxide is a poisonous gas. The concentration in natural way of these gases would be: N_2O – 0.25 ppm and NO_2 – 0.5 to 4 ppm. But, from pollution point of view NO and NO_2 are significant and they are represented together as NO_x. Oxides of nitrogen are formed either by natural way or by artificial fixation of nitrogen from the atmosphere or from nitrogen compounds present in organic matter. As a source of pollutants, oxides of nitrogen are produced by the combustion of coal, oil, natural gas and organic matter. Thus NO_x is released into the atmosphere from automobile exhausts, coal based power plants, incinerators, furnace stacks and similar other sources. The NO_x released through industrial activity and man-made sources might be more than 50 to 100 times than created by natural sources. This is more in urban areas than in rural areas. The density of these pollutants vary with sunlight and traffic density at a given point of time and place.

Oxides of nitrogen in large quantities will create many respiratory diseases, bronchities, impairment of lungs, loss of appetite, corrosion of teeth and headache etc.

Sulphur Dioxide (SO_2)

Any material having sulphur as one of its contents, will release sulphur dioxide on burning, along with S_3. Hence this mixture is called S_x. Natural pollution of S_x may be due to volcanic activity. Nearly one-third of atmospheric SO_2 is the result of human activities like combustion of fuels, coal, coal-fired industries etc

Sulphur dioxide, as a pollutant would cause damage to respiratory system, chest congestion, aggravation of asthma, irritation of throat and eyes, suffocation and also death. We have already studied about the adverse effect of SO_2 in plants causing lesser productivity

Hydrocarbons

As indicated earlier, hydrocarbons are emitted into the atmosphere through automobile exhausts, burning of coal, oil and wood etc. The annual global emission of hydrocarbon by man-made activities is roughly estimated around 57×10^7 tonnes per year. Natural activities like decomposition of organic matter in water, soil and sediments by micro-organisms release Methane (CH_4) which is the major hydrocarbon and there are different types of hydrocarbons. Hydrocarbons emitted in heavy vehicular traffic zones include ethane, isopentane, isoputane, propane, ethylene, acetylene etc., and types of hydrocarbons identified

by vehicular exhaust emissions are nearly 20 in number. The hydrocarbons get oxidised in the atmosphere through chemical an photochemical reactors and give rise to many end products, such carbon dioxide (CO_2), organic particulates, water soluble acids an aldehydes which are washed down by rain, proving much harmful. Th hydrocarbons are responsible for the formation of "Photochemic Smog".

Hydrocarbons cause irritation in the eyes; in some cases, it m causes unconsciousness also.

Particulates

The expression 'Particulates' means the particles present in t atmosphere in the form of minute dust and soot. They are present aerosols. By 'aerosol' we mean the suspension of fine particles of liqu or solid substance, in pressurized air or gas, like mist, smok insecticides, disinfectant etc., sand and spray can contain su substances. Aerosols of natural origin are called "Aitkin" particl The natural particles existing in atmosphere include dust, smoke, f pollen grains, volcanic ash and bacteria. Dust, mist, smoke etc., m result from human activities. Inorganic particulates may also be pres (i.e., iron oxide, Calcium oxide etc) due to combustion of co metallurgical operations and automobile exhausts. Aerosol mists generated from oxidation of sulphur dioxide SO_2 to SO_3 which presence of water vapour forms drops of hydrochloric acid (H_2SO Organic particulates arise from combustion of fuels and evaporation organic matter from vegetation, besides automobile exhausts.

These *Particulates* have their natural part to play in the atmosph and they are essential for the following operations in the atmosph (1) They provide nuclei or act as carriers of water vapour by conden them. (2) They are responsible for formation of clouds and (3) They absorb gases in the atmosphere and create reactions by b catalysts. Example: the decomposition of ozone is possible onl dust. (4) They maintain the radiation balance and heat balance o earth. (5) Particulates help in the absorption capacity of the g For example, oxygen absorbed on carbon particles might absorb sun more strongly and effectively than what free oxygen would do wit carbon particles. (6) Particulates help several types of chemical reac in the atmosphere by means of oxidation, neutralization and similar activities.

Presence of particulates through natural process is not har on the other hand, very helpful, as stated above. It is stated that

2000 million tonnes of particulate matter are released into the atmosphere by natural agencies like wind and dust storms and volcanic eruptions. Man made activities, such as burning of coal, oil, gaseous fuels, wood, mining operations, forest fires and industrial emissions etc, cause release of about 450 million tonnes of particulates per year. In industrial and urban centres, it is estimated that there may be more than a lakh particulates per cubic centimeter. But actually the harmful effect of the particulates depend not on their number, but on their chemical properties, particularly toxic properties. For instance, *Polycyclic aromatic hydrocarbons* (PAH) are important constituents of several organic particulates which are cancer producing agents.

Particulates of certain sizes can penetrate through throat and lungs and can cause breathing problems. Pulmonary fibrosis, lung diseases, emphysema, eye irritations, cancer etc., are the results of pollution by particulates. Too much of particulates block visibility, causes corrosion of metals and damage to sculptures and paintings.

Apart from the sources of air pollutions above mentioned, there are many other sources. Hydrogen Sulphide, Chlorine, Hydrogen flouride, carbon dioxide, Ammonia, Formaldehyde, radioactive gases etc., beyond tolerant level may act as dangerous pollutants. Arsenic from pesticides, beryllium from nuclear industries, production of fluorescent lamps and motor fuels; boron from detergents; cadmium from nuclear fission plants, electroplating, welding and fertilizer industry; chromium from metallurgical, cement and asbestos units; lead, zinc, manganese, nickel mercury etc., are all sources of pollutants and the list is never-ending.

The damages caused by these pollutants to human beings are too much, besides havoc caused to vegetation, animals and environment.

