(*d*) **Filters.** Cloth bags acting as filters are used to separate the particulates from the stack gases in electric power plants.

(*e*) **Scrubbers.** These are used to remove particle as well as acids and chemical fumes. The polluted air is passed through a tower filled with coke and fine mist of water sprinkled which removes about 99% particles and 80-95% SO_x.

6. **Plantation of trees.** Trees especially broad leaved plants help to reduce excess CO_2 of the environment and also help to deposit the suspended particles from the air and make air less polluted.
7. **Zoning.** To avoid air pollution problems, there should be "buffer zones" between the proper "industrial zones" and domestic areas. Thus dilution of the polluted air takes place before reaching common people.
8. **Enforcement of Air (Prevention and Control) Pollution Act**, **1981.** Air quality standards as recommended by the Central Pollution Control Board must be strictly implemented.

WATER POLLUTION

Water from nature is used by man for drinking, domestic, agricultural, transport and industrial purposes. **Pollution of water** is defined as the presence of foreign organic, inorganic, biological, radiological and physical substances that tend to degrade its quality and constitute health hazards or decrease its quality.

Water may be contaminated by the following:

1. Dissolved gases like H_2S, CO_2, NH_3, N_2 etc.
2. Dissolved minerals like sodium, calcium, magnesium salts.
3. Suspended impurities like clay, sand, mud, organic matter.
4. Micro-organisms like bacteria, viruses, protozoa.
5. Contaminated with radiological substances.

Sources of Water Pollution Include

1. **Domestic sewage.** The domestic and municipal wastes consisting of human excretions, kitchen wastes and other organic wastes drain out into the canal and through it to the rivers and other natural water reservoirs deteriorating its quality and also act as a source of food for micro-organisms. This finally leads to various diseases of stomach and skin for human.
2. **Industrial waters.** Acids, alkalies, metals, salts and numerous other chemicals pollute the water. Particularly, the waste water from paper, sugar, soap, textiles, leather tanneries, pharmaceuticals, oil refineries etc., contributes a lot of pollutants to the water.
3. **Fertilizer plants.** These plants add nitrates, phosphates, ammonia etc., to water.
4. **Agricultural discharges.** Pesticides, insecticides, plant debris, fertilizer manures etc., are the pollutants.
5. **Natural pollutants from other sources.** Clay, fines of soil, oil, detergents, bacteria, viruses, protozoa, dead bodies of animals and human etc., cause water pollution which finally causes outbreak of infectious diseases.
6. Processing of **radioactive materials** causes water pollution.

Control of Water Pollution

The problem of water pollution can be controlled by adopting the following procedures:

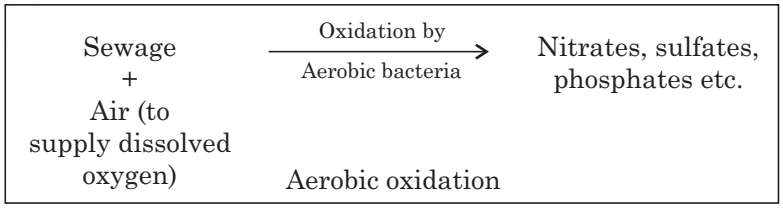
1. By reducing the waste at source.
2. Diluting the waste water from different sources before discharging since the dissolved oxygen of diluting water helps in biodegradation of different toxic chemicals by micro-organisms to inocuous chemicals before mixing with natural water.
3. By chemical treatment the polluted water can be made safe.
4. By physical methods like reverse osmosis, electrodialysis, ion-exchange etc., polluted water can be purified.
5. By recycling of waste water before discharging involves treatments like use of activated sludge, trickling filter etc.
6. Reclamation of waste water: sewage water can be made useable for irrigation, fish-farm raising, as it contains essential nutrients.

Sewage and its Treatment

Sewage is the liquid waste from domestic and municipal waste water, industrial waste water, ground wastes etc. **Domestic-sewage** has objectionable odour due to S and N containing compounds and a grey to green color due to the presence of discharges from kitchens, bath and lavatories.

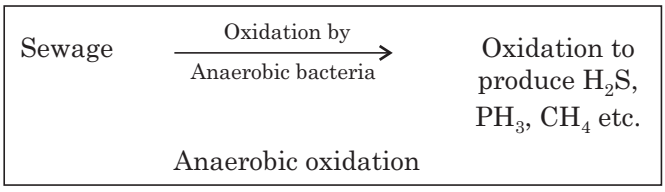
Industrial wastes have different color or odour depending on types of industries present and the chemical constituents also vary accordingly. The treatments consist of **aerobic and anaerobic** oxidations, which are brought about by the aerobic or anaerobic bacteria present in the sewage.

The aerobic bacteria oxidize the organic compounds present in the sewage by the dissolved oxygen leading to the formation of nitrates, sulfates and phosphates which is called aerobic oxidation.



In the absence of the supply of free oxygen, the anaerobic bacteria convert the organic compounds in the sewage to methane, H_2S, ammonium sulfide etc. (offensive odour).

In this type of anaerobic oxidation process the required oxygen is supplied by the nitrates, sulfates and organic compounds.



