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ENVIRONMENTAL POLLUTION MITIGATION

DEM 202

SELF-LEARNING MATERIAL

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Course Advisors

Dr R.R. Haque, Associate professor and Head, Dept. of Environmental Science, Tezpur University
Dr Nimali Gogoi, Associate professor and Head, Dept. of Environmental Science, Tezpur University
Dr Dipak Nath. Assistant Professor, Centre for Disaster Management , Tezpur University

Programme Coordinator/s

Dr Nimali Gogoi, Associate professor and Head, Dept. of Environmental Science, Tezpur University
Dr Dipak Nath. Assistant Professor, Centre for Disaster Management , Tezpur University

Course Contributors

Dr R.R. H aque, Associate professor and Head, Dept. of Environmental Science, Tezpur University
Dr Kh Ashalata Devi, Assistant Prpfessor, Dept of Environment Science , Tezpur University

Course authors

Sumi Handique
Ashalata
Manish kumar
Dr Nimali Gogoi
Satya Sundar

Course Editor/s

Dr Dipak Nath. Assistant Professor, Centre for Disaster Management , Tezpur University

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DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT 1: INTRODUCTION

- Definition of pollution
- Types of pollution
    - Air, Water and soil pollution
    - Noise pollution
    - Marine pollution
    - Thermal pollution
    - Nuclear hazard
- Point and non-point sources of pollution
- Role of individual in pollution prevention

Objectives:

a) To study the different types of pollution affecting the environment

b) To study the various natural and anthropogenic sources of the different types of pollution

c) To discuss the role of individual in pollution prevention

DEFINITION OF POLLUTION

Pollution is the adverse change in the natural environment due to the introduction of the contaminants into it. It may be defined as "the excessive discharge or addition of undesirable substances or unwanted foreign matters into the environment, thereby adversely altering the natural quality of the environment, and causing damage to human, plants or animal life and unreasonable interfere with the comfortable life and unreasonable interfere with the comfortable life or the conduct of business." The substances which cause pollution are termed as pollutants. Pollutants, can be either foreign substances/energies or naturally occurring contaminants.

According to the Environmental Protection Act of India 1986, Environment pollutant means "any solid, liquid or gaseous substances in such concentration as may be or tend to be injurious to environment, and environmental pollution means the presence of any such environmental pollutants in the environment.

1. AIR POLLUTION:

Air pollution can be defined as the presence of air contaminants in the atmosphere in such quantities and duration that they may tend to be injurious to life, or property, or they may interfere with the comfortable enjoyment of life or property, health and safty. These contaminants include gases, fumes, vapours, aerosols and liquids and particulate matter. The main region of occurrence of air pollution is troposphere.

Sources of Air pollution:

The sources of Air pollution can be classified into two major categories which are:

1. Natural Sources:

- Dust from natural sources, usually large areas of land with little or no vegetation
- Methane, emitted by the digestion of food by animals, for example cattle.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colourless, odourless, naturally occurring, radioactive noble gas that is formed from the decay of radium. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking
- Smoke and carbon monoxide from wildfires.
- Vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NO_x, SO_2, and anthropogenic organic carbon compounds—to produce a seasonal haze of secondary pollutants.
- Volcanic activity, which produce sulphur, chlorine, and ash particulates

2. Anthropogenic sources (human activity):

- "Stationary Sources" include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung.
- "Mobile Sources" include motor vehicles, marine vessels, aircraft and the effect of sound etc.
- Chemicals, dust and controlled burn practices in agriculture and forestry management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.
- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents
- Waste deposition in landfills, which generate methane. Methane is not toxic; however, it is highly flammable and may form explosive mixtures with air.
- Military, such as nuclear weapons, toxic gases, germ warfare and rocketry

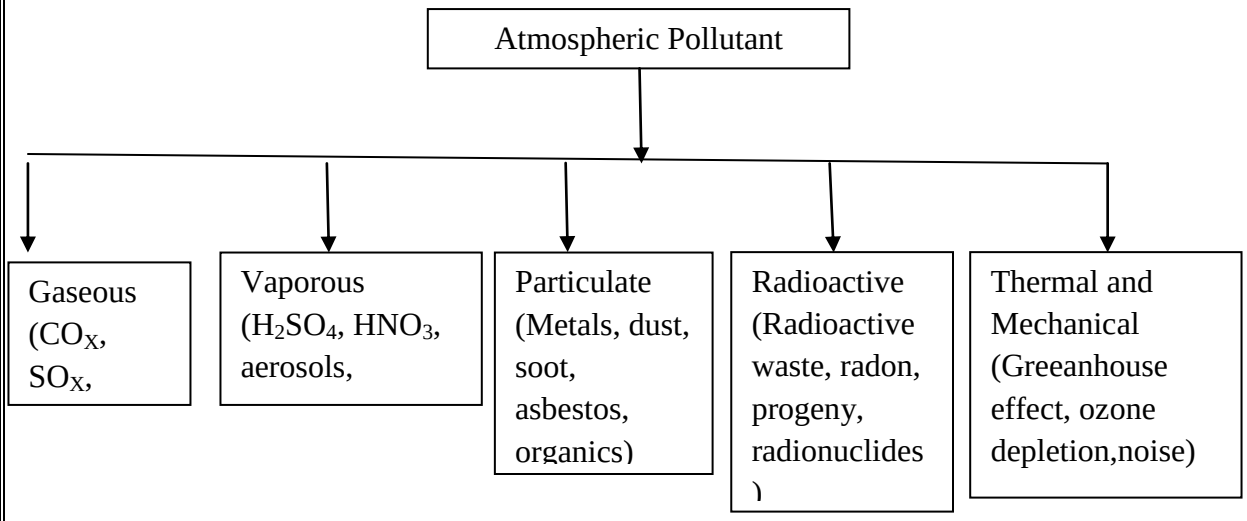


Fig: Forms of atmospheric pollutants

Effects of Air pollution:

1. Health Hazard:

Numerous scientific studies have linked air pollution to a variety of health problems including: (1) aggravation of respiratory and cardiovascular disease; (2) decreased lung function; (3) increased frequency and severity of respiratory symptoms such as difficulty breathing and coughing; (4) increased susceptibility to respiratory infections; (5) effects on the nervous system, including the brain, such as IQ loss and impacts on learning, memory, and behavior; (6) cancer; and (7) premature death. Some sensitive individuals appear to be at greater risk for air pollution-related health effects, for example, those with pre-existing heart and lung diseases (e.g., heart failure/ischemic heart disease, asthma, emphysema, and chronic bronchitis), diabetics, older adults, and children.

2. Effect on plants:

Plants are also affected by the air pollutants, but the severity of damage depends upon: i) Pollutant concentration and duration, ii) Sensitivity of species, strains, etc. iii) Growing conditions. The pollutants of major concern include Ozone, Sulfur dioxide, Nitrogen dioxide, Fluorides, Peroxyacetyl Nitrate, Nitrogen dioxide, Chlorine, Hydrochloric acid, Ammonia, Particulate matter. The symptoms occur in plants due to these pollutants includes

- Chlorosis - chlorophyll destruction
- Necrosis - killing of tissues
- Growth abnormalities like, reduced growth, Accelerated senescence, bolting of flower buds, Abscission of plant parts, Curvature of leaf petiole (epinasty).

3. Effects on the environment:

Due to the increase in the concentration of the atmospheric pollutants the greenhouse gas's concentration increases resulting global climate change. Carbon dioxide, a greenhouse gas, is the main pollutant that is warming Earth. Though living things emit carbon dioxide when they breathe, carbon dioxide is widely considered to be a pollutant when associated with cars, planes,

power plants, and other human activities that involve deforestation, the burning of fossil fuels such as gasoline and natural gas. In the past 150 years, such activities have pumped enough carbon dioxide into the atmosphere to raise its levels higher than they have been for hundreds of thousands of years. Other greenhouse gases include methane—which comes from such sources as swamps and gas emitted by livestock—and chlorofluorocarbons (CFCs), which were used in refrigerants and aerosol propellants until they were banned because of their deteriorating effect on Earth's ozone layer. Another pollutant associated with climate change is sulphur dioxide, a component of smog. Sulphur dioxide and closely related chemicals are known primarily as a cause of acid rain. But they also reflect light when released in the atmosphere, which keeps sunlight out and causes Earth to cool. Volcanic eruptions can spew massive amounts of sulphur dioxide into the atmosphere, sometimes causing cooling that lasts for years.

Greenhouse effects: it is the behaviour of the earth's atmosphere that causes heat from the sun to be trapped near the earth's surface. The green house gases prevent the heat from escaping into outer space and thus maintain the temperature inside greenhouse. But due to the increase in concentration of the greenhouse gases they intensify the greenhouse effect by re-radiating the earth's atmosphere more, which ultimately results in global warming. It has adverse effects on human health and ecosystem, increases the sea water level and initializes the melting of polar ice sheets and glaciers.

4. Effects on building and materials:

Acid rain reacts with $CaCO_3$ present in Limestone (and other rock) which causes surface to crumble and also forms a coating of black gypsum (calcium sulphate)

$$CaCO_3 + H_2SO_4 + H_2O \text{ ------ > } CaSO_4.H_2O + CO_2$$

Paints of building are damaged by soiling of the particulate matter. One example is damage to auto paint from some pollutant 'fallout'. Ozone causes cracking and deterioration of rubber.

Control of air pollution:

Prevention of air pollution is not as simple as explained in words. It is impractical to provide at reasonable cost all the growing needs and amenities of modern life without causing some pollution in the air. However, much of the pollution would be prevented without undue cost by careful planning and its sincere implementation. Following are some simple steps that can be taken in this regard:

1. There should always be a distance between the industrial and residential area. The chimneys must be tall in size so that the emissions must be released higher up in the environment. The filters and precipitators must be used in the chimneys. The scrubber or spray collector must be used to remove the poisonous gases. The ash production must be reduced by the high temperature incinerators. The sulphur must be removed after the combustion.

2. The automobiles must be pollution free by making the fuel alcohol based and using the battery power. The emission control system must be present in the automobiles.

3. The wastes must be removed and recycled in the industrial plants and refineries.

4. Afforestation or planting of trees on a large scale. There are certain plants which have the ability to fix the carbon monoxide. These should be grown in the larger numbers. It includes the ficus and coleus. There are also certain plants which have the ability to metabolize the nitrogen oxides and other pollutants. It includes the pinus and ribes.

5. Establishment of industries after proper environmental impact assessment.
6. The use of green energy sources like nuclear power, geothermal power, solar, tidal and wind power.

WATER POLLUTION

Water pollution refers to harmful substances released into surface or ground water, either directly or indirectly. Hydrologic impacts refer to changes in surface (streams and rivers) and groundwater flows. The term 'water pollution' can be briefly defined as any alteration in physical, chemical or biological properties of water, rendering the water harmful to public health and safety.

Sources of water pollution:

1. Natural sources

Important natural sources are meteorological and geographical like volcanic activity and earthquakes, landslide and surface run-off, seepage from ground water and swamp drainage, dissolved minerals, aquatic growth and decay. Leachates from animal excreta, decaying bodies of animals and plants, solid waste landfill sites and the decay of large quantities of organic matter in swamps or deep ponds also introduce appreciable amounts of soluble organics and microorganisms which in turn contaminate the adjacent ground water.

2. Anthropogenic sources

Anthropogenic sources are the result of industrial, domestic, agricultural and mining activities of man.

a. Industrial sources

Nowadays, industries are the major contributors of water pollution. Water is an essential raw material in almost all manufacturing plants. In India, industries such as tanneries, sugar mills, pulp and paper mills, distilleries, oil refineries, etc. generate a large quantity of wastewater which is discharged into natural waterways either without treatment or after partial treatment.

b. Domestic sources

In urban areas, municipal sewage is discharged into the nearby canal, thus polluting the canal and also deteriorating the ground water. Municipal sewage includes wastewater from houses, commercial buildings and institutions. The important pollutants present are biodegradable organic matter, coliforms and pathogens.

c. Agricultural sources

Pollutants discharged into water courses due to agricultural activities include:

1. Soil and silt removed by erosion

2. Agricultural run-off

3. Synthetic fertilizers, herbicides and insecticides

4. Plant residue.

d. Mining sources

Natural or man-made geochemical alterations are also sources of wastewater pollution. Fines from ore washings disposed off in water suspension may be transferred to the natural water bodies to pollute them in due course. Mining operation also produces soluble toxic materials depending on the geological formation. Acid drainage from coal mines and arsenic residue from gold mines are some of the burning problems of environmental concern.

The sources of water pollution can also be divided into point and non-point sources. Point sources include domestic, municipal and sewer discharge, power generation plants and industrial discharge. Some of them like, breweries, slaughterhouses and sanitary operations, paper mills and waste water treatment plants contribute major quantities of oxygen demanding substances. These substances can deplete dissolved oxygen (DO) and creat anaerobic conditions in water bodies. Suspended matter also contributes to oxygen depletion in water bodies by blocking penetration of sunlight and interfering with photosynthetic activity. This results in an increase in oxygen demand- biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Non-point sources are storm drainage, operations involving agricultural, timber and forest product operations.

Biochemical oxygen demand (B.O.D.) is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

Dissolved Oxygen (DO) is the amount of gaseous oxygen (O_2) dissolved in an aqueous solution.

Chemical Oxygen Demand (COD) is the amount of oxygen required for the chemical oxidation of organic matter with the help of strong chemical oxidants.

Effects of Water Pollution

a. Eutrophication

Water bodies are being constantly polluted by dumping of sewage which includes organic matter and by the runoff from the agricultural fields that contains fertilisers. Pollutants like sewage, organic wastes and fertilisers contain good amount of inorganic nutrients like nitrates and phosphates. These nutrients enrich the water promoting the growth of algae. The water turns green. This is called algal bloom. Rich algal growth leads to great increase in the number of the decomposers. All these life forms-decomposers, algae, other plants, fishes and other aquatic animals, use the oxygen in the water for respiration. This causes great demand for oxygen and results in depletion of oxygen. Eutrophication also results in overgrowth of plants like Eicchornia that covers the entire surface of water. This reduces the light reaching the lower layers in water. Thus, enrichment of water with inorganic nutrients like nitrates and phosphates is called eutrophication.

b. Biomagnification

There are many pollutants like the DDT that are not bio-degradable. These accumulate in the organisms and cause serious health problems. The contamination of water with these pollutants results in their entry into the microscopic plants and animals. These organisms are fed upon by higher aquatic life like the fish. The fish in turn are fed upon by the land animals including man. Thus, the pollutant reaches the body of man. At each step in the food chain, the contaminant increases in quantity. This is because a fish feeds on large quantity of smaller plants and man eats fish. These contaminants like DDT remain in the fats and are not degraded in the body. Over the years the amount of DDT increases in the body. This is called biomagnification.

Pollutants like DDT also reach the human body through milk if the cattle are exposed to DDT sprayed grass or contaminated water. This causes serious blood and nervous disorders in man and other animals.

c. Epidemics

Pollution of water by organic wastes is a major cause for occurrence of epidemics like cholera, gastroenteritis in India. The microorganisms causing these diseases enter the water bodies through the organic wastes and then into the bodies of healthy persons causing diseases.

Control of Water Pollution

a. Sewage Treatment

The sewage before being let into the water bodies must be purified.

This is done in three steps as follows:

Primary Treatment: The water is sieved through coarse sieves and made to stand in sedimentation tanks. This makes the heavy suspended matter settle down. It is then passed through a bed of rocks.

Secondary Treatment: The organic materials that are biodegradable are treated with the help of decomposers and oxygen. Then, the water is also chlorinated to remove the germs.

Tertiary Treatment: This step removes the inorganic pollutants like the nitrates, phosphates, detergents, metal ions, etc. by passing the water through activated charcoal that acts as a filter.

Effluent Treatment: The industrial wastes should be treated before being let into the water bodies. The toxic materials should be removed, the metallic compounds should be precipitated, the acids and alkalis should be neutralized and the temperature of the hot waters should be reduced.

b. Public Awareness

The public should be made aware of the dangers of water pollution. This will ensure that the water bodies are not contaminated and are maintained clean.

SOIL POLLUTION:

Definition:

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effects on plant growth and animal health. A soil pollutant is any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil.

Soil is the thin layer of organic and inorganic materials that covers the Earth's rocky surface. The organic portion, which is derived from the decayed remains of plants and animals, is concentrated in the dark uppermost topsoil. The inorganic portion made up of rock fragments, was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food.

Types of Soil Pollution

• Agricultural Soil Pollution

• Soil pollution by industrial effluents and solid wastes

• Pollution due to urban activities

Causes of Soil Pollution

Soil pollution is caused by the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage links, excess application of pesticides, herbicides or fertilizer, percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. This occurrence of this phenomenon is correlated with the degree of industrialization and intensities of chemical usage.

Pesticides, herbicides or fertilizer:

Soil nutrients are important for plant growth and development. Plants obtain carbon, hydrogen and oxygen from air and water. But other necessary nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and more must be obtained from the soil. Farmers generally use fertilizers to correct soil deficiencies. Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate ($NH_4.NO_3$), phosphorus as P_2O_5, and potassium as K_2O. For instance, As, Pb and Cd present in traces in rock phosphate mineral get transferred to super phosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers, becomes an indestructible poison for crops. The over use of NPK fertilizers reduce quantity of vegetables and crops grown on soil over the years. It also reduces the protein content of wheat, maize, grams, etc., grown on that soil. The carbohydrate quality of such crops also gets degraded. Excess potassium content in soil decreases Vitamin C and carotene content in vegetables and fruits. The vegetables and fruits grown on over fertilized soil are more prone to attacks by insects and disease. To kill unwanted populations living in or on their crops, farmers use pesticides. The first widespread insecticide use began at the end of World War II and included DDT (dichlorodiphenyltrichloroethane) and gammaxene. Insects soon became resistant to DDT and as the chemical did not decompose readily, it persisted in the environment. Since it was soluble in fat rather than water, it biomagnified up the food chain and disrupted calcium metabolism in birds, causing eggshells to be thin and fragile. As a result, large birds of prey such as the brown pelican, ospreys, falcons and eagles became endangered. DDT has been now been banned in most western countries. Ironically many of them including USA, still produce DDT for export to other developing nations whose needs outweigh the problems caused by it. The most important pesticides are DDT, BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furodan, etc. The remnants of such pesticides used on pests may get adsorbed by the soil particles, which then contaminate root crops grown in that soil. The consumption of such crops causes the pesticides remnants to enter human biological systems, affecting them adversely.

An infamous herbicide used as a defoliant in the Vietnam War called Agent Orange (dioxin), was eventually banned. Soldiers' cancer cases, skin conditions and infertility have been linked to exposure to Agent Orange. Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil. Some of the pesticides are quite stable and their bio- degradation may take weeks and even months.

Dumping of solid wastes:

In general, solid waste includes garbage, domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboards, plastics, glass, old construction material, packaging material and toxic or otherwise hazardous substances. The portion of solid waste that is hazardous such as oils, battery

metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to. These can in the long run, get deposited to the soils of the surrounding area and pollute them by altering their chemical and biological properties. They also contaminate drinking water aquifer sources. More than 90% of hazardous waste is produced by chemical, petroleum and metal-related industries and small businesses such as dry cleaners and gas stations contribute as well. Solid Waste disposal was brought to the forefront of public attention by the notorious Love Canal case in USA in 1978. Toxic chemicals leached from oozing storage drums into the soil underneath homes, causing an unusually large number of birth defects, cancers and respiratory, nervous and kidney diseases.

Deforestation and Soil Erosion

Deforestation, agricultural development, temperature extremes, precipitation including acid rain, and human activities contribute to soil erosion. Humans speed up this process by construction, mining, cutting of timber, over cropping and overgrazing. It results in floods and cause soil erosion. Forests and grasslands are an excellent binding material that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide innumerable feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. During the past few years quite a lot of vast green land has been converted into deserts. The precious rain forest habitats of South America, tropical Asia and Africa are coming under pressure of population growth and development (especially timber, construction and agriculture).

Pollution Due to Urbanisation

Urban activities generate large quantities of city wastes including several Biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, carcasses, plant twigs, leaves, cloth wastes as well as sweepings) and many non-biodegradable materials (such as plastic bags, plastic bottles, plastic wastes, glass bottles, glass pieces, stone / cement pieces). On a rough estimate Indian cities are producing solid city wastes to the tune of 50,000 - 80,000 metric tons every day. If left uncollected and decomposed, they are a cause of several problems such as

• Clogging of drains: Causing serious drainage problems including the burst / leakage of drainage lines leading to health problems.

• Barrier to movement of water: Solid wastes have seriously damaged the normal movement of water thus creating problem of inundation, damage to foundation of buildings as well as public health hazards.

• Foul smell: Generated by dumping the wastes at a place.

• Increased microbial activities: Microbial decomposition of organic wastes generate large quantities of methane besides many chemicals to pollute the soil and water flowing on its surface.

Many dangerous chemicals like cadmium, chromium, lead, arsenic, selenium products are likely to be deposited in underground soil. Similarly underground soil polluted by sanitary wastes generates many harmful chemicals. These can damage the normal activities and ecological balance in the underground soil.

Table: Effects of Soil Pollution

Agricultural	Industrial	Urban
Reduced soil fertility.	Dangerous chemicals	Clogging of drains.

Reduced nitrogen fixation. Increased erodibility. Larger loss of soil and nutrients. Deposition of silt in tanks and reservoirs. Reduced crop yield. Imbalance in soil fauna and flora.	entering underground water. Ecological imbalance. Release of pollutant gases. Release of radioactive rays causing health problems. Increased salinity. Reduced vegetation.	Inundation of areas. Public health problems. Pollution of drinking water sources. Foul smell and release of gases.

Control of soil pollution:

To help prevent soil erosion, we can limit construction in sensitive area. In general we would need less fertilizer and fewer pesticides if we could all adopt the three R's: Reduce, Reuse, and Recycle. This would give us less solid waste.

Reducing chemical fertilizer and pesticide use: Applying bio-fertilizers and manures can reduce chemical fertilizer and pesticide use. Biological methods of pest control can also reduce the use of pesticides and thereby minimize soil pollution.

Reusing of materials

Materials such as glass containers, plastic bags, paper, cloth etc. can be reused at domestic levels rather than being disposed, reducing solid waste pollution.

Recycling and recovery of materials

This is a reasonable solution for reducing soil pollution. Materials such as paper, some kinds of plastics and glass can and are being recycled. This decreases the volume of refuse and helps in the conservation of natural resources. For example, recovery of one tonne of paper can save 17 trees.

Reforesting

Control of land loss and soil erosion can be attempted through restoring forest and grass cover to check wastelands, soil erosion and floods. Crop rotation or mixed cropping can improve the fertility of the land.

Solid waste treatment

Proper methods should be adopted for management of solid waste disposal. Industrial wastes can be treated physically, chemically and biologically until they are less hazardous. Acidic and alkaline wastes should be first neutralized; the insoluble material if biodegradable should be allowed to degrade under controlled conditions before being disposed. The hazardous waste should be introduced into deep well injection and more secure landfills. Burying the waste in locations situated away from residential areas is the simplest and most widely used technique of solid waste management. Environmental and aesthetic considerations must be taken into consideration before selecting the dumping sites.

Incineration of other wastes is expensive and leaves a huge residue and adds to air pollution. Pyrolysis is a process of combustion in absence of oxygen or the material burnt under controlled atmosphere of oxygen. It is an alternative to incineration. The gas and liquid thus obtained can be

used as fuels. Pyrolysis of carbonaceous wastes like firewood, coconut, palm waste, corn combs, cashew shell, rice husk paddy straw and saw dust, yields charcoal along with products like tar, methyl alcohol, acetic acid, acetone and a fuel gas.

NOISE POLLUTION:

Noise pollution is a disturbance to the human environment that is escalating at such a high rate that it will become a major threat to the quality of human lives. Noises in all areas, especially in urban areas, have been increasing rapidly. Poor urban planning gives rise to noise pollution

Sources of noise pollution

The main source of noise pollution is transportation systems especially motor vehicle, factories, and industries, community and religious activities. The other sources are aircraft noise and rail noise. Besides transportation noise, other sources are office equipment, factory machinery, appliances, power tools, lighting and audio entertainment systems. Construction equipment also produces noise pollution.

Effects of noise pollution

Due to heavy industrialization, exposure of high level of noise gives rise to stress factor in modern life. It may leads to many hazards. The effect of noise on health depends on both, loudness and frequency. Any source producing sound levels of more than 80 to 90 db (decibel) for more than eight hours is harmful to human ear. Frequency of sound is denoted by Hertz (Hz). Human ear can hear frequencies between 20 to 20,000 Hz. Effect of noise on human health depends on i) quality ii) duration iii) sensitivity of the individual the noise pollution produces the following three main effects:

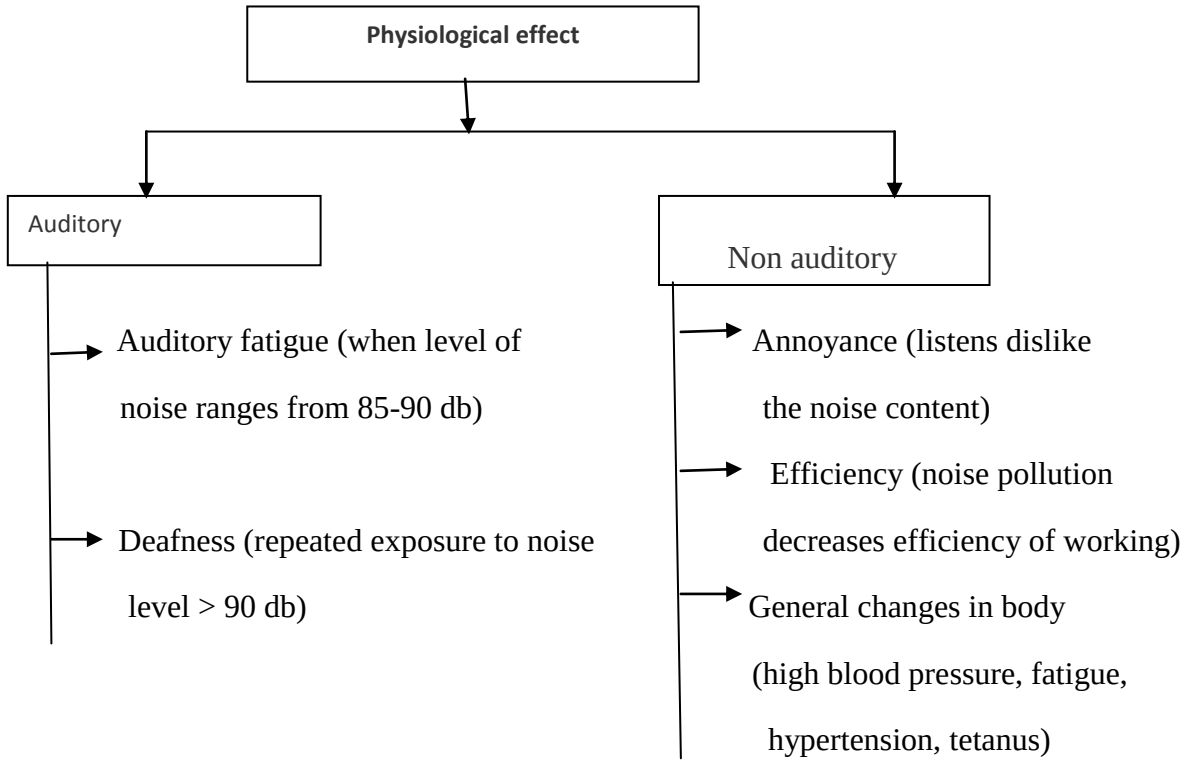
i) Psychological effect

Noise leads to emotional disturbances, however, are difficult to measure. Irritating noise at work place reduces concentration efficiency and working capacity.

ii) Masking effect

Masking noise prevents the ear from registering other important sounds and signals. These effects change the balance in predator /prey detection, by disturbing and interfering the sounds of communications especially during reproduction time period and loss of hearing.

iii) Physiological effect



Control of noise pollution

Noise pollution can be controlled by reducing noise at source. Making a change in design and operation of machines, vibration control, by using sound absorbing materials, can reduce noise pollution. It can also be reduced by prescribing noise limits for vehicular traffic and planning industrial establishments, amusement areas, residential colonies and hospitals to make them noise proof. The other control methods of noise pollution are:

1. Locate the building as far as possible from noise source.

2. Interrupting the path of the sound (by screens and absorbers). For example, Trees like ashok, neem, coconut etc. can be planted to provide some absorption of sound.

3. Government has already passed the "Noise Pollution Control Act" to meet the special Indian condition. Laws should be made for controlling noise hazards at city level.

4. People can be educated through radio, TV, street play etc. about noise pollution and try to reduce the sound level.

MARINE POLLUTION:

The introduction of substances to the marine environment leading to the obstruction of marine activities, deterioration of quality of sea water and producing harmful effects on human health is marine pollution.

Causes/ sources of marine pollution:

1. Discharge of waste: industrial effluents, sewage sludge, synthetic detergents, agrochemicals solid wastes, toxic metals, radioactive substances etc. Which are dumped into the rivers, ultimately mixes with sea and causes marine pollution.

2. The other source of marine pollution is the catchment area i.e. the coastline, where human settlements in the form of hotels, industry, agricultural practices have been established and pollution from these settlements directly pollute the sea.

3. Oil: every year nearly around 3.5 metric ton of oil (accidental and non accidental) mix into sea water. Ballast water containing oil are released into the sea by oil tankers and ships during the return journey, polluting the sea water. Off shore oil exploration or extraction also pollutes sea water.

4. Introduced dangerous metals include mercury, lead, and copper. Heavy Metals are a great concern because they enter the food chain. Fuel combustion, electric utilities, steel and iron manufacturing, fuel oils, fuel additives and incineration of urban refuse are the major sources of oceanic and atmospheric contamination by heavy metals Copper is dangerous to marine organisms and has been used in marine anti-fouling paints. Mercury and lead poisoning cause brain damage and behavioral disturbances in children Contaminated land runoff, rain of pollutants from the air and fallout from shipwrecks pollute the ocean with dangerous metals. Human activities release 5 times as much mercury and 17 times as much lead as is derived from natural sources.

Effects of marine pollution:

1. The sewage being primarily organic in nature is decomposed by bacterialactivities. This activity reduces oxygen concentration of sea water affecting fish or other sea animals.

2. Oil in the sea water affects sensitive flora and fauna. Various species of invertebrates, coral reefs, fish, birds and mammals are effected by oil pollution.

3. Oil coating on sea water obstructs sunlight to penetrate. This effects photosynthesis of sea plants, thereby degrading sea water. This again disturbs the ecosystem.

4. Aromatic compounds in sea water affect the fisherman and sailors.

Control of marine pollution:

1. Toxic pollutants from industries and sewage treatment plants should not be discharged in coastal waters.

2. Sewages should be treated to make it free from BOD (Biological Oxygen Demand) before discharging into the sea.

3. Developmental activities on coastal areas should be minimized and should be allowed to continue only under stringent laws.

4. Run- off from non point sources should prevented to reach coastal areas.

5. Oil ballast should not be dumped into sea. In ecologically sensitive coastal areas drilling should not be allowed.

6. Oil and grease should be processed for reuse.

THERMAL POLLUTION:

Thermal pollution is a temperature change in natural water bodies caused by human influence. The temperature change can be upwards or downwards. Thermal pollution is the degradation of water quality by any process that changes ambient water temperature. In the Northern

Hemisphere, a common cause of thermal pollution is the use of water as a coolant, especially in power plants. Water used as a coolant is returned to the natural environment at a higher temperature. Increases in water temperature can impact on aquatic organisms by (a) decreasing oxygen supply, (b) killing fish juveniles, which are vulnerable to small increases in temperature, and (c) affecting ecosystem composition. In the Southern Hemisphere, thermal pollution is commonly caused by the release of very cold water from the base of reservoirs, with severe affects on fish (particularly eggs and larvae), macro-invertebrates and river productivity.

Sources:

The production of energy from a fuel source can be direct, such as the burning of wood in a fireplace to create heat, or by the conversion of heat energy into mechanical energy by the use of a heat engine. Examples of heat engines include steam engines, turbines, and internal combustion engines. Heat engines work on the principal of heating and pressuring a fluid, the performance of mechanical work, and the rejection of unused or waste heat to a sink. Heat engines can only convert 30 to 40 percent of the available input energy in the fuel source into mechanical energy, and the highest efficiencies are obtained when the input temperature is as high as possible and the sink temperature is as low as possible. Water is a very efficient and economical sink for heat engines and it is commonly used in electrical generating stations.

The waste heat from electrical generating stations is transferred to cooling water obtained from local water bodies such as a river, lake, or ocean. Large amounts of water are used to keep the sink temperature as low as possible to maintain a high thermal efficiency. When this used water returned to the natural environment it has a very high temperature resulting thermal pollution.

Another contributor to thermal pollution is municipal sewage. When sewage discharged into water, not only does the stream temperature rises to measurable extent but also the level of dissolved oxygen in the water decreases.

Effects of thermal pollution:

The primary effects of thermal pollution are direct thermal shock, when a power plant first opens or shuts down for repair or other causes, fish and other organisms adapted to particular temperature range can be killed by the abrupt change in water temperature known as "thermal shock." When temperature increases it typically decreases the amount of dissolved oxygen in water. This can harm aquatic animals such as fish, amphibians and other aquatic organisms. In addition, raising the water temperature increases the decomposition rate of organic matter in water, which also depletes dissolved oxygen. Because water can absorb thermal energy with only small changes in temperature, most aquatic organisms have developed enzyme systems that operate in only narrow ranges of temperature. These stenothermic organisms can be killed by sudden temperature changes that are beyond the tolerance limits of their metabolic systems. The cooling water discharges of power plants are designed to minimize heat effects on local fish communities. However, periodic heat treatments used to keep the cooling system clear of fouling organisms that clog the intake pipes can cause fish mortality. A heat treatment reverses the flow and increases the temperature of the discharge to kill the mussels and other fouling organisms in the intake pipes. Small chronic changes in temperature can also adversely affect the reproductive systems of aquatic organisms and also make them more susceptible to disease.

Thermal pollution may also increase the metabolic rate of aquatic animals, as enzyme activity, resulting in these organisms consuming more food in a shorter time than if their environment were not changed. High temperature limits oxygen dispersion into deeper waters, contributing

to anaerobic conditions. This can lead to increased bacteria levels when there is ample food supply. Many aquatic species will fail to reproduce at elevated temperatures. Primary producers are affected by warm water because higher water temperature increases plant growth rates, resulting in a shorter lifespan and species overpopulation. This can cause an algae bloom which reduces oxygen levels. Temperature changes of even one to two degrees Celsius can cause significant changes in organism metabolism and other adverse cellular biology effects. Principal adverse changes can include rendering cell walls less permeable to necessary osmosis, coagulation of cell proteins, and alteration of enzyme metabolism. These cellular level effects can adversely affect mortality and reproduction. A large increase in temperature can lead to the denaturing of life-supporting enzymes by breaking down hydrogen- and disulphide bonds within the quaternary structure of the enzymes. Decreased enzyme activity in aquatic organisms can cause problems such as the inability to break down lipids, which leads to malnutrition. Fish migration is affected due to formation of various thermal zones.

Control of thermal pollution:

The dilution of cooling water discharges can be effectively accomplished by various types of diffuser systems in large bodies of water such as lakes or the ocean. The effectiveness of the dilution systems can be monitored by thermal infrared imaging using either satellite or airborne imaging systems. Power plants may not be located in the estuarine areas as these areas are breeding and nursery areas for many aquatic plants and animals. power plants are required to discharge at a point where mixing and dispersion is very rapid. A propely designed and located multiport diffuser system at the end of sea fallout provides an efficient method of maximising initial dilution and achieving the regulatory requirements. Use of cooling ponds, cooling towers is also required by thermal power plants.