Acid Rain

'Acid Rain' is a phenomenon associated with too much of air pollution with large scale emission of sulphur oxides and nitrogen oxides into the atmosphere by big industrial areas. Large quantities of SO_x and NO_x remain in the atmosphere for a long time and they are converted into H_2SO_4 (sulphuric acid) and HNO_3 (Nitric acid) by means of various chemical and photochemical reaction. Finally, they form into droplets of acid. However, these acid droplets are partly neutralised with bases like NH_3, particulate lime etc. The remaining acid droplets of H_2SO_4 and HNO_3 along with salts and HCL (Hydro chloric acid) released into the atmosphere by man-made and natural emissions give rise to acidic precipitation of rain, popularly known as

"*Acid Rain*". In simpler way this can be stated as *rain water being made too much acidic*, due to contribution of three acids, viz., H_2SO_4, HNO_3 and HCL. The contributions from these three would be in the order $H_2SO_4 > HNO_3 > HCL$. Longer the sulphur oxides and nitrogen oxides remain in the atmosphere due to too much of pollution, greater will be chances of their oxidation and conversion into hydrochloric acid and nitric acid. This will create greater opportunities for the rain water precipitation becoming more acidic.

In this context, it should be understood that rain water by itself even without pollution will be little acidic in its natural course of precipitation. This natural activity arises due to rain water interacting with atmospheric CO_2 (Carbondioxide) to produce carbonic acid. This small amount of acidity in rain water is essential to dissolve minerals on the earth's crust to make them available for plants and animals. This is nature's way to maintain ecological balance; and the natural acidity in rain water is not injurious in any way to the soil or to the plants.

But, excessive acidity in rain water, due to the presence of H_2SO_4, HNO_3 and HCL due to large pollution, would be very harmful, as it would make the soil very acidic, and also fresh water very acidic, and all water bodies very acidic which will be injurious.

Another important factor to be noted is that acid rainfall need not be in the place of pollution. It may occur even at a place far away from the region of pollution. It may be even 500 to 1000 Kms away from the source of pollutants. Instances of acid rainfall have been recorded in Canada and Sweden for which large scale emission of SO_x and NO_x had been traced to industrial areas of UK and USA.

Acid rains are harmful and the deleterious effects of acid rainfall can be summarised as follows:-

(i) Acid rain affects all water bodies and make them acidic. Lakes, tanks and other water bodies would lose much of their bicarbonate alkalinity in due course, due to over input of acid precipitation. In such cases, many crustaceans, i.e., aquatic arthopods having hard outer shell, like crabs, lobsters, shrimps etc., may die, as these animals would find it very difficult to mould their outer shells, i.e., exoskeletons due to lack of alkalinity in water.

(ii) Too much of acidity will result in releasing of heavy metals such as mercury and aluminium in water. Theses will in turn affect the animal life in water.

of fish, ... impact on the composition of planktons which are essential for survival of fish.

(iv) Acidification of the soil due to acid rain will have consequential effects on microbial and soil fauna and fixation of nitrogen.

(v) Acid rain will be injurious to the young plants in germination, as well as foliage development. This may lead to depletion of forest productivity.

(vi) Acidity will damage steel, zinc, oil-based paints, old monuments, as it will have corrosive effect. Architectural monuments like Taj Mahal, ancient sculptures carved out of marble, limestone, sandstone would deteriorate in quality.

(vii) Acidic water may prove harmful to human beings as well. Lungs, skin and hair will be much affected.

Acid rain would have its polluting effect in air, water and soil. Of course, the extent of damage depends on factors such as climate, topography, geology etc. The best way to reduce acid rain is to reduce emission of sulphur and nitrogen oxides. Extensive vegetation and forest will reduce the harmful effects of acid rain, as forest canopy modifies the chemical composition of the rain as it falls to the ground through its leaves and trunks. Rain water generally loses hydrogen ions at the leaf surface, especially at the more polluted sites. Trees greatly reduce the acidity of water passing through their crowns. This reduction takes place by using potassium and other base positive ions in the trees. The ground level vegetation beneath forest canopy also can further reduce acidity in rain water to some extent.

Photo chemical smog

Another type of air pollution, resulting from too much of emissions of hydrocarbons from automobile exhausts is called '*Photo chemical smog*'. The word 'smog' is the combination of two words, viz., 'smoke' and 'fog'. But, ordinary smog is different from photochemical smog; the former is coal-induced, while the latter induced by photo chemical reactions.

When the atmosphere is loaded with large quantities of hydrocarbons released from motor vehicles' exhausts, they involve in complicated chemical reactions amongst the various pollutants of the atmosphere in the intense sun light. These reactions result in the formation of certain free radicals of oxygen, hydrocarbons and nitrogen dioxide. Heavy concentration of nitrogen dioxide will impart its

brownish colour to the smog. The smog formation includes substances like peroxides, aldehydes, peroxy acids, sulphur trioxide and some metal particles. Further, photochemical smog contains mixtures of ozone, nitrogen dioxide and nitrates.

Photochemical smog is very injurious to health. It smells like rotten eggs due to the presence of hydrogen sulphide. It reduces visibility, causes irritation of lungs and eyes. It induces *asthma* and bronchial diseases. Photochemical smog is toxic to agricultural crops and forest trees.

Photochemical smog was observed in Los Angels and Denver in USA and this is generally referred to as "Los Angels Smog". Serious and heavy formation of smogs were reported in July 1970 in cities like Tokyo, Rome, Sydney and New York.

The only way to control the formation of photochemical smog is to control the emission of primary pollutants, viz., hydrocarbons and NO_x in the atmosphere.

Ozone Pollution

We studied earlier that the presence of ozone in stratosphere is very vital, as it serves a protecting shield from the harmful effects of ultra-violet rays coming from solar radiation. The life on earth is protected from harmful effects, as ultra-violet rays could not reach the earth due to protective cover of ozone layer. Evidently, any depletion of ozone would lead to harmful effects. Ozone is formed in the stratosphere by means of chemical reaction. But this ozone can be destroyed by *Chlorine* released into the atmosphere and also by reaction with nitric oxide and atomic oxygen and also reactive hydro radical which are also present in the atmosphere. Apart from this, has been discovered that ozone is also destroyed by man-ma chloroflouro carbons (CFCs) which are used in air-condition refrigerators, propellants in aerosol sprays etc. The chloroflouro carb compounds are used as coolants in many cooling and air- condition process. These CFCs may to some extent reduce the ozone cont of stratosphere layer and thereby permit the ultra- violet radia reaching the earth easily. Depletion of ozone in stratosphere consequent thinning out of ozone protective layer is called "*Ozone H*. This was detected over Antarctica in 1985 and this drew the atten of many scientists in the world. Scientists of US National Oceanic Atmospheric Administration collected data of ozone content from ne 60 places around the globe and found out that ozone shield has thin out by about 2 per cent over the USA and UK. USA immedia

banned the use of CFCs in spray cans. Further, in 1987, twenty-four nations of the world met and decided to reduce global production of CFCs by about 35 per cent before 2000 A.D. This agreement was signed in Montreal. Efforts are made to explore possibilities of finding substitutes which are chlorine free.

