CHAPTER 4

Environmental Pollution and Control

4.1 INTRODUCTION

For normal and healthy living a conducive environment is required by all living beings, including humans, livestock, plants, micro-organisms and the wildlife. The favourable unpolluted environment has a specific composition. When this composition gets changed by addition of harmful substances, the environment is called polluted environment and the substances polluting it are called pollutants. **Environmental pollution can, therefore, be defined as any undesirable change in the physical, chemical or biological characteristics of any component of the environment (air, water, soil), which can cause harmful effects on various forms of life or property.** Environmental pollution could be of the following types:

(*i*) Air pollution and Noise pollution
(*ii*) Water pollution
(*iii*) Soil or Land pollution
(*iv*) Thermal pollution
(*v*) Nuclear pollution

The pollutants which cause environmental pollution can be chemical, physical or biological in nature. There is a variety of chemical pollutants in the environment. These may include gases and particulate matter, toxic metals, agrochemicals (pesticides and fertilizers), toxic and hazardous chemicals, etc. The physical pollutants include, odours, heat, sound waves, radiations, radioactive substances while the biological pollutants may be pathogenic organisms, pollen grains, etc. The causes, effects and control technologies are given in details in the relevant category of environmental pollution.

4.2 AIR POLLUTION

It is an atmospheric condition in which certain substances (including the normal constituents in excess) are present in concentrations which can cause undesirable effects on man and his environment. These substances include gases, particulate matter, radioactive substances etc.

Gaseous pollutants include oxides of sulphur (mostly SO_2, SO_3) oxides of nitrogen (mostly NO and NO_2 or NO_x), carbon monoxide (CO), volatile organic compounds (mostly hydrocarbons) etc. Particulate pollutants include smoke, dust, soot, fumes, aerosols, liquid droplets, pollen grains etc.

Radioactive pollutants include radon-222, iodine-131, strontium-90, plutonium-239 etc.

4.2.1 CLASSIFICATION OF AIR POLLUTANTS: PRIMARY AND SECONDARY POLLUTANTS

Air pollutants may occur in gaseous or particulate form and may be organic or inorganic in nature. On the basis of origin of pollutants, these can be classified as primary or secondary pollutants.

(*a*) **Primary pollutants:** These are emitted directly from the point source (identifiable source) *e.g.* carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), hydrocarbons, radioactive substances etc.

(*b*) **Secondary pollutants:** These are formed by interaction of primary pollutant(s) with other primary pollutant(s) or with some natural constituents of atmosphere, *e.g.* ozone (O_3), peroxyacetyl nitrate (PAN), Photochemical smog etc.

HC + NO_2

4.2.2 CAUSES/SOURCES OF AIR POLLUTANTS

The sources of air pollution are natural and man-made (anthropogenic).

(*a*) **Natural sources:** The natural sources of air pollution are volcanic eruptions, forest fires, sea salt sprays, biological decay, photochemical oxidation of terpenes, marshes, extra terrestrial bodies, pollen grains of flowers, spores etc. Radioactive minerals present in the earth crust are the sources of radioactivity in the atmosphere.

(*b*) **Man-made:** Man-made sources include thermal power plants, industrial units, vehicular emissions, fossil fuel burning, agricultural activities etc. Thermal power plants have become the major sources for generating electricity in India as the nuclear power plants couldn't be

installed as planned. The main pollutants emitted are fly ash and SO_2. Metallurgical plants also consume coal and produce similar pollutants. Fertilizer plants, smelters, textile mills, tanneries, refineries, chemical industries, paper and pulp mills are other sources of air pollution.

4.2.3 EFFECTS OF AIR POLLUTION

Air pollution has adverse effects on living organisms and materials.

(a) Effects on human health: Human respiratory system has a number of mechanisms for protection from air pollution. Bigger particles (> 10 μm) can be trapped by the hairs and sticky mucus in the lining of the nose. Smaller particles can reach tracheobronchial system and there get trapped in mucus. They are sent back to throat by beating of hair like cilia (Fig. 4.1) from where they can be removed by spitting or swallowing. Years of exposure to air pollutants (including cigarette smoke) adversely affect these natural defenses and can result in lung cancer, asthma, chronic bronchitis and emphysema (damage to air sacs leading to loss of lung elasticity and acute shortness of breath). Suspended particulates can cause damage to lung tissues and diseases like asthma, bronchitis and cancer especially when they bring with them cancer causing or toxic pollutants attached on their surface. Sulphur dioxide (SO_2) causes constriction of respiratory passage and can cause bronchitis like conditions. In the presence of suspended particulates, SO_2 can form acid sulphate particles, which can go deep into the lungs and affect them severely.

Oxides of nitrogen especially NO_2 can irritate the lungs and cause conditions like chronic bronchitis and emphysema. Carbon monoxide (CO) reaches lungs and combines with haemoglobin of blood to form carboxyhaemoglobin. Haemoglobin has affinity for CO 210 times more than that for oxygen. Haemoglobin is, therefore, unable to transport oxygen to various parts of the body. This causes suffocation. Long exposure to CO may cause dizziness, unconsciousness and even death.

Many other air pollutants like benzene (from unleaded petrol), formaldehyde and particulates like polychlorinated biphenyls (PCBs) toxic metals and dioxins (from burning of polythene) can cause mutations, reproductive problems or even cancer.

Many other hazardous materials like Asbestos, Beryllium, Mercury, Arsenic and radioactive substances cause lung diseases and/or affect other vital organs like kidney, liver, spleen, brain and some may also cause cancer.