Cooling ponds, man-made bodies of water designed for cooling by evaporation, convection, and radiation.

Cooling towers, which transfer waste heat to the atmosphere through evaporation and/or heat transfer.

Cogeneration, a process where waste heat is recycled for domestic and/or industrial heating purposes.

The use of cooling towers has been effective for generating stations located on smaller rivers and streams that do not have the capacity to absorb the waste heat from the cooling water effluent. The cooling towers operate by means of a recirculating cascade of water inside a tower, with a large column of upwardly rising air that carries the heat to the atmosphere through evaporative cooling. Cooling towers have been used extensively at nuclear generating stations in both the United States and France. The disadvantages of cooling towers are the potential for local changes in meteorological conditions due to large amounts of warm air entering the atmosphere and the visual impact of the large towers.

In short the effluent discharges to coastal waters may be in such a way that the water temperature of the receiving water shall not be increase so as to cause any damage or harm to aquatic life or vegetation or interfere with any beneficial use assigned to such waters.

NUCLEAR HAZARDS:

Nuclear hazards can be defined as risk or danger to human health or the environment posed by radiation emanating from the atomic nuclei of a given substance, or the possibility of an

uncontrolled explosion originating from a fusion or fission reaction of atomic nuclei. Nuclear Hazards are caused are caused by radioactivity. Radioactivity is the property of certain elements (thorium, radium, uranium etc.) to spontaneously emit protons (alpha particles) electrons (beta particles) and gamma rays by disintegration of atomic nuclei called nuclides.

A number of nuclear explosions have already been made during recent past in different parts of the world. Irrespective of judgments about the ethics of this practice, these tests occurred, injecting substantial amounts of radioactivity into the environment. Nuclear explosions are very rapid and based on a rough estimate, in an explosion about 50 per cent of the energy goes to the blast, 33 per cent as heat and the rest 17 per cent or so to radioactivity.

Biological effects of radiations

Radioactive substances are among the most toxic substances known. Radium is 25,000 times more lethal than arsenic. The cell, which is the fundamental unit of life, is the primary site of radiation damage. If too many cells are damaged, the symptoms show up in the growing tissues as in the case of loss of hair, ulceration of the mouth, the reddening and haemorrhaging of the skin and lowering of the blood count. If these symptoms grow more severe, death will result.

(i) Somatic effects

These are the direct results of action of radiation on the body cell and tissues. Uranium mineworkers, painters of radium dials and Radiologists suffer most. These effects may be' immediate or delayed. More evidence of degree and kind of damage from radiation came from studies of the Nagasaki and Hiroshima survivors. The survivors are likely to become victim are-cardiovascular disorder, cataract, leukaemia, sterility, premature ageing and shortenings of life span. All these are somatic effects.

(ii) Genetic effects

There is another more serious type of effect of ionizing radiations, known as genetic effect. This arises from the damage to the sex cells. If a sex cell is damaged and if that sex cell is one of the pair that goes into the production of a fertilized ovum, it will give rise to an offspring with various kinds of major or minor physical defects.

Radioactive Wastes from Nuclear Power Plants

The hazards of radioactive materials stem from their basic characteristic that radiation cannot be detected by sense organs except in massive doses. Further, there is no way of destroying radioactivity. The radioactive waste from nuclear plants may be in form of gases, liquids or solids. There is no suitable and cheap method of storing the radioactive waste. At any time, radioactivity is likely to escape from the waste in water bodies, concrete cases and salt formations in high mountains. The nuclear waste is thus likely to get leached into the biosphere.

Among the long-lived fission products the most hazardous are Strontium-90 (half life 28.9y) and caesium- 137 (half life 30.2y). The gaseous fission product iodine-131 (half life 8.1 days) is of hazardous nature in the event of its leakage during reactor operation. The highly toxic alpha-active element plutonium (half life 24,100y) is another reactor product that has to be taken care of. All these elements enter the human system and get deposited in various parts of the body causing cell damage. Some of the radio nuclides in these effluents have long half-lives. Sr-90 is produced in larger amounts than others. Radionuclides have become distributed throughout the

environment and are transmitted to man via the food chain. When taken in by man, some radio nuclides become concentrated in specific organs where they become injurious to health.

Reactor Accidents (Chernobyl Accident)

A reactor is one in which fission of atomic fuel occurs. The power plants are designed in a way that there is no leakage of radioactive materials in any form. However, no nuclear plant is contamination proof. During recent years nuclear power programmes have been beset with problems. These problems have reached a climax with two accidents - Three Mile Island in US in 1979 and Chernobyl in Ukraine (erstwhile USSR) in 1986. These two major accidents have greatly shaken the public's confidence in the inherent safety of nuclear power. Significantly both the accidents were due to human error. The Chernobyl accident was relatively more serious.

The accident occurred during a low power engineering experiment, when safety systems were bypassed. Radioactive gases and dust particles were environmentally released, causing radioactive contamination all around the world in varying intensity. It is estimated that about 7,000 kilograms of highly radioactive material containing iodine-131, strontium-90 and caesium-137 and plutonium as well as other nuclides with a total activity of 50-100 million curies were released in the explosion.

The radioactive dust got dispersed over vast areas in Europe, affecting (in addition to USSR), France and even parts of UK. Dose values as high as 760 microsievert per year, has been reported for some European countries following the accident. In the weeks following the accident, fresh vegetables in many parts of Europe showed levels of radioactivity much above the permissible levels. Cattle grazing on contaminated grass were soon producing milk with significant radioactivity. Large populations in the area around the reactor were evacuated. The soil samples from the farmland in the area show radioactivity 170 times the value regarded as tolerable. Some forecasts suggest that the radioactive fallout from Chernobyl could cause as many as 40,000 deaths from cancer world-wide, mainly in Europe.

POINT AND NON POINT SOURCE OF POLLUTION:

Point sources of pollution can be defined as pollutants that enter the transport routes at discrete identifiable locations and that can usually be measured". It is a type of pollution that comes from a single source.

Nonpoint pollutants are defined as "contaminants of [air, and] surface and subsurface soil and water resources that are diffuse in nature and cannot be traced to a point location".

Point source pollutants, in contrast to nonpoint source pollutants, are associated, as the name suggests, with a point location such as toxic-waste spill site As such, point source pollutants are, compared to non- point source pollutants, characteristically (i) easier to control, (ii) more readily identifiable and measurable, and (iii) generally more toxic. Nonpoint sources of pollution are the consequence of agricultural activities (e.g. irrigation and drainage, applications of pesticides and fertilizers, runoff and erosion); urban and industrial runoff; erosion associated with construction; mining and forest harvesting activities; pesticide and fertilizer applications for parks, lawns, roadways, and golf courses; road salt runoff; atmospheric deposition; livestock waste; and hydrologic modification (e.g. dams, diversions, channelization, over pumping of groundwater, siltation). Point sources include hazardous spills, underground storage tanks, storage piles of chemicals, mine-waste ponds, deep-well waste disposal, industrial or municipal waste outfalls, runoff, and leachate from municipal and hazardous waste dumpsites, and septic tanks. Compared to point source pollution, nonpoint source pollution is more difficult, related to monitoring and enforcement of mitigating controls,

due to the heterogeneity of soil and water systems at large scales. Characteristically, nonpoint source pollutants (i) are difficult or impossible to trace to a source, (ii) enter the environment over an extensive area and sporadic timeframe, (iii) are related (at least in part) to certain uncontrollable meteorological events and existing geographic/geomorphologic conditions, (iv) have the potential for maintaining a relatively long active pres- ence on the global ecosystem, and (v) may result in long- term, chronic (and endocrine) effects on human health and soil-aquatic degradation. One type of non-point source pollution is fertilizer. Fertilizer contains nitrogen compounds called nitrates. When fertilizer is applied excessively or just prior to a rainstorm, it washes off the lawn and into the gutter, where it makes its way through the storm sewer system and into a river or lake. Once in the water, these nitrates have the same effect on algae as they do on lawns - they make it grow! Overgrown algae can have devastating effects on a lake or stream, consuming all the oxygen and suffocating fish and other aquatic wildlife. This is called eutrophication. Increased awareness of alternative practices such as xeriscaping and using native grasses can help cut down on fertilizer use. Other types of non-point source pollutants include pesticides, pet waste, motor oil, and household hazardous wastes.
Historically, point source pollutants have received the greatest attention, both publicly and scientifically, because of the conspicuous severity of their impacts at a localized point (e.g. Love Canal (Mercer et al., 1983) and Woburn (Harr, 1995)). However, over recent years, public, political, and scientific attention has shifted more and more toward pollutants that are widespread. This shift reflects an awareness of the scope and potential impact of the non-point source pollution problem (see Corwin and Loague, 1996; Corwin et al., 1999).

ROLE OF INDIVIDUAL IN PREVENTION OF POLLUTION:

Pollution is global problem. It has reached dangerously at high levels. Therefore, for controlling pollution, we just not to depend fully upon the government. Since a few decades, in addition to governmental departments and agencies, NGOs are also doing a lot of work in this direction. Yet, the role of individuals in preventing pollution can never be underestimated. Individuals should take more interest in pollution prevention due to many reasons. Pollution prevention is the reduction or elimination of wastes and pollutants at their sources.

There are many pollutants that can be reduced by changes in our day-to-day activities. These include Pollutants like the cosmetic use of pesticides, car exhaust, and components of household cleaning supplies. There are other pollutants that are emitted by industries and commercial operations in the production of consumer products. These are pollutants like VOCs from solvent usage in printing, surface coating and degreasing operations, flame retardants integrated into textiles and plastic products (polybrominated diphenyl ethers PBDEs), pthalates in plastic products, and dyes used in paper and textile production. Other pollutants are emitted by industries that produce energy and raw materials. Examples of these pollutants are radioactive waste from nuclear plants, emissions from waste incinerators, and by products from mining and smelting operations.

There are also some toxic chemicals that are intentionally released into the environment. Examples include pesticides used in agriculture, forestry and aquaculture, and salt and other de-icing agents used in the de-icing of roads and planes.

Depending on the origin of the pollutant, citizens can practice pollution prevention in a number of ways. Individual action can result in the reduction of some pollutants, and citizens can advocate for changes in industrial, commercial and institutional policies.

The Pollution Prevention Act of 1990

Following passage of the Pollution Prevention Act of 1990, the U.S. Environmental Protection Agency developed a formal definition of P2 and a strategy for making it a central guiding mission. Under Section 6602(b) of the Pollution Prevention Act, Congress established a national policy that:

• Pollution should be prevented or reduced at the source whenever feasible;

• Pollution that cannot be prevented should be recycled in an environmentally safe manner whenever feasible;

• Pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and

• Disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner.

The government of India has also established many laws and policies to prevent pollution which includes:

1. Environmental protection Act, 1986
2. Air pollution (prevention and control) Act, 1981
3. Water pollution (prevention and control) Act, 1981

Individuals can contribute to pollution prevention and environmental protection at many levels:

• By reducing consumption of energy and resources through conservation, recycling, and reuse of products and materials, and by minimizing reliance on automobiles and throw-away products, each person can reduce his or her net impact on the environment.

• Our individual efforts to conserve resources and prevent waste can serve as examples to our families and friends, thereby perpetuating an ethic of conservation and environmental awareness.

• By expressing a preference for environmentally improved goods through our purchasing decisions, we can send a message to manufacturers that they must focus on reducing the environmental impacts of their goods in order to remain competitive.

• In the workplace, we can strive to find ways to reduce the environmental impacts associated with whatever industry, economic activity, or service we are involved in.

• As voters and citizens, we can support political leaders who will be proactive on environmental issues, and who will help ensure that laws are passed to protect environmental quality and spur prevention- oriented actions within all economic sectors. We can also become active in grassroots efforts to ensure that industry and other pollution sources remain accountable to communities, pressuring them when necessary to maximize their efforts to reduce environmental impacts and protect human health.

Pollution prevention has an important role in efforts to achieve global sustainable development. The essence of Pollution prevention is this: to reduce the overall environmental burden associated with meeting our needs and carrying out our activities (including economic production, transportation, communication, recreation, etc.) and increase the efficiency with which we use materials and energy. This is clearly consistent with sustainable development. Pollution prevention, combined with stabilization of world population, sustainable resource

management, and reduced reliance on nonrenewable energy sources, represents the path toward sustainable development.

References:

1. V. Krishnakumar, "An overview of thermal pollution with reference to Indian Coastal waters" Encology, Vol. 9, No. 4, September 1994.

2. Marine Ecosystem: EMCBTAP-ENVIS Newsletter, Department of Geology, University of Kerala, Kariavattom - 695 581 Vol. 1, No. 2, 2003.

3. Encyclopedia of Hydrological Sciences. Edited by M G Anderson. 2005 John Wiley & Sons, Ltd. Keith Loague and Dennis Corwin Point and Non Point Source Pollution

4. "Introductory Pollution Prevention Materials" National Pollution Prevention Center for Higher Education. Pollution Prevention Concepts and Principles September 1995.

Short questions:

1) Define the terms source and sink of pollution.

2) What are the natural and anthropogenic sources of air pollution?

3) Do you think people should recycle newspapers? Why or why not?

4) Which is more important, increasing people's standard of living, or protecting the environment? Think of a situation in your area involving this issue. Which side would you choose?

5) Do you think overpopulation is an important environmental issue? Why or why not?

6) What are the environmental impacts of nuclear and hazardous wastes? Discuss the steps to control the problem.

7) What is global warming? What are the effects of global warming?

8) What is environmental pollution? Discuss the role of individual in controlling environmental pollution.

9) Discuss the environmental impacts of noise pollution and its control strategies

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-2: AIR POLLUTION

UNIT STRUCTURE

2.0 OBJECTIVE

The objective of this unit is to,-

1. To understand about the air pollution, indoor and out door pollution of air

2. To get an idea about the different sources of air pollutants and effect of them on plant and animal health

3. To understand the mechanism of transportation of different air pollutants based on some air pollution models

4. To discuss about the techniques of air pollution monitoring and how air quality standards can be obtained.

2.1 INTRODUCTION

Air is never found clean in nature due to natural and manmade pollution. Gases such as CO, SO_2 and H_2S are continuously released into the atmosphere through natural activities,e.g. volcanic activity, vegetation decay and forest fires. Besides, tiny particles of solids or liquids are distributed throughout the air by winds,volcanic explosions and other similar natural disturbances. In addiotion to these natural pollutants, there are manmade pollutants-gases,mist and particulates,aerosols-resulting from the chemical and biological processes used by man. Air pollutants are present in the atmosphere in concentrations that disturb the dynamic equilibrium in the atmosphere and thereby affect man and his environment. Another source of air pollution is indoor air. The levels of pollutants in the air inside homes, schools, and other buildings can be higher than the level of pollutants in the outdoor air. Indoor air pollution comprises a mixture of contaminants penetrating from outdoors and those generated indoors. In the last several years, the amount of scientific evidence has indicated that the air within homes and other buildings can be

more seriously polluted than the outdoor air in even the largest and most industrialized cities. Other research indicates that people spend approximately 90 percent of their time indoors. In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease. Sources of outdoor or ambient air pollution are varied and include both natural and man-made ones. Natural outdoor air pollution includes oxides of sulphur and nitrogen from volcanoes, oceans, biological decay, lightning strikes and forest fires, VOCs and pollen from plants, grasses and trees, and particulate matter from dust storms. Natural pollution is all around us all of the time. However, sometimes concentrations can increase dramatically, for example after a volcanic eruption, or at the beginning of the growing season.

2.2 POLLUTION SOURCES AND HEALTH EFFECTS AND SOURCE CONTROL

2.2.1 SOURCES OF PRIMARY AIR POLLUTANTS

There are five primary air pollutants which together contribute more than 90% of global air pollution. These are:

i) Carbon monoxide, CO
ii) Nitrogen oxides, NO_x
iii) Hydrocarbons, HC
iv) Sulphur oxides, SO_2
v) Particulates

A. Carbon Monoxide (CO)

The basic chemical reactions yielding CO are:

a. Incomplete combustion of fuel or carbon containing compounds:
$2C + O_2 \rightarrow 2CO$

b. Reaction between CO_2 and carbon containing materials at elevated temperatures in industrial processes,e.g.,in blast furnaces
$CO_2 + C \rightarrow 2CO$

c. Dissociation of CO_2 at high temperatures
$CO_2 \leftrightarrow CO + O$

Sources and sinks of CO:

Natural processes like volcanic action, natural gas emission, electrical discharge during storms, seed germination,marsh gas production,etc. contribute in a small measure to CO in the atmosphere. The significant contribution is from human activities.Following are some of the human activities which produces CO

1. Transportation contributes about 64% of CO (motor vehicles 59%, air crafts 2.4% and railroads 0.1%
2. Miscellaneous sources contributes about 16.9% (forest fires 7.2%, agricultural burning 8.3%,etc.)

3. Industrial processes, mainly iron and steel industries and petroleum and paper industries , constitute the third largest contributor of CO (9.6%) to the air.

The annual input of CO into the atmosphere by human activities is expected to double its concentration in the ambient (surrounding) atmosphere every five years. But the actual increase in global CO concentration is much less. The major sink of CO is some soil micro-organisms. These includes some fungi-*Penicillium* and *Aspergillus*.

Control of CO pollution:

The transportation sources are responsible for 74% of all CO emissions .Hence, the considerable efforts for control of CO pollution are mainly directed at automobiles. Extensive investigations have been and are being made for control of automotive emissions along the following lines:

1. Modification of internal combustion engines to reduce the amounts of pollutants formed during fuel combustion.
2. development of exhaust system reactors which will complete the combustion process and change potential pollutants into more acceptable materials.
3. Development of substitute fuels for gasoline, which will yield low concentrations of pollutants upon combustion
4. Development of pollution free power sources to replace the internal combustion engine.

Use of catalytic converters in two stages helps in eliminating pollutants from exhaust gases before they are discharged in to the atmosphere. In the first converter $(NO)_x$ is reduced to N_2 $(+NH_3)$in the presence of finely divided Pt, as catalyst,and the reducing gases,CO and hydrocarbons.The production of NH_3 is kept at a minimum under carefully controlled conditions. In the second converter,air is introduced to provide oxidizing atmosphere for complete oxidation of HC and CO into H_2O and CO_2 in the presence of finely divided Pt catalyst.One problem of the Pt catalyst is that it is liable to be poisoned by heavy metals (e.g. Pb) present in gasoline itself. Hence, Pb-free gasoline must be used for proper function of the catalytic converters.

The third possible approach to CO-pollution problem is a substitute fuel for gasoline. Natural gas in both compressed (CNG) and liquiefied forms (LNG) has been used as fuel. Although it is an attractive pollution free fuel,there are problems of steady supply and economic storage. Alcohols are other substitutes, but their combustion products aldehydes are eye irritants.

The fourth possible solution to automotive emission problem is alternate power sources,e.g., steam,electric and gas turbine engines. But none of these economically viable as gasoline.

B. Nitrogen oxides (NO_x)

It represents composite atmospheric gases,nitic oxide (NO), and nitrogen dioxide (NO_2), which are primarily involved in air pollution. The formation of NO is favoured at high temperatures, normally attained during many combustion processes involving air (1210 to 1763 ^oC).Natural bacterial action discharges about 5×10^3 tonnes of NO_x, mainly in the form of NO. The man made sources annually releases 5×10^7 tonnes of NO_x.The distribution of NO_x from natural sources is more or less uniform on a global basis, but that from man-made sources varies depending on urban/rural areas. In urban areas NO_x is 10 to 100 times greater than in rural areas.

Control of NO_x pollution: The use of catalytic converters for control of automotive emissions provides for removal of NO_x in the first stage.

C. Hydrocarbon and photochemical smog:

Natural sources, particularly trees, emit large quantities of hydrocarbons in the atmosphere. CH_4 is the major naturally occurring hydrocarbon emitted in to the atmosphere.It is produced in considerable quantities by bacteria in the anaerobic decomposition of organic matter in water,sediments and soil. Domesticated animals contribute about 85 million tones of CH_4 to the atmosphere each year.It has been estimated that anthropogenic sources (human activities)contribute about 15% of the hydrocarbons emitted to the atmosphere each year. Automobiles are the major source in this resp[ect. Hydrocarbons from human activities are generally found in areas of high population density where the maximum damage to human beings and plants can occur.

Hydrocarbons are removed from the atmosphere by several chemical and photochemical reactions. They are thermodynamically unstable towards oxidation and tend to be oxidized through a series of steps. The end products are CO_2 and solid organic particulate matter that settle from the atmosphere or water soluble products,e.g., acids and aldehydes,which are washed by rain.

Photochemical Smog

Majority of the harmful effects of hydrocarbon pollutions are not due to the hydrocarbons themselves but the products of photochemical reactions in which they are involved. Hydrocarbons donot react readily with sunlight,but they are reactive towards other substances produced photochemically. An important characteristic of atmosphere which is loaded with large quantities of automobile exhausts trapped by an inversion layer and at the same time exposed to intense sunlight,is the formation of photochemical oxidants in the atmosphere.This gives rise to the phenomenon of photochemical smog. Photochemical smog is characterized by brown,hazy fumes which irritates the eyes and lungs and also leads to the cracking of rubber and extensive damage of plant life.

D. Sulphur Dioxide,SO_2

It is a colourless gas with a pungent odour. It is produced from the combustion of any sulphur bearing material. It is always accompanied by a little SO_3.The mixture is denoted by SO_x.Natural processes e.g. volcanoes provide 67% of the SO_x pollution and it is eventually distributed all over the globe.Man made sources contribute about 33% of SO_x pollution which is however localized in some urbarn areas. Among them fuel combustion (coal) in stationary sources accounts for 74%, industries 22% and transportation 2% of the total SO_x emission. In other words, coal fired power stations are the major culprits in this respect, followed by industrial plants. Sulphate aerosols in urbarn air are generally smaller than 2 μ so they can easily penetrate the innermost passages of the lungs of humans and cause severe respiratory troubles, particularly among the older people.

Control of SO_x pollution:

There are four possible approaches to the removal and control of SO_x emission:

1. Removal of SO_x from fuel gases
2. Removal of sulphur form fuel burning

3. Use of low sulphur fuels
4. Substitution of other energy sources for fuel combustion

Power plant, the major anthropogenic sources of SO_x pollution are normally built with tall smokestacks to disperse the plume over a wide area. This reduices the local problem but creates problems in areas far remote from the power plants. SO_x from flue gases can be conveniently eliminated by using chemical scrubbers. The flue stack gases are passed through a slurry of limestone, $CaCO_3$ which absorbs SO_2 quite efficiently.This method appears economical, but is not favoured by power plant official since the primary drawback is that $CaSO_3$ in large amount posses a waste disposal problem. An alternative process is based on a reaction between HSO_3^- ions (from SO_2) and citrate ions. The flue gas is cooled to 50^0C or lower and freed from particulates and traces of H_2SO_4. It is then led into an absorption tower and brought into contact with a solution containing citrate ions. The solution is next fed into a closed vessel in which H_2S is bubbled. Sulphur precipitates out and is later melted and removed from the solution.

E. Particulates

Small solid particules and liquid droplets are collectively termed particulates. These are present in the atmosphere in fairly large numbers and sometimes pose a serious air-pollution problem. In general, the properties of elements in atmospheric particulate matter depend on their relative abundances in the parent material. Atmospheric particulate matter present a wide diversity of chemical compositions. Organic matter, nitrogen compounds,sulphur compounds, several metals and radionuclides are present in polluted urban atmospheres.The most important physical property is the size. Particulates range in size from a diameter of 0.0002 μ (about the size of small molecule) to a diameter of 500 μ with lifetimes varying from a few seconds to several months. This lifetime however depends on the settling rate, which again depends upon the size and density of the particules and turbulence of air.

There are numerous natural processes injecting particulate matter into the atmosphere. Examples are volcanic eruptions, blowing of dust and soil by the wind, spraying of salt and other solid particules by the seas and oceans, etc. The contributions from the manmade activities are flyash from power plants, smelters and mining operations, and smoke from incomplete combustion processes.

Metal oxides comprise a major class of inorganic particulate matter in the atmosphere. They are produced whenever fuels containing metals are burnt.The organic particulate matter occurs in a wide variety of compounds in the atmosphere. Polycyclic aeromatic hydrocarbons (PAH) are important components of organic particulate matter because of their carcinogenic nature.

Flyash

The bulk of the mineral particulate matter in a polluted atmosphere exists as oxides and other compounds resulting from the combustion of high ash fossil fuel. Smaller ash particules called flyash enter furnace flues and emerge from the stack,in the absence of collector devices, and enter the atmosphere.

Control of particulate emission:

The removal of particulate matter from gas streams is an essential step for air pollution control.There are four types of equipments used for this purpose

1. Gravity settling chamber: Effluent gases are led in to a chamber which is large enough to permit gas velocities to decrease and dust or droplets to settle. This method is not suitable for the particles which require longer settling time.
2. Cyclone collector: A gas flowing in tight circular spiral produces a centrifugal force on suspended particles,forcing them to move upward through the gas streamto a wall where they are collected. Thus it is possible to remove 95% particles in the diameter range of 5-20 μ.
3. Wet scrubbers: these utilize a liquid (usually H_2O) to help remove solid,liquid or gaseous contaminants. The extent of collect and interaction are increased by the use of spray chambers or towards where the liquid is introduced into the gas stream as fine spray.
4. Electrostatic precipitators: these are based on the principle that aerosol particles acquire charges when subjected to an electrical field.

Effects of atmospheric pollution: Atmospheric pollutants are present largely in the troposphere and lower stratosphere, the layer of air near the ground,1-100 m high,is generally very much polluted in urbarn areas and industrial sites. Some pollutants are absorbed into vegetation, building and water surfaces. The next layer of air, 100-2000m high, contains pollutants which are well mixed by the turbulent air currents and part of which is washed out by drizzle,rain and fog. The thired layer extending up to the tropopause contains major amount of water vapour and clouds. Some pollutants may be dissolved or turn into nuclei in the cloud water droplets. Subsequently, they are eliminated as rain or discharged again into the atmosphere on evaporation of water. The lower stratosphere contains low concentration of pollutants, dust by direct injection from volcanic eruptions, ground and air nuclear explosion and also the products of photochemical reactions involving CH_4 and SO_3.The pollutants however stay in the stratosphere for a long period due to very little movement of air mass in this region.

Particulate effects:The large concentration of particulates in the atmosphere over large cities and industrial areas produces some general effects. Smoke and fumes tend to increase the atmospheric turbidity reducing visibility and the quantum of solar radiation reaching the earth's surface. Solid particulates participate in cloud formation.Pollution and water vapour emission in urban air tend to increase cloud cover by 10% giving 10% more wet days, more mist, fog and smogrelative to rural areas. These processes combine to increase the deposit of large sized particulateson the ground. These led to erosion and corrosion of building materials,metals and also damage to plants.

Effects in the biosphere: The primary pollutants discharged into the atmosphere suffer chemical changes in presence of H_2O,O_2 and ultraviolet rays of sunlight to form secondary pollutants. These pollutants have some overall effects on soil,vegetation,crops animals, man and materials. Plants are affected by gaseous pollutants and deposition of particulates on soil. Acid rain over a period of time tends to lower the soil pH and makes it acidic. Furthermore, deposition of toxic metals as the latter inhibit the action of some plant enzymes. On the otherhand particulates such as dust and soot,deposited on plant leaves,block the stomata of the plants. This in turn affects the plants by restricting the absorption of CO_2 and reducing the rate of photosynthesis as well as the rate of transpiration. The net result is the retarded growth of plants and the decreased yield of crops. O_3 and PAN behave as an oxidizing agents in solution and they probably attack plants by oxidizing their SH groups of proteins into disulphides. This oxidation results in inhibition of individual enzyme activity. Photosynthesis is also affected by both O_3 and PAN. The mechanism is not yet known. SO_2 seems to exert similar physiological effect on plant stomata. Stomatal opening is promoted by low dosage and stomatal closure by high dosage. The biochemical effect of SO_2 on plant metabolism requires further exploratory work. However the visible effects are : less yield, leaf damage and depression of pollen tube.Cattle are

also affected by air pollution.They developed breathing troubles and may died. The presence of SO_2 in polluted air accelerates the corrosion of metals. This represents the heavy price man has to pay for air pollution interms of repair or replacement of corroded structures and also anticorrosion measures.Most of the corrosion problems are associated with corrosion of iron and its alloys and nonferrous metals like Zn,Cu,Al used in outdoor constructions.

Air pollutants show maximum concentration in urban areas so that urban population is exposed to these gases indoors where they spend most of their time.

2.3 TRANSPORT AND DIFFUSION OF POLLUTANTS (AIR POLLUTION MODELS)

Air pollution modeling is a numerical tool used to describe the causal relationship between emissions, meteorology, atmospheric concentrations, deposition, and other factors. Air pollution measurements give important, quantitative information about ambient concentrations and deposition, but they can only describe air quality at specific locations and times, without giving clear guidance on the identification of the causes of the air quality problem. Air pollution modeling, instead, can give a more complete deterministic description of the air quality problem, including an analysis of factors and causes (emission sources, meteorological processes, and physical and chemical changes), and some guidance on the implementation of mitigation measures. Air pollution models play an important role in science, because of their capability to assess the relative importance of the relevant processes. Air pollution models are the only method that quantifies the deterministic relationship between emissions and concentrations/depositions, including the consequences of past and future

scenarios and the determination of the effectiveness of abatement strategies. This makes air pollution models indispensable in regulatory, research, and forensic applications. The concentrations of substances in the atmosphere are determined by: 1) transport, 2) diffusion, 3) chemical transformation, and 4) ground deposition. Transport phenomena, characterized by the mean velocity of the fluid, have been measured and studied for centuries. For example, the average wind has been studies by man for sailing purposes. The study of diffusion (turbulent motion) is more recent. Among the first articles that mention turbulence in the atmosphere, are those by Taylor (1915, 1921).

Sir Graham Sutton derived an air pollutant plume dispersion equation in 1947 which did include the assumption of Gaussian distribution for the vertical and crosswind dispersion of the plume and also included the effect of ground reflection of the plume.

Under the stimulus provided by the advent of stringent environmental control regulations, there was an immense growth in the use of air pollutant plume dispersion calculations between the late 1960s and today. A great many computer programs for calculating the dispersion of air pollutant emissions were developed during that period of time and they were called "air dispersion models". The basis for most of those models was the Complete Equation For Gaussian Dispersion Modeling Of Continuous. Buoyant Air Pollution Plumes shown below

$$C = \frac{Q}{u} \cdot \frac{f}{\sigma_y \sqrt{2\pi}} \cdot \frac{g_1 + g_2 + g_3}{\sigma_z \sqrt{2\pi}}$$

where:

f = crosswind dispersion parameter

$$= \exp\left[-y^2/\left(2\,\sigma_y^2\right)\right]$$

g = vertical dispersion parameter = $g_1 + g_2 + g_3$

g_1 = vertical dispersion with no reflections

$$= \exp\left[-(z-H)^2/\left(2\,\sigma_z^2\right)\right]$$

g_2 = vertical dispersion for reflection from the ground

$$= \exp\left[-(z+H)^2/\left(2\,\sigma_z^2\right)\right]$$

g_3 = vertical dispersion for reflection from an inversion aloft

$$= \sum_{m=1}^{\infty} \{\exp\left[-(z-H-2mL)^2/\left(2\,\sigma_z^2\right)\right]$$

$$+ \exp\left[-(z+H+2mL)^2/\left(2\,\sigma_z^2\right)\right]$$

$$+ \exp\left[-(z+H-2mL)^2/\left(2\,\sigma_z^2\right)\right]$$

$$+ \exp\left[-(z-H+2mL)^2/\left(2\,\sigma_z^2\right)\right]\}$$

C = concentration of emissions, in g/m³, at any receptor located:

x meters downwind from the emission source point

y meters crosswind from the emission plume centerline

z meters above ground level

Q = source pollutant emission rate, in g/s

u = horizontal wind velocity along the plume centerline, m/s

H = height of emission plume centerline above ground level, in m

σ_z = vertical standard deviation of the emission distribution, in m

σ_y = horizontal standard deviation of the emission distribution, in m

L = height from ground level to bottom of the inversion aloft, in m

exp = the exponential function

The above equation not only includes upward reflection from the ground, it also includes downward reflection from the bottom of any inversion lid present in the atmosphere.

The sum of the four exponential terms in g_3 converges to a final value quite rapidly. For most cases, the summation of the series with $m = 1$, $m = 2$ and $m = 3$ will provide an adequate solution.

σ_z and σ_y are functions of the atmospheric stability class (i.e., a measure of the turbulence in the ambient atmosphere) and of the downwind distance to the receptor. The two most important variables affecting the degree of pollutant emission dispersion obtained are the height of the emission source point and the degree of atmospheric turbulence. The more turbulence, the better the degree of dispersion.

Other Models

Many additional models are available either for regulatory applications or for R&D

studies. We provide a brief list below

A. Meteorological Models

1. CALMET:

CALMET is a meteorological diagnostic model that combines data from surface stations, upper-air stations, over-water stations, precipitation stations, with geophysical data like land use, terrain elevations, albedo, etc.,to produce a fully 3-dimensional diagnostic gridded wind field for the duration of the CALPUFF simulation. This wind field is then passed into CALPUFF and is used to transport the emitted substances. CALMET can link to prognostic meteorological models (i.e., MM5, ETA, RUC2, RAMS) and use their data to produce the gridded wind field.The PSU/NCAR mesoscale model (known as MM5) is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to

simulate or predict mesoscale atmospheric circulation. The model is supported by several pre- and post-processing programs, which are referred to collectively as the MM5 modeling system. The MM5 modeling system software is mostly written in Fortran, and has been developed at Penn State and NCAR as a community mesoscale model with contributions from users worldwide.

RAMS, the Regional Atmospheric Modeling System, is a highly versatile numerical code developed by scientists at Colorado State University for simulating and forecasting meteorological phenomena, and for depicting the results. Its major components are:

1. An atmospheric model which performs the actual simulations

2. A data analysis package which prepares initial data for the atmospheric model from observed meteorological data

3. A post-processing model visualization and analysis package, which interfaces atmospheric, model output with a variety of visualization software utilities.

2. Plume Rise Modules

Most air pollution models include a computational module for computing plume rise, i.e., the initial behavior of a hot plume injected vertically into a horizontal wind flow. In particular, AERMOD includes PRIME (Plume Rise Model Enhancements) PRIME is an algorithm for simulating plume rise effects, including downwash as the plume travels over buildings.

3. Particle Models

Particle models are based on Lagrangian methods for simulating atmospheric diffusion. In these models, plumes are represented by thousands (even hundreds of thousands) of "fictitious" particles, which often move with semi-random trajectories in order to recreate the random components of atmospheric turbulence. These high-resolution models are particularly useful for simulating short-term releases from sources with highly variable emission rates in complex dispersion scenarios. Particle models are capable of simulating very short-term concentrations (e.g., 1-minute averages). Examples are listed below:

4. Deposition Modules

Many air pollution models include a computational module for computing the fraction of the plume deposited at the ground as a consequence of dry and wet deposition phenomena.

5. Odor Modeling

The mechanisms of dispersion of odorous chemicals (e.g., mercaptans) in the atmosphere are the same as the dispersion of other pollutants. However, when multiple pollutants are emitted, masking and enhancing effects may occur. In this case, the relationship between concentrations of individual chemicals and odor is not well defined and odor must be characterized in terms of an odor detection threshold value for the entire mixture of odorous chemicals in the air. This is why, in odor modeling applications, it is often preferred to express the emission in "odor units". Odor models must include algorithms to simulate instantaneous or semi-instantaneous concentrations, since odors are instantaneous human sensations.

6. Statistical Models

Statistical models are techniques based essentially on statistical data analysis of measured ambient concentrations. These models are not deterministic, in the sense that they do not establish nor simulate a cause-effect, physical relationship between emissions and ambient concentrations. Two main types of statistical models exists:

7. Air Quality Forecast and Alarm Systems:

Statistical techniques (e.g., time series analysis, spectrazl analysis, Kalman filters) have been used to forecast air pollution trends a few hours in advance for the purpose of alerting the population or, for example, blocking automobile traffic. For a review of these techniques, see Finzi and Nunnari (2005).