Biological Oxygen Demand (BOD)

BOD of a sewage is defined as the amount of free oxygen required to oxidize the organic matter present in the sewage by the aerobic bacteria present in it at 27°C for a period of 3 days. The unit of BOD is ppm or mg/litre. BOD, therefore, gives an idea of the level of pollution of the sewage as it is an index of the amount of decomposable organic matter. Higher the BOD, greater is the degree of pollution. An average sewage has a BOD level 100–150 ppm.

Determination of BOD

The BOD test is based on mainly bio-assay procedures which measures the dissolved oxygen consumed by micro-organism while assimilating and oxidising the organic matter under aerobic condition.

A known volume of sample is diluted with dilution water (which is aerated to a known dissolved oxygen concentration). It is incubated at 27°C for 3 days in dark. After this the dissolved oxygen concentration is determined, the principle of which is given below. The difference between the initial and final dissolved oxygen gives the BOD.

Principle for DO

It is the modified Winkler method. By this method a ppt of manganous hydroxide is formed first which rapidly absorbs oxygen dissolved in water forming a higher oxide.

$$MnSO_4 + 2KOH \longrightarrow Mn(OH)_2 + K_2SO_4$$

$$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2$$

On acidification in presence of iodide, I_2 is liberated in a quantity equivalent to the dissolved oxygen present.

$$MnO(OH)_2 + 2KI + H_2O \longrightarrow Mn(OH)_2 + I_2 + 2KOH$$

The liberated I_2 is titrated with standard sodium thiosulfate solution using starch solution as indicator.

$$I_2 + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^{1-}.$$

Chemical Oxygen Demand (COD)

It is a measure of the oxidizable impurities present in the sewage. It represents both the biologically oxidizable as well as biologically non-oxidizable impurities present and hence the value is higher than the corresponding BOD of the sewage. It is advantageous to measure COD to assess the level of impurities since COD determination takes only 3 hrs.

Determination of COD

250 ml of the sample of water is refluxed for 1 $\frac{1}{2}$ hrs. with a known excess of 1N $K_2Cr_2O_7$ and dil H_2SO_4 and a little Ag_2SO_4 as catalyst. After the oxidation is over the excess $K_2Cr_2O_7$ is titrated back with standard Mohr's salt solution. The oxygen equivalent of $K_2Cr_2O_7$ consumed for the oxidation reaction is the measure of COD.

1 ml of 1N $K_2Cr_2O_7 \equiv 0.008$ gm of oxygen.

Municipal Sewage Treatment

Disposal of sewage has become of prime importance as it causes undesirable and harmful effects on living beings and the environment. The main objectives of sewage treatment are (*i*) removal of compounds causing bad odour, (*ii*) removal of impurities causing public health problem, (*iii*) rendering the sewage finally safe to be discharged to natural water reservoirs such that aquatic life is not disturbed.

Municipal sewage treatment processes are called sewarage and it involves the following steps:

(*i*) **Primary treatment.** First the sewage is subjected to mechanical processes like flowing, dilution and sedimentation to remove the coarse solid materials. It is passed through a series of filters of graded openings and then flows to a sedimentation tank. Coarse materials collect at the sedimentation tank called sludge. The liquid effluent then undergoes secondary treatment.

(*ii*) **Secondary treatment.** This is a purely biological treatment having two phases– aerobic and anaerobic. The aerobic process involves aerobic digestion of sludge by processes like trickling filters, oxidation ponds and activated sludge process.

In the **trickling filter process** the effluent from the primary treatment is allowed to flow through 6–10 ft deep bed of crushed stone, gravel, coal etc. It is sprayed over the bed when it gets saturated with aerial oxygen and the micro-organisms present start aerobic digestion while the water passes through the filter bed, degrading the organic compounds and finally rendering the effluent harmless which collects at the bottom and enters the tertiary treatment (Fig. 27.4).

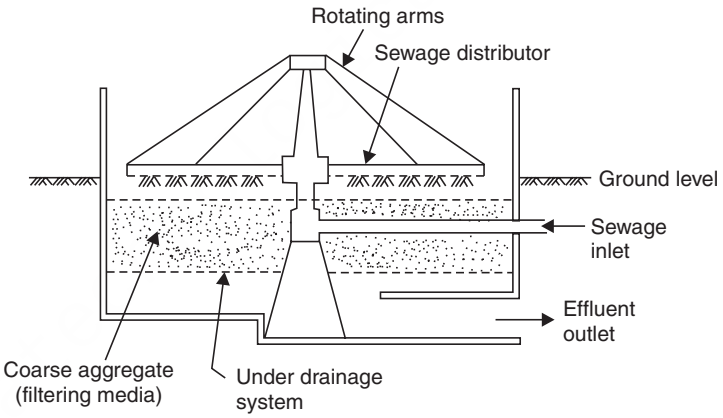


Fig. 27.4 Trickling filter.

In the **oxidation ponds** which are shallow ponds the water is exposed to atmosphere whereby the algae *Chlorella pyrenoidosa* grow and their growth helps in maintaining the aerobic condition in the sewage and the microorganisms present digest the organic matters present and render the water harmless.