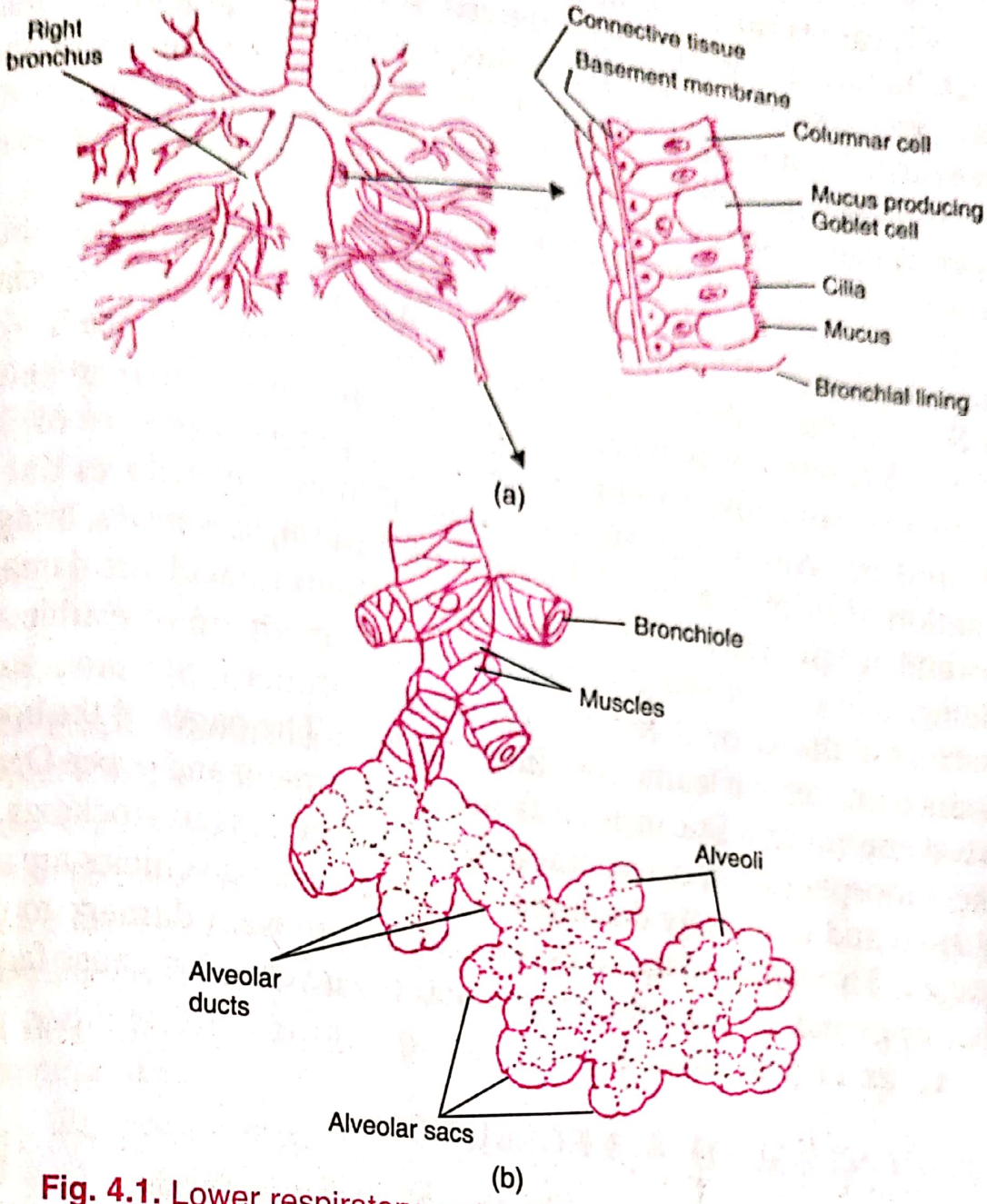

Fig. 4.1. Lower respiratory system of human beings (*a* and *b*) and cross-section of bronchial lining showing cilia and goblet cells.

(*b*) **Effects on plants:** Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis. During the day time the stomata are wide open to facilitate photosynthesis. Air pollutants during day time affect plants by entering the leaf through these stomata more than during night. Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought and frost. Damage to leaf structure causes ***necrosis*** (dead areas of leaf), ***chlorosis*** (loss or reduction of chlorophyll causing yellowing of leaf) or ***epinasty*** (downward curling of leaf), and ***abscission*** (dropping of leaves). Particulates deposited on leaves can form encrustations and plug the stomata and also reduce the availability of sunlight. The damage can result in death of the plant.

SO_2 causes bleaching of leaves, chlorosis, injury and necrosis of leaves. NO_2 results in increased abscission and suppressed growth. O_3 causes flecks on leaf surface, premature ageing, necrosis and bleaching. Peroxyacetyl nitrate (PAN) causes silvering of lower surface of leaf, damage to young and more sensitive leaves and suppressed growth. Fluorides cause necrosis of leaf-tip while ethylene results in epinasty, leaf abscission and dropping of flowers.

(*c*) **Effects on aquatic life:** Air pollutants mixing up with rain can cause high acidity (lower pH) in fresh water lakes. This affects aquatic life especially fish. Some of the freshwater lakes have experienced total fish death.

(*d*) **Effects on materials:** Because of their corrosiveness, particulates can cause damage to exposed surfaces. Presence of SO_2 and moisture can accelerate corrosion of metallic surfaces due to formation of sulfuric acid. Metal parts of buildings, vehicles, bridges, wires and metallic railway tracks are affected. Sulfuric acid also damages buildings and causes disfigurement of statues made up of marble and limestone. Sulfuric acid formed by the atmospheric SO_2 and water vapours damages the leather binding of books. The pages of the books also become brittle. SO_2 can affect fabric, leather, paint and paper. Ozone in the atmosphere can cause cracking of rubber. Nylon stockings are weakened and ultimately damaged. Tyres of various vehicles are also damaged. These days chemicals are added to prevent damage to tyre rubber by ozone. Oxides of nitrogen and ozone can also cause fading of cotton and rayon fibres.

4.2.4 CONTROL OF AIR POLLUTION

Air pollution can be minimized by the following methods:

- Siting of industries after proper Environmental Impact Assessment studies.

  By dilution of emission. This can be done by increasing the stack height (though up to permissible height), beyond inversion layer. Wind currents will disperse the pollutants.

  But this results in interstate dispute and is not considered to be solution for air pollution problem.
- Minimize activities which cause pollution like transportation and energy production.
- Modification of process and/or equipments.
- Use of appropriate material.
- Using low sulphur coal in industries.
- Removing sulphur from coal (by washing or with the help of bacteria).