8. Modeling of Adverse Effects

Special models or mathematical techniques are available to calculate the adverse

effects of air pollution. These models include:

• Health effects (e.g., cancer risk)

• Visibility impairment

• Global effects, such as climate change

• Damage to materials

• Ecological damages

2.4 TRANS BOUNDARY POLLUTION, ACID RAIN

Transboundary air pollution is a particular problem for pollutants that are not easily destroyed or react in the atmosphere to form secondary pollutant. These are cross boundary pollutants that can be generated in one country and felt in others; these require international actions and collaboration to control their formation and effects. Transboundary air pollutants can survive for periods of days or even years and can be transported 100s or thousands of miles before they affect the air we breathe, soils, rivers, lakes and/or our food. Transboundary air polutants cause a number of different problems: e.g. formation of particles, ground level ozone which are hazardous to health, the formation of acid rain which can damage buildings and sensitive ecosystems and some that are toxic to human health and the environment.

Acid rain is a broad term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric and sulfuric acids. The precursors, or chemical forerunners, of acid rain formation result from both natural sources, such as volcanoes and decaying vegetation, and man-made sources, primarily emissions of (SO_x) and nitrogen oxides (NO_x)resulting from fossil fuel combustion. In the United States, roughly 2/3 of all SO_2 and 1/4 of all NO_x come from electric power generation that relies on burning fossil fuels, like coal. Acid rain occurs when these gases react in the atmosphere with water, oxygen, and other chemicals to form various acidic compounds. The result is a mild solution of sulfuric acid and nitric acid. When sulfur dioxide and nitrogen oxides are released from power plants and other sources, prevailing winds blow these compounds across state and national borders, sometimes over hundreds of miles.

2.5AIR POLLUTION MONITORING, EMISSION INVENTORIES AND AIR QUALITY STANDARDS

In 1971,the United States Environmental Protectation Agency set national air quality standards. It is not correct to evaluate pollutant gases in terms of their tonnage since it doesnot take into account the possibility of one pollutant being much more harmful than another. Thus particulates are the most toxic pollutants in the list although,tonnagewise,CO is at the top of the list. The relative toxicity values are however qualitative,but they gives clues to the pollution problem.The national Environment Engineering Institute (NEERI) is operating a national wide air quality monitoring network since 1978. The programme sponsored by Central pollution Control Board since1990, has generated a time series on air quality for ten major Indian cities.

The database facilities evaluation of long term air quality trends for health related criteria pollutants such as inhalable dust, sulphurdioxide, hydrogen sulphide, ammonia, lead and polycyclic aromatic hydrocarbons.

Assessment of heterogeneous ionic species, viz,. sulphate, nitrate, chloride, fluoride, ammonia, sodium, potassium, calcium and magnesium has been conducted. These species manifest atmospheric reactions during dry depodition processes, and enable source appointment of the air pollutants.

The characterization and speciation of aerosols from size fractionated respirable particulates (<P10) have been carried out for toxic trace metals, organic fractions for carcinogenic compounds and secondary pollutants formed during the atmospheric reactionsfrom criteria pollutants.

There are two types of standards -- primary and secondary. Primary standards protect against adverse health effects; secondary standards protect against welfare effects, such as damage to farm crops and vegetation and damage to buildings. Because different pollutants have different effects, the NAAQS are also different. Some pollutants have standards for both long-term and short-term averaging times. The short-term standards are designed to protect against acute, or short-term, health effects, while the long-term standards were established to protect against chronic health effects.

The several units for expressing air pollutants and air quality parameters are given below:

Gases and vapours, $\mu g/m^3$ (also ppm by volume)

Weight of particulate matter, $\mu g/m^3$

Particulate matter count, no.per cubic meter

Visibility,km

Emission and sampling rates,m^3/min

Pressure, mm Hg

An emission inventory is an accounting of the amount of pollutants discharged into the atmosphere. An emission inventory usually contains the total emissions for one or more specific greenhouse or air pollutants, originating from all source categories in a certain geographical area and within a specified time span, usually a specific year.

2.6 CASE STUDY

a) TCDD Accident at Seveso,Italy (July,1976): An explosion took place in a chemical plant manufacturing herbicide (2,4,5 trichlorophenoxy acetate). A white cloud of poisonous gas consisting of TCDD (2,3,7,8 tetra chlorobenzo-10-dioxin came out and engulfed the area. The building, ground and soil were contaminated. After three weeks of the accident the Italian government evacuated about 800 people from the worst affected areas. However the dioxin pollution continued to spread and particulates are deposited over widespread area.About 200 people including children suffered from skin diseases and some of them from liver troubles. About 1% of the babies born after the accident were deformed and also premature. According to experts,dioxin will continue to contaminate soil, water and affect water resources and natural biological cycles.

b) The Bhopal Disaster: It was on 3rd December, 1984 at Bhopal, Madhya Pradesh,India. The source of the pollution was from the Union carbide Factory, manufacturer of Carbaryl (Carbamate pesticide) using methyl isocyanate)i.e. MIC. It is invariably accompanied by $COCl_2$ (2%). The threshold limiting value (TLV) for MIC is 0.02 ppm and $COCl_2$ 0.1 ppm. The toxic effect of MIC is enhanced by $COCl_2$. Exposure to MIC leads to chest tightness,breathing troubles and eyeache and also cyanide generation in the body,which ultimately turns fatal.About 28,000 gas victims have died so far while an estimated 10-15 people are dying every month from exposure related ailments.More than 120,000 survivors are said to be still suffering from a variety of chronic illnessi9ncluding lung's disease,hypertension and anxiety,respiratory tract problems,diminished vision,acute depression,muscular fatigue,gynecological disorder and recurrent fever,etc.

2.7 SUGGESTED READINGS

1. Environmental Science By S.C. Santra .Published by New Central Book Agency (P) Ltd.
2. Environmental management By N.K. Uberoi Published by Excel BooksNew Delhi.
3. Environmental Chemistry (seventh Edition) By A.K. De Published by New Age International Publishers,New Delhi.
4. http://www.envirocomp.org/books/chapters/2aap.pdf

2.8 PROBABLE QUESTIONS

1. How do you propose to control
   a. CO emission
   b. Hydrocarbon emission
   c. NO_2 emission
   d. SO_2 emission
   e. Particulate emission
2. Write a short note on the following
   a. Flyash b. Bhopal disaster
3. Write a note on indoor air pollutants
4. What are the primary air pollutants? Discuss their sources and relative contribution to air pollution.
5. Write a note on air pollution models

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-3: WATER POLLUTION

UNIT STRUCTURE

ABSTRACT

Water is a critical resource in the lives of people who both benefit from its use and who are harmed by its misuse. Water is a finite and vulnerable resource. Consequently, consumption of polluted water puts lives and livelihoods at risk because water has no substitute. There are many ways in which water intended for human consumption can get polluted. These include wastes from industries like mining and construction, food processing, radioactive wastes from power generating industries, domestic and agricultural wastes and by various microbiological agents.

Water quality monitoring is one of the first steps required in the rational development and management of water resources. In the field of water quality management, there has been a steady evolution in procedures for designing system to obtain information on the changes of

water quality. The ‘monitoring’ comprise all activities to obtain ‘information’ with respect to the

water system. The present unit covers the importance of water as a resource and how its quality have been degraded due to human activities. The description of water quality and monitoring guidelines and how to counteract with water deterioration.

3.1 INTRODUCTION

Water pollution is a serious problem in India as almost 70% of its surface water resources and a growing percentage of its groundwater reserves are contaminated by biological, toxic, organic, and inorganic pollutants. In many cases, these sources have been rendered unsafe for human consumption as well as for other activities, such as irrigation and industrial needs. This shows that degraded water quality can contribute to water scarcity as it limits its availability for both human use and for the ecosystem.

Water quality is a complex subject, which involves physical, chemical, hydrological and biological characteristics of water and their complex and delicate relations. From the user's point of view, the term "water quality" is defined as "those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water". For example for drinking water should be pure, wholesome, and potable. Similarly, for irrigation dissolved solids and toxicants are important, for outdoor bathing pathogens are important and water quality is controlled accordingly. Textiles, paper, brewing, and dozens of other industries using water, have their specific water quality needs.

The composition of surface and underground waters is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and varies with seasonal differences in runoff volumes, weather conditions and water levels. Large natural variations in water quality may, therefore, be observed even where only a single watercourse is involved. Human intervention also has significant effects on water quality. Some of these effects are the result of hydrological changes, such as the building of dams, draining of wetlands and diversion of flow. More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin.

In 1995, the Central Pollution Control Board (CPCB) identified severely polluted stretches on 18 major rivers in India. Not surprisingly, a majority of these stretches were found in and around large urban areas. The high incidence of severe contamination near urban areas indicates that the industrial and domestic sectors' contribution to water pollution is much higher than their relative importance implied in the Indian economy. Agricultural activities also contribute in terms of overall impact on water quality. Besides a rapidly depleting groundwater table in different parts, the country faces another major problem on the waterfront—groundwater contamination—a problem which has affected as many as 19 states, including Delhi. Geogenic contaminants, including salinity, iron, fluoride, and arsenic have affected groundwater in over 200 districts spread across 19 states.

3.1.1 THE UNIQUE PROPERTIES OF WATER

Water is so common that we take it for granted. In fact, nearly every physical and chemical property of water is unusual when compared with other liquids, and these differences are essential to life as we know it. Before presenting the more specific description of physico-chemical properties it is worth to enumerate properties of water that familiar to all of us. Water can be characterized as follows:

- It`s colourless;
- It`s odourless;

- It`s tasteless;
- It feels wet;
- Its distinctive in sound when dripping from a faucet or crashing as a wave;
- It dissolves nearly everything;
- It exist in three forms: solid, liquid and gas;
- It can absorb a large amount of heat;
- It sticks together into beads or drops;
- It's part of every living organism on the planet.

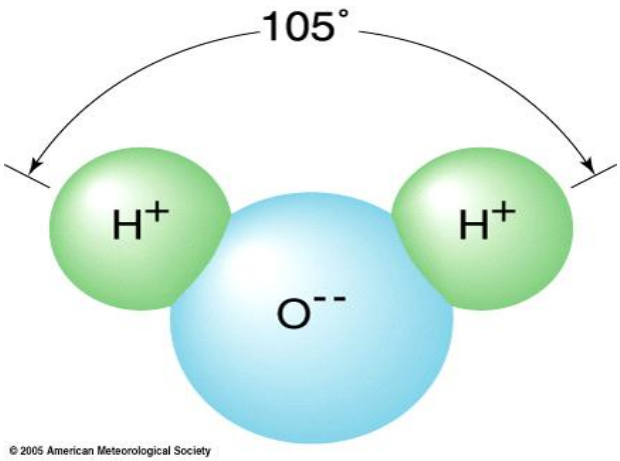


Fig 3.1 A water molecule is dipolar; that is, it appears to have a positive charge at one end and a negative charge at the other. This dipolar character helps explain a number of water`s unique properties.

Density

Water is the only common liquid that expands when it freezes. In fact, a plot of density versus temperature shows a maximum density at 4ºC, which means that as temperatures move away from this point, water continuously becomes lighter and more buoyant. As a result, ice floats. If it did not, ice that would form on the surface of bodies of water would sink to the bottom, making it possible for rivers and lakes to freeze solid from the bottom up. The expansion of water as it freezes also contributes to the weathering of rocks literally breaking them apart when water freezes in the cracks. When water is warmed beyond 4ºC, it becomes buoyant once again, so warm water floats on top of cold water in lakes.

Melting and Boiling Points

Water has unusually high boiling and freezing temperatures for a compound having such a low molecular weight. If water were similar to other "H_2X" substances, such as H_2S, H_2Se and H_2Te, it could boil at normal Earth temperatures, so it would mostly exist as a gas rather than a liquid or solid. It also has an unusually high difference in temperature between the melting point and boiling point, thus remaining a liquid over most of the globe. It is only the substance that appears in all three states, gaseous, liquid, and solid (ice), within the normal range of temperatures on Earth. With only slightly different phase change temperatures, life on Earth would be very different, if it could exist at all.

Specific Heat

Water has a higher heat capacity (4,184J/kg ºC) than any other known liquid except ammonia. It is five times higher than the specific heat of most common heavy solids, such as rock and concrete. As a result, it takes water longer to heat up and to cool down than almost anything else. This high heat capacity helps make the oceans the major moderating factor in maintaining the temperature of the surface of the Earth. It also serves the important function of protecting life from rapid thermal fluctuations, which are often lethal.

Heat of Vaporization

The heat required to vaporize water (2,258kJ/kg) is one of the highest of all liquids. This high heat of vaporization means that water vapor stores an unusually large amount of energy, which is released when the water vapor condenses. This property is important in distributing heat from one place on the globe to another and is a major factor affecting the Earth`s climate.

Water as a Solvent

Water dissolves more substances than any other common solvent. As a result, it serves as an effective medium for both transporting dissolved nutrients to tissues and organs in living things as well as eliminating their wastes. Water also transports dissolved substances throughout the biosphere.

Greenhouse Effect

The 105ºC bond angle for water is actually an average value. The hydrogen atoms vibrate back and forth, causing the bond angle to oscillate. This H-O-H bending vibration resonates with certain wavelengths of electromagnetic radiation coming from the sun, allowing water vapor in the atmosphere to absorb solar energy. Other vibrations in water molecules also cause absorption of infrared radiation leaving the Earth`s surface. Earth`s temperature depends to a significant degree on the absorption of incoming solar radiation and outgoing infrared radiation.

3.1.2 TYPES OF WATER POLLUTANTS

1. INFECTIOUS AGENTS

The most serious water pollutants in terms of human health worldwide are pathogenic organisms. The main source of these pathogens is from untreated or improperly treated human wastes. In developed countries, sewage treatment plants and other pollution-control techniques have reduced or eliminated most of the worst sources of pathogens in inland surface waters. The situation is quite different in less-developed countries. The United Nations estimates that at least 2.5 billion people in these countries lack adequate sanitation, and that about half these people also lack access to clean drinking water. Water quality control personnel usually analyze water for the presence of coliform bacteria, any of the types that live in the colon or the intestines of humans and other animals (e.g. E. coli)

Table 3.1 -- Major categories of water pollutants

Category	**Examples**	**Sources**

A. Causes health problems		
1. Infectious agents	Bacteria, viruses, parasites	Human and animal excreta
2. Organic chemicals	Pesticides, plastics, detergents, oil, and gasoline	Industrial, household, and farm use
3. Inorganic chemicals	Acids, caustics, salts, metals	Industrial effluents, household cleansers, surface runoff.
4. Radioactive materials	Uranium, thorium, cesium, iodine, radon	Mining and processing of ores, power plants, weapons production, natural sources
B. Causes ecosystem disruption		
1. Sediment	Soil, silt	Land erosion
2. Plant nutrients	Nitrates, phosphates, ammonium	Agricultural and urban fertilizers, sewage, manure
3. Oxygen-demanding wastes	Animal manure and plant residues	Sewage, agricultural runoff, paper mills, food processing
4. Thermal	Heat	Power plants, industrial cooling

2. OXYGEN-DEMANDING WASTES

The amount of oxygen dissolved in water is a good indicator of water quality and of the kinds of life it will support. The addition of certain organic materials, such as sewage, paper pulp, or food-processing wastes, to water stimulates oxygen consumption by decomposers. Biochemical oxygen demand (BOD): a standard test of the amount of dissolved oxygen consumed by aquatic microorganisms over a five-day period. Dissolved oxygen content (DO): measure dissolved oxygen content directly using an oxygen electrode. The oxygen decline downstream from point source is called the oxygen sag. Immediately below the source of pollution, oxygen levels begin to fall as decomposers metabolize waste materials.

3. PLANT NUTRIENTS AND CULTURAL EUTROPHICATION

Water clarity is affected by sediments, chemicals, and the abundance of plankton organisms, and is a useful measure of water quality and water pollution. Oligotrophic means the rivers and lakes that have clear water and low biological productivity. Eutrophic describes the waters that are rich in organisms and organic materials. Human activities can greatly accelerate eutrophication (cultural eutrophication). High biological productivity of eutrophic systems is often seen in "blooms" of algae or thick growth of aquatic plants stimulated by elevated phosphorous or nitrogen levels. Eutrophication also occurs in marine ecosystems, especially in near-shore waters and partially enclosed bays or estuaries.

4. INORGANIC POLLUTANTS

Some toxic inorganic chemicals are released from rocks by weathering, are carried by runoff into lakes or rivers, or percolate into groundwater aquifers. Humans can accelerate the rate of release of these inorganic chemicals through the mining, processing, using, and discarding of minerals.

- **Metals:**
- Many metals such as mercury, lead, cadmium, and nickel are highly toxic.
- A famous case of mercury poisoning occurred in Japan in the 1950s.
- Heavy metals released as a result of human activities also are concentrated by hydrological and biological processes so that they become hazardous to both natural ecosystems and human health.
- Mine drainage and leaching of mining wastes are serious sources of metal pollution in water.
- **Non-metallic salts:**
- Desert soils often contain high concentrations of soluble salts, including toxic selenium and arsenic.
- Salts such as sodium chloride that are nontoxic at low concentrations also can be mobilized by irrigation and concentrated by evaporation, reaching levels that are toxic for plants and animals.
- **Acids and bases:**
- Acids are released as by-products of industrial processes (e.g. leather tanning, metal smelting and planting)
- Coal and oil combustion also leads to formation of atmospheric sulfuric and nitric acids, which are disseminated by long-range transport processes.

5. ORGANIC CHEMICALS

Many chemicals used in the chemical industry to make pesticides, plastics, pharmaceuticals, pigments, and other products we use in everyday life are highly toxic. The two most important sources of toxic organic chemicals in water are improper disposal of industrial and household wastes and runoff of pesticides. Many of the toxic organic chemicals (e.g. DDT, Dioxins, and other chlorinated hydrocarbons) in water are passed through ecosystems and accumulated at high levels in certain non target organisms. Hundreds of millions of toxic hazardous organic wastes are thought to be stored in dumps, landfills, lagoons, and underground tanks in the United States.

6. SEDIMENT

Rivers have always carried sediment to the oceans, but erosion rates in many areas have been greatly accelerated by human activities. Sources of erosion include forests, grazing lands, and urban construction sites. Sediment fills lakes and reservoirs, obstructs shipping channels, clogs hydroelectric turbines, and makes purification of drinking water more costly. Excess sediment deposits can fill estuaries and smother aquatic life on coral reefs and shoals near shore. Sediment can also be beneficial. Mud carried by rivers nourishes floodplain farm fields.

7. THERMAL POLLUTION AND THERMAL SHOCKS

Raising or lowering water temperatures from normal levels can adversely affect water quality and aquatic life. Humans cause thermal pollution by altering vegetation cover and runoff patterns, as well as by discharging heated

water directly into rivers and lakes. The cheapest way to remove heat from an industrial facility is to draw cool water from an ocean, river, lake, or aquifer, run it through a heat-exchanger to extract excess heat, and dump the heated water back into the original source. In some circumstances, introducing heated water into a water body is beneficial. For example, warming catfish-rearing ponds and attract fish, birds, and marine mammals that find food and refuge there, especially during cold weather.

3.1.3 CONCEPT OF CONCENTRATION

The specific contaminants leading to pollution in water include a wide spectrum of chemicals, pathogens, and physical or sensory changes such as elevated temperature and discoloration. While many of the chemicals and substances that are regulated may be naturally occurring (calcium, sodium, iron, manganese, etc.) the concentration is often the key in determining what is a natural component of water, and what is a contaminant.

The quality of water may be described in terms of the concentration and state (dissolved or particulate) of some or all of the organic and inorganic material present in the water, together with certain physical characteristics of the water. It is determined by in situ measurements and by examination of water samples on site or in the laboratory. The main elements of water quality monitoring are, therefore, on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings. The results of analyses performed on a single water sample are only valid for the particular location and time at which that sample was taken. One purpose of a monitoring programme is, therefore, to gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality.

The quality of the aquatic environment is a broader issue which can be described in terms of: water quality, the composition and state of the biological life present in the water body, the nature of the particulate matter present, and the physical description of the water body (hydrology, dimensions, nature of lake bottom or river bed, etc.).

Complete assessment of the quality of the aquatic environment, therefore, requires that water quality, biological life, particulate matter and the physical characteristics of the water body be investigated and evaluated. This can be achieved through: chemical analyses of water, particulate matter and aquatic organisms (such as planktonic algae and selected parts of organisms such as fish muscle), biological tests, such as toxicity tests and measurements of enzyme activities, descriptions of aquatic organisms, including their occurrence, density, biomass, physiology and diversity (from which, for example, a biotic index may be developed or microbiological characteristics determined), and physical measurements of water temperature, pH, conductivity, light penetration, particle size of suspended and deposited material, dimensions of the water body, flow velocity, hydrological balance, etc.

3.2 WATER QUALITY MONITORING GUIDELINES

Water quality monitoring is one of the first steps required in the rational development and management of water resources. In the field of water quality management, there has been a steady evolution in procedures for designing system to obtain information on the changes of

water quality. The ‘monitoring’ comprise all activities to obtain ‘information’ with respect to the

water system.

Water quality monitoring is a complex subject, and the scope of it is both deep and wide. Water

quality monitoring has a direct relation with chemistry, biology, statistics and also economics. Its

scope is also related to the types of water uses and functions which are manifold and the nature of the sources of water such as surface water (rivers and lakes), sea water groundwater.

Monitoring is defined by the International Organization for Standardization (ISO) as: "the

programmed process of sampling, measurement and subsequent recording or signalling, or

both, of various water characteristics, often with the aim of assessing conformity to specified

objectives". This general definition can be differentiated into three types of monitoring activities that distinguish between long-term, short-term and continuous monitoring programmes as follows:

Monitoring is the long-term, standardised measurement and observation of the aquatic environment in order to define status and trends.

Surveys are finite duration, intensive programmes to measure and observe the quality of the aquatic environment for a specific purpose.

Surveillance is continuous, specific measurement and observation for the purpose of water

quality management and operational activities.

The Central Pollution Control Board (CPCB) is an apex body in the field of water quality management in India. For rational planning of any water quality management programme, CPCB needs to know the nature and extent of water quality degradation. Therefore, a sound scientific water quality monitoring programme is prerequisite. Realising this fact, water quality monitoring was started in 1976 by CPCB with 18 stations on the Yamuna river. The programme was gradually extended. Today, there are1032 monitoring stations in the country spread over all important water bodies.

The water quality monitoring is performed with following objectives.

- For rational planning of pollution control strategies and their prioritisation;
- To assess nature and extent of pollution control needed in different water bodies or their part;
- To evaluate effectiveness of pollution control measures already is existence;
- To evaluate water quality trend over a period of time;
- To assess assimilative capacity of a water body thereby reducing cost on pollution control;
- To understand the environmental fate of different pollutants.
- To assess the fitness of water for different uses.

3.2.1 INDIAN LAWS AND REGULATION ON WATER QUALITY MANAGEMENT

The conservation of water resources expressed in the Constitution is embodied in the following regulations:

The Water (Prevention & Control of Pollution) Act, 1974 as amended deals comprehensively with water issues. It empowers the Government to constitute Pollution Control Boards to maintain the wholesomeness of national water bodies. It enables Central and State Pollution Control Boards to prescribe standards and has provisions for monitoring & compliance and penal provisions against the violators of the Act. It provides the permit system i.e. **"Consent"** procedure to prevent and control of water pollution. The Act empowers State Boards to issue

directions to the defaulters.

Water Cess Act, 1977 was adopted to strengthen the Pollution control Boards financially, to promote water conservation. This Act empowers the Central Government to impose a **Cess** on water abstracted from natural resources by industries and local authorities.

Environment (Protection) Act, 1986 has a broad coverage in which 'Environment' includes **water**, air and land and there exists an interrelationship among water, air, land, human beings and other creatures. It empowers to take measures in protecting and improving the quality of the environment through preventing, controlling and abating environmental pollution. The Government is authorized to set national standards for ambient environmental quality and controlling discharges to regulate industrial locations, to prescribe procedure for hazardous

substance management and to collect and disseminate information regarding environmental pollution. The Act provides for severe penalties for those who fail to comply with or contravenes any provision of the Act.

The Manufacture, Storage, Import of Hazardous Chemicals Rules, 1989 and its amendments under EPA, 1986 has identified the responsibilities of various stakeholders for management of chemicals and containment of spillage.

The Hazardous Wastes (Management and Handling) Rules, 1989 and its subsequent Amendment 2000 were created to provide 'cradle-to grave' or comprehensive guidance to the generators, transporters and operators of disposal facilities among others, and monitoring norms for State governments.

The Municipal Wastes (Management & Handling) Rules, 1999 fix responsibilities to every municipalities responsible for the collection, segregation, storage, transportation and disposal of municipal wastes.

The Bio-medical waste (Management & Handling) Rules, 1998 are likewise directed at institutions that generate and bio-medical wastes in any form

3.2.2 APPROACH TO MONITORING

The monitoring activities under national network serve various assessment goals. These goals are determination of natural freshwater qualities in the absence of significant direct human impact, determination of long term trends in the levels of critical water quality indicators in freshwater resources and determination of the fluxes of organic matter, suspended solids, nutrients, toxic chemicals and other pollutants from major river basins to the seawater/coastal water interfaces. To meet the objectives and goals, highly selective network of strategically located monitoring stations is created and operated in the major, medium and minor watersheds of rivers, lakes, ponds, tanks, creeks, drains, canals and subsurface aquifers in the country. Three types of monitoring stations are set up for monitoring i.e. baseline, trend and impact or flux stations

Groundwater quality problems have reached to a cause of concern throughout the country. Salinisation and use of agrochemicals mandate the monitoring of trends in important aquifers, particularly of the arid and semi-arid climate belt. Trace contaminants, Fluoride and Nitrates, by levels and trends, are the primary monitoring concerns for aquifers in agriculture, industrialized and grossly polluted areas. Monitoring of groundwater quality needs to be strengthened for parameters from pollution point of view.

3.2.3 WATER QUALITY MONITORING NETWORK

Central Pollution Control Board started national water quality monitoring in 1978 under Global Environmental Monitoring System (GEMS), Water Programme. Monitoring Programme was started with 24 surface water and 11 groundwater stations. Parallel to GEMS, a National Programme of Monitoring of Indian National Aquatic Resources (MINARS), was started in 1984, with a total of 113 stations spread over 10 river basins. The present network comprises of 870 stations on rivers, lentic water bodies and sub surface waters. The number of locations on mainstream of the major river and their tributaries, medium and minor rivers, lakes, ponds, tanks and other water bodies is given in parenthesis.

3.2.4 WATER QUALITY CRITERIA

The Central Pollution Control Board has classified water resources of the country according to their uses for setting water quality objectives for different water bodies. The classification system is presented in Table 3.2.

Table 3.2: Primary water quality criteria for various uses of fresh water

Designated best use	Class	Criteria
Drinking water source without conventional treatment but after disinfections	A	*Total coliform organisms MPN/100mL shall be 50 or less. *pH between 6.5 and 8.5 *Dissolved oxygen 6 mg/l or more *Biochemical oxygen demand 2 mg/l or Less
Outdoor bathing (organised)	B	*Total coliform organisms MPN/100ml shall be 500 or less *pH between 6.5 and 8.5 *Dissolved oxygen 5 mg/l or more *Biochemical oxygen demand 3 mg/l or Less
Drinking water source with con-ventional treatment followed by disinfection	C	*Total coliform organisms MPN/ 100ml shall be 5000 or less *pH between 6 and 9 *Dissolved oxygen 4 mg/l or more

		*Biochemical oxygen demand 3 mg/l or Less
Propagation of wild life, fisheries	D	*pH between 6.5 and 8.5 *Dissolved oxygen 4 mg/l or more *Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, con-trolled waste disposal	E	*pH between 6.0 and 8.5 *Electrical conductivity less than 2250 micro mhos/cm *Sodium absorption ratio less than 26 *Boron less than 2mg/l

3.3 SOURCES OF WATER POLLUTION

The sources of water pollution are generally grouped into two categories based on their origin.

3.3.1 POINT SOURCE POLLUTION

Point source pollution refers to contaminants that enter a waterway through a discrete conveyance, such as a pipe or ditch. Examples of sources in this category include discharges from a sewage treatment plant, a factory, or a city storm drain.

3.3.2 NON POINT SOURCE POLLUTION

Non-point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often accumulative effect of small amounts of contaminants gathered from a large area. The leaching out of nitrogen compounds from agricultural land which has been fertilized is a typical example. Nutrient runoff in stormwater from "sheet flow" over an agricultural field or a forest are also cited as examples of NPS pollution.

Contaminated storm water washed off of parking lots, roads and highways, called urban runoff, is sometimes included under the category of NPS pollution. However, this runoff is typically channeled into storm drain systems and discharged through pipes to local surface waters, and is a point source. However where such water is not channeled and drains directly to ground it is a non-point source.

Table: 3.3 Characteristics of Point and Non Point Source Pollution

Point Source Pollution	Non Point Source Pollution
Source Characteristics	
• Pollutants discharged from a single source at a discrete point.	• Pollutants entering water at many locations, from many sources, distributed diffusely over an area.

Activity Origins	
• Usually associated with use and disposal water for industrial, commercial or municipal purposes. • Discharges are non-random and may be consistent from place to place between similar activities.	• Usually associated with runoff from random precipitation movements or with the movement of groundwater. • Significant place to place variation due to geologic and geographic conditions.
Source abatement	
• Readily monitored, usually in water. • Pollution can feasibly be abated and/or controlled through regulatory permits, inspections, monitoring and compliance processes, voluntary compliance, or regulation.	• Difficult or impossible to monitor. Monitoring that occurs is usually on land. • Usually best prevented by modifying activities, practices or operations on the land, or by changing land use activities, either through the use of financial incentives, voluntary compliance or regulation.
Pollution Control Mechanism	
• Usually controlled through use of wastewater treatment technologies to remove pollutants before discharge	• Usually controlled by reducing or preventing availability, release or transport of pollutants that adversely affect water quality.

NY State Dept. of Environmental Conservation 1990 (in Nix, 1994); Novotny and Olem (1994)

3.4 CAUSES OF WATER POLLUTION

Effluents and solid wastes from various industries and municipalities, indiscriminate use of toxic chemicals, indiscriminate use of pesticides, insecticides and fungicides, leaching of soils, wastes and rocks are the principal causes of water pollution. Objectionable level of pollution of water due to oils and oily substances may be found mainly in surface waters near the industries using heavy quantities of lubricating oils, greases, and liquid fuels, or refineries, big oil storages, etc. Ground water may also be polluted due to soaking of oil in the ground or by indiscriminate disposal of oil sludge. The heaviest polluting source for surface water is sewage from cities.

Oxygen-depleting substances may be natural materials, such as plant matter (e.g. leaves and grass) as well as man-made chemicals. Other natural and anthropogenic substances may cause turbidity (cloudiness) which blocks light and disrupts plant growth, and clogs the gills of some fishes.
Many of the chemical substances are toxic. Pathogens can produce waterborne diseases in either human or animal hosts. Alteration of water's physical chemistry includes acidity (change in pH), electrical conductivity, temperature, and eutrophication. Eutrophication is an increase in the concentration of chemical nutrients in an ecosystem to an extent that increases in the primary productivity of the ecosystem. Depending on the degree of eutrophication, subsequent negative environmental effects such as anoxia (oxygen depletion) and severe reductions in water quality may occur, affecting fish and other animal populations.

3.5 EFFECTS OF WATER POLLUTION

Lack of water, sanitation, and hygiene results in the loss of 0.4 million lives while air pollution contributes to the death of 0.52 million people annually in India (WHO 2007). Environmental factors contribute to 60 years of ill-health per 1,000 population in India compared to 54 in Russia, 37 in Brazil, and 34 in China. The socio-economic costs of water pollution are extremely

high: 1.5 million children under 5 years die each year due to water related diseases, 200 million person days of work are lost each year, and the country loses about Rs 366 billion each year due to water related diseases (Parikh 2004).

McKenzie and Ray (2004) also observe similar effects of water pollution; however, the magnitude of the effect was modest. The study shows that India loses 90 million days a year due to water borne diseases with production losses and treatment costs worth Rs 6 billion. Poor water quality, sanitation, and hygiene result in the loss of 30.5 million disabilities adjusted life years (DALY) in India. Groundwater resources in vast tracts of India are contaminated with fluoride

and arsenic. Fluoride problems exist in 150 districts in 17 states in the country with Orissa and Rajasthan being the most severely affected. High concentration of fluoride in drinking water causes fluorosis resulting in weak bones, weak teeth, and anaemia. The presence of arsenic, a poison and a carcinogen, in the groundwater of the Gangetic delta causes health risks to 35–70

million people in West Bengal, Bihar, and Bangladesh.

In India, water pollution due to industrial wastes and sewage has been assuming menancing proportions. Large lakes and large stretches of most of the rivers in India have water which is unsafe for drinking purpose. Survey of industrialized zones show that even ground water has become unfit for drinking due to high concentration of toxic metals and chemicals along with bacteriological contamination.

A brief summary of adverse effects of various pollutants on human and animal life and agriculture are indicated in Table 3.4. It is well known that water borne pathogens cause many diseases. Some common diseases caused by such pathogens are indicated in Table 3.5.