Depletion of ozone and the consequent ultra-violet radiation reaching the earth would spell doom to the living beings. This would result in increasing skin allergies and also cancer. It has been already reported that in South Australia, incidence of skin cancer has been on the increase due to depletion of ozone layer over that part of the earth.

Concentration of too much ozone in the atmosphere is also equally dangerous to human kind and vegetation. Ozone, chemically symbolised as O_3 is a pale blue gas with sweetish odour and unstable. It is very reactive oxidising agent capable of combining with any organic compounds in cells, tissues and also other materials like rubber. Ozone and photochemical oxidants such as peroxyacetyl nitrate (PAN) present in photochemical smog are very injurious.

Potentially phytoxic ozone concentration can occur in many rural areas. Both additive and synergistic effects can occur when ozone is superimposed over mixtures of SO_2 and NO_2. The characteristic symptom of ozone to plants is the appearance of necrotic spots on leaves. It may cause injury to paddy cultivation and reduce productivity.

High level exposure of O_3 would cause irritation of eyes, lungs and respiratory tracts of human beings. It would also create accumulation of fluids in lungs (Pulmonary Tuberculosis) and damage to lung capillaries.

Big cities such as London, Los Angels, Melbourne are experiencing considerable ozone pollution problems.

Thus ozone will be harmful in both ways; i.e., if it is too much or too little. The concentration of ozone should be just the required level to have its beneficial results.

EFFECTS OF DETERIORATING AIR QUALITY ON MAN AND HIS ENVIRONMENT

Presence of any type of pollutants will deteriorate the quality of air we breathe. The extent of deterioration of the quality of air depends on factors like the type of pollutants, the extent of their concentration in the air, their chemical properties and their chemical reactions with other type of climate and weather in the area and the extent of toxic qualities of the air prevailing.

Poor quality of air will affect not only human beings, but also animals, plants and the environment. Hence, we can study the ef of deteriorating quality of air, consequent on the presence of appre concentration of pollutants, under different headings, viz., effect human beings and their health; effects on animals; effects on p and vegetation; effects on materials and goods; and effects on clim

1. Effects on human beings and their health

Polluted air enters the human body mainly through respira system and pollutants in the air make their access into the throat, l and other parts of the respiratory organs. The extent of effect of pollutants depends on their concentration in the inhaled air, the dura of exposure and the capacity to resist by the human being, due to standard of health maintained by the individual. The first system would get impaired by polluted air is the respiratory system and person would have respiratory diseases like bronchitis, tubercul asthma, influenza etc. Toxic substances present in the air may find their access through skin, eyes and also the food consumed. organs affected and the dissease caused depend on the type of pollu that had gained entry into our internal system. Some diseases will h incubation period, during which symptoms of the disease would slowly exhibited, and by effectives medical treatment at the initial sta the disease could be nipped in the bud. But, in the case of cert pollutants, the toxic effect will be sudden and immediate without incubation period or threshold level. For example, inhaling carb monoxide would lead to sudden depletion of oxygen in the system. lack of life giving oxygen to the blood in the form of haemoglo would result in the death of the individual within a very short ti Asphyxiating pollutants like carbon monoxide, hydrogen sulphide e would result in instantaneous loss of life.

Carbon monoxide, sulphur dioxide, nitrogen oxide, ozone pollutants would cause respiratory diseases; and at times may pr fatal if the concentration is large.

Hydrogen sulphide, besides irritating the respiratory system m cause headache, conjunctivitis, sleeplessness, pain in the eyes and a damaging nerve tissues.

Ammonia (NH_3) as a pollutant would damage the respiratory trac and eyes and also corrosive to mucous membranes.

Dust particles of silica, asbestos would causse pulmonary fibros pleural calcification and lung cancer.

The Table 12.1 indicates the type of pollutants and the diseases they may cause, if the concentration exceeds beyond tolerance level.

TABLE 12.1

Air pollutants and their effects on human beings

Air Pollutants	Effects on human beings
1. Carbon Monoxide (CO)	Blood poisoning, useless for respiratory purposes; leads to death.
2. Sulphur dioxide (SO_2)	Suffocation, aggravation of asthma and bronchitis, irritation of throat & eyes.
3. Hydrogen Sulphide (H_2S)	Headache, conjunctivitis, respiratory trouble, blockage of oxygen, asphyxiation and death.
4. Chlorine (Cl_2)	Irritation of eyes, nose and throat, causes edema, i.e., accumulation of fluid in the body cavity.
5. Oxides of Nitrogen $(NO)_x$	Headache, respiratory trouble, bronchitis, edema of lungs, corrosion of teeth etc.
6. Hydrogen Fluoride (HF)	Respiratory diseases, fluorosis of bones, mottling of teeth
7. Hydrocarbons (HC)	Some hydrocarbons have carcinogenic effect
8. Ozone (O_3)	Irritation of lungs, eyes and respiratory system, Damage to lung capillaries
9. Ammonia (NH_3)	Corrosive to mucous membranes, damage to respiratory tracts and eyes
10. Dust particles	Respiratory diseases and lung cancer
11. Formaldehyde (HCHO)	Irritation in skin, eyes and respiratory tract.