- Removing NO_x during the combustion process and controlling the flow of air and fuel in industrial boilers.
- Vehicular pollution can be checked by regular tune-up of engines; replacement of more polluting old vehicles; installing catalytic converters; by engine modification to have fuel efficient (lean) mixtures to reduce CO and hydrocarbon emissions; and slow and cooler burning of fuels to reduce NO_x emission (Honda Technology).
- Using mass transport system, bicycles etc.
- Shifting to less polluting (clean) fuels (hydrogen gas).
- Using non-conventional sources of energy.
- Using biological filters and bio-scrubbers.
- Planting more trees.
- Reduction of pollution at source.

REDUCTION OF AIR POLLUTION AT SOURCE

Gaseous pollutants: Gaseous pollutants can be reduced by physical adsorption on porous solid materials like activated charcoal, silica gel, Fuller's earth, etc. Effluent gases can be absorbed in liquid absorbent, *e.g.* SO_2 absorbed in ammonia solution. They can be removed by condensation which is carried out by cooling medium in tubes where the gases in contact condense and can be collected thereafter. Combustion can be used to reduce pollution by burning the pollutants in combustion equipment at optimal conditions of oxygen and temperature.

Particulate matter: Many devices are available now-a-days, choice of which depends on characteristics of particulate, flow rate, collection efficiency, costs, etc.

(*a*) Cyclones: It consists of a cylinder with an inverted cone attached at the bottomFig. 4.2(*a*) . The gas with particles in it enters tangentially at the top of the cylinder and spins forming a vortex. Due to centrifugal force, the particles strike the wall of the cylinder. The particles then fall in the hopper due to gravity from where they are removed. The spinning gas forms an inner vortex and leaves from the top. The cyclone is very efficient for larger particles. However, smaller particles which pose human health problems are not removed efficiently. Therefore, cyclones are employed before the use of other costly devices.

(*b*) Bag house filters: A bag house filter contains a large number of filter bags made of fabric Fig. 4.2 (*b*). They are hung upside down in several compartments of bag house filter. Dirty gas is passed through

the filter bags which leaves the bags through their pores. The dust particles get deposited on the inner surface of the bag filters and may form a cake which can be removed by shaking. The device is efficient for removal of very small particles and is preferred in various types of industries. The bag house filters are expensive and cannot be operated for moist gases. Corrosive gases may damage the material of the bags. Various types of materials, depending on the nature of the flue gases to be cleaned, are used for making the filter bags.

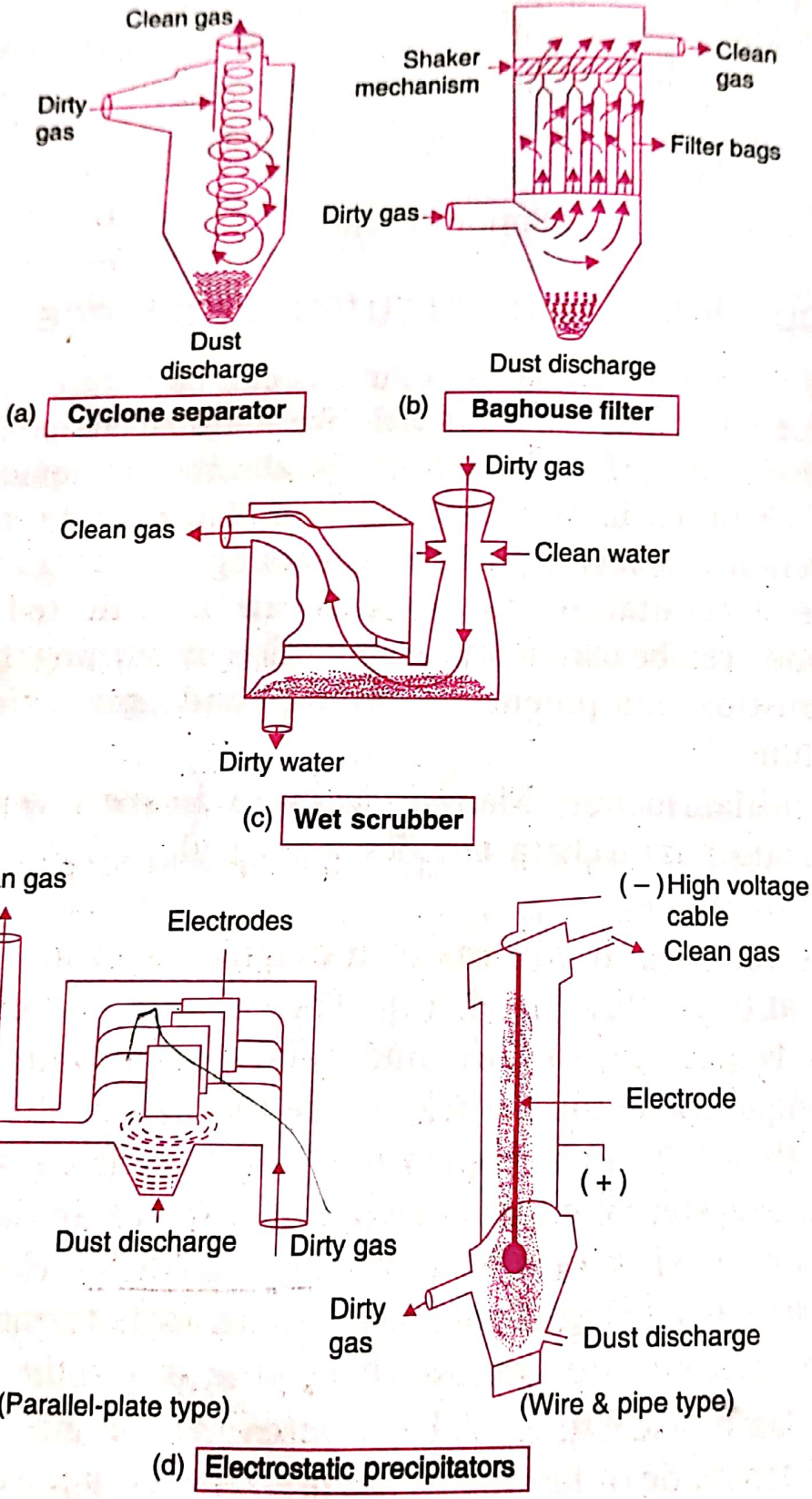

Fig. 4.2. Devices for control of particulate matter

(c) Wet scrubbers: Dirty gases are passed through water in the chamber or water is sprayed on the gas [Fig. 4.2 (*c*)]. Particles are made wet and are removed from the gas stream which leaves from the top of the scrubber. Wet scrubbers are very efficient for removing the particulates. The scrubbers are very useful for removal of toxic and acidic gases also.