Table 3.4 Ill effects of Water pollutants

Sl. No.	*Pollutant*	*Effects*
1.	Zinc (Zn)	Zinc is essential element for humans, animal and plants. It is also an important cell component in several metalloenzymes. Infants need 3–5 mg/day, adult males 15 mg/day, pregnant and lactating females 20–25 mg Zn/day. However, heavy doses of Zn salts (165 mg) for 26 days causes vomiting, renal damage, cramps, etc.
2.	Copper (Cu)	Excess of Cu in human body (more than 470 mg) is toxic, may cause hypertension, sporadic fever, uremia, coma. Copper also produces pathological changes in brain tissue. However, Cu is an important cell component in several metalloenzymes. Lack of Cu causes anaemia, growth inhibition and blood circulation problem.
3.	Barium (Ba)	Excess of Ba (more than 100 mg) in human body may cause excessive salivation, colic, vomiting, diarrhoea, tremors*, paralysis of muscles or nervous system, damage to heart and blood vessels.
4.	Iron (Fe)	It is one of the essential mineral for humans and animals. Degree of absorption depends upon solubility and stability of compound. It is a component of blood cells and liveral metalloenzymes. However, more than 10 mg per kg of body weight causes rapid respiration and pulse rates, congestion of blood vessels, hypertension and drowsiness. It increases hazard of pathogenic organisms, as many of them require Fe for their growth.
5.	Cadmium (Cd)	Cd is very toxic, 50 mg may cause vomiting, diarrhoea, abdominal pains, loss of consciousness. It takes 5–10 years for chronic Cd intoxication. During first phase, discolouration of teeth, loss of sense of smell, mouth dryness occurs. Afterwards it may cause decrease of red blood cells, impairment of bone marrow, lumber pains, disturbance in calcium metabolism, softening of bones, fractures, skeletal deformations, damage of kidney, hypertension, tumor formation, heart disease, impaired reproductive function, genetic mutation, etc.
6.	Mercury (Hg)	Mercury is very toxic. Excess mercury in human body (more than 100 mg) may cause headache, abdominal pain, diarrhoea, destruction of haemoglobin, tremors*, very bad effects on cerebral functions and central nervous system, paralysis, inactivates functional proteins, damage of renal tissues, hyper coagulability of blood, mimamata disease, and even death. It may cause impairment of vision and muscles and even coma. It disturbs reproductive and endocrine system. Also causes insomnia, memory loss, gum inflammation, loosening of teeth, loss of appetite, etc.
7.	Lead (Pb)	More than 400 mg of lead in human body can cause brain damage, vomiting, loss of appetite, convulsions, uncoordinated body movements,

*tremors: *Involuntary agitation/viberation/quavering.*

		helplessly amazed state, coma. It is retained in liver, kidney, brain, muscle, soft tissues, bones. Leads to high rate of miscarriages, affects skin, and respiratory system, damages kidney, liver and brain cells. Disturbs endocrine system, causes anaemia, and long term exposure may cause even death.
8.	Arsenic (As)	Poisonous to fishes, animals and humans. Greater than 25 mg of arsenic causes vomiting, diarrhoea, nausea, irritation of nose and throat, abdominal pain, skin eruptions inflammations and even death. It binds globulin of blood haemoglobin in erythrocytes. May cause cancer of skin, lungs and liver, chromosomal aberration and damage, gangrene, loss of hearing, injury to nerve tissue, liver and kidney damage. Minor symptoms of As poisoning, weight loss, hair loss, nausea, depression, fatigue, white lines across toe nails and finger nails.
9.	Vanadium (V)	It is very toxic, may cause paralysis.
10.	Silver (Ag)	Causes pathological change in kidney, liver and may even damage kidney. May cause Argyria (discolouration of skin). Effects mucous membranes and eyes. In high doses, it may be fatal to humans.
11.	Radioactive materials/ metals/substances	These generally cause 'Gene' mutation, ionization of body fluids, chromosomnal mutations and cancers. Destroy body cell tissue, adversely effects reproductive system. When mother is exposed to radiation during pregnancy, it causes severe mental retardation and leukaemia in infants. Radioactive metals like heavy metals are nephrotoxic and damage kidneys.
12.	Fluoride	Excess fluoride intake in body results in progressive crippling scourge (sponging)/fluorosis of bones, teeth. May cause metabolic alternations in soft tissues and their functional mechanism.
13.	Selenium (Se)	Signs of Se poisoning (more than 4 mg) are fever, nervousness, vomiting, falling of blood pressure, causes damage to liver, kidney and spleen, loss of nails and hair, causes blindness to animals. Cats are most susceptible. It affects enzyme systems and interfere with sulphur metabolism. It can cause growth inhibition, skin discolouration, bad teeth, psychological problem, gastro intestinal problems, but trace amount of Se is protective against poisoning by Hg, Cd, Ag.
14.	Chromium (Cr)	Any chromium compound is toxic but haxavalent Cr greater than 70 mg is very toxic. It causes cancer, anuria, nephritis, gastrointestinal ulceration, perforation in partition of nose. It penetrates cell membrane and badly affects central nervous system. Causes respiratory trouble, lung tumors when inhaled. May cause complications during pregnancy. Has adverse effects on aquatic life. Trace amount of Cr^{III} is essential for normal glucose, protein and fat metabolism and hence it is a essential trace element in diet.
15.	Manganese (Mn)	Mn is essential for mammals but in concentration greater than 100 ppm, is toxic, and causes growth retardation, fever, sexual impotence, muscles fatigue, eye blindness.

16.	Cobalt (Co)	High dose (27 mg or above) can cause paralysis, diarrhoea, low blood pressure, lung irritation, bone defects.
17.	Nickel (Ni)	More than 30 mg may cause changes in muscle, brain, lungs, liver, kidney and can also cause cancer, tremor*, paralysis and even death.
18.	Boron (B)	Essential for plant growth in traces. Harmful to crops and affects metabolic activities of plants in higher concentration. Affects central nervous system.
19.	Alkalinity and Acidity	Permissible range of pH value if violated may cause health problems to human and animals and loss of productivity in agriculture.
20.	Phosphate and nitrates	Soil nutrient and not toxic in low concentration. Deplete oxygen by excess Algae production-giving bad odour and taste of water and detrimental to aquatic life. They are toxic for human and animal life if concentration is beyond permissible limits. Nitrates also cause cynosis or blue body disease.
21.	Chlorine (Cl)	Destroys plant and aquatic life and is a biocide.
22.	Sulphide	Gives bad odour, toxic to many aquatic organisms and animals.
23.	Salinity	Very bad for soils which retain salinity. Destroys agricultural land.
24.	Oil/Grease/Oil Sludge	Petroleum product in general are very harmful for soils, aquatic life, animal, human and plant life. They are very toxic. Agricultural land may suffer accumulation of oily waste affecting aeration and fertility. Many constituents of oily sludge are even carcinogenic and potent immunotoxicants.
25.	Surfactants and detergents	They are toxic and harmful for aquatic life, animals and humans. Inhibit self-purification of water.
26.	Phenols	Toxic and impart objectionable odour. Also subdue plant growth generally. Some phenols (nitrophenyl etc) are carcinogens.
27.	Cyanides	Cyanide poses a serious health hazard. Apart from acute toxicity and chronic toxicity, it leads to development of iodine deficiency disorders.
28.	Pesticides/Insecticides	Highly poisonous for humans and animals. Also they lower seed germination, plays a role in development of Parkinson's disease, destruction of nerve cells in certain regions of brain resulting in loss of dopamine which is used by nerve cells to communicate with brain. Some of these are physical poisons, some are protoplasmic poisons causing liver damage, some are respiratory poisons and some are nerve poisons.
29.	Aluminium (Al)	Toxic specially for brain, sometimes may lead to Alzheimer's disease in humans.

Table 3.5 Diseases due Bacterial Pollution of Water

Sl. No.	*Diseases*	*Bacteria / Virus / Protozoa / Worm*
1.	**Water borne diseases:**	
	Bacterial:	
	• Typhoid	Salmonella typhi
	• Cholera	Vibrio cholerae
	• Paratyphoid	Salmonella parayphi
	• Gastroenteritis	Enterotoxigenic *Escherichia coli*
	• Bacterial dysentery	Variety of *Escherichia coli*
	Viral:	
	• Infectious hepatitis	Hepatitis–A virus
	• Poliomycetis	Polio virus
	• Diarrhoea	Rota-virus, Norwalk agent, other virus Echono-virus, Coxsackie-virus
	Other enteric diseases (Protozoan):	
	• Amoebic dysentery	Ent-amoeba hystolitica
	• Other* intestinal illness	Protozoa Glardia sp. and Cryptosporidium sp.
2.	**Water-washed diseases:**	
	• Sabies	Various skin fungus species
	• Trachoma	Trachoma infecting eyes
	• Bacillary dysentery	*E. coli**
3.	**Water based diseases:**	
	• Schistosomiasis	Schistosoma sp.
	• Guinea worm	Guinea worm
4.	**Infection through water related insect vectors:**	
	• Sleeping sickness	Trypanosoma through tsetse fly
	• Malaria	Plasmodium through Anaphelis
5.	**Infections due to defective sanitation/ polluted water:**	
	• Hookworms	Hookworms, Ascaris

**Note:* *It may be mentioned that 'Shiga toxin' is produced by a virulent form of E. coli bacteria. This toxin can cause ailments ranging from mild intestinal disease to severe kidney complications. The Indian Toxicological Research Institute, Lucknow has confirmed that water of river Ganges has become a home to this virulent form of E. coli.*

3.6 COUNTER MEASURES OF WATER POLLUTION

1. SOURCE REDUCTION

The cheapest and most effective way to reduce pollution is to avoid producing it or releasing it to the environment in the first place. Industry can modify manufacturing processes so fewer wastes are created. Recycling or reclaiming materials that otherwise might be discarded in the waste stream also reduces pollution.

2. NONPOINT SOURCES AND LAND MANAGEMENT:

Among the greatest remaining challenges in water pollution control are diffuse, nonpoint pollution sources. Nonpoint sources have many origins and numerous routes by which contaminants enter ground and surface waters; therefore, it is difficult to identify, monitor, and control all these sources and routes. Some main causes of nonpoint pollution include agriculture, urban runoff, construction sites, and land disposal. Generally soil conservation methods also help protect water quality. In urban areas, reducing materials carried away by storm runoff is helpful. A good example of watershed management is seen in the Chesapeake Bay, America's largest estuary. Principal objectives of this plan include reducing nutrient loading, pollution prevention measures, replanting thousands of hectares of sea grasses, and restoring wetlands that filter out pollutants. Although progress has been made, the goals of reducing both nitrogen and phosphate levels by 40 percent and restoring viable fish and shellfish populations are still decades away.

3. HUMAN WASTE DISPOSAL:

Human and animal wastes usually create the most serious health-related water pollution problems.

Natural Processes

In poorer countries of the world, most rural people simply go out into the fields and forests to relieve themselves as they have always done. When population densities are low, natural processes eliminate wastes quickly. Where intensive agriculture is practiced, it has long been customary to collect human and animal waste to be spread on the fields as fertilizer and become a source of disease-causing pathogens in the food supply. Until about fifty years ago, most rural American families and quite a few residents of towns and small cities depended on a pit toilet or "outhouse" for waste disposal from which the untreated wastes would seep into the ground. The development of septic tanks and properly constructed drain fields represented a considerable improvement in public health.

Municipal Sewage Treatment

Over the past 100 years, sanitary engineers have developed effective municipal wastewater treatment systems to protect human health, ecosystem stability, and water quality. How does a typical municipal sewage treatment facility work? Primary treatment is the first step in municipal waste treatment that physically separates large solids from the waste stream. Secondary treatment consists of biological degradation of the dissolved organic compounds. Tertiary treatment removes plant nutrients, especially nitrates and phosphates, from the secondary effluent. In many American cities, sanitary sewers are connected to storm sewers, which carry runoff from streets and parking lots which generally contain a variety of refuse, fertilizers, pesticides, oils, rubber, tars, lead, and other undesirable chemicals.

Low-Cost Waste Treatment

The municipal sewage systems used in developed countries are often too expensive to build and operate in the developing world where low-cost, low-tech alternatives for treating wastes are needed. One option is effluent sewerage, a hybrid between a traditional septic tank and a full sewer system. Another alternative is to use natural or artificial wetlands to dispose of wastes. Wetland waste treatment systems are now operating in many developing countries. Effluent from these operations can be used to irrigate crops or raise fish for human consumption if care is taken to first destroy pathogens.

4. WATER REMEDIATION

New developments in environmental engineering are providing promising solutions to many water pollution problems. Containment methods confine or restrain dirty water or liquid wastes in situ (in place) or cap the surface

with an impermeable layer to divert surface water or groundwater away from the site and to prevent further pollution. Where pollutants are buried too deeply to be contained mechanically, materials sometimes can be injected to precipitate, immobilize, chelate, or solidify them. Extraction techniques pump out polluted water so it can be treated. Bioremediation that is the use of living organisms can be used effectively and inexpensively to clean contaminated water (e.g. wetlands and reaction vessels containing organisms).

3.7 CASE STUDY

Ganga River

In the recent past, due to rapid progress in communications and commerce, there has been a swift increase in the urban areas along the river Ganga, As a result the river is no longer only a source of water but is also a channel, receiving and transporting urban wastes away from the towns. Today, one third of the country's urban population lives in the towns of the Ganga basin. Out of the 2,300 towns in the country, 692 are located in this basin, and of these, 100 are located along the river bank itself.

The belief the Ganga river is "holy" has not, however, prevented over-use, abuse and pollution of the river. All the towns along its length contribute to the pollution load. It has been assessed that more than 80 per cent of the total pollution load (in terms of organic pollution expressed as biochemical oxygen demand (BOD)) arises from domestic sources, i.e. from the settlements along the river course. Due to over-abstraction of water for irrigation in the upper regions of the river, the dry weather flow has been reduced to a trickle. Rampant deforestation in the last few decades, resulting in topsoil erosion in the catchment area, has increased silt deposits which, in turn, raise the river bed and lead to devastating floods in the rainy season and stagnant flow in the dry season. Along the main river course there are 25 towns with a population of more than 100,000 and about another 23 towns with populations above 50,000. In addition there are 50 smaller towns with populations above 20,000. There are also about 100 identified major industries located directly on the river, of which 68 are considered as grossly polluting. Fifty-five of these industrial units have complied with the regulations and installed effluent treatment plants (ETPs) and legal proceedings are in progress for the remaining units. The natural assimilative capacity of the river is severely stressed.

The principal sources of pollution of the Ganga river can be characterised as follows:

1. Domestic and industrial wastes. It has been estimated that about 1.4 × 106 m3 d-1 of domestic wastewater and 0.26 × 106 m3 d-1 of industrial sewage are going into the river.

2. Solid garbage thrown directly into the river.

3. Non-point sources of pollution from agricultural run-off containing residues of harmful

pesticides and fertilisers.

4. Animal carcasses and half-burned and unburned human corpses thrown into the river.

5. Defecation on the banks by the low-income people.

6. Mass bathing and ritualistic practices.

Yamuna River, New Delhi

With the rapidly growing population in New Delhi, pollution levels are at an all time high and continue to become increasingly dangerous to city residents. New Delhi is subject to pollution in all forms and has been categorized among the top ten most polluted cities in the world. One of the most significant factors contributing to New Delhi's massive pollution levels, though, is extreme contamination of the Yamuna River, the city's primary source of water.

Water pollution has been a major issue in New Delhi for quite some time and there have been numerous acts already set in part to help alleviate the issue. However, none of these acts have been followed through with to the extent necessary and pollution levels continue to grow. New Delhi government and the Pollution Control Board initiated the Environmental Protection Act in 1986. The act was partially successful, promoting greener vehicle use and even cleaner oil. Unfortunately, however, pollution levels simply slowed down for a short while before again becoming out of control. The Central Pollution Control Board started two slightly more minor acts; the Cess Act and the Amendment Act in 1977 and 1988, respectively. Both encouraged better treatment of sewage before being dumped into the Yamuna but neither made any significant progress due to a widespread lack of motivation about the issue.

The pressures behind India's environmental problem are largely industrial. The recent economic boom for India has brought its good qualities, but there has not been regulation on waste handling. Major amounts of pollutant wastes are dumped straight into the Yamuna River. Adding to this hefty problem is the fact that the economic boom further increased the population. The population was already in a poor situation, and the influx of those seeking work in the newly developed financial opportunities only added to this. Of major note is the sewage situation; little has been done to cleanly accommodate these newcomers. As a result, the sewage is building up and not being dealt with properly. Sewage is dumped straight into the Yamuna River, which is where the majority of people in New Delhi bathe and wash their clothes. One of the worst aspects of this method of dumping is that the majority of people don't realize how bad the situation with waste is. The handling of waste in general is simply terrible; a recent survey indicates that two in every five New Delhi residents have pollution related health problems. Yet lack of government motivation and lack of knowledge allows this poor state to worsen.

The things that need to be done can fall into a basic three step process. First of all, the people need to understand exactly how preposterous the situation is. Once the masses of New Delhi are aware, it will be much harder for them to simply ignore the problems they are faced with. With people behind causes, there can be motivation for change. With enough people, this movement can be taken to the next level; government action. Legislation can bring about legal consequences for those who improperly dispose of their waste. As it is currently, the industries have power. They employ a vast amount of people, and it can be guessed that employees will continue to ignore the problem as long as they can work. But these people must be made to realize that the environmental damage being done isn't worth it; the best way to go about this is to get the majority of the populace to understand their situation. Understanding, motivation, legislation; these are steps that could be followed to help deal with New Delhi's terrible health crisis.

The pollution of the Yamuna River has a variety of impacts on New Delhi's environment. Most noteworthy of these issues would be the risk the pollution poses for the citizens' health. This poisonous river is one of the only sources of water for many of the city's inhabitants. The pollution would primarily affect citizens of the lower caste

since the rich Indians are able to afford bottled water from outside of the city. The upper class would hardly be phased by the potential health risks. This leads to a separate impact posed by the immense disparity between the rich and the poor. Since the wealthy citizens are not physically affected by the water pollution, nor are the businesses. Because of this, there are hardly any economic impacts. The pollution of the river is in fact making the rich richer if anything else since it enables them to easily dispose waste without being regulated or taxed. Another impact this then creates is the lack of political motivation to change anything. The people from the higher castes are the ones that run business and politics, and so if they are not compelled to change the system, no legislature has any chance of making it through.

Unfortunately, the state of the biodiversity situated around this vital river is greatly influenced by the river's contamination. The Yamuna River is a crucial asset to much of India's ecosystem, which is why its pollution has the potential to be so detrimental. Many forest groves thrive off the shores of the river; it is a support system for a variety of trees such as the Sal and Chir Pine forests. Also, the Asian Elephant survives off the water from the Yamuna River. If the water were to continue to be polluted at the same rate, the elephants, the forests, and many other forms of wildlife would have to relocate or face extinction.

Impact of urbanization on the quality of water in a natural reservoir: a case study with the Deepor Beel in Guwahati city, India

Case Study by Krishna G. Bhattacharyya & Nibedita Kapil

Fig.1.Deepor Beel ,Guwahati

The Deepor Beel is a natural, freshwater wetland in the south-west corner of Guwahati, India. The Beel harbours a large number of migratory aquatic birds, especially in winter, and is a Ramsar site since 2002. The wetland provides livelihood to the people of the surrounding villages through collection and sale of fish, nymphaea nuts and flower, ornamental fish, orchids, medicinal plants, etc. The water quality of the Beel is threatened by excessive fishing, hunting of

water birds, pollution from pesticides and fertilizers and infestation by water hyacinth.Sampling was carried out at 10 sites for physical and aggregate properties, metallic and nonmetallic constituents, organic contaminants and microbiological parameters.The water of the Beel is overburdened with inorganic and organic pollutants, in many

cases, beyond permissible limits and guideline values. The deterioration in the water quality of the wetland is the cumulative result of human interferences with the natural wetland through encroachment, extensive fishing,

Increasing pollution levels choking India's lakes

By Shudip Talukdar

Increasing pollution levels are threatening fresh water bodies worldwide, but the problem is assuming the shape of an environmental crisis in a developing country like India.A study of lakes in Thane, Maharashtra, undertaken by environmental chemist Pravin Singare of Bhavan's College, Mumbai, and colleagues, shows how they are being contaminated by the byproducts of urbanisation and industrial boom, symptomatic of the slow death of most of India's water bodies.Thane's burgeoning population, thanks to its proximity to Mumbai, and the metro's heavy industrial profile, are apparently choking its six lakes, with the unchecked discharge of sewage, pesticides and industrial effluents. The lakes are -- Jail, Upavan, Masunda, Makhmali, Rewale and Kalwa.The discharge of sewage results in large-scale outbreak of water-borne infections and diseases, epidemics and the growth of wild weeds, MS

Kodarkar, secretary, Indian Association

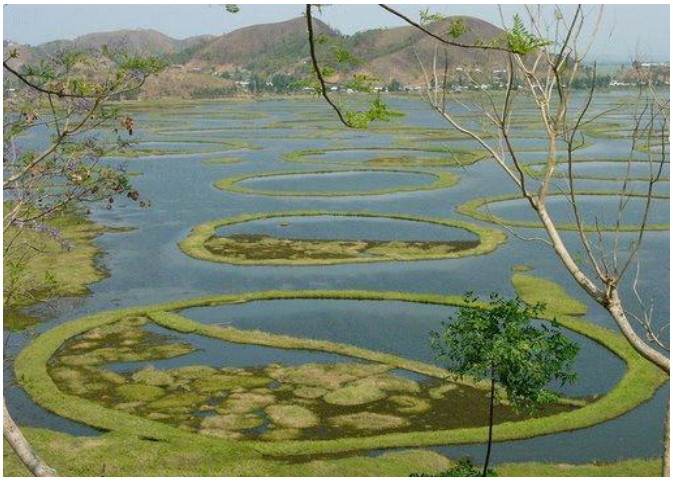


Fig.2 Loktak Lake,Manipur

Fig.3.Sukhna Lake, Chandigarh

of Aquatic Biologists (IAAB), Hyderabad, told IANS."Classic examples" are lakes in Loktak (Manipur), Ropar and Kanjli (Punjab), Sukhna (Chandigarh), Bhopal and the Pong dam (Himachal Pradesh), where the growth of water hyacinth, a wild weed, became instrumental in causing endemic diseases, according to a report by MS Reddy and NVV Char, former secretary and former commissioner (Eastern Rivers), respectively, in the union water resources ministry.Studies have shown presence of high levels of lead, cadmium, arsenic and manganese in Srinagar's Dal Lake which find their way into the fish consumed by people, posing health risks.Some of the biggest polluters are hundreds of houseboats which dump waste into the lake. Pesticides used on floating vegetable gardens are also seeping into the waters."The lakes are primarily most easily accessible sources of freshwater," which bestows "a number of ecological, economical and socio-cultural benefits on its immediate environment", says Kodarkar, also a member of the International Lake Environment Committee.Water bodies are known to recharge the groundwater table, act as a source of water supply, boost aquaculture (fisheries, prawns), regulate and control floods, condition climate, sustain biodiversity and provide nutrient-rich silt as manure.In the larger context, South Asia, with over a fifth of the world's population, is facing a serious water crisis, warns Kodarkar. This region is "in the grip of flood and drought cycles and there is a need to have a long-term strategy for management of its water resources".The presence of heavy metals like iron, copper, nickel and zinc, detected in Thane lakes above permissible levels, and also the alarming concentrations of mercury, arsenic and cadmium are wrecking their complex and fragile ecosystem.Exposure to mercury and its compounds can damage the brain, kidneys and developing foetuses. Studies have found it may cause irritability, affect vision, hearing and memory. It also inhibits growth of aquatic plants, says Singare.Arsenic poisoning through water can cause liver and nervous system damage, vascular diseases and skin cancer. Plants absorb arsenic easily and so they could be present in the food chain. In the recent past, arsenic was found in drinking water in six West Bengal districts.Another study by V.A. Walavalkar, a researcher from V.P.M. Polytechnic, Thane, under the guidance of Nagesh Tekale, found the 27 acre Masunda lake receives chlorinated water from swimming tanks, vegetable washing and discharge from a sewage plant. It is also used for idol immersion during the Ganesh festival.A 100-kg idol contains 69 percent of Plaster of Paris (PoP), a mix of gypsum, sulphur, phosphorus and magnesium and six percent of paint, which release toxic substances like cadmium and lead.Cadmium is toxic to fish and other aquatic life. Each idol takes 15 days to

Fig4. Hussainsagar Lake, Hyderabad

disintegrate, lowering the level of dissolved oxygen (DO), which is vital for aquatic life, according to Walavalkar.Half-hearted initiatives to clean up Thane lakes have not yielded the desired results. The process is not only prohibitively expensive but also leaves toxic by-products in its wake, compounding the problem, note GT Paratkar, BB Sharma, SS Barve and others, researchers from the VG Vaze College of Arts, Science & Commerce, Mumbai.The condition of Hussainsagar Lake built by the Nizam of Hyderabad in 1562 is no better. The immersion of idols releases toxic substances harmful to aquatic life, dumping of waste, interconnected sewage lines and the usage of the waterbody by slum dwellers are choking the lake.At the other end of the scale is the manner in which the Bhadkal and Surajkund lakes on the outskirts of New Delhi have gone dry, the first since 2006 and the other since 2003, due to illegal mining in the surrounding Aravali hills, which the Supreme Court has now banned.Thus, given the pace at which many of India's lakes are degrading, it would not be surprising if they are lost to posterity in the not too distant future.

Shipbreaking at Alang–Sosiya (India): An ecological distribution conflict

Case study by Federico Demaria

Fig.5. Alang–Sosiya (India)

More than 80% of international trade in goods by volume is carried by sea. The shipping industry constitutes a key element in the infrastructure of the world's social metabolism. Ocean-going ships are owned and used for their trade by developed countries but are often demolished, together with their toxic materials, in developing countries. Ship breaking is the process of dismantling an obsolete vessel's structure for scrapping or disposal. The Alang–Sosiya yard (India), one of the world largest ship breaking yards, is studied here with particular attention to toxic waste management. Ship owners and ship breakers obtain large profits dumping the environmental costs on workers, local farmers and fishers. This unequal distribution of benefits and burdens, due to an international and national uneven distribution of power, has led to an ecological distribution conflict. Thus ship breaking results into water pollution .

Monitoring of Amlakhadi, Ankleshwar

Fig.6.Amlakhadi, Ankleswar

Amlakhadi, an earthen storm water drain in Ankleshwar region, carries effluent generated from the industrial estates located at Ankleshwar, Panoli, and Jhagadia. The partially treated wastewater, discharged from all three estates is routed now through a Final ETP (called FETP) and further conveyed through a closed pipeline leading up to Gulf of Khambhat. The FETP and new conveyance system have been commissioned in November 2006. Following the commissioning of FETP and new conveyance system, the quality of Amlakhadi was monitored by CPCB in November 2006. This monitoring was carried out, along with an industrial pollution control compliance verification exercise at Ankleshwar & Panoli industrial estates. The quality of water in Amlakhadi was found not as per the norms. The results revels that the, organic load like COD, BOD in the drain was as high as 1854 mg/lit, 550 mg/lit. The levels of other parameters like NH_3-N, TDS were also found high. The ground water quality in the nearby area has been found contaminated at some locations, due to the persistent discharge of effluents into the drain for many years.

Quality of Raw and Treated Water at Water Treatment Plants in NCT Delhi

The public supply of drinking water in NCT-Delhi is maintained through seven Water Treatment Plants (WTPs). The raw and treated water at various water treatment plants such as Chandrawal I and II, Wazirabad, Haiderpur, Bhagirathi, Okhla and Nangloi are being monitored on Bimonthly basis. The raw as well as treated water quality has been assessed chemically and micro-biologically for the year 2006. The raw water quality at treatment plant intake confirms to the Primary Water Quality Criteria Class `C' (except in the case of Total Coliforms). Annual average of BOD observed at various raw water intake points of water treatment plant have been within the designated use quality criteria. The levels of core drinking water parameters viz. pH (6.58-7.85), Total Alkalinity (38-247 mg/l), Total Hardness (82-292 mg/l), Chloride (9-161 mg/l), Fluoride (<0.1-0.50 mg/l), Boron (0.19-0.38 mg/l) and Nitrate (0.34-2.82 mg/l) were observed complying with BIS standard's desirable drinking water limits (1991). The treated water has not depicted any coliform contamination.

Survey of Polluting Sources of the River Yamuna Between Delhi (Okhla) and Agra

Fig.7.The Yamuna River, Agra

Agra Water Works and other authorities frequently complain about water quality degradation in the Yamuna River at the intake points of Agra Water Works. The wastewater discharges from Delhi, U.P. and Haryana are responsible for the above problem. In order to assess the nature and magnitude pollution and identify the polluting sources, a detailed survey of the Yamuna River and drains / outfalls joining River Yamuna downstream of Delhi to Agra was carried out during November 20-24, 2006. The detailed survey included industrial and sewage drains in Delhi, U.P. and Haryana. It was observed that the major contributor of pollution load in the Yamuna River on the right bank are Fridabad (Haryana) and Vrindavan, Mathura, Agra (U.P.) and on the left bank Delhi, Noida (U.P.) and Hindon River that includes wastewater from Ghaziabad, Saharanpur, Muzfarnagar (U. P.).

A report on Oil Spill in Arbian Sea

By Maharashtra pollution control board

Kalpataru Point, 3rd floor, Near Sion Circle, Sion (E), Mumbai 400 022.

Fig.8 Sinking of MSC Chitra, Mumbai

MSC Chitra the out bound merchant vessel collided with M V Khalija III at around 5 nautical miles from the shore at 9.50 a.m. dt. 07/08/2010, when the latter was sailing towards the MbPT off Mumbai Harbour for berthing. At the time of incidence, MSC Chitra was carrying 2662 tonnes of fuel oil, 284 tonnes of diesel oil and 88 tonnes of lubricant oil. The accident resulted in oil spill and falling of cargos in sea from MSC Chitra. The collision has led to large quantities of oil spilling in the sea. The oil spill has caused considerable damage to the Marine Ecosystem and to 110 Km shoreline of four districts, Mumbai City, Mumbai Suburban, Thane & Raigad. It has washed to the shore, damaging shoreline, beaches & Mangroves most importantly have resulted in water pollution as well.

Heavy metal contamination of Ganga river at Varanasi in relation to atmospheric deposition

By J. Pandey*, K. Shubhashish & Richa Pandey

Fig.9.The mighty river Ganga, Varanasi

In this study it has been investigated that the mid stream water quality of Ganga river as influenced by aerially – driven heavy metals at Varanasi, India. Twelve sampling stations were selected along a 20 km long stretch of the river. Mid stream sub-surface water samples collected at fortnightly intervals from all the sites were acid digested and analyzed for Cd, Cr, Cu, Ni, Pb and Zn. The data revealed that the mid-stream water of river Ganga at Varanasi is invariably contaminated by heavy metals. Highest concentrations of Cd, Cr, Cu, Ni and Pb were recorded during winter and that of Zn during summer season. The overall concentration of heavy metals in water showed the trend : Zn > Ni > Cr > Pb > Cu > Cd. Concentrations of all the heavy metals were high in down – stream sampling stations. Correlation analysis showed that heavy metal concentration in mid-stream water had significant positive relationship with rate of atmospheric deposition at respective sites. Although the concentrations of these metals in water remained below the permissible limits of Indian standards for drinking water, levels of Cd, Ni and Pb at three stations, were above the internationally recommended (WHO) maximum admissible concentrations (MAC). These observations suggest that use of such water for drinking may lead to potential health risk in long-run. The study has further relevance in understanding the atmosphere – water interaction in polluted environment and for management of water bodies even those situated away from direct anthropogenic discharge.

Development of water quality index: a case of Sabarmati river front development project

Bina Patel

Fig.10.The Sabarmati River, Ahmedabad

Sabarmati River Front is of particular importance in the study of surface water pollution because recreational activities, urban run-off etc. are discharged and stagnant condition into the river bringing about considerable change in the river water quality. These anthropogenic activities for recreational purposes on the river Sabarmati pose a serious threat not only to organisms in the river but also the downstream water. In addition, once the surface water is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor the quality of the water and to device ways and means to protect it.This study is conducted to develop the water quality index of the Sabarmati River Front Development Zone for water quality parameters are DO, FC, pH, BOD5, Total Phosphate (PO4), Nitrate (NO3), Turbidity & Total Solids (TS) by using Modified Delphi Techniques. The results of the laboratory test and developed water quality suggested that the water quality of the river Sabarmati, in river front zone, falls under category medium to bad. The critical parameters used here are BOD, DO and Fecal Coliforms. Water Quality is not suitable for recreational purposes and is only fit for other purposes like non sensitive pesiculture, livestock drinking and irrigation.

Summary

Water is a renewable natural resource. Due to ever increasing industrialization, urbanization, this precious resource is continuously under stress. There are multiple dimensions to water quality and its deterioration. Water pollution is rendering much of the available water unsafe for consumption. The pressure of increasing population, loss of forest cover, untreated effluent discharge from industries and municipalities, use of non-biodegradable pesticides/ fungicides/herbicides/insecticides, use of chemical fertilizers instead of organic manures, etc are causing water pollution. Moreover, there are numerous water borne diseases like cholera, diarrhoea, dysentery etc. which are transmitted by drinking contaminated water.

Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses can be considered pollution. Worldwide, the most serious water pollutants, in terms of human health, are pathogenic organisms from human and animal wastes. In industrialized nations, toxic chemical wastes have become an increasing problem. Agricultural and industrial chemicals have been released or spilled into surface waters and are seeping into groundwater supplies. Major causes of ocean pollution are oil spills from tanker bilge pumping or accidents and oil well blowouts. Surface runoff and sewage outfalls discharge fertilizers, pesticides, organic nutrients, and toxic chemicals that have a variety of deleterious effects on marine ecosystems. The

major water pollutants in terms of quantity are silt and sediments. Addition of salts and metals from highway and farm runoff and industrial activities also damage water quality. In some areas, drainage from mines and tailings piles deliver sediment and toxic materials to rivers and lakes.

Water pollution is a major source of human health problems. Appropriate land-use practices and careful disposal of industrial, domestic, and agricultural wastes are essential for control of water pollution. Natural processes and living organisms have a high capacity to remove or destroy water pollutants, but these systems become overloaded and ineffective when pollution levels are too high. Municipal sewage treatment is effective in removing organic material from wastewater, but the sewage sludge is often contaminated with metals and other toxic industrial materials.

BIBLIOGRAPHY

Appelo, C., & Postma, D. (2005). Geochemistry, groundwater and pollution Taylor & Francis.

Bhardwaj.R.M. (2005). Water quality monitoring in india- Achievements and constraints. IWG-Env, International Work Session on Water Statistics, Vienna, June 20-22.

Central Pollution Control Board (2003). Water Quality in India Status and Trend (1990-2001), New Delhi, MINARS/20/2001-2002, pp.

Central Pollution Control Board (2007). Guidelines for Water Quality Monitoring Delhi MINARS/27/2007-08

Dasgupta, P. (2004). Valuing health damages from water pollution in urban delhi, india: A health production function approach. Environment and Development Economics, 9(01), 83-106.

Karn, S. K., & Harada, H. (2001). Surface water pollution in three urban territories of nepal, india, and bangladesh. Environmental Management, 28(4), 483-496.

Kathuria, V. (2002). Vehicular pollution control in delhi. Transportation Research Part D, 7(5), 373-387.

Nagdeve, D. A. (2004). Environmental pollution and control: A case study of delhi mega city. Population & Environment, 25(5), 461-473.

Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., et al. (1997). Water resources: Agriculture, the environment, and society. Bioscience, 47(2), 97-106.

Rao. K.L, (1979), India's Water Wealth Its Assessment, Uses and Projections, Orient Long-man, New Delhi, pp.39-70.

Sharp. K. A. (2001).Water: Structure and Properties. USA Encyclopedia of life sciences © 2001, John Wiley & Sons, Ltd.

Sharma, Dinesh. By order of the court: Environmental cleanup in india. 2005 Available from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1257623.

Shiva, V. (2002). Water wars: Privatization, pollution and profit South End Press.

South Asian Voices. Problems of indian development. 2000 Available from http://india_resource.tripod.com/environ.html.

Thorne, R. S. J., & Williams, W. P. (1997). The response of benthic macro invertebrates to pollution in developing countries: A multimetric system of bioassessment. Freshwater Biology, 37(3), 671-686.

World Bank, and South Asia Region. Environmental health in india. 2001 Available from http://siteresources.worldbank.org/INDIAEXTN/Resources/Reports-Publications/APHealth.pdf.

SUGGESTED READINGS

A.K De, Environmental Chemistry, Wiley Eastern Limited , 2000.

Eisenberg . D and Kauzmann. W. (1969). The Structure and Properties of Water. Oxford: Oxford University Press.

G. Fellenberg Chemistry of Pollution, John Wiley and Sons, 1999

S.E. Manahan, Environmental Chemistry, Lewis, 1994

Questions with answer

Q1. Define water pollution.

Ans: Any physical, biological, or chemical change in water quality that adversely affects living organisms or makes water unsuitable for desired uses can be considered water pollution.

Q2. Define water quality.

Ans: Water quality is a complex subject, which involves physical, chemical, hydrological and biological characteristics of water and their complex and delicate relations. From the user's point of view, the term "water quality" is defined as "those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water".

Q3. What are the objectives of water quality monitoring?

Ans: The objectives of water quality monitoring are as follows:

- For rational planning of pollution control strategies and their prioritisation;
- To assess nature and extent of pollution control needed in different water bodies or their part;
- To evaluate effectiveness of pollution control measures already is existence;
- To evaluate water quality trend over a period of time;
- To assess assimilative capacity of a water body thereby reducing cost on pollution control;
- To understand the environmental fate of different pollutants.
- To assess the fitness of water for different uses.

Q4. Categorize the different sources of water pollution?

Ans: The sources of water pollution are generally grouped into two categories based on their origin. They are:-

Point source pollution refers to contaminants that enter a waterway through a discrete conveyance, such as a pipe or ditch. Examples of sources in this category include discharges from a sewage treatment plant, a factory, or a city storm drain.