Air Pollutants	Effects on human beings
12. Hydrochloric Acid (HCL)	Ulcer in respiratory tract, clouding of cornea etc.
13. Radioactive gases and dusts	Leukemia, cancer, cataracts, genetic effects; reduction in life expectancy
14. Beryllium (Be)	Damage to skin, pulmonary troubles, at times cancer
15. Boron (B)	Irritation, inflammation and death
16. Cadmium (Cd)	Kidney damage, gastric disorders, heart, liver and brain diseases; renal dysfunction, anemia, hypertension and cancer
17. Chromium (Cr)	Skin ulcers, perforation of nasal septum, toxic to body tissues
18. Lead (Pb)	Liver and kidney damages, gastro-intestinal damage, mental retardation in children, abnormalities in fertility & Pregnancy.
19. Zinc (Zn)	Corrosive effect on skin, damage to mucous membrane
20. Nickel (Ni)	Respiratory disorders, cancer of lungs and sinus
21. Vandium (V)	Gastro-intestinal disorder, heart diseases and also cancer
22. Mercury (Hg)	Protoplasmic poisoning, highly toxic, damage to brain and nervous system.

The Table 12.1 reveals that specific type of pollutants a exclusively certain organs of the body, like kidney, lungs, liver, b heart, eyes etc. Cases of air pollution disasters have been reco from many countries, even during times when pollution was not a ser problem. In October 1948, in the town of Donora, Pennsylvani temperature inversion trapped the pollutants from indust establishments and factories and caused major havoc. As many as

people fell sick and about 20 of them died due to this calamity. In London, a severe air pollution in 1952, lasted for five days, causing 4000 deaths.

Extensive researches in America have brought to light that increasing concentration of nitrogen dioxide and sulphur dioxide in the air are satistically correlated with increasing death rates from diseases associated with cancer, diabetes, heart diseases etc. Most of the gases are responsible for respiratory diseases. Added to these is the problem of pollution created by tobacco smoking.

Air pollution is responsible for many industrial disseases and this affects major part of the population, leading to larger absenteeism in establishments and also poor productivity by workers. This is more so in developing countries. In India, every alternate person will have some health problem; and a healthy man is an exception, due to poor quality of the air we breathe.

2. Effects on animals

Farm animals would be affected by means of pollutants in the air. The pollutants may gain entry through forage crops consumed by the livestock, as the air-borne contaminants accumulate in vegetation and fodder. Flourides, lead and arsenic pollutants are very injurious to livestock. Arsesnic would create salivation, thirst in farm animals, leading to liver necrosis, inflammation and the damage of the central nervous system. Dairy farms situated near industrial centres where arsenic pollutinon is prevelant, should exercises extraordinary caution, as the livestock would be affected very easily by this poison. Further, flourides also affect farm cattle in a variety of ways. Flourine toxity in farm animals would induce flurosis of teeth and bones. The milk yield of dairy animals would be conspicuously reduced. Continued exposure would lead to death of farm animals. In Florida, it had been reported that there was heavy cattle mortality by flouride emissions from factories processing phosphate for fertilizers. Lead is another dangerous pollutant which can harm horses and cattle. Lead contamination would create symptoms of loss of appetite, depression, gastritis, breathing trouble and paralysis. Farm animals near metallurgical smelters emitting lead poison are susceptible to these types of diseases, resulting in heavy toll of animals. In a country like India, where agriculture is the main source of national income, in which income from livestock is sizable, protecting the farm animals from possible dangers of air pollution requires greater

3. Effects on plants and vegetation

Air pollution could cause serious damage to plants and vegetation. It has been estimated the crop losses due to pollution exceed 150 million dollars annually in California. Extensive studies carried out in England in seventies revealed that there was significant reduction in the yield of such plants as lettuce, radish and flowering plants grown in highly polluted parts of industrial centres than villages away from such polluted centres. Sulphur dioxide, hydrogen flouride, particulate flourides, smog oxidants like ozone, chlorine, herbicides and weedicides sprays have toxic effect on vegetation. The damages can manifest in the form of visual injury, such as, yellowing, marking and banding of the leaves resulting in retardation of plant growth and final extinction. Pollutant particles settle down on the surface of the leaves and block the stomata pores, affecting production of chlorophyll in the leaves which will cause ultimate retardation of plant growth. Ozone at levels of 0.02 ppm can cause damages to tomato, bean, pine, tobacco etc. Flourides enter the leaves through stomata and take their courses through the water stream inside the plant and finally settle down on the leaf margin forming necrosis at the edge of leaf. Flourides affect rose plants and pine.

Plants in polluted environment exhibit symptoms of injury, general debility and also premature ageing. Trees growing near thermal power stations, steel factories and smelters and also brick kilns exhibit symptoms of necrosis of leaves, defoliation of young terminal branches, hardening of floral buds, necrosis of fruit tips and also reduction in the size of the fruit. These effects are mainly due to sulphur dioxide and other pollutants in the atmosphere near the above mentioned industrial spots. Nitrogen oxides also cause defoliation, chlorosis, necrotic spots and general retardation of growth. Generally, plants are not much affected by carbon monoxide, as human beings and animals. However, high concentration of carbon monoxide results in leaf curling, ageing and reduction in the size.

We studied already under 'ozone pollution', how ozone pollution is injurious to plants. Ozone toxicity results in the appearance of necrotic spots on leaves. It has been found out there exists a definite correlation between the extent of leaf damage and the duration of exposure of plants to ozone levels exceeding 4 p.p.h.m. Many big cities of the world like Los Angels, London, Melbourne etc., have considerable ozone pollution problems.

The effects of air pollution is not only confined to plants and vegetation of higher order, but also of lower order. Considerable research work had been done to find out the effect of air pollutants

on Lichens and Bryophytes. Lichens are of lower order of plants in the vegetative kingdom. They are flowerless plants formed by the composition of fungi growing in symbiosis with certain algae. Bryophytes are also one of the main groups of the vegetable kingdom. In ordinary language, we call these lower order of plants as mosses and liverworts which will be found on trees, stones and also on walls in the form of green patches, due to humidity and dampness.