(d) Electrostatic precipitators: The electrostatic precipitators may be plate type or cylinder type [Fig. 4.2 (*d*)]. Vertical wires are placed between the parallel plates or wire is hung along the axis of the cylinder. High negative voltage is applied to the wire. Dust particles while passing from the lower end get negatively charged (ionized) and are collected on the positively charged surface (plate/cylindrical body) while the clean gas leaves from the top.

The deposited dust particles fall down in the dust collector or are removed by scrapping or by liquids. Electrostatic precipitators utilize electrical energy and can efficiently remove even submicroscopic particles.

4.3 AUTOMOBILE POLLUTION

Development of internal combustion engine (gasoline engine) in the late 1800s revolutionised modes of transportation. It was in 1900s that road transport progressed rapidly. Production of vehicles has doubled from 70 lakh vehicles in the year 2004 to 140 lakh in 2010. The number of personal vehicles increased amazingly due to convenience, safety and affordability. This has come with a cost to the environment.

People specially in the urban areas are exposed to vehicular exhaust. The most vulnerable group is the traffic policemen. Pollutants from automobiles are emitted to the atmosphere through exhaust pipe (70%), crank case (20%) and by evaporation from fuel tank and carburettor (10%). The following pollutants are emitted from the vehicular exhaust, carbon monoxide (CO), unburnt hydrocarbons, oxides of nitrogen (NO_x), oxides of sulphur (SO_x), particulate matter, smoke and odour. The petrol engine exhaust contains carbon monoxide, unburnt hydrocarbons, nitrogen oxides and particular matter. It is almost colourless. The diesel engine exhaust contains unburnt hydrocarbons, nitrogen oxides, sulphur oxides, particulate matter, smoke and odour. This exhaust is dirty and generally blue or black. Unleaded petrol which was considered to be green fuel for vehicles emits benzene (a cancer causing pollutant) into the atmosphere. Compressed natural gas (CNG)

introduced recently as vehicular fuel is also not safe and environmental friendly. Recent study by Central Pollution Control Board (CPCB), New Delhi says that CNG burning produces potentially hazardous carbonyl emissions. Retrofitted CNG engines (almost all car CNG engines in India) produce 30% more methane that originally fitted CNG engines. Methane is a strong green house gas and is responsible for global warming.

Emission of carbon monoxide and hydrocarbons is high during idling and deceleration, and low during acceleration and high speed while levels of NO_x are high during acceleration and high speed and low during idling, deceleration and low speed. Levels of these pollutants are minimum at the recommended uniform speed. Millions of vehicles spew into the atmosphere hundreds of metric tonnes of pollutants per day. Carbon monoxide contributes about 70% of the vehicular exhaust.

(*a*) Effects of vehicular pollution: The ill effects of air pollutants have been discussed in the air pollution chapter. Vehicular pollution may produce from minor effects to serious illness sometimes leading to premature deaths. Vehicular pollution produces and aggravates respiratory and cardiovascular diseases. In the metros the situation is of special concern as thousands of people die prematurely due to this type of pollution. The worst affected cities are Delhi, Kolkata, Agra, Ahmedabad, Jaipur, Kanpur, Nagpur, Mumbai, Chennai etc. The pollution problems are aggravated in the cities where alongwith SO_2, the particulate (suspended particulate matter) concentration is also high. This increases morbidity and mortality due to their synergistic (enhancing each others toxicity) effects. Particulate matter upto 2.5 micron ($PM_{2.5}$) is produced during combustion in vehicles and is so small that it escapes through apparatus fitted in Euro II and Euro III cars. Metals especially lead present in $PM_{2.5}$ penetrates deep into lungs and cause asthma and even cancer.

Besides affecting human health, vehicular pollution affects environment also. Vehicular pollutants produce photochemical smog in the presence of sunlight. Los Angeles has a large number of vehicles and abundant sunshine and experiences frequent incidents of photochemical smog. For this reason it is called the pollution capital of the world. Vehicular pollution contributes to the major green house gas CO_2 which contributes to climate change (global warming). Vehicles are responsible for one third of worlds total oil consumption resulting in depletion of this resource at a faster rate. Vehicular pollution seriously affects the living beings and crops especially when pollutants get trapped under inversion layer in winter months.

(b) **Control measures:** Vehicle pollution can be minimized or controlled by adopting some of the following measures:

- Use of alternate fuel which generates less pollutants on combustion.
- Ensure complete combustion of fuel which changes pollutants into less harmful products.
- Use of catalytic converters.
- Modification of internal combustion engine for improvement of its efficiency.
- Replacement of internal combustion engine with the engine which produces less pollutants.

4.4 INDUSTRIAL POLLUTION

Industrialization in the last few decades in India has resulted in widespread environmental pollution. The type of pollution caused depends on the nature of emissions and effluents which are industry specific. Pollutants released from thermal power plants, nuclear power plants, iron and steel, metals and mineral, pulp and paper, tanneries, textile, chemicals, foundry, cement, fertilizers, distilleries, pharmaceuticals, mining, etc. are of major concern.

Industrial effluents (liquid wastes) may contain heavy metals from electroplating (nickel, copper, zinc), tanneries (chromium) textile and chemical industries.

Organic pollutants are discharged by distilleries, sugar, food processing, pulp and paper, tannery, pharmaceuticals, etc. These cause water pollution or land pollution when discharged. Air pollution is also caused by industries. The main pollutants are particulate matter, oxides of sulphur and nitrogen which are produced due to burning of fossil fuels. Other industrial pollutants, such as hydrocarbons, volatile organic compounds, hydrogen sulphide, lead, hazardous waste, oils and solvents, etc., are produced by various types of industries.