Non-point source (NPS) pollution refers to diffuse contamination that does not originate from a single discrete source. NPS pollution is often accumulative effect of small amounts of contaminants gathered from a large area. The leaching out of nitrogen compounds from agricultural land which has been fertilized is a typical example. Nutrient runoff in stormwater from "sheet flow" over an agricultural field or a forest are also cited as examples of NPS pollution.

PROBABLE QUESTIONS

- What is monitoring?
- List the unusual characteristics of water.
- List the major categories of water pollutants and give an example for each category.
- Do you think that water pollution is worse now than it was in the past? What considerations go into a judgment like this? How do your personal experiences influence your opinion?
- What are the different control measures of water pollution?
- What are the major sources of water pollution, and according to you which among them poses the most severe impact?
- Why water monitoring is important?
- What are the various measures to curve the water pollution?
- What characteristics of water makes it most vulnerable to detoriation?
- Multiple choice question :-
- **Q.** 1.Most of the fresh water on Earth is

  a. located underground in aquifers.

  b. frozen in the polar icecaps.

  c. located in rivers, lakes, streams, and wetlands.

  d. found in Earth's atmosphere.
- Q2 Which of the following is *not* an example of point-source pollution?

  a. oil that is escaping from a damaged tanker

  b. heavy metals that are leaching out of an underground mine

  c. water runoff from residential lawns

  d. untreated sewage that is accidentally released from a wastewater treatment plant
- **Q3.** Which of the following pollutants causes artificial eutrophication?

  a. heavy metals from unlined landfills

  b. inorganic plant nutrients from wastewater and fertilizer runoff

  c. toxic chemicals from factories

d. radioactive waste from nuclear power plants

- **Q4.** Pumping large amounts of water from an aquifer may cause the

  a. water table to rise.

  b. recharge zone to shrink.

  c. wells in an area to run dry.

  d. percolation of groundwater to stop.

- **Q5.** Oil pollution in the ocean is mostly caused by

  a. major oil spills, such as the 1989 *Exxon Valdez* oil spill.

  b. the cumulative effect of small oil spills and leaks on land.

  c. decomposed plastic materials.

  d. intentional dumping of excess oil.

- **Q6.** Thermal pollution has a harmful effect on aquatic environments because

  a. water has been circulated around power plant generators.

  b. it increases the number of disease-causing organisms in aquatic environments.

  c. it reduces the amount of dissolved oxygen in aquatic environments.

  d. it decreases the nutrient levels in aquatic environments.

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-4: NOISE POLLUTION

UNIT STRUCTURE

4.1 AIMS AND OBJECTIVE

It is expected that students understand the basic concepts of noise pollution through this unit. Able to identify the different sources of noise pollution, quantify the noise levels, the various adverse impacts of noise pollution on human health and its control measures. To get familiar with the statutory limits for both the ambient noise levels and the noise levels at a workspace environment.

4.2 INTRODUCTION

Noise is a sound without value undesired by the person which means wrong sound in the wrong place at the wrong time. The word noise is derived from the Latin word *nausea* meaning 'seasickness'. The two properties of noise are loudness or intensity and frequency. Loudness or intensity depends on the amplitude of vibrations which initiated the noise. Loudness is measured in decibels (dB). Noise has been defined as 'unwanted sound', or 'sound that is loud, unpleasant or unexpected' and considered as a potential hazard to health and communication broadcasted into the environment. However, prolonged and loud sound is generally considered as noise which is mostly caused because of industries, vehicles, airplanes, etc. Sound, which pleases the listeners, is music and without agreeable musical quality that which causes pain, irritating to ear and annoyance is noise. At times, what is music for some can be noise for others. In simple terms, noise is unwanted sound. Sound is a form of energy which is emitted by a vibrating body and on reaching the ear causes the sensation of hearing through nerves. It has several physical properties among which 'frequency' and 'intensity' is the most relevant. Sound frequency is the rate at which compression waves arrive at or pass a fixed point. Frequency is the number of times that a sound source vibrates in a unit of time and it is expressed as hertz (Hz) or cycles per second (CPS), a measure of sound frequency. "Pitch" is the human perception of sound frequency (and also intensity to some extent). Sound intensity is the acoustical power (i.e. the energy delivered by sound) per unit area. 'Loudness" is the human perception of the sound intensity (and also intensity to some extent). Sound is a physical phenomenon stimulating the hearing mechanism and formed

sound is a physical phenomenon stimulating by the waves created through air pressure (Scott et al. 2004). Technically, "sound consists of disturbance which propagates in an elastic medium in the form of sound wave at a speed that is determined by the properties of that medium. On the other hand, sound is changing air pressure. The comparison of the air molecules causes a local increase in air density and pressure. The alternating pressure changes are the sound detected by the human ear. However, sounds produced by all vibrating bodies are not audible. The frequency limits of audibility are from 20 Hz to 20,000 Hz (or 20 kHz). Sounds of frequencies less than 20 HZ are called infrasonics and greater than 20,0000 HZ are called ultrasonics. Humans generally hear sounds that vibrate the air as slow as 20 times per second (or 20 Hz) to as high as 20,000 Hz. So, humans are considered to have hearing that spans from 20 Hz to 20 kHz. The range of frequencies which is best heard by humans is 200 to 3000 Hz (human speech).

A noise problem generally consists of three inter-related elements i.e. the source, the receiver and the transmission path. This transmission path is usually the atmosphere through which the sound is propagated, but can include the structural materials of any building containing the receiver (Figure 1).

Noise may be continuous or intermittent. Noise may be of high frequency or of low frequency which is undesired for a normal hearing. For example, the typical cry of a child produces sound, which is mostly unfavorable to normal hearing. Since it is unwanted sound, we call it noise.

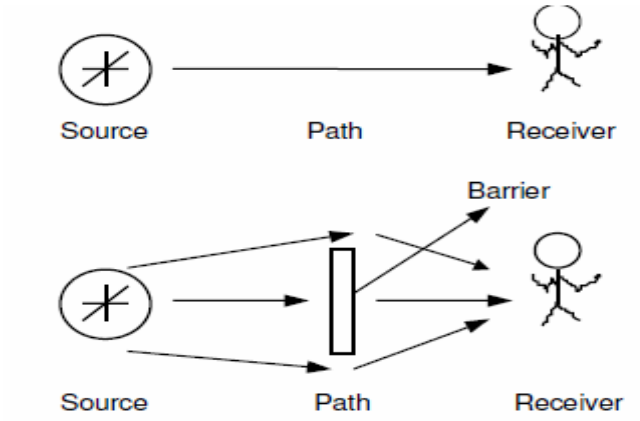


Figure 1. Inter-relationship between the elements of noise.

Pollution caused by 'unwanted sound' is called noise pollution. Noise pollution is the pollution caused by displeasing human or machine created sound that disrupts the environment. It is generally refers to unwanted sound produced by human activities-unwanted in that it interferes with communication, work, rest, recreation, or sleep. There is no clear cut definition of noise pollution. Broadly speaking, a sound may be considered noise pollution if it disturbs any natural process or causes human harm, even if the sound does not occur on a regular basis. On the other hand, any sounds may be considered noise pollution if they adversely affect human activity causing an adverse effect on the mental and psychological well being, wildlife, or are capable of damaging physical structures on a regular, repeating basis. Unlike other forms of pollution, such as air, water, and hazardous materials, noise does not remain long in the environment.

4.3 SOURCES OF NOISE

Noise is generated from various sources, which is considered as the by-product of domestic activities, natural source, urbanization, commercialization and industrialization. Majority of noise arise from roads traffic, aircraft, railroads, construction, industry, noise in buildings, and consumer products. The noise pollution has two main sources, i.e. industrial and non- industrial. The industrial source includes the noise from various industries and big machines

working at a very high speed and high noise intensity. Non- industrial source of noise includes the noise created by transport/vehicular traffic and the neighborhood. Sources of noise can be broadly be discussed under three categories namely, transport noise, occupational noise, neighbourhood noise and construction Noise.

Transport Noise

The major prevailing source of artificial noise pollution is from transportation, creating problems in the vicinity of traffic installations such as airports, roads and railway lines. Traffic noise originates from propulsion, wheels and air flow and is emitted into the atmosphere. In rural areas, train and airplane while in urban areas, automobile, motorcycle, and even entertainment noise are the main sources of noise pollution cause sleep disruption in humans and animals, hearing loss, heart disease, and in severe cases even mental instability. Transport noise can be subdivided into three categories, i) Road traffic noise, ii) Aircraft noise, and ii) Rail traffic noise.

i) Road traffic noise – Of all the sources of noise pollution, road traffic is the most prevalent and perhaps the most damaging sources of noise pollution and recognized as the main contributor to human noise annoyance. In the city, the main sources of traffic noise are the motors and exhaust system of autos, smaller trucks, buses, and motorcycles. This type of noise can be augmented by narrow streets and tall buildings, which produce a canyon in which traffic noise reverberates. More people are exposed to noise from motor vehicles than any other single source of noise and thus the impacts of traffic noise are a major factor in human society. Traffic noise has been increasing over the years continuously. This is because of steady increase of the number of road vehicles and consequently increases of road traffic density. The noise volume increases with increase in traffic speed. Modern highways and traffic system encourage higher speeds. Road traffic noise varies depending on a number of operating factors of vehicles and also on traffic density and the hour of day. Heavy diesel-engine trucks are the noisiest vehicles on roads now.

ii) Aircraft noise – Aircraft noise is growing and become a matter of concern with the increasing number of a large number of domestic flights and ever increasing frequency of landing, flying overhead and take-off. However, it differs from road traffic noise in the sense that it is not continuous but intermittent. There are peak noise levels when aircrafts fly overhead or take-off and land at airports the noise being produced from aircraft engines. The peak frequency varies with the number and type of aircraft as well as the operational height. Now-a-days, the problem of low flying military aircraft has added a new dimension to community annoyance, as the nation seeks to improve its nap-of the- earth aircraft operations over national parks, wilderness areas , and other areas previously unaffected by aircraft noise has claimed national attention over recent years. Noise of supersonic aircraft is of particular concern due to its intensity.

iii) Rail traffic noise – This type of noise is not considered as a serious nuisance as compared to the road and aircraft traffic noise because of its lower frequency than that of street vehicles and furthermore, most railway tracks run through rural area. The level of the noise associated with rail traffic is related to the type of engine or rolling stock used, the speed of the train and track type and condition. The majority of noise emitted by trains is produced by the engines or by the interaction of the wheels with the track. Other sources of noise in railways include warning signals at crossings, whistles and horns, freight classification yards, and railroad construction and maintenance equipments. The introduction of diesel and all-electric locomotives has greatly reduced rail traffic noise.

Of course, buildings located beside railways tracks are exposed to noise menace. The noise from locomotive engines, horns and whistles, and switching and shunting operation in rail yards can impact neighboring communities and railroad workers. For example, rail car retarders can produce a high frequency, high level screech that can reach peak levels of 120 dB at a distance of 100 feet, which translates to levels as high as 138, or 140 dB at the railroad worker's ear.

Occupational noise

This is mainly produced by industrial machines and process which affects millions of people. It also includes noise from domestic gadgets (consumer products). Certain household equipment, such as washing machines, vacuum cleaners, food blenders, dryers, mixer grinder, etc have been and continue to be noisemakers, although their contribution to the daily noise dose is usually not very large.

These interior noise sources generated from various types of running machines have significant impacts on industrial workers, among whom noise- induced hearing loss is unfortunately common. Industrial workers are exposed to noise for 8 hours per day and 6 days per week. Noisy industrial processes and conditions have significant impacts on industrial workers, among whom noise- induced hearing loss is unfortunately common. Millions of industrial workers are victims of occupational noise for up to 1800 hours per year and for 30 years of their lives. Industrial noise not only effects the occupational workers but it also create problems to the neighborhood areas because interior noise can also be transmitted to the community through open windows and doors, and even through building wall, although industrial noise is one of the less prevalent community noise problems. Neighbors of noisy manufacturing plants can be disturbed by sources such as fans, motors, and compressors mounted on the outside of buildings. Noise reduction is essential so that workers do not suffer progressive hearing damage, efficiency may be enhanced and accidents are reduced. This would ensure all round improvement in working conditions.

Neighbourhood noise

This implies variety of source of noise which disturbs and annoys the general public by interfering with their comfort and welfare. Such sources are loud TV and radio sets, loud cassettes, loudspeakers in public functions and entrainments etc. Disco music and dance in late evenings cause noise nuisance to nearby residents. Apartment dwellers are often annoyed by noise in their homes, especially when the building is not well designed and constructed. In this case, internal building noise from plumbing, boilers, generators, air conditioners, and fans, can be audible and annoying. Improperly insulated walls and ceilings can reveal the sound of amplified music, voices, footfalls and noisy activities from neighboring units. External noise from emergency vehicles, traffic, refuse collection, and other city noises can be a problem for urban residents, especially when windows are open or insufficiently glazed.

Construction Noise

Construction noise is the noise emitted by construction equipment. Like industrial equipment, construction equipment tends to produce more noise in the lower end of the frequency spectrum. But unlike industrial equipment, which emits noise that primarily affects workers within a facility, construction equipment tends to be used outdoors, and thus affects many other people other than the workers at the side. The noise from the construction of highways,

city streets, and buildings is a major contributor to the urban scene. Construction noise sources include pneumatic hammers, air compressors, bulldozers, loaders, dump trucks (and their back-up signals), and pavement breakers.

4.3.1 MEASUREMENT INDICES OF NOISE POLLUTION

Unit of measurement of noise

Noise levels can be measured by decibel method giving units called "decibels", abbreviated as "dB" ('deci' comes from the Latin word for ten, and a 'bel' is 'the logarithm of a ration of any two acoustical or electrical intensities). A decibel is the standard for the measurement of noise. The zero on a decibel scale is at the threshold of hearing, the lowest sound pressure that can be heard. The response of ear to sound is proportional to the logarithm of its intensity or pressure. Thus the loudness of two sounds is judged subjectively by the ear by the ratio of their intensities or pressures. In terms of sound, a 'decibel" (dB) is ten times the logarithm of the ratio of two sound intensities, one being the intensity of any sound of interest (I) and the other being a reference sound (I_o).

$$\text{Sound Intensity Level (dB)} = 10 \log_{10} \frac{\text{Sound intensity measured (I)}}{\text{Reference sound intensity } (I_o)}$$

Another parameter of the acoustic (sound) wave which is generally used to assess sound exposure to humans is the sound pressure level. The intensity of sound is measured in sound pressure levels (SPL) and common unit of measurement is decibel, dB. If the sound levels are measured in terms of pressure, then, sound pressure level, Lp or dB SPL is given by,

$$\text{Sound Pressure Level (dB SPL)} = 20 \log_{10} \frac{\text{Measured sound pressure level (p1)}}{\text{Standard reference pressure (p0)}}$$

The Lp or dB SPL is measured against a standard reference pressure, p0= 2 x 10^{-5} N/m^2 which is equivalent to zero decibels (which is approximately the threshold of hearing), where p1 is actually measured sound pressure level of a given sound. In the logarithmic scale the range of human ear's audible sounds is from 0 dB SPL (hearing threshold) to 120-140 dB SPL (pain threshold) as given in table 1. This logarithmic scale takes cares of wide range of sound pressure and activities. The reference intensity used is the threshold of hearing which means sound which can be first heard at a sound pressure of 2 x 10^{-5} Newton m^{-2} or sound intensity of 10^{-12} watt m^{-2} (table 2).

Table 1. The examples of sound pressure levels in relation to hearing threshold and pain threshold (in dB SPL)

Source / observing situation	**Typical sound pressure level (db SPL)**
Hearing threshold	0 dB
Leaves fluttering	20 dB
Whisper in an ear	30 dB

Normal speech conversation for a participant	60 dB
Cars/vehicles for a close observer	60-100 dB
Airplane taking-off for a close observer	120 dB
Pain threshold	120-140 dB

Table 2. The relationship between sound pressure, sound intensity and intensity level.

Sound pressure (N/m^2)	Intensity (W/m^2)	Intensity level (dB)
2×10^{-5}	10^{-12}	0
2×10^{-4}	10^{-10}	20
2×10^{-3}	10^{-8}	40
2×10^{-2}	10^{-6}	60
2×10^{-1}	10^{-4}	80
$2 \times (2 \times 10^{0})$	10^{-2}	100
$20(2 \times 10^{1)}$ 200	1 (10^{0})	120
(2×10^{2})	l00 (10^{2})	140

Equipment used in the measurement of noise levels

Noise measurement is an important analytical and diagnostic tool for the reduction and control of noise problems. It provides definite quantities that describe and rate sound and permit precise, scientific analysis of annoying sound. The objective of noise measurement is to make accurate measurement which gives us a purposeful act of comparing noises under different conditions for assessment of adverse impacts of noise and adopting suitable control techniques for noise reduction.

Table 3. Equipment used in the measurement of noise levels

Equipment	**Specification/objectives**

Sound level meter (SLM)	Type-0 : Laboratory reference standard Type-1: Lab use and field use in specified controlled environment Type-2: General field use (Commonly used) Type-3: Noise survey
Impulse meters	For measurement of impulse noise levels e.g. hammer blows, punch press strokes etc.
Frequency analyzers	The objective of frequency analysis is to determine how the overall level is distributed over a range of frequencies. The most usual analysis for occupational hygiene noise studies is octave band analysis. For more detailed information, narrower bands can be used such as one-third octave analysis or constant bandwidth analysis. A number of analyzers are available for use with the sound level meter. The simplest models are sets of passive filters (octave or one third octave) that can be inserted between the two amplifiers of the Sound level meter
Graphic recorders	Attached to sound level meter. Plots the SPL as a function of time on a moving paper chart. It is used to obtain a permanent record of the evolution of the sound level, providing that their writing speed is compatible with the SLOW or FAST characteristics of the SLM.
Noise dosimeters	Used to find out the noise levels in a working environment. It is a small, light and compact instrument to be worn by the worker. It measures the total A-weighted sound energy received and expresses it as a proportion of the maximum A-weighted energy that can be received per day. This instrument is particularly useful whenever the exposure varies appreciably during the working day.
Calibrators	For checking the accuracy of sound level meters. Microphones are individually calibrated at the factory, and the calibration chart must be delivered with the instrument. In the field, calibration is performed by applying a known sound pressure level at a fixed frequency to the microphone. Calibrators are small, battery driven and operate on different principles. One operates at 250 Hz and produces a sound level of 124 dB, accurate to + 0.2 dB. To obtain the best results, the microphone should be well sealed in the coupler opening.

Noise is measured commonly with a sound level meter. These instruments measure noise in decibels. A sound level meter or sound meter is an instrument which measures sound pressure level, commonly used in noise pollution studies for the quantification of different kind of noise generated from different sources. A sound level meter consists basically of a microphone and an electronic circuit including an attenuator, amplifier, weighting networks or filters and a display unit. Further amplification prepares the signal either for output to other instruments such as a tape

recorder or for rectification and direct reading on the meter. The rectifier gives the RMS value of the signal. The RMS signal is then exponentially averaged using a time constant of 0.1 s ("Fast") or 1 s ("Slow") and the result is displayed digitally or on an analog meter. The microphone converts the sound signal to an equivalent electrical signal. The signal is passed through a weighting network which provides a conversion and gives the sound pressure level in dB. An example of the components of the sound level meter is shown in Figure 2.

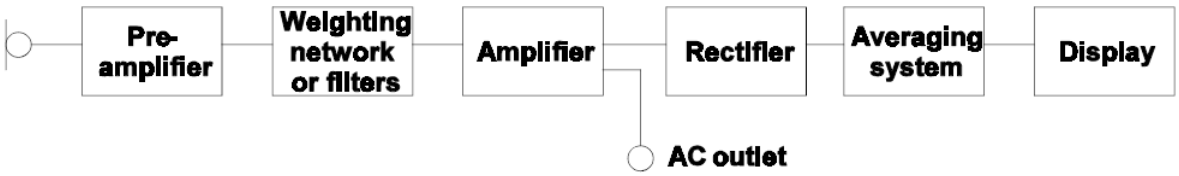


Figure 2. Sound level meter block diagram.

Relatively steady sounds are easily measured using the "fast" response and unsteady sounds using "slow" response. When measuring long-term noise exposure, the noise level is not always steady and may vary considerably, in an irregular way over the measurement period. This uncertainty can be solved by measuring the continuous equivalent level, which is defined as, the constant sound pressure level which would have produced the same total energy as the actual level over the given time. It is denoted as Leq. The display of Leq facility is also available in certain models of sound level meters. This is the desired parameter for assessment of ambient noise levels. In addition to the Sound level meter, there are other equipments used in the measurement of noise levels (Table 3).

1.4 EFFECT OF METEOROLOGICAL PARAMETERS ON SOUND/NOISE PROPAGATION

The weather has a fundamental influence of the outdoors sound/noise propagation. The propagation of sound in the atmosphere depends strongly on the state of the atmosphere. . The "bending" of sound rays occurs because of changes in the speed of sound. The speed of sound is a function of an air-density parameter called virtual temperature and is also affected by the wind vector. The meteorological effect on sound propagation has a diurnal and an annual variation mostly due to changing sun height at the various times of the day and the year. Meteorological influences including, the effects of wind and temperature gradients, effect noise propagation from source to receiver. An atmospheric state in which the air temperature increases with altitude is termed **"***temperature inversion***"** which often occurs in the evening and at night. When temperature inversions occur sound travels faster in warmer air than in cold air, so that during an inversion the top of a "sound wave" will move faster than the bottom. This bends sound back towards the ground. The result is a "trapping" of sound energy near the ground and an increase in noise levels. Similarly, daytime air temperatures typically reduce with altitude (approximately 1-2^{0C}/100m called the **"**adiabatic lapse rate**"**) and sound refracts upward slightly. As wind generally increases with altitude, wind blowing towards a receiver from the source will diffract sound waves downwards, resulting in increased noise levels. Conversely, wind blowing from the receiver to the source will diffract sound upwards, resulting in reduced noise levels.

The values of atmospheric absorption need to be calculated for the local climate based on hourly values of temperature, relative humidity and atmospheric pressure over at least two years instead of using some global mean value. Changing meteorological conditions can easily cause fluctuations in sound levels by 10-20 dB over time periods of minutes. Errors of the order of 20 dBA could be introduced if weather is not taken into account. The longer the transmission path, the larger are the fluctuations in levels. The sound level decreases as it gets further and further away from its source. While absorption by air is one of the factors attributing to the weakening of a sound during transmission, distance plays a more important role in noise reduction during transmission. The reduction of a sound is called attenuation. The effect of distance attenuation depends on the type of sound sources. Most sounds or noises we encountered in our daily life are from sources which can be characterized as *point* or *line sources*. If a sound source produces spherical spreading of sound in all directions, it is a point source. For a point source, the noise level decreases by 6 dB per doubling of distance from it. If the sound source produces cylindrical spreading of sound, such as stream of motor vehicles on a busy road at a distance, it may be considered as a line source. For a line source, the noise level decreases by 3 dB per doubling of distance from it.

Outdoor sound propagation is affected by many mechanisms, including:

a) Source geometry and type (point, line, coherent, incoherent)

b) Meteorological conditions (wind and temperature variations, atmospheric turbulence)

c) Atmospheric absorption of sound

d) Terrain type and contour (ground absorption of sound, reflections)

e) Obstructions (buildings, barriers, vegetation, etc)

The three most significant meteorological effects on sound propagation are: *refraction, scattering by turbulence* and *atmospheric absorption.*

Refraction

Sound travels through still air with a uniform temperature at all altitudes, sound rays emanating an all directions from a source on the ground will travel in straight lines. The speed of the sound is affected by the temperature of the medium, the wave moving faster at higher temperature and slows at cool temperature. When a part of sound is in layers of a medium at different temperature and therefore is traveling at different velocity, the directions of propagation of the wave changes. This effect is called refraction. Refraction of sound rays occurs if the sound velocity and/or wind speed changes along the ray path, i.e., there are gradients of wind and temperature. The refraction influences the sound level. The angle of sound incidence at the ground changes, which results in varying ground attenuation. A temperature lapse (in upwind conditions) is the common daytime condition during most of the year and causes ray paths to curve/ bent upward. Within the temperature inversion or in downwind conditions, the temperature increases with height and ray paths curve/bent downward. Finally, when the temperature change with elevation is initially negative, close to the ground, and then begins to increase at higher altitudes, and/or the wind is initially opposite to the propagation direction close to the ground and then reverses direction at a higher altitude, a more complex pattern occur.

Upwind conditions and/or lapse create areas, known as sound shadow zones, where no direct sound ray can reach. The refractive effects of temperature gradients and wind component gradients in the direction of propagation are additive. As the refractive conditions change, the path lengths of the various waves intersecting at the receiver change. Thus, depending on the phase relationships between these waves, some frequencies will be amplified and others muted.

Turbulence

Turbulence has a twofold effect on sound propagation. First, temperature fluctuations lead to fluctuations in the velocity of sound. Secondly, turbulence velocity fluctuations produce additional random distortions of the sound wave front. Turbulence scatters sound into sound shadow zones and causes fluctuations of the phase and the amplitude of the sound waves, thus destroying the interference between different rays reaching the receiver. This gives higher sound levels than expected for frequencies where the ground effect has its maximum. The effect of turbulence can be disregarded for low frequencies and distances up to a few hundred metres. When making measurements, integration over many turbulence cycles reduces the effect of turbulence on the sound level. Mean values over 5-10 minutes give more reproducible results than just an instantaneous measurement.

Atmospheric absorption

The loss in the total sound power as the sound propagates through the atmosphere occurs as a result of small amounts of heating and viscous losses and energy exchange between air molecules as a sound wave passes. This is called atmospheric absorption. Atmospheric absorption varies strongly with the frequency, relative humidity, temperature and atmospheric pressure. This loss is greatest at high frequencies and in hot, dry air. A small part of a sound wave is lost to the air or other media through various physical processes. One important process is the direct conduction of the vibration into the medium as heat caused by the conversion of the coherent molecular motion of the sound wave into incoherent molecular motion in the air or other absorptive material. The viscosity of the medium also affects sound transmission. These two physical causes combine to produce the classical attenuation of a sound wave. Atmospheric absorption increases linearly with distance and becomes more important the longer sound propagation is under study. Very little attenuation is found for low values of relative humidity or temperature. Monthly and diurnal variations in relative humidity and temperature introduce large variations in atmospheric absorption.

4.5 NOISE EXPOSURE LEVEL AND STANDARDS

Noise limits and guidelines are very different from country to country. However, the noise standards are generally set on the basis of World Health Organisation (WHO) requisites. WHO has set 65 dB permissible noise from an industrial area during both day and night. In commercial area it is 60 dB whereas 55 and 45 dB are prescribed for commercial, residential and silence zones, respectively. In India, Statutory Regulatory guidelines were prescribed both for the ambient noise levels and for workspace environment noise levels. Factories Act, 1948 prescribes the protection of workers against high noise levels (noise level > 90 dB (A)). The State Pollution Control Board and Inspector of Factories have powers to administer the control of noise pollution. Ambient noise is all encompassing noise associated with any given environment and is usually a composite of sounds from many sources near and far.

According to the Noise Pollution (Regulation and Control) Rules, 2000 framed under the Environment (Protection) Act, 1986., schedule [see rule 3(l) and 4(l)] the Ambient Air Quality Standards in respect of Noise is given in table 4 and for workspace environment noise levels in table 5. A comparison shows that in India the noise standards set are more or less in tune with the WHO specification, but the major lacuna seems to be in the implementation.

Table 4. Indian Standards for ambient noise levels.

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

Source: Environment (Protection) Act, 1986 as amended in 2002.

Note:

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 defined as an area comprising not less than 100 metres around hospitals, educational institutions and courts. The silence zones are zones which are 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.

The Noise Pollution (Regulation and Control) Rules, 2000 (The Principal Rules were published in the gazette of India, vide S.O.123 (E), dated 14.2.2000 and subsequently amended vide S.O. 1046(E), 22.11.2000, S.O. 1088(E), dated 11.01.2002,S.O. 1569(E),dated 19.09.2006 and S.O. 50(E)dated 11.01.2010 under the Environment (Protection) Act, 1986.)

Table 5. Damage risk criteria for hearing loss Occupational Safety & Health Administration (OSHA) regulations.

Maximum allowable duration per day hours	Sound pressure level, dB (A)
8	90
6	92
4	95
3	97
2	100
1.5	105
0.75	107
0.5	110
0.25	115

No exposure in excess of 115 dB(A) is permitted.

Source:

Industrial Safety and Pollution Control Handbook, (ed.), 1991. Associate (Data)

Publishers Pvt., Secunderabad.

Rao, P.R. (ed). 1995. Noise Pollution and Control, Encyclopedia of Environmental

Pollution and Control, Vol.-2, Environmedia Publications, India.

Maximum permissible noise levels and noise levels of some of the sources are given in table 6 and 7, respectively.

Table 6. Noise threshold limit value.

Maximum permissible noise levels	
Situation	**Permissible noise, dBA**
Road traffic near residential areas	70
Ear protection to be worn	85
Factory work for 8-hr a day, 6 days a week	105

Prolonged noise causing permanent damage	100
Threshold of pain-duration of 30 seconds (Maximum)	120
Maximum for impulse noise (sonic boom)	150
Absolute limit with ears protected	150
Eardrum rupture	180
Lung damage	195

Table 7. Typical noise levels of some point sources.

Source	**Noise level dB(A)**
Quiet garden	30
Ticking clock	30
Computer rooms	55-60
Type institute	60
Printing press	80
Lathe Machine	87
Sports car	80-95
Steam turbine (12,500 kW)	91
Pulveriser	92
110 KVA diesel generator	95
Riveting	95
Trains	96
Trucks	90-100
Car horns	90-105
Air compressors	95-104

Power operated portable saw	108
Milling machine	112
Pneumatic Chiseling	118

Source:

Industrial Safety and Pollution Control Handbook, (ed.), 1991. Associate (Data) Publishers Pvt., Secunderabad.

Muralikrishna, K. V. S. G. (ed.), 1995. Air Pollution and Control, Kaushal & Co., Kakinada, AP.

4.6 NOISE CONTROL AND ABATEMENT MEASURES

Noise control and abatement measures is an active or passive means of reducing sound emissions thereby minimizing the risks of noise induced hearing loss. There are many methods which help to control the noise pollution. Elimination of the noise source should be the primary measures of noise control. The main source of noise need to be verified and must be reduced eeffectively. Possible effort should be given to reduce the noise from these sources as near the source at possible.Reduction in the path of transmission of sound, and minimize noise at receiver level through engineering controls. Administrative controls and use of personal hearing protection equipment also minimize the risks of noise problems. However, ppractical and efficient noise control is wholly reliant on an accurate diagnosis of what is causing the noise.

There are four basic principles of noise control are *sound insulation, sound absorption, vibration damping and vibration isolation*. Sound insulation prevents the transmission of noise by the introduction of a mass barrier. Common materials have high-density properties such as brick, concrete, metal etc. Sound absorption acts as a 'noise sponge' by converting the sound energy into heat within the material. Common sound absorption materials include porous material like open cell foams and fiberglass. Vibration damping is applicable for large vibrating surfaces. The damping mechanism works by extracting the vibration energy from the thin sheet and dissipating it as heat. A common material is sound deadened steel. Vibration isolation prevents transmission of vibration energy from a source to a receiver by introducing a flexible element or a physical break. Common vibration isolators are springs, rubber mounts, cork, etc.

Techniques for noise control

The techniques employed for noise control can be broadly classified into three categories (Franken, 1974; Muralikrishna, 1995; Rao, 1995) namely, *control at source*, *control in the transmission path,* and *using protective equipment.*

Noise Control at Source

Reducing noise at the source or elimination of noise sources is the most effective way to prevent risks to workers, and should always be considered when new work equipment or workplaces are planned. The noise pollution can be controlled at the source of generation itself by employing certain techniques like,

i. *Reducing the noise levels from domestic sectors***:** Noise coming from domestic appliances like radio, music system, television sets, mixers and grinder, washing machines, cooking operations can be minimized by their selective and judicious operation. By usage of carpets, or fixing damping material to surfaces or any absorbing material, the noise generated from felling of items in house can be minimized.

ii. *Maintenance of machines and automobiles***:** Improving maintenance programs by proper lubrication and maintenance of machines, regular servicing and tuning of vehicles will reduce the noise levels. Fixing of silencers to automobiles, two wheelers etc., will reduce the noise levels.

iii. *Control over vibrations***:** Using lagging to dampen vibrating surfaces will work efficiently to control over the vibrations of materials. Proper foundations, rubber padding etc. may be made to reduce the noise levels caused by vibrations of materials.

iv. *Low voice speaking***:** Speaking at optimum low voices enough for communication with others reduces the excess noise levels.

v. *Prohibition on usage of loud speakers***:** By not permitting the usage of loudspeakers in the habitant zones except for important meetings/functions. Now-a-days, the urban Administration of the metro cities in India is becoming stringent on usage of loudspeakers.

vi. *Selection of machinery***:** Checking the noise levels of machinery tools or equipment before purchasing it and having a company policy of purchasing only quiet equipment reduces excess noise levels.

Control in the transmission path

*i) Installation of barriers***:** Installation of barriers between noise source and receiver can attenuate the noise levels. Fitting flexible or fixed screens or curtains of sound absorbent material in order to blocked the noise transmission path.

ii) Design of building: Fitting suitable sound absorbing material to wall/door/window/ceiling will reduce the noise levels. The approximate reduction of outside noise levels using typical exterior wall construction.

iii) *Green belt development***:** Plantation and development of green plants like shrubs and trees in and around the building largely attenuate the sound levels. However, the degree of attenuation varies with species of greenbelt. The statutory regulations direct the industry to develop greenbelt four times the built-up area for attenuation of various atmospheric pollutants, including noise.

Control in receiver level (Administrative controls and using protection equipment)

Preventing staff exposure to noise and the usage of protective equipment can be minimized through certain measures.

i. *Job rotation***:** Rotating staff in noisy areas so that each person's daily exposure to noise is reduced and the adverse impacts of occupational noise can be minimized.

ii. *Exposure reduction***:** The schedule of the workers should be planned in such a way that, they should not be over exposed to the high level of noise and as far as possible a few workers are present.

iii. *Personal hearing protection***:** The ultimate ways to control noise problems is to use personal hearing equipment like earmuffs, ear plugs etc. are the commonly used devices for hearing protection. Hearing protection must be worn for the entire duration of a noisy shift. Wearing hearing protection for only part of the shift is not sufficient. Routine maintenance and replacement procedures are also needed for the personal hearing protection equipment.

Noise abatement

Noise abatement measures include measures at the source, in the propagation area and at receiver level, as discussed in the control measures for the noise. Insulation or a noise barrier between source and receiver reduce noise by interfering with the propagation of sound waves. Different materials and designed may be employed for construction of noise barriers to best suit the surrounding environmental and mitigate noise to maximum effect. Construction of noise barriers for separating urban housing and nearby highway visually impact not only on the people living in close proximity to the road but also on drivers and passengers. It is therefore important to use barrier designs that are appropriate to the specific location where they are installed to reduce the noise level produced from heavy traffic vehicles. Altering the traffic flow in a town or city may also reduce the level of noise in an area. Imposing a ban on heavy vehicles in an area and imposing a slower speed limit may reduce noise levels.

Adopting the 'green city' or ‘greenbelt development’ concept, noise pollution can be reduced through absorption and screening by vegetation in housing and cities areas.

Zoning of the areas with respect to rural, urban, commercial, residential, industrial, etc. is very important for the abatement measures of noise pollution. Restructuring of urban areas to maintain a separation between residential areas and zones of excessive noise is needed. Systematic coordination of development in an industrialized area to ensure proper zoning of factories from nearby residential buildings is need to be formulated to solve the problems of noise pollution.