Lichens are slow-growing, but long-lived organisms with a special ability to accumulate toxic substances from their environment. They are much susceptible to many pollutants present in the air or pollutants brought down in the rain. Bryophytes also are delicate plant body capable of absorbing and accumulating polluting substances from the environment like lichens. These plant bodies act as sinks for heavy metals. In fact, these lower plants possess physical characteristics which make them ideal monitors of air quality. They are considered as tools and indicators of pollution. Lichens are very sensitive to every kind of pollution; more so the pollutants like flourides, heavy metals etc., in noxious gases. Research studies in England had revealed that due to increasing industrial pollution in big cities, many lichen species had been exterminated. The extent of SO_2 pollution can be found out by noting the species of lichens in the locality. Larger the kinds of species indicates lesser pollution by SO_2. In some regions of England, where there were about 120 recorded species of lichens, a century ago, have now only 30 species; the rest destroyed by increasing SO_2 pollution. These regions are called "Lichen Desserts". Lichens of a particular variety did not occur on sand-stone walls of England when the annual average concentration of SO_2 exceeded beyond some limits.

Similarly, pollutants of the air affect aquatic species, as well, when those pollutants are brought down to the seas by means of rain.

4. Effects on materials and goods

Almost all materials of utility, comfort and luxury are susceptible to deterioration in their qualities, due to air pollution. The extent of damage on different materials and goods of our every day use depends on the type of materials, the nature of pollutants in the air together with the humidity prevailing and also temperature and movement of air. The degree of concentration of the pollutants accelerate the damage.

Textile goods, leather, paper, rubber, glass, enamels, surface coatings etc., would be affected by pollutants. The damages will be in the form of either corrosion, abrasion and also deposition, making physical or chemical changes on the surface of the goods and materials, and thereby make them lose their luster, brightness, smoothness and

also texture. Sulphur dioxide with high concentration would react o building materials, metals textile goods, paper and paints, resulting surface erosion, corrosion, discolouration etc. Ozone can react o rubber materials, particularly tyres and tubes of vehicles by creatin cracks in them and thereby reducing their life. Paper will becom brittle, if SO_2 and other acids are present in the air.

The Table 12.2 indicate the different types of pollutants that coul damage the materials and the nature of damages.

Table 12.2
Air Pollution on materials and goods

Main pollutants present in the air	Materials affected	Type of Damage	Other factors influencing the rate of attack
SO_x and other acids	Metals	Corrosion, Soiling & Tarnishing	Moisture, Salt Temperature
SO_x, NO_2 and acid gases, particulates	Textiles	Soiling, reduced texture, spotting etc.	Moisture & Sunlight
SO_2, H_2S, O_3 and sticky particulates	Paints	Discoloration and surface erosion	Moisture, sunlight, fungus & micro organisms
HF, acid gases	Ceramics	Change in surface appearance	Moisture
Ozone, Oxidants	Rubber	Cracking and Weakening	Sun light
SO_x, other acid gases	Building materials	Corrosion, leaching and dis-coloration	Moisture Temperature
SO_x, other acid gases	Leather	powdered surface	physical ware
	Paper	Embrittlement	Moisture, sunlight

5. Pollution of Historical Monuments

Atmospheric pollutants may cause great damage to historical monuments like statues, memorial buildings, temples, churches and tombs of architectural excellence etc. Many of these monuments have withstood the ravages of nature for centuries. Monuments in the midst of pollution free atmosphere with dry climate may stand for ages without any damage. Atmospheric humidity and presence of gases like SO_2 and other pollutants would have deleterious effects on the monuments.

The problem of deteriorating Taj Mahal in Agra is well known. The Oil Refinery in Mathura, some 65 Km from Agra, poses a threat to the beauty and brilliance of this "wonder of the world". The obnoxious gases and corrosive fumes and pollutants discharged from Mathura Oil Refinery are supposed to be attacking the marble surface of Taj Mahal, and the monument is said to be losing its lusture. Though the expert committee appointed by the government of India on 'Environmental Impact of Mathura Refinery' expressed that the refinery may not pose a serious problem or threat to the Taj Mahal, scientists have expressed their doubts about it. They fear that not only Taj Mahal, but also other monuments would be seriously affected by the pollutants discharged from the refinery; and a day would come, when more money will have to be spent on protecting the Taj Mahal, than what Shah Jehan had spent to build the monument. The National Environment Engineering Research Institute (NEERI), Nagpur revealed that SO_2 emission from refineries could certainly affect, not only Taj Mahal built of marble, but also Red Fort and the tomb at Fatehpur Sikri, built out of sandstone. It is feared that ancient temples at Mathura and the bird santury near Bharatpur might be affected sooner or later.

Similarly, the famous Humayun's tomb in Nizamuddin (Delhi) is said to be affected by the obnoxious fumes and pollutants discharged from the Indraprastha Power Plant.

Many ancient monuments had been disfigured due to the harm inflicted by industrialisation and man-made pollution. The marble temples of Acropolis in Athens (Greece), the world famous Madonna in Milan's Cathedral (Italy), and the Lincon Memorial in USA and Stephen's Cathedral in Vienna and also Notre Dame de Paris have become victims of pollution and they exhibit various degrees of corrosion, spoilage, disfigurement and discolouration.

6. Effects of pollutants on climate and weather

Air pollutants (aerosols) are capable of effecting notable changes in cloud formation, temperature of the atmosphere and precipitation

of rain. Depending on the local and regional conditions, these coul change the climatic conditions prevailing.

The darkening of the sky may be caused by thick smoke, du storms or fog and thereby reduce the visibility due to the particulat contained in the industrial fumes. The intensity of these effects depen upon the size of the particles, aerosol density, angle of the sun, thickne of the affected air mass, humidity in the atmosphere and wind spee

The weather conditions in a region depends on the dispersions pollutants in the air. It is a well-known fact that emissions from ma industrial units in urban areas, combined with thick population lea to increase in the temperature of the region, than the temperature the nearby rural areas. This increase in temperature plays a vital ro in the dispersion of pollutants in big cities. Apart from the he produced in industrial emissions, the main source of increas temperature is from buildings made of concrete and asphalt in citi These 'concrete jungles' in cities which are responsible for the wa prevailing, tend to store heat better than soil or vegetation. The thi source of heat is the warm air arising from combustion processes a use of air conditioners.