There are 17 categories of the most polluting industries which include:

- Aluminium Smelter
- Cement
- Distilleries
- Fertilizers
- Tanneries
- Caustic Soda
- Copper Smelter
- Dyes and Dye Intermediates
- Integrated Iron and Steel
- Pesticides

- Petrochemicals
- Pulp and Paper
- Sugar
- Zinc Smelters.
- Drugs and Pharmaceuticals
- Oil Refineries
- Thermal Power Plants

Distillery sector is one of the 17 categories of most polluting industries in India. This produces large volume of dark brown coloured waste waters, which contain: Total Dissolved Solids (TDS) ranging from 85,000–95,000 mg/L, Biological Oxygen Demand 45,000–60,000 mg/L and Chemical Oxygen Demand ranging from 80,000–1,20,000 mg/L.

Effluents when discharged on land would cause soil salinity and if discharged in water bodies will lower the dissolved oxygen content thereby affecting aquatic life, phytoplankton and fish production. Thermal power plants use coal for energy production. Andhra Pradesh experiences a boom in coal based power plants. One such plant is a 4000 MW Krishnapatnam Ultra Mega Power Project. Alongwith the new fleet of coal based power plants Andhra Pradesh would become world's top 20 carbon emitters. Industries cause air, water, soil and noise pollution. Details of the effects and control are described in relevent section of this chapter.

Special care is taken about the siting and operation of 17 categories of most polluting industries. These units are normally not allowed to be established in thickly populated areas. By the court order industrial units belonging to 17 categories of highly polluted industries were shifted out of Delhi.

In May, 2011 Haryana State Pollution Control Board has ordered closure of 639 polluting industries and launched prosecution against 151 polluting industries.

4.6 WATER POLLUTION

Water pollution can be defined as alteration in physical, chemical or biological characteristics of water making it unsuitable for designated use in its natural state.

4.6.1 SOURCES OF WATER POLLUTION

Water is an essential commodity for survival. We need water for drinking, cooking, bathing, washing, irrigation, and for industrial operations. Most of water for such uses comes from rivers, lakes or groundwater sources. Water has the property to dissolve many substances in it, therefore, it can easily get polluted. Pollution of water can be caused by **point sources** or **non-point sources. Point sources** are specific sites near water which directly discharge effluents into them. Major point sources of water pollution are industries, sewage treatment plants, power plants, underground coal mines, offshore oil wells, oil tankers, etc. It is easy to control water pollution by point sources. Many advanced countries have stricter legislation for the same. However, such control is not effective in most of the developing nations. The discharge from **non-point sources** is not at any particular site, rather, these sources are scattered, which individually or collectively pollute water. Surface run-off from agricultural fields, overflowing small drains, rain water sweeping roads and fields, atmospheric deposition etc. are the **non-point sources** of water pollution. It is difficult to control water pollution by non-point sources because of the high cost and difficulty in identifying and treating the pollutants from diffused sources.

4.6.2 MAJOR POLLUTANTS OF WATER AND THEIR SOURCES

The major pollutants and sources of **surface water pollution** are:

1. **Sewage:** Emptying the drains and sewers in fresh water bodies causes water pollution. The problem is severe in cities.
2. **Industrial effluents:** Industrial wastes containing toxic chemicals, acids, alkalis, heavy metals, phenols, cyanides, ammonia, radioactive substances, etc. are sources of water pollution. They also cause thermal (heat) pollution of water.
3. **Synthetic detergents:** Synthetic detergents used in washing and cleaning produce foam and pollute water.

4. **Agrochemicals:** Agrochemicals like fertilizers (containing nitrates and phosphates) and pesticides (insecticides, fungicides, herbicides etc.) washed by rain-water and surface run-off pollute water.
5. **Oil:** Oil spillage into sea-water during drilling and shipment pollute it.
6. **Waste heat:** Waste heat from industrial discharges increases the temperature of water bodies and affects distribution and survival of sensitive species.

There are a number of potential sources of **ground water pollution** also. Septic tanks, industry (textile, chemical, tanneries), deep well injection, mining etc. are mainly responsible for ground water pollution which is irreversible. Ground water pollution with arsenic, fluoride and nitrate are posing serious health hazards.

(*a*) The major sources of groundwater arsenic are
- weathering of minerals and ores having arsenic
- infiltration or runoff from sites of mining activities in the past.

(*b*) Sources of nitrates in groundwater are:
- use of synthetic nitrogen fertilizers
- relatively thin soil or soils with poor buffering capacity.

(*c*) Sources of fluoride in groundwater are:
- sediments of marine origin of mountainous area
- volcanic rock
- igneous and metamorphic rock.

In India, high concentration of fluoride in villages in Andhra Pradesh, Punjab, Haryana, Rajasthan, Uttar Pradesh, Tamil Nadu and Gujarat have been reported.

CASE STUDY

Arsenic Pollution in Groundwater in Andhra Pradesh

Patancheru industrial development area, about 40 km away from Hyderabad, has in its vicinity about 320 industries manufacturing pesticides, chemicals, pharmaceutical products and steel. A Common Effluent Treatment Plant (CETP) is installed by about 110 industries that bring effluents in tankers for treatment purpose. After treating these effluents, wastewater is discharged in a water stream called Peddavagu, which meets the main stream Nakkavagu

flowing through Patancheru area. This Nakkavagu finally meets the river Manjira that is one of the main source of drinking water for Hyderabad City.

Trace metals like arsenic present in the soil form complexes with the organic acids, which help these pollutants to migrate faster through the soil and contaminate the aquifers. The decomposition rate of organic matter is very high due to tropical conditions.