4.7 IMPACT OF NOISE ON HUMAN HEALTH

Perception of sound to be a pleasing or unpleasing is subjective. One person’s noise may be music to the ears of others. In any case, the exposure to high levels of sound intensity which may be noise or music to anyone may have harmful physical, physiological or emotional effects. Effect of noise pollution are immediate in terms of annoyance, they are cumulative in terms of temporary or permanent hearing loss. The physical damage to the ear could be temporary hearing loss (temporary threshold shift or TTS) manifested in reduced perception of low level sound or permanent loss of hearing (noise-induced permanent threshold shift or NIPTS). Scientists have recently found that continuous exposure to noise with a volume more than 70 decibels can lead to permanent hearing damage. Apart from direct hearing loss problems, the indirect physiological effects of continuous exposure to noise pollution could be significant. Increase of heart rate, blood pressure, and blood cholesterol, change in the pulse rate could be related to excessive exposure to high noise levels. Large amounts of noise every day not only causes stress for people but

can also contribute to mental illness. The emotional impact could be far more severe, that continuous exposure to elevated noise levels will cause irritability, anxiety, stress and in extreme cases depression.

In 1971, a World Health Organization (WHO) working group concluded that noise is a major threat to human well-being (Suter, 1991). The WHO has documented seven categories of adverse health effects of noise pollution on humans namely, hearing impairment, interference with spoken communication, sleep disturbances, cardiovascular disturbances, disturbances in mental health, impaired task performance, and negative social behavior and annoyance reactions (Berglund 1995; Lisa and Louis 2007). According to the World Health Organisation (WHO), generally 60 dB sound can make a man deaf temporarily and 100 dB sound can cause complete deafness.

1. HEARING IMPAIRMENT

Hearing impairment is typically defined as an increase in the threshold of hearing as clinically assessed by audiometry. The major cause of hearing loss is occupational exposure, although other sources of noise, particularly recreational noise, may produce significant deficits. Noise induced hearing impairment may be accompanied by abnormal loudness perception (loudness recruitment), distortion (paracusis), and tinnitus. There is general agreement that exposure to sound levels less than 70 dB does not produce hearing damage, regardless of the duration of exposure (Berglund 1995; Shapiro 1991).

2. INTERFERENCE WITH SPOKEN COMMUNICATION

Noise pollution interferes with the ability to comprehend normal speech and may lead to a number of personal disabilities, handicaps, and behavioral changes. These include problems with concentration, fatigue, uncertainty, lack of self confidence, irritation, misunderstandings, decreased working capacity, disturbed interpersonal relationships, and stress reactions.

3. SLEEP DISTURBANCES

The primary sleep disturbances are difficulty falling asleep, frequent awakenings, waking too early, and alterations in sleep stages and depth, especially a reduction in rapid eye movement (REM) sleep. Continuous noise in excess of 30 dB disturbs sleep and for intermittent noise, the probability of being awakened increases with the number of noise events per night (Berglund 1995). Apart from various effects on sleep itself, noise during sleep causes increased blood pressure, increased heart rate, increased pulse amplitude, vasoconstriction, changes in respiration, cardiac arrhythmias, and increased body movement (Hobson 1989).

4. CARDIOVASCULAR DISTURBANCES

The effects of cardiovascular disturbances begin to be seen with long-term daily exposure to noise levels above 65 dB or with acute exposure to noise levels above 80 to 85 dB (Berglund 1995; Suter, 1991). Acute exposure to noise activates nervous and hormonal responses, leading to temporary increases in blood pressure, heart rate, and vasoconstriction. Studies of individuals exposed to occupational or environmental noise show that exposure of sufficient intensity and duration increases heart rate and peripheral resistance, increases blood pressure, increases blood viscosity and levels of blood lipids, causes shifts in electrolytes, and increases levels of epinephrine, norepinephrine, and cortisol (Suter, 1991). Even though the increased risk for noise-induced cardiovascular disease may be small, it assumes public health importance because both the number of people at risk and the noise to which they are exposed continue to increase.

5. DISTURBANCES IN MENTAL HEALTH

Noise pollution is not believed to be a cause of mental illness, but it is assumed to accelerate and intensify the development of latent mental disorders. Noise pollution may cause or contribute to the following adverse effects: anxiety, stress, nervousness, nausea, headache, emotional instability, argumentativeness, sexual impotence, changes in mood, increase in social conflicts, neurosis, hysteria, and psychosis. Population studies have suggested associations between noise and mental-health indicators, such as rating of well-being, symptom profiles, the use of psychoactive drugs and sleeping pills, and mental-hospital admission rates. Children, the elderly, and those with underlying depression may be particularly vulnerable to these effects because they may lack adequate coping mechanisms (Berglund 1995). Children in noisy environments find the noise annoying and report a diminished quality of life (Stansfeld, 2003; Bronzaft, 2006). Noise levels above 80 dB are associated with both an increase in aggressive behavior and a decrease in behavior helpful to others (Konenci, 1975; Korte, et al. 1980; Mathews, 1975).

6. IMPAIRED TASK PERFORMANCE

The effects of noise pollution on cognitive task performance have been well-studied. Noise pollution impairs task performance at school and at work, increases errors, and decreases motivation (Evans, 1993; Cohen, 1980). Reading attention, problem solving, and memory are most strongly affected by noise. Two types of memory deficits have been identified under experimental conditions: recall of subject content and recall of incidental details. Both are adversely influenced by noise. Cognitive and language development and reading achievement are diminished in noisy homes, even though the children's schools may be no noisier than average (Bronzaft, 2000). Noise produces negative after-effects on performance, particularly in children in terms of learning, reading, problem solving, motivation, school performance, and social and emotional development. These findings suggest that more attention needs to be paid to the effects of noise on the ability of children to learn and on the nature of the learning environment, both in school and at home.

7. NEGATIVE SOCIAL BEHAVIOR AND ANNOYANCE REACTIONS

Annoyance is defined as a feeling of displeasure associated with any agent or condition believed by an individual to adversely affect him or her. Annoyance increases significantly when noise is accompanied by vibration or by low frequency components.[32] The term annoyance does not begin to cover the wide range of negative reactions associated with noise pollution; these include anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion. Lack of perceived control over the noise intensifies these effects (Berglund 1995; Stansfeld, 2003).

Social and behavioral effects of noise exposure are complex, delicate, and indirect. These effects include changes in everyday behavior (eg, closing windows and doors to eliminate outside noises; avoiding the use of balconies, patios and yards; and turning up the volume of radios and television sets); changes in social behavior (eg, aggressiveness, unfriendliness, nonparticipation, or disengagement); and changes in social indicators (eg, residential mobility, hospital admissions, drug consumption, and accident rates); and changes in mood (increased reports of depression) (Berglund 1995). The degree of annoyance produced by noise may vary with the time of day, the unpleasant characteristics of the noise, the duration and intensity of the noise, the meaning associated with it, and the nature of the activity that the noise interrupted. Other less direct effects of annoyance are disruption of one's peace of mind, the enjoyment of one's property, and the enjoyment of solitude.

4.8 MITIGATION OF NOISE POLLUTION

Mitigation of noise pollution refers to any actions that will be taken to reduce the effects of noise or the noise levels on a receptor. Adverse noise effects generated by a facility can be avoided or reduced at the point of source thereby diminishing the effects of the noise at the point of reception.

Controlling noise at source is usually regarded as the principal method for mitigation of noise pollution. Noise mitigation is a set of strategies to reduce the problems of noise pollution arising from different sources mainly from transportation, industrial, construction sites, neighbourhood, etc. However, measures which attempt to limit the spread of noise, once generated, are often of considerable value as well. As it has been discussed well noise is transmitted through a path from the source and then arrives at the receiver. The noise is perceived as a problem when the noise is high enough and creates annoyance to the receiver. The severity of the problem depends on the strength of the noise source or the length of the transmission path, that is, how large is the separation between the noise source and the receiver.

Road traffic noise can be reduced by constructing noise barriers, speed limits as per types of vehicles, entry limitation of heavy vehicles in urban area, use of traffic controls that smooth vehicle flow to reduce braking and acceleration, and tire design. A noise barrier or acoustic shield reduces noise by interrupting the propagation of sound waves. With proper design and selection of material for the noise barrier or acoustic shield, noise reaching a noise sensitive receiver would be primarily through diffraction over the top of the barrier and around its ends. The acoustical "shadow zone" created behind the barrier is where noise levels are substantially lowered. To function well, the barrier must prevent the line-of-sight between the noise source and the receiver. Effective noise barriers can reduce noise levels by as much as 20 dB(A).

Rail traffic noise may be reduced by maintaining low speed. At low speeds the power unit contributes significantly to noise generation, but at higher speeds the interaction of wheels and rail becomes the dominant source of noise. It is also possible to minimized by reducing or control the roughness of both wheels and rails and to reduce the formation of wheel flats and rail corrugations.

Generally, mitigation of air traffic noise needs good land use planning, providing adequate spatial separation of noise sources and noise-sensitive area. In addition to this, air traffic noise can be reduced by using quieter jet engine and altering flight paths and time of day runway. Control and regulation of aircraft operation in the vicinity of airports has benefited residents near airports. Even though the noise emission from aircraft has decreased with the development of quieter power units, the increasing volume of air traffic has added another crisis with no net reduction in air traffic noise.

Industrial noise is generated by a wide and mixed collection of various types and forms of noise sources. Industrial noise control is really a subset of interior architectural control of noise, with emphasis upon specific methods of sound isolation from industrial machinery and for protection of workers at their task stations. Therefore, a generalized measure to control industrial noise can be used of silencers, attenuators or mufflers, in connection with rotating machinery and ducts/pipes leading to/from the source. By employing improved sound insulation of buildings, for walls, windows, doors, openings, ventilation etc. Home sound proofing is also a type of receptor

shielding and is typically the only available solution to noise impacts from airborne aircraft. It can be very effective for reducing sound exposure within the home; however, it does not address the outdoor environment and is typically only considered when other options are not available.

Noise mitigation at receiver level largely emphasized on used of ear plugs, earmuffs and headphones; which are very effective and inexpensive when utilized. Though these hearing equipments are viable and common solutions to high noise in the work place but are poor solutions to community noise issues.

India has developed many rules and regulations from time to time to ensure that the noise levels in the country are maintained at a nominal level. As Motor Vehicles are the chief source of noise pollution, the Motor Vehicle Act of 1998, gave numerous powers to the state Administration to monitor the noise levels at their own level. Although there have been many more provisions but as none of them have been implemented as they were supposed to be, the noise levels seems to be growing day by day.

4.9 CASE STUDY

Case 1: Urban Corridor Noise Pollution: A case study of Surat city, India

Tandel et al. (2011) highlights the noise pollution study carried out on three of the busiest urban corridors of Surat city. Traffic related noise pollution accounts for nearly two-third of the total noise pollution in an urban area. Noise, a by product of urbanization, industrialization and motorization, is increasingly recognized as an environmental nuisance that effects human health and wellbeing. Traffic noise on existing urban roadways lowers the quality of life and property values for persons residing near these urban corridors Surat is now the tenth largest city of India having an estimated population of 40 lakhs plus at present. An inconceivable population growth rate of 76.02 % was observed in the last decade as a result of rapid industrialization. Surat is well known as diamond city and is also famous for silk and jari industry. Owing to its rapid industrialization and better job opportunities, observation is made for the migration from all over India and particularly from Orissa, U.P., M.P., Bihar and Rajasthan. Due to explosion of population and rapid industrialization the transportation in the city increased to unimaginary heights, but due to the want of efficient Mass Transit System, individual vehicular growth also touched escalating heights. As on 31-12-2006, the vehicles registered at R.T.O. is 13 lakhs plus. This is equivalent to the highest growth rate of Delhi. Thus the explosion of population, rapid industrialization and highest growth rate in vehicle population made the traffic problems complicated.

Case 2: Diwali special: Excessive noise can drive you mad (Published on Tuesday, Oct 18, 2011, 11:45 IST by DNA Correspondent, Mumbai, India.)

When Dr YTOke, one of Mumbai's pioneering campaigners against noise pollution, speaks at anti-noise pollution forums he relates a tragic story to drive home the devastating effects of loud noise: 12 years ago, a 78-year-old Greek was sentenced to life imprisonment for murdering a neighbour who insisted on playing loud music when he wanted to hear the news.

Though the Greek incident is an extreme example, it shows that prolonged exposure to excessive noise can be mentally disturbing and can drive people to murderous insanity.

Oke says that when he was a school student in the 1940s, the trundling electric trams and the sirens from factories were the main source of noise. This changed in the mid-1950s when loudspeakers became popular during Satyanarayan pujas and other religious and social functions in the city's mill areas. "This became a trend and families would even borrow money to hire loudspeakers," said Oke.

When he returned to India in 1966, Oke remembers that he had grown more sensitive to noise. "The concept of noise pollution and that excessive noise could damage the body physically and mentally was not understood."

In 1979, in a seminar on 'Noise Pollution' in Mumbai, Dr PP Karnik, ENT professor at KEM Hospital, spoke about deafness caused by noise. The same year, in one of the first court cases involving noise pollution, residents of Jayvijay building in Vile Parle, including Oke, filed a suit against an industrial shed that was being built in the neighbourhood. Oke argued that noise pollution from the shed would cause high blood pressure and affect the functioning of the vital organs of the body, including the heart and brain. The shed was demolished in 1986 because no new factory could come up in a residential zone.

The state government had permitted the use of loudspeakers atop religious places. In the 1980s, Navaratri became noisy as 'Disco Dandiyas' became a trend.

In 1985, Oke along with the Association of Medical Consultants filed a petition in the High Court. The group produced before the court a report by an NGO SOCLEEN (Society for Clean Environment), which had studied noise levels during festivals. The study said that there was an increase in decibel levels in residential areas during festivals from 50-60 db to 90-100db and due to crackers in Diwali up to 115-120db.

The HC appointed an 8-member committee to study noise pollution in Mumbai and suggest remedial measures.

4.10 SUMMING UP

To understand noise, one must know something about sound and how loudness is measured. Physically, sound is a mechanical disturbance propagated as a wave motion in air and other medium. Physiologically, sound is an auditory sensation evoked by this physical phenomenon. Sound that travels through the air in waves has two major properties: the frequency or speed at which the waves vibrate and the intensity of each vibration. We detect sound by means of a set of sensory cells in the inner ear. The sensitivity and discrimination of our hearing is remark able. Normally, humans can hear sounds from about 20 Hz to 20,000 Hz. Loudness is measured by a decibel scale (expressed as dB), but to reflect human hearing more accurately a modified version of this scale, known as the A scale, has been developed. On the A scale, loudness is measured in dB(A). The scale increases logarithmically so that an increase of 10 dB indicates a doubling of loudness, and an increase of 20 dB represents a sound that is four times louder. The most common instruments used for measuring noise are the Sound Level Meter (SLM). It is important that you understand the calibration, operation and reading the instrument before use.

When we talk about noise pollution, it is the pollution generated by any unwanted sound or any sound that interferes with hearing, causes stress, or disrupts our lives. Noise pollution like other pollutants is also a by-product of industrialization, urbanizations and modern civilization but the difference is that noise as a pollutant, does not remain longer in the environment. Noises come from many sources. Traffic is generally the most omnipresent noise in the city. Cars, trucks, buses, bikes create lot of noise that permeates nearly everywhere. Around airports, peak noise levels release when aircrafts fly overhead or take-off and land at airports. Noise from, lawn-mowers, chain saws, music from radios, TVs, and loudspeakers, domestic appliances, construction sites, industries, etc. create noise problems everywhere. Broadly, there are three major sources of noise pollution, industry and machinery noise, transportation (surface and air traffic) and community activity noise like entertainment, construction works etc.

Noise pollution is a slow poisoning which has irreversible serious complications in the longer run of our lives. The growth in noise has led to research examining the impact of noise on the lives and activities of reasonable people. The result has been a body of evidence that strongly suggests noise is hazardous to good mental and physical health. Noises are especially troublesome at night when one is trying to sleep, and a good night's sleep is vital to good health. An increasing number of people are affected by noise in their environment. We have known that prolonged exposure to high level of noises, such as loud music or the roar of machinery can result to hearing impairment. Evidence now suggests that noise-related stress also causes a wide range of psychological and physiological problems ranging from irritability, annoyance to cardiovascular disease.

In consideration of increasing magnitude of noise related problem on human health, we can no longer afford to neglect the issue of noise pollution. Time has come that we all take this problem seriously, and begin implementing solutions. Suitable precautionary measures are required to be taken up in order to reduce the intensity of noise to the receiver. The source of noise must be reduced. The path of transmission of sound must be stopped and the receiver of noise must be safe guarded. Providing barriers and use of hearing equipments are few of the meaningful ways to mitigate the noise effect on human health.

Noise is still all around us, it is always need to minimize the generation of noise at individual levels and there are law and statutory regulations relating to noise pollution and abatements measures to control noise at different levels. However, general awareness programme to educate the people about the hazardous effects of noise pollution need to be done among the people particularly, to those people who generally lack consciousness of the hazardous effects of noise pollution.

Educational institutions like schools and colleges should involved as target areas to teach young children and teenagers about the used and effects of high sound producing equipments which cause noise pollution. Perhaps if we all understood the dangers of noise and the permanence of hearing loss, we would have a quieter environment.

4.11 SUGGESTED READINGS

Assessment and Control of Noise Pollution in Mining Industry, Proceedings of National Seminar held by Institution of Engineers at Madras, 1989.

Berger E.H., Ward W.D., Morill J.C., Royster L.H. (eds.). American Industrial Hygiene Association (Akron, Ohio), pp. 97-176.

Berglund B, Lindvall T. 1995. (eds.) Community Noise. *Archives of the Center for Sensory SensoryResearch.* 2:1-195. Available at: http://www.who.int/docstore/peh/noise/guidelines2.html. Accessed January 6, 2007.

Bronzaft, A.L. 2000. Noise: Combating a ubiquitous and hazardous pollutant. *Noise Health*, 2:1-8.

Bronzaft, A.L. It takes a silent village to harm a child. Available at:

http://www.lhh.org/hrq/24-1/village.htm .

Chatwal, G. R. 1989. (ed.). *Environmental Noise Pollution and Its Control.* Columbia: South Asia Books

Cohen, S. 1980. After effects of stress on human performance and social behavior: a review of research and theory. *Psychol Bull*,88:82-108.

Cyril M. Harris. 1994. *Noise Control in Buildings: A Practical Guide for Architects and Engineers.*

Despres, B., Leplay, A., and Thiery L. 1995. Practical experience of noise exposure measurement and homogeneous exposure groups. *Proceedings of Euro-Noise 95*, Lyon. CETIM, pp.1061-1064.

Energy and Environment 1990: Transportation-Induced Noise and Air Pollution. Washington, DC: Transportation Research Board.

Environmental Noise Pollution and its Control, Proceedings of Specialist Course, Institution of Engineers, Roorkee, India.1992.

Evans, G.W. and Lepore, S.J. 1993. Non-auditory effects of noise on children; a critical review. *Children's Environments*,10:42-72.

Franken A. Peter. 1974. (ed.). Community Noise Pollution, Industrial Pollution, Van Noistr and Reinhold Company, New York.

Harris, C. M. (ed.). 1991. *Handbook of acoustical measurements and noise control*. 3rd edition, New York, McGraw-Hill, Inc.

Hawkins, N.C., Norwood, S.K., and Rock, J.C. 1991. A strategy for occupational exposure assessment. *American Industrial Hygiene Association* (Akron, Ohio), p.179.

Hobson, J.A. 1989. *Sleep. Scientific American Library.* W.H. Freeman and Company, New York.

Industrial Safety and Pollution Control Handbook, Associate (Data) Publishers Pvt., Secunderabad, 1991 (ed.).

Jeva, R. et. al. 1996. Noise Impact Assessment - an approach, Energy Environment Monitor, Vol.: 12, September.

Konenci, V.J. 1975. The mediation of aggressive behavior. Arousal level versus anger and cognitive labeling. *J Person Soc Psychol*,32:706-712.

Korte ,C., Ypma, I. and Tappen, A. 1980. Traffic noise, environmental awareness, and pedestrian behavior. *Environ Behav*,12:408-420.

Leidel, N.A., Busch, K.A. and Lynch, J.R. 1977. *Occupational exposure sampling strategy manual*. National Institute for Occupational Safety and Health (U.S. Government Printing Office, Washington), publication No. 77-173, p. 132.

Lisa Goines, RN and Louis Hagler, MD. 2007. Noise Pollution: A Modern Plague. Southern Medical Journal, 100(3):287-294.

Malchaire J. 1994. *Programmes de conservation d' audition*. Paris, Masson (Ed.), p.162.

Mathews, K.E. Jr, and Cannon L. 1975. Environmental noise as a determinant of helpful behavior. *J. Pers. Soc. Psychol*,32:571-577.

Mathur, J.S.B. 1981 (ed.). Noise Control : Legislation, Planning and Design, Industrial Effluent Treatment, Vol.:2, Applied Science Publishers Ltd., London.

Mathur J.S.B. 1981. (ed.). Noise Control: Methods of Reduction, Industrial Effluent Treatment, Vol.: 12, Applied Science Publishers Ltd., London.

Muralikrishna, K.V.S.G. (ed.) 1995. Air Pollution and Control, Kaushal & Co., Kakinada, AP, India.

Noise: A Leaflet Published by Steel Authority of India Limited.

OECD Staff. 1991. *Fighting Noise in the Nineteen Nineties.* Washington, DC: Organization for Economic Cooperation and Development.

P.S. Jaiswal and Nistha Jaiswal – Environmental Law, Second End. 2003, p.327.

Parivesh News Letter: Central Pollution Control Board, December, 1996.

Randall, F.B. and Barron, F.B. 2002. Industrial Noise. *Control and Acoustics*, Marcel Dekker, New York. ISBN 978-0-8247-0701-9.

Rao, P.R.1995. (ed.). Noise Pollution and Control, Encyclopedia of Environmental Pollution and Control, Vol.-2, Environmedia Publications, India.

Royster, L.H., Berger, E.H. and Royster, J.D. 1986. Noise surveys and data analysis. In: *Noise and hearing conservation manual*.

Scott, D.F., Greayson, R.L., and Edward, A. 2004. Diseases and illness in U. S. mining, 1983-2001. *Journal of Occupational and Environmental Medicine*, 46(12), 1272-1277.

Shapiro, S.A. 1991. The Dormant Noise Control Act and Options to Abate Noise Pollution: Administrative Conference of the United States. Available at: http://www.nonoise.org/library/shapiro/shapiro.htm . Accessed October 10, 2006.

Stansfeld, S.A. 2003. Matheson MP. Noise pollution: non-auditory effects on health. *Br Med. Bull*,68:243-257.

Suter, AH. 1991. Noise and its Effects. Administrative Conference of the United States. Available at: http://www.nonoise.org/library/suter/suter.htm .

Tandel, B., Macwan, J. and Ruparel, P.N. 2011. Urban Corridor Noise Pollution: A case study of Surat city, India. *IPCBEE.*12., IACSIT Press, Singapore.

4.12. PROBABLE QUESTIONS

1. What is the difference between sound and noise?

2. What is the frequency range of infrasonic and ultrasonics?

3. List out typical sources of noise pollution.

4. What are the ambient noise limits?

5. What are the impacts of noise?

6. What are the physiological and physiological effects of noise?

7. Explain the different types of noise measuring equipments.

8. What are the methods to control noise pollution?

9. Discuss the methods employed for the control of noise.

10. Write short note on noise mitigation.

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-5: SOIL POLLUTION

UNIT STRUCTURE

5.0 OBJECTIVES

1) To understand how physico-chemical properties of soil are affected by various pollutants.

2) To suggest certain mitigation measures that can be taken to reduce soil pollution

3) To learn in detail about phyto-remediation and bioremediation as eco friendly measures to reduce soil pollution

5.1 INTRODUCTION

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents, which have adverse effects on plant growth and animal health.

Soil is the thin layer of organic and inorganic materials that covers the Earth's rocky surface. The organic portion, which is derived from the decayed remains of plants and animals, is concentrated in the dark uppermost topsoil. The inorganic portion made up of rock fragments, was formed over thousands of years by physical and chemical weathering of bedrock. Productive soils are necessary for agriculture to supply the world with sufficient food.

5.2 PHYSICO-CHEMICAL PROPERTIES OF SOIL

Physical Properties

Soil “horizons” are discrete layers that make up a soil profile. They are typically parallel with the ground surface. In some soils, they show evidence of the actions of the soil forming processes.

O horizons are dominated by organic material. Some are saturated with water for long periods or were once saturated but are now artificially drained; others have never been saturated.

A horizons are mineral layers that formed at the surface or below an O horizon, that exhibit obliteration of all or much of the original rock structure, and that show one or both of the following:

- an accumulation of humified organic matter intimately mixed with the mineral fraction and not dominated by properties characteristic of E or B horizons
- modification as a result of the actions of cultivation, pasturing, or similar kinds of disturbance

E horizons are mineral layers that exhibit the loss of silicate clay, iron, aluminum, humus, or some combination of these, leaving a concentration of sand and silt particles. These horizons exhibit obliteration of all or much of the original rock structure.

B horizons are mineral layers that typically form below an A, E, or O horizon and are dominated by obliteration of all or much of the original rock structure and show one or more of the following:

- illuvial concentration of silicate clay, iron, aluminum, humus, carbonate, gypsum, or silica, alone or in combination
- evidence of removal of carbonates
- residual concentration of sesquioxides
- coatings of sesquioxides that make the horizon conspicuously lower in value, higher in chroma, or redder in hue than overlying horizons without apparent illuviation of iron
- alteration that forms silicate clay or liberates oxides or both and that forms granular, blocky, or prismatic structure if volume changes accompany changes in moisture content; or brittleness

C horizons are mineral layers which are not bedrock and are little affected by pedogenic processes and lack properties of O, A, E or B horizons. The material of C layers may be either like or unlike that from which the overlying soil horizons presumably formed. The C horizon may have been modified even if there is no evidence of pedogenesis.

R horizons are layers of hard bedrock.

Soil texture: Has a large influence on water holding capacity, water conducting ability and chemical soil properties.

Soil Texture Classification:

Soil Texture	equivalent diameter size (mm)
gravel	> 2 mm
sand	0.05 - 2 mm
very coarse	1 - 2 mm
coarse	0.5 - 1 mm
medium	0.25 - 0.5 mm
fine	0.1 - 0.25 mm
very fine	0.05 - 0.1 mm
silt	0.002 - 0.05 mm
clay	< 0.002 mm (< 2 micrometer)

Bulk Density

Bulk density is the proportion of the weight of a soil relative to its volume. It is expressed as a unit of weight per volume, and is commonly measured in units of grams per cubic centimeters (g/cc).

Bulk density is an indicator of the amount of pore space available within individual soil horizons, as it is inversely proportional to pore space:

Pore space = 1 – bulk density/particle density

For example, at a bulk density of 1.60 g/cc, pore space equals 0.40 or 40%. At a bulk density of 1.06 g/cc, pore space equals 0.60 or 60%.

The addition of even a small percentage of organic soil material to a mineral soil can affect the bulk density of that soil. Compare the two soil samples below:

Soil “A”: 100% mineral soil material; bulk density = 1.33 g/cc

Soil "B": 95% mineral soil material and 5% organic soil material; bulk density = 1.26 g/cc

The difference in bulk density relates to a difference in "particle density" of mineral soil material versus organic soil material. The average particle density of mineral soil material is 2.65 g/cc, which approximates the density of quartz. Conversely, the average particle density of organic soil material is 1.25 g/cc. Organic soil material weighs less than mineral soil material, so it will lower the bulk density of a mineral soil when added, as it reduces the overall weight of the soil.

Soil Structure:

The arrangement and organization of soil particles in the soil, and the tendency of individual soil particles to bind together in aggregates; aggregation creates intra-aggregate and inter-aggregate pore space, thereby changing flow paths for water, gases, solutes and pollutants.

Effects on plant growth through:

1. Aeration

2. Soil compaction

3. Water relations

4. Soil temperature

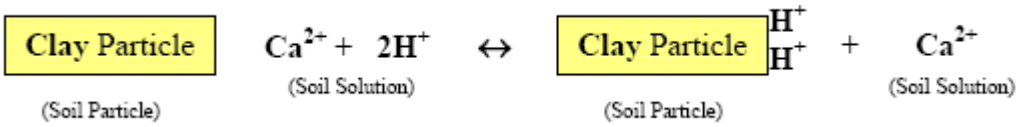
Structure development is influenced by:

- Amount and type of clay, as well as the exchangeable ions on the clay (also water acts as bridge between clay particles)
- Amount and type of organic matter, since it provides food for soil fungi and bacteria and their secretion of cementing agents (polysaccharides)
- Presence of iron and aluminum oxides (cementing agents).
- Binding between organic and inorganic compounds (aluminium oxides, cations, clays)
- Vegetation: produces OM, roots act as holding soil together, and protects soil surface

Soil Chemical Properties

a. Cation Exchange Capacity (CEC)

Some plant nutrients and metals exist as positively charged ions, or "cations", in the soil environment. Among the more common cations found in soils are hydrogen (H+), aluminum (Al+3), calcium (Ca+2), magnesium (Mg+2), and potassium (K+). Most heavy metals also exist as cations in the soil environment. Clay and organic matter particles are predominantly negatively charged (anions), and have the ability to hold cations from being "leached" or washed away. The adsorbed cations are subject to replacement by other cations in a rapid, reversible process called "cation exchange".



Cations leaving the exchange sites enter the soil solution, where they can be taken up by plants, react with other soil constituents, or be carried away with drainage water.

The "cation exchange capacity", or "CEC", of a soil is a measurement of the magnitude of the negative charge per unit weight of soil, or the amount of cations a particular sample of soil can hold in an exchangeable form. The greater the clay and organic matter content, the greater the CEC should be, although different types of clay minerals and organic matter can vary in CEC.

Cation exchange is an important mechanism in soils for retaining and supplying plant nutrients, and for adsorbing contaminants. It plays an important role in wastewater treatment in soils. Sandy soils with a low CEC are generally unsuited for septic systems since they have little adsorptive ability and there is potential for groundwater.

5.3 INDUSTRY INDUCED SOIL POLLUTION AND ITS MITIGATION

Mining

The ores and minerals are rich source of heavy metals. These ores and minerals upon weathering release heavy metals such as aluminium, chromium, cadmium, iron, lead, manganese, nickel and zinc. In process of opening the mines, the ores and minerals are exposed. The soil dug out of the mines are known as overburdens. The overburdens spread over the mining area cause pollution to the soil of that area.

Dumping of solid wastes

In general, solid waste includes garbage, domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations. The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to. These can in the long run, get deposited to the soils of the surrounding area and pollute them by altering their chemical and biological properties. They also contaminate drinking water aquifer sources. More than 90% of hazardous waste is produced by chemical, petroleum and metal-related industries and small businesses such as dry cleaners and gas stations contribute as well.

Pollution Due to Urbanization

Urban activities generate large quantities of city wastes including several Biodegradable materials (like vegetables, animal wastes, papers, wooden pieces, carcasses, plant twigs, leaves, cloth wastes as well as sweepings) and many non-biodegradable materials (such as plastic bags, plastic bottles, plastic wastes, glass bottles, glass pieces, stone / cement pieces). On a rough estimate Indian cities are producing solid city wastes to the tune of 50,000 - 80,000 metric tons every day.

Pollution due to industries

The steel and allied industries, dispose huge amounts of basic slags. Similar to lime sludge, basic slag has ameliorative properties of acid soils, but high contents of iron and manganese in it will be additive to the iron rich acid soils. Moreover the slag is very hard to crush for use. Deposits of the by-product if remains unused may pollute the soil.

The Thermal Power Plants use of coal daily for combustion, as a result of which, these plants discharge large quatity of flyash daily which is a rich source of heavy metals such as iron, manganese, zinc, copper, lead, nickel, chromium, cobalt. These heavy metals leaking into the soil cause hazards to environment.

Phosphatic fertilizer factories release ammonia gas and sulphuric acid to the environment which are absorbed in soil and cause toxicity. Phosphogypsum, the by-product of these industries deposited around the factories cause soil pollution by release of free acid and excess sulphur.

Mitigation measures:

a) Since a significant amount of urban solid waste tends to be paper and food waste, the majority is recyclable or biodegradable in landfills.

b) When a site is to be developed for an industry, it is advisable that a site assessment study be conducted to establish the baseline soil conditions for future assessment of land contamination.

c) In case of heavily polluted soils, remove the contaminated soil for proper disposal and carry out soil testing to ensure that all the pollutants have been removed.

5.4 IRRIGATION INDUCED SOIL POLLUTION AND MITIGATION

Irrigation has contributed significantly to poverty alleviation, food security, and improving the quality of life for rural populations. However, the sustainability of irrigated agriculture is being questioned, both economically and environmentally. The increased dependence on irrigation has not been without its negative environmental effects.

- Water logging and salinization: Another problem associated with excessive irrigation on poorly drained soils is waterlogging. This occurs (as is common for salinization) in poorly drained soils where water can't penetrate deeply. For example, there may be an impermeable clay layer below the soil. It also occurs on areas that are poorly drained topographically. What happens is that the irrigation water (and/or seepage from canals) eventually raises the water table in the ground -- the upper level of the groundwater -- from beneath. Growers don't generally realize that waterlogging is happening until it is too late -- tests for water in soil are apparently very expensive. The raised water table results in the soils becoming waterlogged. When soils are water logged, air spaces in the soil are filled with water, and plant roots essentially suffocate -- lack oxygen. Waterlogging also damages soil structure. Water logging concentrates salts, drawn up from lower in the soil profile, in the plants' rooting zone. Alkalization, the build-up of sodium in soils, is a particularly detrimental form of salinization which is difficult to rectify. Irrigation-induced salinity can arise as a result of the use of any irrigation water, irrigation of saline soils, and rising levels of saline groundwater combined with inadequate leaching. When surface water or groundwater containing mineral salts is used for irrigating crops, salts are carried out into the root zone. In the process of evapotranspiration, the salt is left behind in the soil, since the amount taken up by plants and removed at harvest is quite negligible. The more arid the region, the larger is the quantity of irrigation water and, consequently, the salts applied, and the smaller is the quantity of rainfall that is available to leach away the accumulating salts.

- Stagnant water tables at the soil surface are known to increase the incidence of water borne diseases. Water-borne or water-related diseases are commonly associated with the introduction of irrigation. The diseases most directly linked with irrigation are malaria, bilharzias (schistosomiasis) and river blindness (onchocerciasis), whose vectors proliferate in the irrigation waters. Other irrigation-related health risks include those associated with increased use of agrochemicals, deterioration of water quality, and increased population pressure in the area. The reuse of wastewater for irrigation has the potential, depending on the extent of treatment, of transmitting communicable diseases. The population groups at risk include agricultural workers, consumers of crops and meat from the wastewater-irrigated fields, and people living nearby.
- Increased nutrient levels in the irrigation and drainage water resulting in algal blooms, proliferation of aquatic weeds and eutrophication in irrigation canals and downstream waterways

Mitigation measures

The following items should be considered when planning irrigation water management:

a) Managing precipitation effectiveness, crop residues, and reducing system losses.

b) Measurement and determination of flow rate is a critical component of irrigation water management and pressure gauge should be used to maintain the flow.

c) The quality of irrigation water and the potential impact to crop quality and plant development, and the potential effect on the soil's physical and chemical properties, such as soil crusting, pH, permeability, salinity, and structure.

d) Irrigation water rates and amounts required for each irrigation event shall be determined to adequately replenish the root zone without exceeding the soil's water holding capacity.