Aerosols of sulphuric acid, ammonium sulphate and other vapo can influence the temperature of the atmosphere by mixing a dispersion and the build up of aerosols. Automobile emissions a also discharge from steel mills could cause "Ice Nuclei" which is a ty of particle. These occur in atmosphere in low concentrations and th are responsible for modifying the cloud structures at sub-z temperatures. At times, the effect of ice nuclei are so severe that precipitation potential of such cold clouds may also become alter Another type of particles called *Cloud Condensation Nuclei* (CC resulting from forest fires and paper mills are capable of modify precipitation from clouds that have temperatures above zero centigra

Some air pollutants are capable of coating cloud particles thereby influence cloud and aerosol coagulation and evaporation. Ot air pollutants like acid fumes, ammonia and SO_2 can affect the P rain water; and some other chemicals can interact in the atmosph resulting in an amplification of their effects. For instance SO_2 NH_3 by themselves react slowly in the atmosphere. But, their react is accelerated considerably in the presence of cloud droplets. So other air pollutants affect aerosols involved in cloud processes cause change in structure and distribution of clouds. The net re would be change in the pattern of precipitation of rain. Already, have studied about the precipitation of "Acid Rain" due to SO_x

deaths. Nearly 2,00,000 people of Bhopal were affected and of which some 50,000 had been seriously affected and many had gone blind.

Apart from these massive causualities, children born to women who were pregnant, had either died or had deformities. It has been estimated that every 3 children born, only one survived and out of 1350 new born babies, 16 were physically deformed and 60 premature births. Deformities include children suffering from coginital hearts, holes in arms and impaired eyesight. High levels of thiocyanates were detected in water in Bhopal and continued exposure caused malfunctioning of organs, particularly thyroid glands which in turn affect pregnancy.

The vegetation in an area of 3.5 sq.Km around the Union Carbide factory was severely affected. Cultivated plants and fruits were much affected than wild plants; and plants submerged in water were less affected. Consumption of fruits like Mango, Papaya and tamarind was avoided by the people, as these plants were much affected by the pollution. The immediate cause of death for many people was due to formation of fluid in their lungs due to pollution of the air due to MIC leakage.

AIR QUALITY CONTROL

It is imperative on the part of Governments to ensure air quality by properly undertaking air pollution control programmes by means of effective legislation and implementation. Certain minimum standards of air quality should be prescribed. The air quality standards indicate the level of pollutants present in the air and which cannot exceed during a specific period, in a specified geographical area, beyond certain limits. Just as 'Sanitary Standards' and 'Hygienic Standards' by which the individual's health is protected and his physical and mental capacities are maintained, the air quality should also be ensured by prescribing certain standards.

Air Monitoring

The first step in prescribing ambient air quality standards is to collect base-line data about industrial pollution in big cities and towns and assess the extent of pollution, the causes of pollution and also the probable ways and means of preventing or reducing such pollutions. This can be done only by means of scientific *"air monitoring methods"*. This requires collection of atmospheric sampling, measurement of pollution and base- line information and control data suitable for source detection and trend evaluation. Collecting techniques should be varied between gaseous pollutants and particulates. Air monitoring should have both 'Physio-chemical' monitoring and 'Biological' monitoring along

with fumigation studies with selected plants and pollutants; the capacity of leaves, bark; concentration of chlorophyll etc. Both physio-chemical monitoring and biological monitoring should be effectively integrated to have correlations of physical-chemical monitoring and biological monitoring. There are different methods and techniques for "air monitoring". Filtration techniques, Gravity techniques, Precipitation techniques are used in "particulate" air pollutants. In the case of *gaseous pollutants*, absorption, adsorption, cold-trapping methods can be adopted. In addition to base-level data, continuous monitoring should be done for gases such as CO, SO_2, NO_x etc. Concentration of particulates should also be monitored at regular intervals.

The World Health Organisation in 1973 established a global programme of air quality monitoring to help countries use the data collected to protect human health and promote exchange of information. Some 50 countries participated in the project, gathering data on SO_2 and suspended particulate matter (SPM) from 175 locations in 75 cities. The project also studied wide range of aspects, such as population distribution, industrial development, topography and climatology.

The National Environmental Engineering Research Institute (NEERI), Nagpur, initiated the air quality monitoring programme in 1978 in 10 cities in India. This was the first organised effort to record comparable, continuous and concurrent data on gaseous and particulate pollutant levels in ambient air. It provides data to study the air quality trends on a long-term basis. The test rules were selected according to the Global Environmental Monitoring norms, representing three activity zones, viz., Industrial zone, Commercial zone; and Residential zone. Five pollutants as index parameters were chosen which, besides helping in establishing the trends of the pollution problem in three major activity zones to urban centres, also defined the problems and highlighted the major contribution sources at the urban centre. Subsequently, the scope of studies was enlarged to include air quality monitoring index pollution of SO_2, NO_2, H_2S, Mercaptane, NH_3, F and SPM.

An analysis of about 11 year data revealed that annual mean values of the SPM indicated *positive trend* in Bombay, Cochin and Jaipur; SO_2 levels also showed a positive trend in Cochin, Delhi and Nagpur; NO_2 levels showed a positive trend in Bombay, Cochin, Calcutta, Delhi, Hyderabad, Kanpur and Nagpur. Cochin appears to indicate increasing trends with respect to all pollutants. Delhi and Nagpur showed increased trends with respect to gaseous pollutants. Increased trend of NO_x levels indicated higher levels of automobile pollution.

Identification of sources

The second step in air quality control is to identify exact sour of pollution. This is rather difficult in the case of air pollution. Whereas in the case of water pollution, the sources can be easily identified, the dispersion of polluted water could be traced. On the other hand in the case of air pollution, the topography and meteorological conditio would make the dispersion of polluted air to the length and breadth of the region or beyond that and it would be very difficult to identify a particular source or sources. Knowledge of topography, the science of meterology, the nature of dispersion of air is essential to find out the source of pollution. The pollutants are emitted either by "mobile" sources or by "stationary" sources. Motor cars, trucks, powered two wheelers, railway engines and the plethora of transport traffic, come under the category of mobile sources of air pollution. Under stationary sources, we have all the industrial units, factories, processing centres and power plants, besides commercial and residential complex in urban areas.