Arsenic pollution in surface and groundwater has been reported in Patancheru and Bolaram industrial development areas. The values of arsenic in stream water near Common Effluent Treatment Plant are as high as 40,000 ppb. It clearly indicates that the source of arsenic is not from natural rocks but from the industrial effluents brought by different industries to CETP for treatment. Water samples from Peddavagu and Nakkavagu streams are showing high arsenic concentration of upto 5,000 ppb. Groundwater samples from some of the villages *i.e.*, Bandalguda, Muthangi, Patelgudem, etc., are having high concentration of arsenic. In some of the wells the arsenic concentration was found to be 750 ppb while the permissible limit is only 50 ppb. As the soil is normally not contaminated in the area, it is evident that the source of arsenic is not from the surrounding rocks, which are granite.

Arsenic present in Peddavagu, which is released by Common Effluent Treatment Plant, migrates vertically and horizontally and contaminates the groundwater in the wells of adjoining villages which is indicated by the high values of arsenic in well water.

4.6.3 EFFECTS OF WATER POLLUTION

Following are some important effects of various types of water pollutants:

(*a*) **Oxygen demanding wastes:** Organic matter which reaches water bodies is decomposed by micro-organisms present in water. For this degradation oxygen dissolved in water is consumed. Dissolved oxygen (DO) is the amount of oxygen dissolved in a given quantity of water at a particular temperature and atmospheric pressure. Amount of dissolved oxygen depends on aeration, photosynthetic activity in water, respiration of animals and plants and ambient temperature.

The saturation value of DO varies from 8–15 mg/L. For active fish species (trout and Salmon) 5–8 mg/L of DO is required whereas less desirable species like carp can survive at 3.0 mg/L of DO.

Lower DO may be harmful to animals especially fish population. Oxygen depletion (deoxygenation) helps in release of phosphates from bottom sediments and causes eutrophication.

(*b*) Nitrogen and Phosphorus compounds (nutrients): Addition of compounds containing nitrogen and phosphorus helps in the growth of algae and other plants which when die and decay consume oxygen of water. Under anaerobic conditions foul smelling gases are produced. Excess growth or decomposition of plant material will change the concentration of CO_2 which will further change pH of water. Changes in pH, oxygen and temperature will change many physico-chemical characteristics of water.

(*c*) Pathogens: Many wastewaters especially sewage contain many pathogenic (disease causing) and non-pathogenic micro-organisms and many viruses. Water borne diseases like cholera, dysentery, typhoid, jaundice etc. are spread by water contaminated with sewage.

(*d*) Toxic compounds: Pollutants such as heavy metals, pesticides, cyanides and many other organic and inorganic compounds are harmful to aquatic organisms.

The demand of DO increases with addition of biodegradable organic matter which is expressed as biological oxygen demand (BOD). BOD is defined as the amount of DO required to aerobically decompose biodegradable organic matter of a given volume of water over a period of 5 days at 20°C. More BOD values of any water sample are associated with poor water quality. The non-biodegradable toxic compounds biomagnify in the food chain and cause toxic effects at various levels of food chain.

Some of these substances like pesticides, methyl mercury etc. move into the bodies of organisms from the medium in which these organisms live. Substances like DDT are not water soluble and have affinity for body lipids. These substances tend to accumulate in the organism's body. This process is called **bioaccumulation.** The concentration of these toxic substances builds up at successive levels of food chain. This process is called **biomagnification.** Following is the example of biomagnification of DDT in aquatic food chain:

Component	DDT concentration (ppm)
Birds	10.00
↑	↑
Needle fish	1.0
↑	↑
Minnows	0.1
↑	↑
Zooplankton	0.01
↑	↑
Water	0.000001

Toxic substances polluting the water ultimately affect human health. Some heavy metals like lead, mercury and cadmium cause various types of diseases. Mercury dumped into water is transformed into water soluble methyl mercury by bacterial action. Methyl mercury accumulates in fish. In 1953, people in Japan suffered from numbness of body parts, vision and hearing problems and abnormal mental behaviour. This disease called **Minamata disease** occurred due to consumption of methyl mercury contaminated fish caught from Minamata bay in Japan. The disease claimed 50 lives and permanently paralysed over 700 persons. Pollution by another heavy metal cadmium had caused the disease called **Itai-itai** in the people of Japan. The disease was caused by cadmium contaminated rice. The rice fields were irrigated with effluents of zinc smelters and drainage water from mines. In this disease bones, liver, kidney, lungs, pancreas and thyroid are affected.

Arsenic pollution of ground water in Bangladesh and West Bengal is causing various types of abnormalities.

Nitrate when present in excess in drinking water causes **blue baby syndrome** or **methaemoglobinemia**. The disease develops when a part of haemoglobin is converted into non-functional oxidized form.

Nitrate in stomach partly gets changed into nitrites which can produce cancer-causing products in the stomach.

Excess of fluoride in drinking water causes defects in teeth and bones called **fluorosis.**

Pesticides in drinking water ultimately reach humans and are known to cause various health problems. DDT, aldrin, dieldrin etc. have therefore, been banned. Recently, in Andhra Pradesh, people suffered from various abnormalities due to consumption of endosulphan contaminated cashew nuts.

4.6.5 CONTROL OF WATER POLLUTION

It is easy to reduce water pollution from point sources by legislation. However, due to absence of defined strategies it becomes difficult to prevent water pollution from non-point sources. The following points may help in reducing water pollution from non-point sources.

(*i*) Judicious use of agrochemicals like pesticides and fertilizers which will reduce their surface run-off and leaching. Avoid use of these on sloped lands.

(*ii*) Use of nitrogen fixing plants to supplement the use of fertilizers.

(*iii*) Adopting integrated pest management to reduce reliance on pesticides.

(*iv*) Prevent run-off of manure. Divert such run-off to basin for settlement. The nutrient rich water can be used as fertilizer in the fields.

(*v*) Separate drainage of sewage and rain water should be provided to prevent overflow of sewage with rainwater.

(*vi*) Planting trees would reduce pollution by sediments and will also prevent soil erosion.

For controlling water pollution from point sources, treatment of wastewaters is essential before being discharged. Parameters which are considered for reduction in such water are:

Total solids, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates and phosphates, oil and grease, toxic metals etc.

Wastewaters should be properly treated by primary and secondary treatments to reduce the BOD, COD levels upto the permissible levels for discharge.