Agriculture induced soil pollution and its mitigation

Pollution in soil due to agricultural activities:

• Indiscriminate use of fertilizers

• Indiscriminate use of pesticides, insecticides and herbicides

• Dumping of large quantities of solid waste

• Deforestation and soil erosion

Indiscriminate use of fertilizers

Soil nutrients are important for plant growth and development. Plants obtain carbon, hydrogen and oxygen from air and water. But other necessary nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, sulfur and more must be obtained from the soil. Farmers generally use fertilizers to correct soil deficiencies. Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate (NH_4NO_3), phosphorus as P_2O_5, and potassium as K_2O. For instance, As, Pb and Cd present in traces in rock phosphate mineral get transferred to super phosphate fertilizer. Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers becomes an indestructible poison for crops. The over use of NPK fertilizers reduce quantity of vegetables and crops grown on soil over the years. It also reduces the protein content of wheat, maize, grams, etc., grown on that soil. The carbohydrate quality of such crops also gets degraded. Excess potassium content in soil decreases

Vitamin C and carotene content in vegetables and fruits. The vegetables and fruits grown on over fertilized soil are more prone to attacks by insects and disease.

Indiscriminate use of pesticides, insecticides and herbicides

Plants on which we depend for food are under attack from insects, fungi, bacteria, viruses, rodents and other animals, and must compete with weeds for nutrients. To kill unwanted populations living in or on their crops, farmers use pesticides. The first widespread insecticide use began at the end of World War II and included DDT (dichlorodiphenyltrichloroethane) and gammaxene. Insects soon became resistant to DDT and as the chemical did not decompose readily, it persisted in the environment. Since it was soluble in fat rather than water, it biomagnified up the food chain and disrupted calcium metabolism in birds, causing eggshells to be thin and fragile. As a result, large birds of prey such as the brown pelican, ospreys, falcons and eagles became endangered. DDT has been now been banned in most western countries. Ironically many of them including USA, still produce DDT for export to other developing nations whose needs outweigh the problems caused by it. The most important pesticides are DDT, BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furodan, etc. The remnants of such pesticides used on pests may get adsorbed by the soil particles, which then contaminate root crops grown in that soil. The consumption of such crops causes the pesticides remnants to enter human biological systems, affecting them adversely. Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil. Some of the

pesticides are quite stable and their bio- degradation may take weeks and even months. Pesticide problems such as resistance, resurgence, and heath effects have caused scientists to seek alternatives.

Soil erosion

Soil Erosion occurs when the weathered soil particles are dislodged and carried away by wind or water. Humans speed up this process by construction, mining, cutting of timber, over cropping and overgrazing. It results in floods and cause soil erosion. Forests and grasslands are an excellent binding material that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide innumerable feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. During the past few years quite a lot of vast green land has been converted into deserts. The precious rain forest habitats of South America, tropical Asia and Africa are coming under pressure of population growth and development (especially timber, construction and agriculture). Many scientists believe that a wealth of medicinal substances including a cure for cancer and aids, lie in these forests. Deforestation is slowly destroying the most productive flora and fauna areas in the world, which also form vast tracts of a very valuable sink for CO_2.

Mitigation measures

a) The increase in soil fertility through organic manure

b) By maintaining habitat diversity in agricultural landscapes in order to provide ecosystem services.

c) No-till farming or conservation agriculture. The systems basically comprise various combinations of reduced mechanical inversion of the soil – particularly ploughing – combined with the establishment of cover crops or green manures.

Soil salinity and reclamation measures

Factors responsible for formation of saline and alkali soils:

i. In arid regions, where evaporation exceeds the precipitation, the soluble salts accumulates near the soil surface.

ii. The ground water of arid regions usually contains considerable quantities of soluble salts. If it is used for irrigation it spoils the good soil. The extent of damage depends not only upon the salt

content of irrigation water but also on the nature of salts and type of soils on which the water is to be used. The sodium salts are more harmful than Calcium & Magnesium salts. Farmers do not get their well waters tested and continue to irrigate the lands till they lose productivity.

iii. Sometimes the salts may have originated directly from chemical weathering of rocks.

iv. Excessive applications of irrigation water and seepage from canals and tanks raises the ground water level sufficiently to permit continuously to accumulate salts at the surface due to capillary action and evaporation. If the quality of the subsurface water is saline, the accumulation rate would be much faster.

v. Poor drainage keeps the salts in the surface soil and prevents the leaching of salts down below the root zone. Many saline soils in command areas are formed due to inadequate and impaired drainage.

vi. Soil salinization in the coastal area is due to the accumulation of salts from the inundated sea water. Irrigation water contains a high concentration of soluble salts, particularly sodium salts which lead to salinity.

Harmful effects

The saline soils do not support plant growth primarily because of excessive salts in the soil solution which, due to high osmotic pressure, prevent absorption of moisture and nutrients in adequate amounts. An excess of sodium ions also exert antagonistic effect on the absorption of calcium and magnesium. Under alkali soil conditions, the damage is not due to salt concentration as the conductivity of the soil solution is low. The sodium absorbed by soil clay and organic colloids causes dispersion of clay which results in a loss of desirable soil structure. Such effect on physical properties reduces drainage, aeration and microbial activity. Under saline alkali conditions, the crop may suffer due to high salinity as well as due to unfavorable effects of alkalinity on the nutrient availability.

Reclamation measures:

The following information is essential before taking up the reclamation work:

• Quality of the soil as judged from its physicochemical properties.

• Quality of irrigation water to be used.

• Nature and distribution of salts in the soil profile.

• Level of underground water table.

• Drainage facility.

• Availability of suitable amendment.

• The crops which will suit the given conditions

Approaches for reclamation of saline soils

Removal of excess salt to a desired level in the rooting zone is the basic principle of reclamation of saline soils.

Leaching with water of good quality and adequate drainage are the two essential components of permanent solution of the salinity problem.

- **Leaching**

Leaching is the process of transporting soluble salts by downward movement of applied water. But, water used for leaching also contains soluble salts which accumulate in soil in proportion to the salt content and depth of the applied water. The leaching requirement (LR) has been defined as that fraction of excess water that must be leached through the root zone to control soil salinity at a specified level.

- **Drainage**

Drainage is the removal of excess water from the soil. Drainage may be surface drainage or sub surface drainage. The former is for draining off excess surface ponding, where as, the latter is for lowering the root zone accumulation and the water table. The depth at which tile drains are to be placed is calculated based the hydraulic conductivity of different layers of soil below the surface. Out of the various methods of drainage systems and reclamation of saline soils, subsurface drainage system will be most effective and long lasting. This system includes laying of perforated PVC pipes or clay tiles underground in a grade and draining the accumulated salts along with water to a common outlet and then out of the field. The drained water will be tested for its quality

and if found suitable, the same water can be recycled generally by mixing with good quality water.

- **Management practices**

Proper Water Management and selection of cropping system are very important for crop production in saline soils and to control further development of soil salinity. Rice is considered a

satisfactory crop during the initial years of reclamation. After rice, growing a suitable legume for the region is recommended. Cultivation of salt tolerant crops and varieties is the other management practice. Some of the crops categorized as high, medium, and low salt tolerant are listed below:

- High salt tolerant : Sesbania, rice, sugarcane, oats
- Medium salt tolerant : Castor, cotton ,sorghum, millet, maize, mustard, wheat
- Low salt tolerant : Pulses, pea, gram, linseed

Approaches for Reclamation of sodic soils

The problem of sodic soils is the high exchange sodium percentage. Obviously, the basic principle underlying reclamation of these soils is to adopt those ameliorative measures by which the exchangeable sodium will be replaced by calcium and the exchangeable sodium thus released as sodium salt is leached out of the root zone. Use of amendments and adequate leaching are the prerequisites for any reclamation measures.

• Because of low cost and easy availability, Gypsum and sulphur have been used widely and intensively as an amendment for reclamation. The Gypsum converts sodium soil into calcium soil, lowering of pH and improvement in soil physical conditions. A large quantity of Gypsum is required to reclaim alkali soils. On an average for every one milli equivalent of sodium to be replaced, 1.7 tons of gypsum or 0.32 tons of sulphur is required.

• Iron pyrites which is abundantly available is also an economical amendment for sodic soils. The use of molasses along with press mud and basic slag is also found good in some areas.

• Bulky organic manures, green manures, crop residues and other biomass materials are also used for reclamation of sodic soils. Addition of organic matter helps in lowering the pH, improving the soil structure and availability of Nitrogen to the crops.

• Leaching with good quality water must follow the application of the reclaiming materials.

• Proper choice of crops, adoption of best suited cultural and crop management practices are essential for management of sodic soils. Growing of crops tolerant to high exchangeable sodium can ensure reasonable returns during the initial years of reclamation.

5.5 PHYTOREMEDIATION AND BIOREMEDIATION

Plants have been used to stabilize or remove metals from soil and water. The three mechanisms used are *phytoextraction*, *rhizofiltration*, and *phytostabilization*.

- Rhizofiltration is the adsorption onto plant roots or absorption into plant roots of contaminants that are in solution surrounding the root zone (rhizosphere). Rhizofiltration is used to decontaminate groundwater. Plants are grown in greenhouses in water instead of soil. Contaminated water from the site is used to acclimate the plants to the environment. The plants are then planted on the site of contaminated ground water where the roots take up the water and contaminants. Once the roots are saturated with the contaminant, the plants are harvested including the roots. In Chernobyl, Ukraine, sunflowers were used in this way to remove radioactive contaminants from groundwater (EPA, 1998).
- Phytostabilization is the use of perennial, non-harvested plants to stabilize or immobilize contaminants in the soil and groundwater. Metals are absorbed and accumulated by roots, adsorbed onto roots, or precipitated within the rhizosphere. Metal-tolerant plants can be used to restore vegetation where natural vegetation is lacking, thus reducing the risk of water and wind erosion and leaching. Phytostabilization reduces the mobility of the contaminant and prevents further movement of the contaminant into groundwater or the air and reduces the bioavailability for entry into the food chain.
- Phytoextraction

Phytoextraction is the process of growing plants in metal contaminated soil. Plant roots then translocate the metals into aboveground portions of the plant. After plants have grown for some time, they are harvested and incinerated or composted to recycle the metals. Several crop growth cycles may be needed to decrease contaminant levels to allowable limits. If the plants are incinerated, the ash must be disposed of in a hazardous waste landfill, but the volume of the ash is much smaller than the volume of contaminated soil if dug out and removed for treatment. Phytoextraction is done with plants called hyperaccumulators, which absorb unusually large amounts of metals in comparison to other plants. Phytoextraction is easiest with metals such as nickel, zinc, and copper because these metals are preferred by a majority of the 400 hyperaccumlator plants. Several plants in the genus *Thlaspi* (pennycress) have been known to take up more than 30,000 ppm (3%)of zinc in their tissues. These plants can be used as ore because of the high metal concentration (Brady and Weil, 1999).

Bioremediation

Case Study

Mr Madhawanand Joshi, Almora District, Uttaranchal, India observed that local water supply – a spring arising from a forested catchment directly above his farm – has been diminishing

continuously for a decade or so. He attributes this decrease in flow largely to the degradation of the original banj oak (Quercus leucotrichophora) forest, whose branches are lopped for fodder, and the consequent ingress of chir pine (Pinus roxburghii). In 1995, Joshi began to create an experimental protection-cum-conservation area of two hectares around the springhead, where he has (with the help of the local Soil Conservation Branch) designed and dug conservation trenches and planted trees. Livestock are excluded. He calls it pata pani (pata = leaves; pani = water). Joshi has planted alder, willow and banj oak trees. His experience is that these trees have 'a water-conserving capacity': rainwater is captured by the trees, flows down the stems, is conserved by the litter and seeps into the ground. Pata pani is therefore basically a recreation of natural broadleaved 'forest floor' conditions. As a result of his initiative – according to him – several springs in the neighborhood are again yielding water. He is recognized by the Government Department of Agriculture and the local research station as a man with a valid technique and a relevant message. Joshi has also developed a biopesticide utilizing Melia azedarach tree leaves and chilli peppers: remarkably, a woman innovator in Kenya, Mrs Agnes Mughi, who used practically the same ingredients (in fact a closely related tree – Azadirachta indica – and with the addition of aloe leaves). Agnes has various other initiatives, including a verdant gully garden in semi-arid Mwingi District (adapted from Critchley and Brommer, 2003a).

5.6 SUGGESTED READINGS

1) Altieri, M.A., Nicholls, C.I. (2003): Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystems. *Soil and Tillage Research* 72(2), pp 203-211.

2) DNRQ (1997) Salinity Management Handbook. Department of Natural Resources Queensland.

3) Baker, A.J.M., and R.R. Brooks. 1989. Terrestrial plants which hyperaccumulate metallic elements – a review of their distribution, ecology, and phytochemistry. Biorecovery 1:81:126.

4) Brady, N.C., and R.R. Weil. 1999. The nature and properties of soils. 12th ed.

Prentice Hall. Upper Saddle River, NJ.

5.7 PROBABLE QUESTIONS

1) How does salinity and sodicity affect the physico-chemical properties of soil? Discuss the measures taken to reduce soil salinity and sodicity.

2) What are hyper accumulators? How do they help in reclaiming polluted soil?

3) How do agricultural practices induce soil pollution? What measures can be taken to reduce such pollution?

4) What is 'cation-exchange capacity' of soils? How does CEC help us to know about the soil fertility?

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-6: WASTE MANAGEMENT

UNIT STRUCTURE

6.0 OBJECTIVE

Economic and industrial development has created several environmental problems, among which huge production of both solid and liquid waste is one of the most severe one. The principal aim of this particular course is to address the problem under environmental perspectives including presentation of some sustainable utilization options.

- To define and describe different types of wastes including their nature and properties.
- To elaborate the causes and effects of various wastes on the environment.
- To present various aspects of energy and resource recovery from solid wastes in a lucid and illustrative manner.

6.1 INTRODUCTION

Wastes are materials that are not prime products (i.e. products produced for the market) for which the generation has no further use in terms of producer's own purposes of production, transformation or consumption and of which he/she wants to dispose. Presently in India about 960 MT (Million Ton) of solid waste is being generated annually as byproducts during industrial, mining, municipal, agricultural and other process. Annually, Asia alone generates around 4.4 Billion tones of solid waste among which municipal solid waste comprise 790 MT of which about 48(6%) MT is generated in India. By the year 2047, MSW (Municipal Solid waste) generation in India is expected to reach 310 MT. To dispose off such huge amount of solid waste total requirement of land would be around 169.6 sq. km. However at present in our country

around 55 MT of MSW and 38 billion liters of sewage are produced on an average. Hence, finding out useful disposal pathways of wastes is the most challenging tasks of the present time.

Source:

Yoshizawa S, Tanaka M, Shekdar AV. Global trends in waste generation. In: Gaballah I, Mishar B, Solozabal R, Tanaka M, editors. Recycling, waste treatment and clean technology. Spain: TMS Mineral, Metals and Materials publishers; 2004. p. 1541–52 (II).

Central Pollution Control Board (CPCB). Report on management of municipal solid WASTES, Delhi. India, 2000.

Saxena, M. Solid wastes generation in India and their recycling potential in building materials.

The wastes can be defined in various ways. However, the Basel Convention gives one of the most appropriate and comprehensive definition of waste. The Basel Convention on the Control of Trans boundary Movements of Hazardous Wastes and Their Disposal, usually known simply as the Basel Convention, is an international treaty that was designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries (LDCs). It does not, however, address the movement of radioactive waste. The Convention is also intended to minimize the amount and toxicity of wastes generated, to ensure their environmentally sound management as closely as possible to the source of generation, and to assist LDCs in environmentally sound management of the hazardous and other wastes they generate. The Convention was opened for signature on 22 March 1989, and entered into force on 5 May 1992. According to Basel Convention substances which are not useful are called waste. Substances or object which are disposed off or intended to be disposed off or are required to be disposed off by the provision of law.

(Source: en.wikipedia.org/wiki/Basel_Convention)

6.1.1 TYPES OF WASTE

a. MUNICIPAL SOLID WASTE:

Solid waste that include household garbage, rubbish, construction and demolition debris, sanitation residues, packaging materials, trade and industrial refuges etc. are managed by any municipality.

b. BIO MEDICAL WASTE:

Solid or liquid waste including containers, intermediate or end product generated during diagnosis, treatment and research activities of medical sciences.

c. HAZARDOUS WASTE:

Such waste has the properties like ignitability, corrosivity, reactivity and toxicity. Majority of such waste are generated by chemical industries followed by petroleum, coal, metal, gas and sanitary industries.

d. RADIO ACTIVE WASTE:

Waste containing radioactive materials that are product of nuclear process. Sometimes industries that are not directly involved in nuclear activities also produce some radioactive wastes.

e. **e-WASTE**:

These are the electronic wastes, e.g. CRT (Cathode Ray Tube), damaged accessories such as DVDs, CDs, switches etc.

6.1.2 CAUSE AND EFFECTS OF WASTE:

The main causes of waste generation are:

- **Changing life style**- The drastic change in consumption trend has resulted in uncontrolled way of waste generation.
- **Inadequate planning**-Inadequate long term planning for waste management has resulted in improper waste handling practices.
- **Inadequate finance and infrastructure in waste management**-The cost of handling and disposal of hazardous waste is yet another causal agent against management of waste.
- **Insufficient training of various stakeholders**-Lack of awareness among the waste generators is another hurdle in the process of waste management.

Waste if not managed properly:

- Affects our health
- Affects our socio-economic conditions
- Affects our environment
- Affects our climate

6.2 DISPOSAL AND MANAGEMENT OF WASTES

The disposal of solid waste or liquid waste is a big problem as it leads to pollution and contamination of the environment. Hence to sustainably manage the waste and transform it into valuable entities process of energy and resource recovery have been devised by technological innovation. Some of these processes can be understood as under:

6.2.1 LANDFILL GAS

Landfill gas is produced through bacterial decomposition, volatilization and chemical reactions. Chemical reactions occur when different waste materials are mixed together during disposal operations. Moisture plays an important role in speeding up the decomposition process.

Landfill gas production & composition:

In general, during anaerobic conditions, the composition of landfill gas is approximately 50% methane and 50% carbon dioxide with trace amounts of nitrogen, oxygen and hydrogen sulfide, hydrogen and non-methane compounds (NMCs). The bacterial decomposition of organic waste occurs in four phases:

Phase 1: The bacteria degrade the long chains of carbohydrates, proteins and lipids releasing carbon dioxide. Nitrogen content is high in this phase that decreases subsequently towards the end of the process. This phase continues until the available oxygen is depleted.

Organism involved *Pseudomonas aeruginoca, P. striate, Bacillus spp., Clostridium spp.* etc.

Phase 2: It starts when the oxygen in the landfill has been used up. In this phase the anaerobic bacteria convert the compounds created by the aerobic bacteria into different organic acids like acetic, formic, lactic acids etc and alcohols like ethanol and methanol. The by products are hydrogen and carbon dioxide.

Organism involved *Lactobacillus spp., Leuconostoc spp.* etc.

Phase 3: It starts when certain kinds of bacteria consume the organic acids produced by the anaerobic bacteria and form acetate. The neutral environment leads to the colonization of methane –producing bacteria. The methane producing bacteria and acid forming bacteria have a close symbiotic relationship that leads to the consumption of the excess carbon dioxide and acetate that is toxic.

Phase 4: This phase begins when both the consumption and production rates of landfill gas remain relatively constant. The landfill gas in this phase contains 45-60% methane by volume, 40-60% carbon dioxide and 2-9% other gases such as sulfides.

Organism involved *Methanogenium spp. Methanosarcina acetovorans, etc, Methanococcus thermolithotrophicus* etc.

Factors affecting landfill gas production:

Gas production depends on the rate of decomposition, which in turn is affected by moisture content of the waste, temperature, soil cover permeability, amount of precipitation, composition of the waste, refuse particle size, compaction and land filling particles.

Hydrogen sulfide:

Hydrogen sulfide is a colorless, flammable gas and is one of the most common sulfides responsible for landfill odors. The higher concentration of hydrogen sulfide is believed to be associated with the gypsum board component present in the construction and demolition(C & D) materials. Hydrogen sulfide is generated as a result of a series of reactions that biologically reduce sulfate leached from gypsum contained in the C & D material. Factors contributing to hydrogen sulfide production are anaerobic conditions, p^H, moisture, organic matter content in the presence of sulfate.

Methane & Carbon dioxide:

Methane and carbon dioxide are generated through the biological decomposition of waste. Methane is naturally occurring flammable, colorless and odorless gas and is the principal explosive component in the landfill gas. Carbon dioxide is colorless, odorless and slightly acidic gas naturally found at low concentration in the atmosphere.

Landfill gas migration:

The landfill gas produced within the landfill mass generally moves away from the landfill. The migration may occur through soil or ambient air. The production of landfill gas results in the pressure gradients (advection) and concentration gradients (diffusion) between the landfill and the surrounding environment. Landfill gas migrates from source area along the path of least resistance due to pressure, density and concentration gradients. This usually results in landfill gas moving upward through the landfill surface into landfill gas collection system or through sub surface soils into ambient air.

(Source : Mijin Kim, 2003 PhD thesis on The study on landfill microbial communities using landfill gas and landfill gas condensate. Thesis submitted for PhD in Drexel University)

6.2.2. PROCESS OF RESOURCE RECOVERY

Composting

Farmyard manure is the oldest manure known to mankind and is made up of solid excreta or dung of animals, urine and plant remains which are allowed to decay with the help of soil micro-organisms capable of decomposing complex organic debris into substances that are easily assimilated by plants. Composting can be done in various ways. Some of them can be discussed as under:

i. **Composting from night soil**: The pits are filled layer by layer. The bottom layer consists of green plants and aquatic weeds, followed by a layer of silt-straw and finally a layer of animal excreta. This process is repeated until the pit is filled.

ii. **Pit method**: The pit method utilizes a bottom layering of urine-soaked vegetable wastes, fodder remnants, green matter, etc. The bed layer is sprinkled with slurry of cow dung and mixed with well decomposed manure from previous batch. The layering pattern is continued until the pit is filled.

iii. **Heap method**: The base material is put on a hard like pigeon pea stalks, cotton etc. Then a heap of garbage and green waste is poured over it and plastered with mud. Within a period of 2-3 months the plaster is broken, materials stirred and again mud plastered. The final product becomes a heap of well decomposed organic matter.

iv. **High temperature composting:** It is done by heaping alternate layers of night soil, urine, sewage, animal dung and chopped plant parts. The base material consists of hard stalks of crops and this is followed by layering with other materials. Water is added at optimum levels. The entire heap is shaped finally with mud plaster taking care to insert bamboo or maize stalks into the mud covered heap all the way to the bottom of the heap. After 24 hours, the bamboo poles are withdrawn to leave behind holes for ventilation. Within 4-5 days, the temperature rises to 60-70^0C when holes are closed and sealed with mud plaster. After a period of 2 weeks the mud plaster is broken and the contents are mixed followed by resealing the plaster. At the end of 2 months, the decomposed compost free from pathogens is ready for use.

Vermicomposting

The use of earthworms in composting process is known as vermicomposting. The earthworms are aerators which make tunnels in the soil and also enhance its texture. The earthworms being voracious feeders, can consume different kinds of organic materials in large quantities. Beneficial effects of these worms in improving aeration, structure, nutrient status of soils and, thereby, the growth of crop has been reported since long. Vermicomposting technology helps in decomposing different organic materials with the help of large numbers of aerobic microorganisms and these results, in general, in better nutrient status of the produced compost materials as compared to those prepared by traditional composting systems. There are about 3000 earthworm species in the world and 500 in India alone. Based on their feeding behavior earthworms can be divided into 3 types- epigeic, endogeic and anecic.

Epigeic earthworms live on the upper surface of soil. E.g. *Eisenia foetida, Eudrillus euginae.*

Endogenic earhworms live deep inside the soil and feed organically rich soil. E.g. *Octochaetona thrustoni, Metaphir posthuma.*

Anecic earthworms reside little beneath soil surface and feed organic materials mixed with soil. These are geophagous in nature. E.g. *Lampito mauritii, Octochaetona swensis.*

A series of compost pits are dug with sloping sides. Bamboo poles are placed at the bottom of the pits and lined with gunny sack to avoid the escape of worms. The pits are filled with moist farm wastes, animal manure and leaves that are well chopped. The worms are picked by hand from the boxes and placed into the pit. By incubating the compost pit in the shade and keeping it moist but not water logged for 2 months, a good organic matter rich vermicompost can be prepared for use on farm.

(Source: N.S. Subba Rao, 2008, Book on Soil Microbiology, Oxford & IBH Publishers)

6.2.3. PROCESSES OF ENERGY RECOVERY

Solid wastes contain organic as well as inorganic matter. The latent energy present in organic fraction can be recorded for gainful utilization through adoption of suitable waste processing and treatment technologies.

Benefits that we obtain through energy recovery:

- The total quantity of waste gets reduced by nearly 60% to over 90%, depending upon the waste composition and adopted technology
- Demand for land, which is already scarce in cities, for land filling is reduced
- The cost of transportation of waste to far away land fill sites also gets reduced proportionately
- Net reduction in environmental pollution

Basic techniques of energy recovery:

Energy can be recovered from organic fraction of waste (biodegradable as well as non-biodegradable) through two methods:

i. Thermo-chemical conversion: This process entails thermal decomposition of organic matter to produce either heat energy or fuel oil or gas.

ii. Bio-chemical conversion: This process is based on enzymatic decomposition of organic matter by microbial action to produce methane gas or alcohol.

Thermo-chemical conversion processes are useful for wastes containing high percentage of organic non-biodegradable matter and low moisture content. The technological options are as follows:

- Incineration
- Pyrolysis
- Gasification

Bio-chemical conversion processes are useful for wastes having high percentage of organic biodegradable matter and high moisture content, which aids microbial activity. The technological option is anaerobic digestion also referred as bio-methanation.

Parameters affecting energy recovery:

- Quantity of wastes
- Physical and chemical characteristics

The actual production of energy will depend upon specific treatment process employed, the selection of which is also critically dependent upon the above two parameters, apart from certain other factors that we will discuss later on.

So, anaerobic information on the waste materials, including percentage variations thereof with time is therefore of utmost importance. The important physical parameters are:

i. Size of the constituents- Smaller the size of the constituents faster is the decomposition process.

ii. Density- High is the density; high will be the proportion of bio-degradable organic matter and moisture.

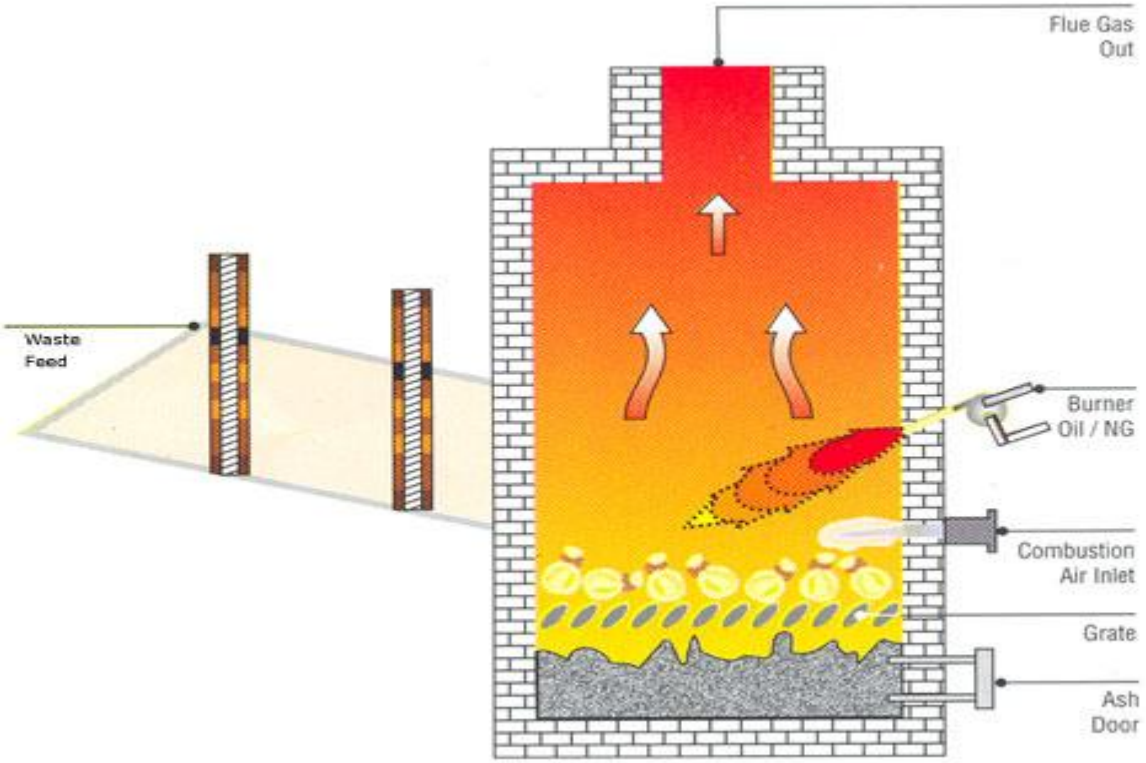
iii. Moisture content-High moisture content in wastes causes rapid decomposition of bio-degradable fraction and makes wastes unsuitable for thermo-chemical conversion for energy recovery as heat must first supplied to remove moisture.

Important chemical parameters for determining energy recovery potential:

- Volatile solids
- Fixed carbon
- Inerts
- Calorific value
- C/N ratio
- toxicity

Incineration

Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials and converts the waste to ash, flue gas and heat. It is a technique of thermo chemical conversion which is an energy recovery process.



Source: maharashtradirectory.com

Incinerators and their types:

Incinerator can be understood more precisely as a furnace where waste is burnt. Following are the types of plants for burning waste:

1. **Moving Grate**: It is the incineration plant used for treating Municipal Solid Waste. This grate is capable of taking 35 metric ton of waste every hour of treatment.
2. **Fixed Hearth Incinerator**: It is used for medical and municipal waste incineration. These plants are also called trash-to-steam plants.
3. **Rotary Kiln Incinerator**: Solid waste as well as liquid waste generated by industry is destroyed by on-site and commercial site rotary kiln incinerator systems. The rotary kiln provides excellent mixing through tumbling action that distributes heat evenly to all the waste materials contained within it.
4. **Liquid injection**: In this sort of incineration, air is blown at high speed over a sand bed. The air gets going through the bed when a point comes where sand granules separates and let air pass through them and here comes the part of mixing and churning. Therefore, a fluidized bed comes into being and fuel and waste are then can be introduced.

5. **Specialized incineration**: These are special incinerators used for furniture industries where handling of waste requires crucial handling and care. These incinerators are installed with back prevention systems and are very much necessary for dust suspensions when they are more able to catch up the fire generate liquid waste that contain toxic organics.

Gaseous emissions:

- Dioxin & Furan
- CO_2
- SO_2,
- HCl
- Heavy metals(Pb, Cd, Zn, Cu, etc)
- Fine particles

Solid outputs:

- Fly ash
- Bottom ash

Advantages:

- Incineration can generate electricity and heat that can substitute power plants powered by other fuels.
- The bottom ash residue can be safely put into landfills or recycled as construction aggregate.
- Incineration of medical waste and sewage sludge produces a safe and sterile end product.
- Incineration of municipal solid waste avoids the release of methane.
- Volume of combusted waste is reduced by 90%, increasing the life of landfills.

Disadvantages:

- The Incinerator Bottom Ash (IBA) has high levels of heavy metals (Cr, Vn, Mn, Ni, Hg, As, etc) with eco-toxicity.
- The fly ash is highly toxic end product that may cause concerns for local residents.

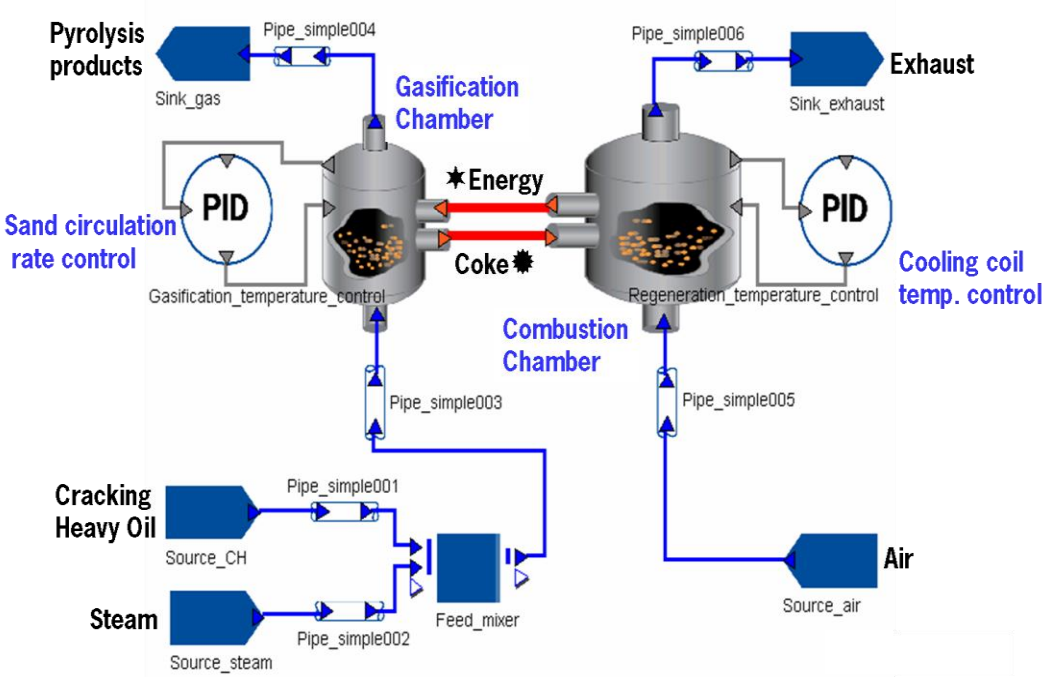
Conclusion:

The incinerators are normally found in large factories that deal with waste products or disposal of waste products. Modern incinerators use a pollution free mechanism of energy generation and waste treatment.

(Source:en.wikipedia.org/wiki/Incineration)

Gasification

Gasification is a chemical process by which carbonaceous materials are converted to a synthesis gas by means of partial oxidation with air, oxygen and/or steam. Gasification was first used to produce "town gas" for light and heat.



Source: psenterprise.com

Process:

1. **Dehydration**: It is carried out at around 100^0C that results in steam mixed into gas flow involving subsequent chemical reactions, notably water-gas reaction. The process is dependent on the properties of the carbonaceous material and determines the structure and composition of char, which will then undergo gasification reactions.
2. **Combustion**: It occurs as the volatile products and some of the char reacts with oxygen to primarily form carbon dioxide and small amounts of carbon monoxide which provide heat for subsequent gasification reactions.

3. **Gasification**: It occurs as the char reacts with carbon and steam to produce carbon monoxide and hydrogen.

4. In addition, the reversible gas phase water gas shift reaction reaches equilibrium very fast at the temperatures in a gasifier. This balances the concentration of carbon monoxide, steam, carbon dioxide and hydrogen.

Types of Gasification:

1. **Low temperature gasification**: Occurs at a relatively lower temperature 700-1000^0 C.
2. **High temperature gasification**: Occurs at a temperature of about 1200-1600^0 C.
3. **Air gasification**: The simplest gasification process where air is used as a gasifying agent.
4. **Steam gasification**: Unlike air gasification, steam gasification requires an external heat source if steam is used as a sole gasifying agent.
5. **Oxygen gasification**: In this type, gasification is carried out in an oxygen environment.
6. **Hydrogen gasification**: The fuel feed stock is converted to gaseous fuel in the presence of hydrogen under high pressure.

Applications:

- Gasifiers offer a flexible option for thermal application.
- Industrial-scale gasification is currently most used to produce electricity.
- Gasification plants produce heat and generate power that is used in most of the countries.
- The producer gas generated from gasifying fossil fuel can be used as a substitute for existing diesel engines, spark ignition engines, SOFC fuel cells, etc.
- Gasification leads a way towards the use of clean fuel from any organic material or plastic waste. Hence renewable energy can be generated.

Gasifiers and their types:

1. **Counter-current fixed bed (up draft) gasifier**: In this gasifier, the gasification agent moves in a counter-current direction through the fuel.