Control of pollution

The third step in air quality control is reduction of pollutants in the air by means of adopting efficient and modern technology. These control measures should be incorporated through appropriate legal methods, prescribing pollution control measures at the unit level in the case of 'stationary' sources and at the individual vehicle level in the case of 'mobile' sources. Minimum standards of air-quality should be prescribed. Effective monitoring of air should be undertaken periodically to ensure air quality. Enforcement of air pollution control measures should be done irrespective of the sector in which the limit is functioning. Generally in our country, the standards and implementation of laws prescribed are enforced strictly in private sector units, whereas the government would be lukewarm in the case of public sector units. Glaring differences can be seen between the emission of heavily polluted smoke from public transport vehicles, maintained under public sector, as against private sector.

There are various procedures available to control air pollution, depending on the technology used. The first step in this is to *contain* the pollution to maximum extent possible by adopting appropriate engineering technology, so that the release of toxic substances from the exhausts and chimneys is considerably reduced. The second process is to *replace or substitute* old technology with new technologies by which there will be reduction of pollution. The third process is to have

the released pollutants ineffective by means of dilution or self- cleansing, so that the concentration effects of pollution would be reduced. Thus, the procedures of pollution control is a three-pronged drive, at the technological level, unit level and at the environmental level. All these procedures haves to be effectively coordinated by means of legal policies and implementation of the laws relating to the pollution control.

Let us discuss air pollution control procedures above indicated in a detailed manner with reference to 'mobile' units and then 'stationary units'.

I. Pollution control in automobiles

In our country, the type of automobiles are two-wheelers, three-wheelers, powered vehicles with two-stroke and four-stroke petrol engines and diesal engine trucks and buses, besides diesel engine units of the railways. In recent years, there had been spectacular increase in the number of these vehicles and also the extent of pollution caused by theses in almost all cities, towns and semi-urban areas. The extent of pollution from an automobile unit depends on the engine design, the type of the fuel used, the extent of fuel consumption and also the operational efficiency of the engine. Considerable amount of research work is going on in the modification of engine designs to make them more efficient to minimise emission of pollutants during combustion of gasoline. Similarly, fuel substitutes for gasoline would reduce concentration of pollutants. It is found that methane, natural gas, reformed gasoline, blends of light hydrocarbons etc., could reduce noxious pollutants in the exhaust gases. Some fuel additives, such as barium salts have been reported to give excellent results in reducing pollutants. Modification of existing fuels or introducing substitute fuels could be done after elaborate research and field trials about the toxicological contents of the exhaust fumes.

It is estimated that in India, an average evaporative emissions of hydrocarbons from a passenger car is around 20 Kg per year and many methods are tried to control the evaporative emission. In Japan, "Stratified Charge Engines" are developed. These engines are provided with an additional chamber for combustion, where a fuel-rich mixture is introduced and ignited with spark. This sets in combustion at a relatively low temperature and as a consequence, the formation of NO_x is greatly minimised. Then the burning mixture is allowed to enter the large main chamber, where it gets mixed lean-fuel mixture, i.e., air-fuel mixture with higher percentage of air and lesser percentage of fuel. This ensures complete combustion of CO and hydrocarbons without

stopping the engine and at the same time NO_x build up is limited due to lower temperature maintained in the chamber.

II. Pollution control in stationary units

In establishing a factory or an industrial unit, due assessment should be done about the probable extent of pollutants that would be discharged. If it is not conducive for the health of the air and environment, starting of factories or industrial plants should be totally prohibited in that region. This decision has to be arrived at after carefully examining the meteorological conditions, humidity of the atmosphere and the type of environment.

The industrial units should be equipped with all modern devices to control gaseous pollutants and also particulate emissions.

In the control of *gaseous pollutants*, the following methods and equipment should be ensured in the industrial units: (i) *Combustion*: Good combustion should be ensured by having well-equipped combustion chamber with adequate supply of oxygen to eliminate dark smoke with half-burnt and unburnt dust and ashes. (ii) *Absorption*: In this process, the gaseous effluents are passed through absorbers or scrubbers containing the suitable liquid to act as absorbent to remove or modify the pollutants present in the gas stream. The equipment used for this purpose may be of different kinds, viz., Spray Towers, Plate Towers, Packed Towers, Liquid Jet Scrubber Towers etc. The various absorbing liquids used are : water, alkaline water, sulphites of calcium, Sodium or Barium etc., for absorbing SO_2. For absorbing H_2S, soda ash, ammonia liquor, sodium alamine, tripotassium phosphate etc., should be used. For NO_x, water or NHO_3 could be used. (iii) *Adsorption*: In this, the gaseous effluents are passed through suitable porous solid adsorbents in containers. Through interface between the effluent and the containers with chemical materials, the pollutants would get absorbed. Iron oxide for instance is used for absorbing H_2S. Limestone pellets of NaF are used to absorb hydrogen flouride. Silica gel, activated alumina and synthetic zeolite could absorb water vapour from a mixture of water vapour and organic pollutants. Pulverised limestone or dolomite, alkalised alumina are used to absorb SO_2. Petroleum fractions could be absorbed through bauxite.

Not only this, the emission of waste gases could be altogether prevented by reusing them in the factory. If the waste gas contains higher concentrations of SO_2, or NO_x, the gases could be recovered and used for the manufacture of H_2SO_4 and HNO_3. Industrial chemistry

would be much useful in controlling the pollution through appropriate absorbents and adsorbents.

In the case of particulate materials discharging and polluting, *mechanical devices* can be used. These devices depend upon the size, shape, electrical properties of the particulates. These mechanical devices work on the principle of gravity setting in which the velocity of the gas is reduced, passing through a horizontal carrier and in the process, the particles settle down by gravitational force. Another method is to suddenly change the direction of the gas flow which causes the particles to separate out due to their greater momentum.