4.8 SOIL POLLUTION

4.8.1 SOURCES OF SOIL POLLUTION

Soil is the upper layer of the earth crust which is formed by weathering of rocks. Organic matter in the soil makes it suitable for living organisms. Dumping of various types of materials especially domestic and industrial wastes causes soil pollution. Domestic wastes include garbage, rubbish material like glass, plastics, metallic cans, paper, fibres, cloth rags, containers, paints, varnishes etc. Leachates from dumping sites and sewage tanks are harmful and toxic, which pollute the soil.

Industrial wastes are the effluents discharged from chemical industries, paper and pulp mills, tanneries, textile mills, steel industries, distilleries, refineries, pesticides and fertilizer industries, pharmaceutical industries, food processing industries, cement industries, thermal and nuclear power plants, mining industries etc. Thermal power plants generate a large quantity of 'Fly ash'. Huge quantities of these wastes are dumped on soils, thus contaminating them.

Industrial wastes also contain some organic and inorganic compounds that are refractory and non-biodegradable. Industrial sludge may contain various salts, toxic substances, metals like mercury, lead, cadmium, arsenic etc. Agrochemicals released with the wastes of pesticide and fertilizer factories or during agricultural practices also reach the soil and pollute it.

Pesticides are used to kill pests that damage crops. These pesticides ultimately reach the soil and persist there for a long time. Pesticides which are persistent in nature are chlorinated hydrocarbon insecticides *e.g.* DDT, HCH, endrin, lindane, heptachlor, endosulfan etc. Residues of these pesticides in the soils have long-term effects especially under the temperate conditions.

Soil also receives excreta from animals and humans. The sewage sludge contains many pathogenic organisms, bacteria, viruses and intestinal worms which cause pollution in the soil.

The sources of radioactive substances in soil are explosion of radioactive devices, radioactive wastes discharged from industries and laboratories, aerial fall out etc. Isotopes of radium, uranium, thorium, strontium, iodine, caesium and of many other elements reach the soil and persist there for a long time and keep on emitting radiations.

4.8.2 EFFECTS OF SOIL POLLUTION

Sewage and industrial effluents which pollute the soil ultimately affect human health. Various types of chemicals like acids, alkalis, pesticides, insecticides, weedicides, fungicides, heavy metals etc. in the industrial discharges affect soil fertility by causing changes in physical, chemical and biological properties.

Some of the persistent toxic chemicals inhibit the non-target organisms, soil flora and fauna and reduce soil productivity. These chemicals accumulate in food chain and ultimately affect human health. Indiscriminate use of pesticides specially is a matter of concern.

Sewage sludge has many types of pathogenic bacteria, viruses and intestinal worms which may cause various types of diseases. Decomposing organic matter in soil also produces toxic vapours.

Radioactive fallout on vegetation is the source of radio-isotopes which enter the food chain in the grazing animals. Some of these radio isotopes replace essential elements in the body and cause abnormalities *e.g.* strontium-90 instead of calcium gets deposited in the bones and tissues. The bones become brittle and prone to fracture.

Radioisotopes which attach with the clay become a source of radiations in the environment.

Nitrogen and phosphorus from the fertilizers in soil reach nearby water bodies with agricultural run-off and cause eutrophication. Chemicals or their degradation products from soil may percolate and contaminate ground-water resources.

4.8.3 CONTROL OF SOIL POLLUTION

(*i*) Effluents should be properly treated before discharging them on the soil.

(*ii*) Solid wastes should be properly collected and disposed off by appropriate method.

(*iii*) From the wastes, recovery of useful products should be done.

(iv) Biodegradable organic waste should be used for generation of biogas.

(v) Cattle dung should be used for methane generation. Night-soil (human faeces) can also be used in the biogas plant to produce inflammable methane gas.

(vi) Microbial degradation of biodegradable substances is also one of the scientific approaches for reducing soil pollution.

4.9 SOIL AS SINK FOR POLLUTANTS

Soil generally has loose texture and consists of minerals, organic matter, humus air-filled pores microorganisms and soil biota. While complex interactions take place in soil to support plant life, soils also receive large quantities of waste products and pollutants. Soils absorb various gases from the atmosphere and also particulates formed in the atmosphere due to various transformations. A large portion of atmospheric sulphur dioxide, as a result of burning of sulphur containing fuels, returns to soil as dry deposition in the form of sulphates. Likewise soils also receive nitrates forms from atmospheric oxides of nitrogen. Soils also absorb oxides of nitrogen and oxidize them into nitrates. Atmospheric carbon monoxide is also absorbed and converted into carbon dioxide and ultimately to soil biomass by the action of soil microorganisms. Heavy metals from vehicular exhaust and from mines and smelters also find way to the nearby soils.

Soils may also receive leachates from solid waste dump sites, liquid hazardous materials from lagoons, leaking sewers, hazardous materials discharged on land surfaces. Thus soils may also receive various organic compounds also.

Pollutants reaching soils may be sorbed, mobilized, metabolized, detoxified, precipitated or translocated, depending upon various abiotic and biotic factors. Thus soil may act as sink for these pollutants.

During the humification process in the soil, many organic pollutants may get bound to humus. Pollutant organic compounds which have structure similar to humic acid can easily get bound and get immobilized and detoxified. Microbial enzymes help them to get covalently bound to humus. Such compounds bound to humus are called bound residues and are not released by chemicals.

4.13 NOISE POLLUTION

We hear various types of sounds everyday. Sound is mechanical energy from a vibrating source. A type of sound may be pleasant to someone

and at the same time unpleasant to others. The unpleasant and unwanted sound is called noise.

Sound can propagate through a medium like air, liquid or solid. Sound wave is a pressure perturbation in the medium through which sound travels. Sound pressure alternately causes compression and rarefaction. The number of compressions and rarefactions of the molecules of the medium (for example air) in a unit time is described as frequency. It is expressed in Hertz (Hz) and is equal to the number of cycles per second.