2. Co-current fixed bed (down draft) gasifier: It is similar to the counter current gasifier but here the agent gas flows in a co-current configuration with the fuel bed set downwards.

3. Fluidized bed reactor: The fuel is fluidized in oxygen and steam/air. Fuel throughput is higher compared to fixed bed gasifiers.

4. **Entrained flow gasifier:** A dry pulverized solid, an atomized liquid fuel or fuel slurry is gasified with oxygen in co-current flow. Most coals are suitable for this type of gasifier because of high operating temperatures and because of coal particles are well separated from one another.

5. **Plasma gasifier:** The inorganic residue is retrieved as a glass-like substance.

6. **Free radical gasifier:** A single stage gasifier that employs a thermolytic and photolytic conversion process in an oxygen starved environment.

7. **Biomass gasifier:** These systems basically convert woody biomass/ agricultural waste like rice husk, coconut waste, etc into combustible gas which can be used in a number of ways.

Common limitation:

- Gasification is a complex and sensitive process. There exists high level of disagreement about gasification among engineers, researchers and manufacturers.
- Gasifiers require at least half an hour or more to start the process. Raw material is bulky and frequent refueling is often required for continuous running of the system.
- Getting the producer gas is not difficult, but obtaining in the proper state is the challenging task.
- The gasification process requires hard work and tolerance.

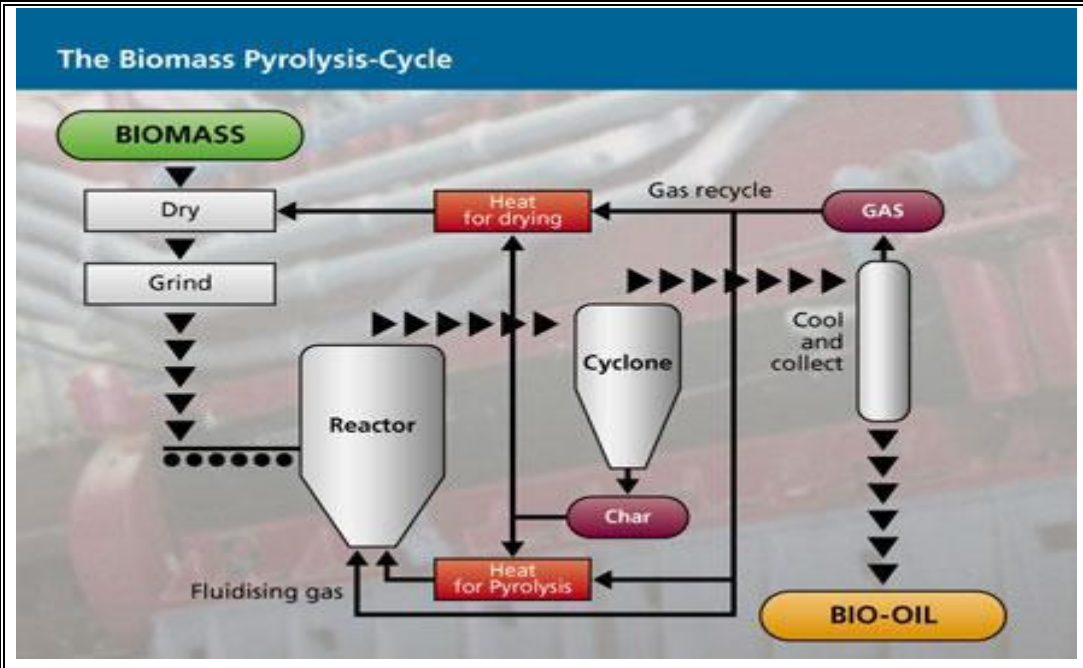
Conclusion:

Gasification offers the most attractive alternative energy system. Efficient gasification technology also offers India the potential to produce a variety of fuels, particularly transportation fuels, and chemicals. Integrated Gasification Combined Cycle (IGCC), an advanced coal-based power generation technology may be an important technology to help India meet its future power needs.

(Source: en.wikipedia.org/wiki/Gasification)

Pyrolysis

Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. The products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide and carbon dioxide in higher temperature (760^0 C). While in lower temperature ($450\text{-}730^0$ C) tar, charcoal and liquids such as oils, acetic acid, acetone and methanol are produced. Hydrated pyrolysis or pyrolysis in the presence of water produces 90% fuel and 10% gas. Pyrolysis in nitrogen atmosphere is done in presence of Cu catalyst and fuel and gas are produced in a ratio of 50:50.There is certain specialized names of pyrolysis such as dry distillation, destructive distillation or cracking.



Source: bioenergyconsult.com

Process:

Pyrolysis is an endothermic process so various methods to provide heat to the reacting biomass particles which have been proposed are:

- Partial combustion of the biomass products through air injection. This results in poor quality products.
- Direct heat transfer with a hot gas, the ideal one being product gas that is reheated and recycled. The problem is to provide enough heat with reasonable gas flow rates.
- Indirect heat transfer with exchangeable surfaces. It is difficult to achieve good heat transfer on both sides of the heat exchange surface.
- Direct heat transfer with circulating solids.

Pyrolysis technologies can be categorized into:

1. Fast pyrolysis

The fast pyrolysis can be further divided into the following:

i. Augers process
ii. Ablative process
iii. Rotating cone
iv. Fluidized bed

v. Circulating fluidized bed

2. Slow pyrolysis

It is a vacuum process where organic matter is heated in a vacuum in order to decrease its boiling point and avoid adverse chemical reactions.

Uses:

a. The pyrolysis of common materials like wood, plastic, and clothing is extremely important for fire safety and fire fighting.

b. Everyday cooking involves pyrolysis that releases many substances that contribute to the flavor, color and biological properties of the final product.

c. Charcoal is obtained by heating wood until complete pyrolysis occurs, leaving only carbon and inorganic ash.

d. Biochar improves the soil texture and ecology, increasing its ability to retain fertilizers and release them slowly.

e. Pyrolysis is used on a massive scale to turn coal into coke for metallurgy.

f. Carbon fibres are produced by spinning and weaving suitable polymer and then pyrolyzing the material at a high temperature.

g. Pyrolysis is the reaction used to coat a preformed substrate with a layer of pyrolytic carbon. Pyrolytic carbon coatings are used in many applications, including artificial heart valves.

h. Anhydrous pyrolysis can also be used to produce liquid fuel similar to diesel from plastic waste.

Advantages:

- It is a thermo chemical decomposition of organic material at elevated temperature without the participation of oxygen.
- It converts toxic material into non-toxic.
- It helps in waste disposal by energy recovery and waste minimization.
- The process doesn't deplete oxygen.
- Plays an important role in cooking processes.

Disadvantages:

- It is difficult to get a oxygen free environment so pyrolysis involves a small amount of oxidation.

- Pyrolysis is not effective in either destroying or physically separating inorganic from the contaminated medium.
- When the off-gases are cooled, liquids condense, producing an oil/tar residue and contaminated water.

Conclusion:

Pyrolysis has been attracting much attention due to its high efficiency and good environmental performance. It has a crucial role to play in waste disposal, energy generation and toxicity remediation.

(Source: en.wikipedia.org/wiki/Pyrolysis)

Anaerobic digestion/biomethanation

The process involves the following steps:

- Segregation of the organic fraction of waste
- Feeding them into a closed container under aerobic condition
- Organic waste undergone bio-degradation and produce methane rich biogas and sludge
- Biogas produced 50-150 m^3/tone depending upon waste composition

Fundamentally, anaerobic digestion process can be divided into 3 stages with 3 distinct physiological groups of micro-organisms.

Stage 1: Fermentative bacteria (anaerobic and facultative micro-organisms) convert complex organic material into carbon-dioxide, ammonia, sulfides etc. e.g: *Clostridium cellobioparum, Bacteroids succinogens, B. cellulosolvens,* etc.

Stage 2: Acetogenic bacteria consume these primary products and produce hydrogen, acetic acid, etc. e.g: *Syntrophomonas wolfei*

Stage 3: Two types of methanogenic bacteria firstly reduce (*Methanobacterium formicicum, M. thermoautotrophium*) and then decarboxylate (*Methanosarcina barkeri, Metahanosaeta spp*.) ultimately forming methane.

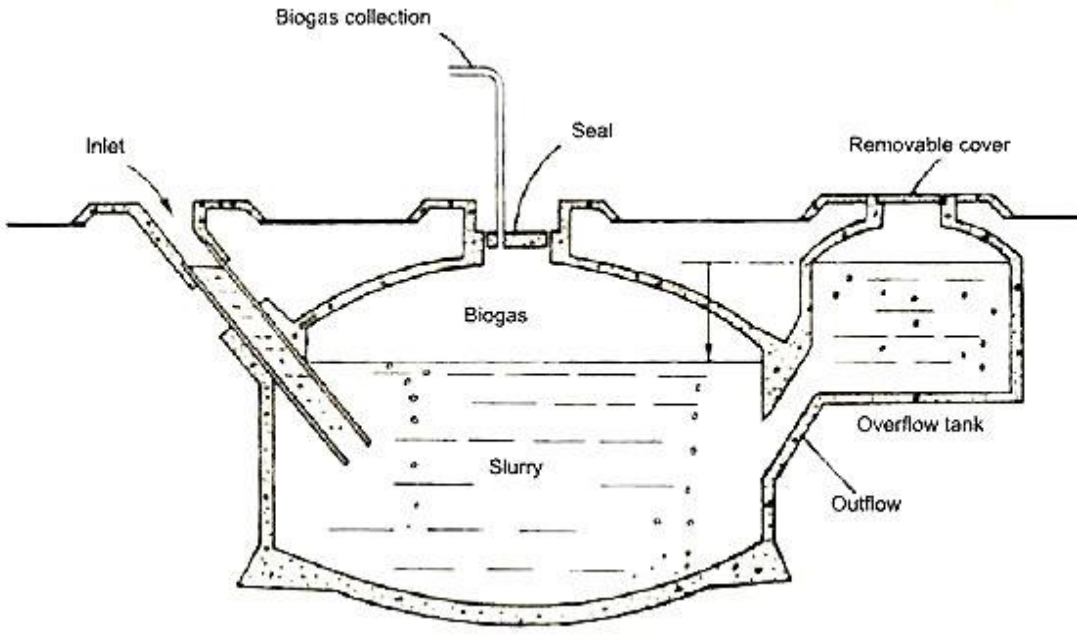
Advantages:

- Anaerobic digestion results in net production of energy

- Quality of digested sludge is better and is not lost by oxidation.
- Its totally enclosed system prevents escape of polluted air to atmosphere.
- Thus the net environmental gain are positive
- No power requirement like aerobic composting where sieving and tumbling of waste pile for oxygen supply is necessary.
- Free from bad odour, rodent and fly menace, visible pollution and social menace.
- Require small area and can be done effectively in small scale.

Biogas & its utilization:

Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. Organic waste such as dead plant and animal material, animal feces, and kitchen waste can be converted into a gaseous fuel called biogas. The main constituents of biogas are methane 60%, Carbon dioxide 40% and small quantities of Ammonia and hydrogen sulfide. Biogas can be utilized for local gas use. The gas is transported by a dedicated pipeline from point of collection to the point of gas use. Single point of use is obviously economical than multiple points. Prior transporting gas must be cleaned, condensates and particulates are removed through a level of filters and/or drier.



Source: i-sis.org.uk

Representative reactions occurring in a biogas chamber:

$C_6H_{12}O_6+4H_2O \longrightarrow 2CH_3COO^-+ 2HCO_3^-+ 4H^+ +4H_2$

$C_2H_5COO^-+3H_2O \longrightarrow CH_3COO^- +H^+ + 2H_2$

$C_4H_7O_2$ or $C_3H_7COO^-+2\ H_2O \longrightarrow CH_3COO^-+ HCO_3^-+ H^+ +2H_2$

$C_6H_6COOH +7H_2O \longrightarrow 3\ CH_3COO^- + HCO_3^-+ 3\ H^+ +3\ H_2$

$CH_3COO^-+ H_2O \longrightarrow CH_4 + HCO_3^-+ H^+$

$4H_2+ HCO_3^-+ H^+ \longrightarrow CH_4 + 3\ H_2O$

Or $4H_2+CO_2 \longrightarrow CH_4+2\ H_2O$

(Source: en.wikipedia.org/wiki/Biogas)

6.3. SUGGESTION READINGS

Lessons from India in Solid waste management by Adrian code. Google books

Handbook of soild waste management by Frank Krith and George Tchobanoglous. Amazon.2012

en.wikipedia.org/wiki/Biogas

en.wikipedia.org/wiki/Pyrolysis

en.wikipedia.org/wiki/Gasification

en.wikipedia.org/wiki/Incineration

N.S. Subba Rao, 2008, Book on Soil Microbiology, Oxford & IBH Publishers

Mijin Kim, 2003 PhD thesis on The study on landfill microbial communities using landfill gas and landfill gas condensate. Thesis submitted for PhD in Drexel University

Yoshizawa S, Tanaka M, Shekdar AV. Global trends in waste generation. In: Gaballah I, Mishar B, Solozabal R, Tanaka M, editors. Recycling, waste treatment and clean technology. Spain: TMS Mineral, Metals and Materials publishers; 2004. p. 1541–52 (II).

Central Pollution Control Board (CPCB). Report on management of municipal solid WASTES, Delhi. India, 2000.

Saxena, M. Solid wastes generation in India and their recycling potential in building materials.2007

6.4. PROBABLE QUESTIONS

1. Define the followings-

a. Waste

b. Disposal

2. What are the beneficial roles of earthworms in the environment? Classify earthworms on the basis of their feeding habit. Which type of earthworms is used in vermicomposting technology?

3. What is bio-methanation? Describe the various steps of bio-methanation with representative reactions. Draw a diagram of a typical biogas digester with appropriate legends.

4. What do you understand by energy recovery from solid waste? State the advantages of energy recovery from waste materials.

5. What do you understand by Incineration? How Incineration can be differentiated from pyrolysis? Describe the advantages and disadvantages of incinerator.

6. Describe in detail the process involved in gasification. How many types of gasifiers are generally found? What are the limitations of gasification process?

7. What is pyrolysis? Write the advantages and disadvantages of pyrolysis. Draw a diagram of biomass pyrolysis cycle.

8. Write short notes:

a. Biogas and its utilization

b. Types of gasification

c. High temperature composting

d. Factors affecting landfill gas

DEM 202: ENVIRONMENTAL POLLUTION MITIGATION

UNIT-7: MANAGING THE OCEANS

UNIT STRUCTURE

- IMPLICATIONS OF UNCONTROLLED EXPLOITATION OF MARINE RESOURCES
- CAUSE AND IMPACT OF MARINE POLLUTION
- STRATEGIES FOR SUSTAINABLE HARVESTING OF OCEANIC RESOURCES
- MARINE POLLUTION CONTROL AND REMEDIAL ACTION

PART 1: IMPLICATIONS OF UNCONTROLLED EXPLOITATION OF MARINE RESOURCES

Man has always been dependent on his environment. He has found out a utility for almost every single thing that he can lay his hands on. Unfortunately, he has not been reciprocating very well with nature. Man has managed only to take but given few in return to the nature. Even though natural resources are deemed inexhaustible, our nature can only support so much. Everything has a limited carrying capacity including the nature. Our seas, which cover almost 71% of the earth's surface, provide us with valuable gifts, the marine resources; most of them are for free. These resources have use in a number of applications in our day to day lives. With time our population has increased so has our demands with severe implications on the marine resources.

Marine resources, simply speaking, are extractable from the oceans which have found a use in our day to day life and are indispensible. These resources can be the basic food needs like fish, energy sources like fuel oil from offshore oil fields or energy from tides and waves.

Marine resources can be categorized as:

1. Physical resources: include petroleum and natural gas, which comes from the buried remains of marine plankton. This category also includes many kinds of minerals as well as fresh water extracted from seawater by desalination.
2. Other energy resources: include electrical power generated from waves and currents, wind, tides, and thermal gradients in the oceans.
3. Biological resources: are marine animals and plants harvested for food and other uses. The commercial fishing industry has fished many commercial fish stocks beyond their maximum sustainable yield.
4. Non-extractive resources: include use of the oceans for transportation and recreation.

> ***Renewable resources are replaced by natural processes, while nonrenewable resources are present in fixed amounts and are not replaced (or are replaced extremely slowly, much more slowly than humans are extracting and using them).***

Marine resources:

a. Petroleum and natural gas
b. Mineral resources
c. Sand and gravel
d. Methane hydrates
e. Evaporative salts
f. Fresh water (by reverse osmosis)
g. The sea as a source of energy (waves and current, tides, wind and thermal gradient)
h. Biological organisms

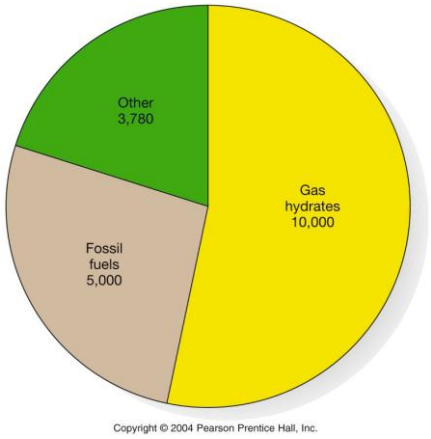


Fig 1: Diagrammatic representation of the sea resources

Implications and causes of the present scenario of pressure on the marine resources

1. Population pressure: Coastal cities around the world have grown dramatically over the past 50 years and are predicted to continue doing so for the near future. The main reasons for this increase are the appeal of living near the coast, increased tourism, sufficient wealth for coastal retirement opportunities, an increase in coastal holiday-home purchases, and the quest for employment and basic livelihoods.
2. Coastal land use: With population pressure, the problem of coastal land use for a variety of purposes has increased leading to bank degradation, desertification, loss of fishing grounds etc.
3. Pressure on estuaries: Estuaries comprise a key component of coastal and marine ecosystems as spawning grounds, contributing significantly to overall fisheries production. The most severe direct pressures on estuaries are reductions in freshwater input and water quality, habitat alteration, changing mouth dynamics, over-exploitation of resources (for example, fish), sedimentation, recreational disturbance, and pollution.
4. Invasive alien species: Marine fauna and flora have accidentally, and occasionally intentionally, been transported around the globe through human activities. Some stunning examples include invasion of Tierra del Fuego, an archipelago off the southernmost tip of the South American mainland, across the Strait of Magellan by beavers from North America, where they have a substantial impact on landscape and local ecology through their dams.
5. Water quality and emissions to sea: Pollution of coastal waters can originate from land-based sources (industrial, municipal, agricultural run-off), shipping activity (accidental or deliberate discharges, garbage, and dumping) and atmospheric gases.
6. Oil pollution: Oil is released into the oceans both by anthropogenic as well as natural causes, although the former accounts a lot more than the latter. Oil spill is the release of a liquid petroleum hydrocarbon into the environment, especially marine areas, due to human activity, and is a form of pollution. Oil spills may be due to releases of crude

oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil. Major oil spills during the gulf wars had affected a large number animals as well as humans.

7. Harmful algal blooms: Phytoplankton forms the basis of primary productivity in marine ecosystems and is essential in supporting large fisheries. Blooms of certain phytoplankton species can occur because of increased nutrient loads, either natural or human-induced, often resulting in harmful, toxic conditions.
8. Climate change : During the past decade, it has become globally accepted that the Earth's climate is rapidly changing and that the effects of anthropogenic activities are becoming increasingly evident. The Intergovernmental Panel on Climate Change (IPCC) states that global average surface temperatures have increased, global mean sea level is rising, and the concentration of ozone in the stratosphere has decreased. Average annual rainfall has also changed and the intensity and frequency of extreme weather events seem to have increased.

Marine pollution occurs when harmful, or potentially harmful effects, can result from the entry of chemicals, particles, industrial, agricultural and residential waste, noise, or the spread of invasive organisms into the ocean. Most sources of marine pollution are land based. The pollution often comes from nonpoint sources such as agricultural runoff and wind-blown debris and dust.

PART 2: CAUSE AND IMPACT OF MARINE POLLUTION

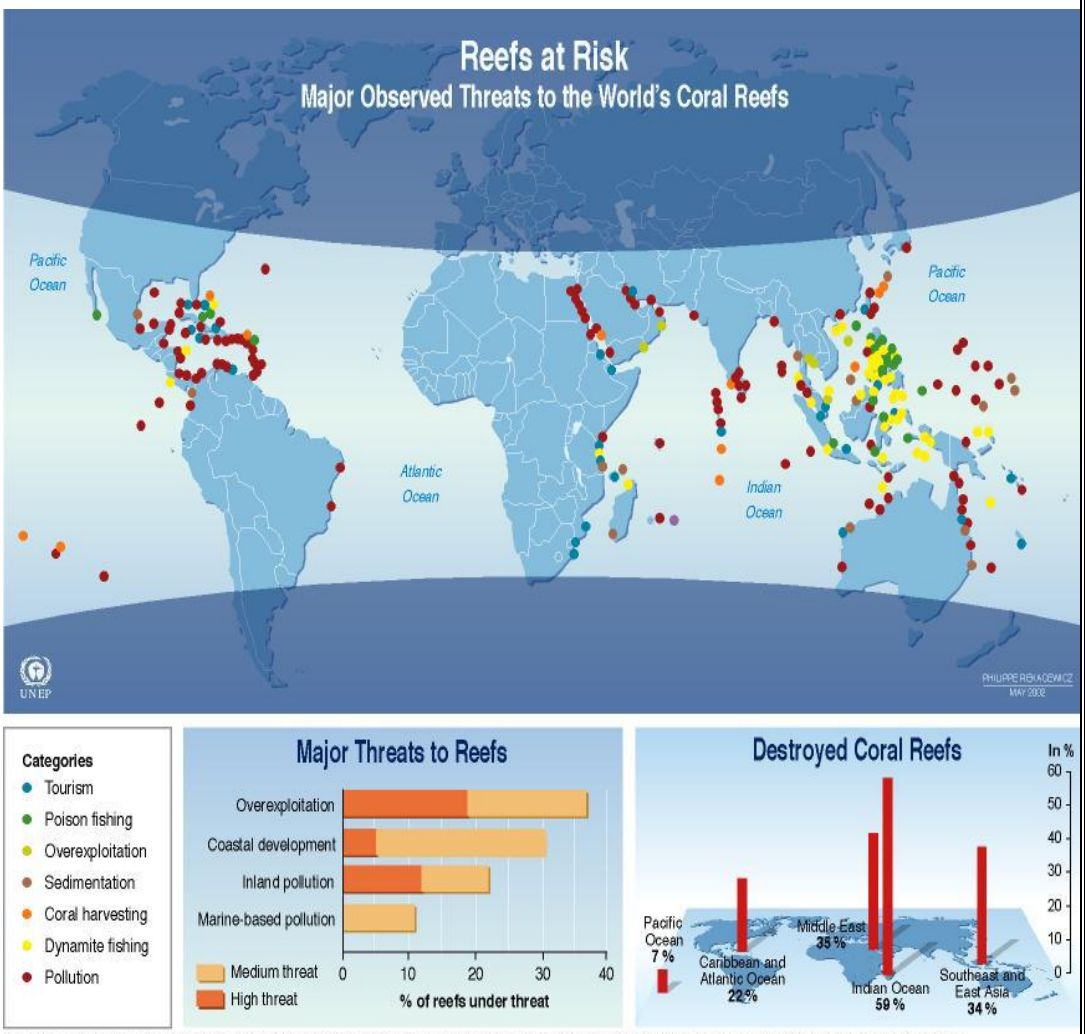
1. Toxic Ocean Pollutants: Toxic pollutants in the ocean ecosystem have massive impacts on the plants and animals. Heavy metal poisoning (such as lead and mercury) from industrial effluents accumulate in the tissues of top predators such as whales and sharks (so do not hesitate to support ban of hunting whales and sharks but to the dislike of many others). Many a times such poisoning causes birth defects and damages nervous system. Dioxins from the pulp and paper bleaching process can cause genetic chromosomal problems in marine animals and may even cause cancer in humans. PCBs (polychlorinated biphenyls) typically cause reproduction problems in most marine organisms. PCBs usually come from older electrical equipment. Poly-aromatic hydrocarbons (PAHs) are another source of marine toxic pollution and typically come from oil pollution and burning wood and coal. These PAHs are responsible for causing genetic chromosomal aberrations in many marine animals. Lastly, low-level radiation poisoning is also possible in the ocean environment. Though scientists know very little about how radiation affects marine organisms, it cannot be a good thing anyway. Some marine species such as a population of Beluga whales living in the St. Lawrence River area in Eastern Canada are in serious trouble because of marine toxic pollution. These Beluga whales are the victims of ocean pollution ranging from PCBs to heavy metals as well as other pollutants. However, toxic pollution is only the tip of the iceberg in terms of total ocean pollution. The toxic pollution varies from PAHs heavy metal pollution from industrial effluent and fallout, PCB pollution and even possible low level radiation. No matter what we humans do, there is potential for serious pollution of the oceans.

Fig2: A bird affected by oil spill

Did you know? The Gulf War (1990-1991) oil spill is considered to be the worst oil spill in the history; an estimated 8 million barrels of oil was spilled into the Persian Gulf after Iraqi forces opened valves of oil wells and pipelines as they retreated from Kuwait in 1991. The oil slick reached a maximum size of 101 miles by 42 miles and was five inches thick!

2. Marine Garbage: Marine garbage disposal is another major form of ocean pollution. The world's oceans are a virtual dumping ground for trash. Sometimes the garbage includes junked out fishing nets, plastics, general household garbage and even like bulbs. In one case, an island 300 miles from the nearest inhabited island (and 3000+ miles from the nearest continent) had 950 pieces of garbage ranging from plastics to tin cans. Garbage in the oceans is a serious issue as fish entangle themselves in fishing nets and animals sometimes eat trash products and die. There are numerous examples of dolphins, sharks and whales entangling themselves in fishing nets and dying from oxygen starvation. It is possible to clean garbage from the oceans if humanity quits using it as a garbage dump. Marine garbage can often enter into animal gut; plastic pop tab rings accidentally strangle animals and so forth. Controlling this form of pollution is important to maintain a healthy ocean ecosystem. Even simple plastic bags can have large pollutive impacts within the ocean. In one case, a deceased sperm whale was found to have a party balloon blocking its digestive system. The whale died from inability to process its food and died of starvation. Plastics can also have negative impacts to boats if they accidentally plug water intake lines.
3. Non-Point Pollutants: The last major source of ocean pollutant is non-point. Non-point pollution can come from amazingly varying sources, viz., runoff from farmland (fertilizers, manure), industrial runoff (heavy metals, phosphorous), urban runoff (oils, salts, various chemicals) and atmospheric fallout of airborne pollution. Obviously, it is the hardest to control. Point pollution, in contrast, is pollution from a direct source like a factory outfall pipe. The enrichment of water by nutrients, especially compounds of nitrogen and phosphorus, causes an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms and the quality of the water (Eutrophication). Input of nutrients like nitrogen and phosphorus to the sea is a natural prerequisite for life, not an environmental problem. It becomes a problem only when the input increases to such levels that the original properties or functions of the ecosystem change. Then, it becomes too much of a good thing. When this manifests in marine waters or a lake, it is referred to as eutrophication - a concept covering a series of events in the aquatic environment. Input of too large amounts of nutrients, followed by other events and effects is ominous and results

in higher levels of nutrients in the water. Physical, chemical and biological changes that follow tend to reflect in the fauna and flora, oxygen conditions change and other changes in the water mass, in the sediments and on the surface of the bottoms.



Source: Bryant et al., *Reefs at Risk; a Map-Based Indicator of Threats to the World's Coral Reefs*, World Resources Institute (WRI), Washington DC, 1998.

Fig3: Reefs at risk (IPCC)

PART 3: STRATEGIES FOR SUSTAINABLE HARVESTING OF OCEANIC RESOURCES

Humans have evolved and descended from an early primate that lived and collected its food I shallow marine waters some 7 to 9 million years ago. The evolution of our brain and species has always been closely related to the resources of the ocean. Man started with his most basic desires like food, methods for catching fish have been known since the earliest days of mankind, involving spearing, harpooning, trapping, catching with hooks, and use of nets. With age and wisdom man's demands have also increased; the Industrial Revolution had its impact everywhere, and the Second World War led to rapid development of technologies. Now minerals, oil etc. are some of the more important resources that man scourges the seas for, newer and cleaner fuel technologies like hydrogen and geothermal energy are catching the fantasies of man; thus, the ocean is a potentially limitless reservoir. Increasing the efficiency and being more cautious in our endeavours may extend these benefits, both known and unknown yet to be discovered ones to our future generations. Thus, sustainable harvesting of the resources is the answer to the future.

Principles for future—towards solving global problems

1. Accurate assessment of temporal and spatial distribution of marine coastline
2. Integrated (collaborative) water management to alleviate fragmentation
3. Accurate measurement of economic value of water
4. Developing common vision among global stakeholders
5. Ensuring representation of disadvantaged stakeholders in international forums
6. Consideration of ecosystem functions

Administrative initiatives (what the government can do):

1. Focus on how water is used, not just amounts (efficiency)
2. Different water qualities for different uses
3. Decentralized infrastructure supported by human capital
4. Water agencies engage community groups
5. Water users care about services provided by healthy ecosystems
6. Take into account economies of joint decision making (e.g., conjunctive use)

Whaling, i.e., killing of whales for food has been phased out all over the world in an effort to save endangered species of whales, but some countries namely Japan, Norway and Iceland continue to kill thousands of whales each year in the guise of scientific studies.

Fig4: Such a scene of slaughter is quite common in nations like Japan, Norway and Iceland, where thousands of whales are killed each year illegally.

PART 4: MARINE POLLUTION CONTROL AND REMEDIAL ACTION

The coastal marine environment supports a variety of marine ecosystems including the fragile mangroves and coral reefs. Demographic pressures in the urban cities and towns as well as an increase in the rural population and rapid industrialisation have resulted in the production of enormous amounts of waste materials. These wastes reach the marine environment either directly or indirectly through rivers, creeks, bays, posing threat to ecosystems and our coastal resources. In India, for example, the domestic sewage contributes to the largest amount of waste and it has been estimated that approximately 20,000 MLD (Million Litres per Day) reach the coastal environment of the country. Even though the quantity of these wastes varies from place to place, the chemical characteristics of these almost remain similar. Domestic

wastes are discharged mostly in untreated conditions due to the lack of treatment facilities in most of the cities and towns (Government of India, Ministry of Earth Sciences).

Marine pollution control should be objectified and conducted in definite steps. These objectives should be holistic and should encompass the following steps:

1. To establish a knowledge base in the field of bio-geochemical parameters in the coastal shelf and open seas.
2. To operate appropriately structured information system for ready dissemination of various data sets to users in government, industry, research and social institutions.
3. To conceptualize and implement R&D programmes that will continually update the knowledge and information bases and develop analytical frameworks for the quantification of transport rates and inputs of various chemical elements to different reservoirs and to the sea; characterizing the ecosystem and assessing its digestive capacity and in turn delineating policy options and facilitating decision processes in the wake of changing regimes.
4. To provide advisory and technical services to government, industry and public institutions aimed at evolving pollution containment measures.
5. To detect radical changes in the bio-geochemical regimes of the marine system and to alert government, public and social institutions of their implications.
6. To set standards for the measurement of various pollution parameters and to ensure compatibility between the data acquired and processed by various monitoring agencies through definition of equipment specifications, periodic intercalibration exercises, planned crosschecks and training programmes.

Treaties and international legislation can provide crucial support in the protection of marine resources. The following are some of the international treaties and conventions which support protection and conservation of oceans and their resources:

1. The Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA): It is designed to be a source of conceptual and practical guidance for national and/or regional authorities to devise and implement sustained actions to prevent, reduce, control and/or eliminate marine degradation from land-based activities. On November 5, 1995, the GPA was adopted at an intergovernmental meeting in Washington, DC. The aims of the GPA are:

   preventing the degradation of the marine environment from land-based activities by facilitating the realization of the duty of States to preserve and protect the marine environment. [The GPA] is designed to assist States in taking actions individually or jointly within their respective policies priorities and resources, which will lead to the prevention, reduction, control and /or elimination of degradation of the marine environment, as well as to its recovery from the impacts of land-based activities. Achievement of the aims of the Programme of Action will contribute to maintaining and, where appropriate, ensuring the protection of human health, as well as promoting the conservation and sustainable use of marine living resources.

2. Land-Based Sources Protocol for the Wider Caribbean Region: EPA lead the negotiations for the Protocol Concerning Pollution from Land-Based Sources and Activities (LBS Protocol), which was signed in 1999 in Aruba, Netherlands Antilles, and entered into force in 2010 at the Cartagena Convention. The LBS Protocol is a legally binding protocol to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean (Cartagena Convention). The Wider Caribbean Region includes those countries that border: (a) eastern Florida south of 30 north latitude, (b) the Straits of Florida, (c) the Gulf of Mexico or (d) the Caribbean Sea. The seaward boundary of the region is the 200-mile Exclusive Economic Zone of each country.

3. Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (commonly refered to as the *London Convention*). It was **signed in London in 1972. Article I of the London Convention states:**
Contracting Parties shall individually and collectively promote the effective control of all sources of pollution of the marine environment, and pledge themselves especially to take all practicable steps to prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.

4. Protection of the Arctic Marine Environment (PAME): Under the eight-nation Arctic Council, the Protection of the Marine Environment (PAME) working group addresses policy and non-emergency pollution prevention issues associated with protection of the Arctic marine environment from land and sea-based sources. PAME's principal products are coordinated action programs and guidelines that are designed to complement existing legal arrangements. The working group also focuses its expertise on identifying problems in need of further action or measures. PAME works in close conjunction with the other Arctic Council working groups (on environmental monitoring, emergency response, and other programs) and seeks substantive input from indigenous communities, conservation groups, and other elements of the concerned public. EPA currently coordinates the work of all U.S. Government agencies under PAME.

5. Arctic Council Action Plan: In recognition of its commitment to develop practical measures to improve Arctic environmental quality, the Arctic Council formulated a set of projects under an Action Plan to Eliminate Pollution of the Arctic (PDF) (5pp, 119K About PDF Files) in 2000. Through pollution prevention, source reduction, remediation, and technical assistance, these projects address threats to the Arctic marine, terrestrial, and human environment from persistent organic pollutants, heavy metals, radionuclides, and stratospheric ozone depletion. Much of the Action Plan is directed at efforts in the Russian Federation, given that country's size and potential impact on the entire Arctic basin.

6. Living Marine Resources Management Act 1995: It is an Act to promote the sustainable management of living marine resources, to provide for

management plans relating to fish resources, to protect marine habitats and to repeal the Fisheries Act 1959.

Marine protected area

Marine protected areas, like any protected area, are regions in which human activity has been placed under some restrictions in the interest of conserving the natural environment, its surrounding waters and the occupant ecosystems, and any cultural or historical resources that may require preservation or management. Marine protected areas' boundaries will include some area of ocean, even if it is only a small fraction of the total area of the territory.

Natural or historic marine resources are protected by local, state, territorial, native, regional, or national authorities and may differ substantially from nation to nation. This variation includes different limitations on development, fishing practices, fishing seasons and catch limits, moorings, bans on removing or disrupting marine life of any kind.

The Convention on Biological Diversity attempted to solve the uncertainty in classifying marine protected areas by defining the broader term of *marine and coastal protected area* (MCPA);

"Any defined area within or adjacent to the marine environment, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by legislation or other effective means, including custom, with the effect that its marine and/or coastal biodiversity enjoys a higher level of protection than its surroundings."

Exercise:

1. What are marine resources? Classify and explain with examples.
2. How do treaties and legislation provide a framework for protection of marine resources?
3. What is an oil spill? Write the ill effects on the environment.
4. What is marine pollution? Write the causes and effects of marine pollution.
5. Write the reasons for the present scenario of pressure on the marine resources.
6. What can the government do for sustainable harvesting of marine resources?