The most commonly used mechanical devices are buffer chambers, Settling Chambers, and Cyclone Separators. In *Cyclone Separators*, the mechanical device consists of a cylinder with a tangential inlet for gas entry and a vortex by which the suspended particles are collected and periodically removed. There are wet cyclone collectors as well, for the removal of dissolved particulate matter; and in some plants, these collectors would be arranged in a series where 2 or 3 collectors would work, which facilitate removing particles of different size. By this method, nearly 90 per cent of particulate matter could be removed.

Besides above mentioned mechanical devices there are other methods called (a) Filtration system (b) Electrostatic Precipitators; and (c) Wet Scrubbers.

In the *Filtration system*, the particles are trapped in cloth-bag filters or in fabric filter media made from cotton, wool, nylon, asbestos, silicon coated glass cloth etc., depending on the nature and temperature of the particulates.

Electrostatic precipitators contain two electrodes which are insulated and electrically charged with differing potential. When the dust fumes are passed through this, the aerosol particles get precipitated on the electrode with lower potential. This method will be very effective in the case of particles that could be electrically charged and this method is the best for carbons. Electrostatic precipitators can be used singly or in series or an additional equipment, besides cyclone collectors, so that when the gas reaches the chimney stacks, it will be almost pollution free, due to successive treatments. Electrostatic method will cost less, if the volume of gas to be handled happens to be very large.

Wet scrubbers are also very effective devices, particularly when the temperature of the gases to be treated is as high as 300 degree centigrade or more; when the gases happen to be combustible and cooling is desired and addition of water is not objectionable. Scrubbers are

screens of water spray to remove large particles. Wet scrubbers a classified on the basis of the methods used in collecting particles. The are Liquid Carriage type and Particle Conditioning type. In the form method, the gas is allowed to strike a liquid surface within the collect and the liquid carrying the trapped gas particles are discharged in outside collector, from where they are disposed off. In the latt method, the dust particles in the gas stream are brought into intima contact with water and the size of the particles would be enlarged d to water-particulate agglomerates. These can be more easily remove Besides, there are many other varieties of scrubbers called Gravity Spra Scrubber, Wet Centrifugal Scrubber, Impinger Scrubber etc.

Thus, there are various methods of reducing pollution and keepi the air clean. In all methods and programmes of air pollution contr care should be taken to see that they do not aggravate water pollutio or solid waste pollution problems.

In USA, the *Clean Air Act of 1970* authorised Environment Protection Agency (EPA) to prescribe and promote National Ambie Air Quality Standards. The Clean Air Acts regulated five pollutant called "Criteria Pollutants"; and in the year 1978, the list was increase by one more, i.e., Lead to make it six. Besides six "Criteria Pollutants the Act regulated eight as "hazardous" air pollutants. According to EP the list of "Criteria Pollutants" and "hazardous" pollutants and healt effects are given in the table 12.4.

Table 12.4
Health Effects of Regulated Pollutants

Pollutants	Health Concerns
Criteria Pollutants:	
1. Ozone	Respiratory tract problems, Asthma, nasal congestion, premature ageing of lung tissue
2. Particulate Matter	Eye and throat irritation, bronchitis, impaired vision and lung damage
3. Carbon Monoxide	Impaired ability of blood to carry oxygen
4. Sulfur dioxide	Respiratory tract problems, permanent harm to lung tissues

Pollutants	Health Concerns
5. Lead	Retardation and brain damage, especially in children
6. Nitrogen Dioxide	Respiratory illness & Lung damage
Hazardous Air Pollutants	
1. Asbestos	A variety of lung diseases, particularly lung cancer
2. Beryllium	Primary lung diseases, effects on liver, spleen, kidneys and lymph glands
3. Mercury	Effects on several areas of the brain, as well as kidneys and bowels
4. Vinyl Chloride	Lung and liver cancer
5. Arsenic	Cancer
6. Radionuclides	Cancer
7. Benzene	Leukemia
8. Coke oven emission	Respiratory cancer

(Source: "Environmental Progress and Challenges" - Environmental Protection Agency, 1988)

The EPA has established National Ambient Air Quality Standards for each of the six criteria pollutants. Consequent on the strict enforcement of air quality regulations and also the obedience of communities which do not violate the quality standard, there has been considerable decrease in pollution and the quality standard, there has been considerable decrease in pollution and the quality of ambient air has significantly increased during the last 20 years in USA. As per EPA's report, there were considerable reductions in carbon monoxide emissions and nitrogen oxides. But the most significant achievement has been a sharp decrease in air borne lead from a national emission of 23,000 tons annually in 1985 to 9,500 tons in 1986, a 59 per cent decrease achieved largely by continuing reductions in the lead content of gasoline. However, in the cases of other pollutants, most of the urban areas are yet to reach the ambient air quality standards. This

is more so in the case of ozone pollution. According to EPA, 96 cities countries, and other areas of urban settlement failed to meet federal ozone standards (1988) and more than 150 million Americans live in geographical areas that exceed the minimum safe levels of ozone exposure.

Japan, UK and other countries also haves enacted appropriate Air Pollution legislation to ensure Ambient Air Quality.

In India also, the constitution provides for protection of environment through the 42nd Amendment in 1976. There are umpteen Acts to control pollution. We shall study about these in detail in a separate chapter. It is not the number of legal provisions that are important, but the ability of the government to enforce the legislation effectively to realise the objectives of the Acts and also the character of citizens and their civic sense.

INDOOR AIR POLLUTION

The air can be polluted not only outside and it can be polluted inside the houses; afterall the air coming into the house is only a fragment of the polluted air outside. In addition to the pollution created outside, the indoor air in houses and buildings can also be polluted with many types of materials and activities inside the houses. For instance, smoking insides the houses will pollute the indoor air with formaldehyde, nicotine etc. The furnishing material used in the rooms will also cause formaldehyde pollution. Building construction material, concrete and stone will create 'Radon' pollution. According to Spengler and Sexton, the indoor pollutants and emission sources are as follows:

Table 12.5
Indoor Pollutants and their Sources

Pollutants	Emission Sources
Asbestos	Insulation, fire retardant materials
NH_3	Cleaning Products; Metabolic Activity
Mercury	Paints, fungicides
Hydrocarbons, nicotine	Smoking tobacco
Allergens	House dust, insects, mites, fungi etc.