There is a wide range of sound pressures, which encounter human ear. Increase in sound pressure does not invoke linear response of human ear. A meaningful logarithmic scale has been devised. The noise measurements are expressed as Sound Pressure Level (SPL) which is logarithmic ratio of the sound pressure to a reference pressure. It is expressed as a dimensionless unit, decibel (dB). The international reference pressure of 2×10^{-5} Pa is the average threshold of hearing for a healthy ear. Decibel scale is a measure of loudness. Noise can affect human ear because of its loudness and frequency (pitch).

4.13.1 SOURCES OF NOISE POLLUTION

The main sources of noise are various modes of transportation (like air, road, rail-transportation), industrial operations, construction activities and celebrations (social/religious functions, elections etc) electric home appliances. Various sources of noise and their associated sound levels on decibel scale are given in table 4.3.

High levels of noise have been recorded in some of the cities of the world. In Nanjing (China) noise level of 105 dB has been recorded, while in some other cities of the world these levels are: Rome 90 dB, New York 88 dB, Kolkata 85 dB, Mumbai 82 dB, Delhi 80 dB, Kathmandu 75 dB.

Table 4.3: Different sounds and their sound levels on decibel scale

	Sound level (dB)		Source of sound
	180	—	Rocket engine
	170		
	160		
	150	—	Jet plane take off
Threshold of pain	140	—	
	130	—	Maximum recorded rock music
	120	—	Thunder cap
	110	—	Autohorn 1m away

100	—	Jet fly over at 300 m, construction work, Newspaper press
90	—	Motor cycle/8 m away, food blender
80		
70	—	Vacuum cleaner, ordinary conversation
60	—	Air conditioning unit, 6 m away, light traffic noise, 30 m away
50	—	Average living room
40		
30	—	Library, soft whisper
20	—	Broadcasting studio
10	—	Rustling leaf
Threshold of hearing — 0		

Effects of Noise

Noise causes the following effects.

(*i*) **Interferes with man's communication:** In a noisy area communication is severely affected.

(*ii*) **Hearing damage:** Noise can cause temporary or permanent hearing loss. It depends on intensity and duration of sound level. Auditory sensitivity is reduced with noise level of over 90 dB in the mid-high frequency for more than a few minutes.

(*iii*) **Physiological and psychological changes:** Continuous exposure to noise affects the functioning of various systems of the body. It may result in hypertension, insomnia (sleeplessness), gastro-intestinal and digestive disorders, peptic ulcers, blood pressure changes, behavioural changes, emotional changes etc.

4.13.2 INDUSTRIAL NOISE-OCCUPATIONAL HEALTH HAZARDS

Industrial noise is the noise which is created by the machines and processes in the industries. It is of concern as it threatens safety and health of the industrial workers and common people in the industrial environment. Noise levels more than 85 decibels can cause hearing impairment and such industrial environment is not a health environment for the workers. Noise Induced Hearing Loss (NIHL) has been observed in workers of heavy industries like ship-building, iron and steel industry, railway yards etc.

Besides hearing loss other occupational health hazards include:

(*i*) Increased stress
(*ii*) Fatigue
(*iii*) High blood pressure
(*iv*) Annoyance

(v) Headache
(vi) Vertigo
(vii) Speech problems
(viii) Learning impairment
(ix) Aggresion
(x) Anxiety
(xi) Stomach ulcers
(xii) Depression.

Permissible noise levels for varying number of hours per day exposure have been given by Occupational Safety and Health Act.

Generally 90 dB(A) sound levels are permissible for 8 hours a day exposure. However, it has been observed that over a period of 10 years exposure to these levels of noise a significant number of employees would suffer noise-induced hearing loss, suggesting that occupational noise levels for 8 hours per day exposure be reduced to 85 dB(A).

Occupational noise environment is not acceptable if after 10 years of 8 hour per day exposure, the average employee has suffered a permanent work induced hearing loss of 10 decibels at 1000 Hertz, 15 decibels at 2000 Hertz, or 20 decibels at 3000 Hertz or above.

4.13.3 STANDARDS

Central Pollution Control Board (CPCB) Committee has recommended permissible noise levels for different locations as given in Table 4.4.

Table 4.4: Ambient air quality standards in respect of noise

Area code	Category of area/zone	Limits in dB(A) Leq*	
		Day time	Night time
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Notes: 1. Day time shall mean from 6.00 a.m. to 10.00 p.m.
2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. Silence zone is an area comprising not less than 100 metres around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority.
4. Mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

*dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

A "decibel" is a unit in which noise is measured.

"A", in dB(A). Leq, denotes the frequency weighting in the measurement of noise and corresponds to frequency response characteristics of the human ear.

Leq: It is an energy mean of the noise level over a specified period.

4.13.4 METHODS OF CONTROL OF NOISE

1. *Reduction in sources of noise:* Sources of noise pollution like heavy vehicles and old vehicles may not be allowed to ply in the populated areas.
2. Machine noise can be reduced by proper machine design involving process modification, changes in shape and material.
3. Noise making machines should be kept in containers with sound absorbing media. The noise path will be in interrupted and will not reach the workers.
4. Proper oiling will reduce the noise from the machinery.
5. Noise levels can be reduced by reducing the noise radiating surfaces.
6. Heavy machines transmit vibrations to the hard surfaces in touch which in turn radiate noise. This type of secondary noise can be reduced by providing pads of suitable material (rubber, felt, cork, etc) to absorb and reduce noise transmission.
7. High frequency noise which gets reflected like beam of light or heat can be reduced by providing sound absorbing acoustical barriers or shields between the noise source and work place. Porous materials absorbent-fibres, glass wool, etc. are sound absorbing materials which can absorb upto 90% of sound energy falling on them depending on the angle of incidence. Ceilings and walls may be provided with layers of such sound absorbing materials to reduce workplace noise.
8. Workers may be deployed in noisy environment with maximum permissible noise levels and the relatively quieter areas in shifts so that the time of exposure to high noise level doesn't exceed that recommended by the Occupational Safety and Health Act.
9. Workers may be provided with ear protectors to reduce noise reaching the eardrums.
10. Planting more trees having broad leaves.
11. *Through law:* Legislation can ensure that sound production is minimized at various social functions. Unnecessary horn blowing should be restricted especially in vehicle-congested areas.