In the activated sludge process the sewage is vigorously aerated and due to the presence of microorganisms colloidal aggregates of "floccules' are formed which finally settle down after a long-time. This settled sludge is the 'activated sludge' which consists of a large number of very actively metabolizing bacteria, yeasts, molds and protozoa. When this activated sludge is added to the fresh batch of aerated sewage, flocculation takes place in very short period and hence the whole process takes very short time. This method is also known as **activated sludge process.** But disposal of this activated sludge is a problem.

Anaerobic Digestion

The sludge collected after primary treatment is added to the anaerobic digestion tank which is a closed tank and the micro-organisms digest the organic compounds in the absence of oxygen for about 30 days. The gaseous products consist of 60-70% CH_4, 20-30% CO_2, small amount of H_2S, H_2, N_2. This gas can be used as a fuel for power generation or for city supply. 400 to 600 litres of gas is produced per kg. of solid sludge.

(*iii*) **Tertiary treatment.** The effluent from secondary treatment contains nitrate, phosphate etc. This is subjected to chemical treatment. After the chemical treatment the water is chlorinated to free it from micro-organisms. After this tertiary treatment the water is safe for human use (Fig. 27.5).

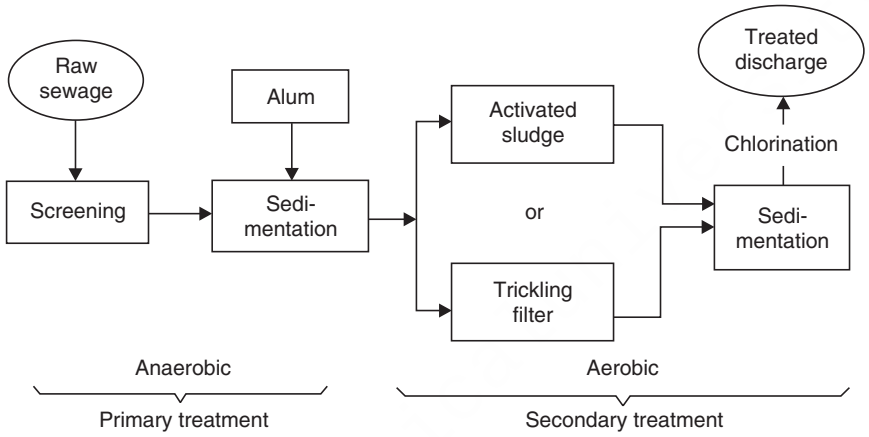


Fig. 27.5 Flow diagram for sewage treatment.

Water pollution can be prevented by:

(*a*) Preventing the use of chemical fertilizers

(*b*) Using bio-degradable detergents.

(*c*) Proper treatment of sewage before draining to natural reservoirs.

(*d*) **Phyto-plankton,** a layer of the tiny animals and plants that live on the surface of sea water. They are capable of absorbing floated minute particles, dirt and help to check water pollution. The pollution in water hampers the growth of plankton and affects marine life.

SOIL POLLUTION

The contamination of soil or land with rain, excess of fertilisers, wrong fertilisers, insecticides and herbicides is called soil pollution.

Sources of Soil Pollution

1. Repeated and excess use of fertilizers and pesticides cause soil pollution. By excess use of $(NH_4)_2\ SO_4$, the SO_4^{2-} ion accumulates into the soil and makes it infertile due to acidity. Similarly, repeated use of fertilizers containing KNO_3, $NaNO_3$ etc., causes accumulation of Na^+, K^+ and leads to alkalinity of the soil.
2. Soil is polluted by the cysts of entamoeba, ascaris, pigworm etc., which enter the food chain and infect human being.
3. The sewage containing human and animal excreta, solid and liquid wastes pollutes soil.
4. Spraying of insecticides and herbicides for fruits and vegetables also causes soil pollution. These also enter the food chain and thereby entering human and animal bodies. This can be taken care of by properly washing the vegetables, fruits, seeds with sufficient water before their intake.
5. Acid rain is also a source of soil pollution.
6. Soil erosion takes place due to deforestation, unplanned irrigation and defective methods of cultivation.

7. Soil is erroded due to removal of upper fertile layer.
8. Dumping of wastes from mines, power generation plants and metal smelting cause land pollution.
9. Radioactive wastes discharged from industrial and research centres cause pollution.
10. All sorts of chemicals in the atmosphere, plastic bodies ultimately lead to soil pollution.

Control of Soil Pollution

1. Control use of fertilizers and pesticides.
2. Before dumping the sewage the harmful chemicals should be removed.
3. Deforestation is to be minimised and plantation carried out.
4. Avoiding the spillage of garbage, ash, sludge, bottles, plastics etc.
5. Industrial waste to be treated properly before disposal.
6. Precaution to be taken to neutralise acid rain.
7. The waste gases releasing from automobiles and industries should be purified before reaching the ground.
8. The digging of larger pits or grooves in view of granite mines, aquaculture, addition of various chemicals to grow water bodies etc., are to be avoided to protect the soil pollution.

RADIOACTIVE POLLUTION

This is mainly due to (*i*) nuclear explosions, (*ii*) discharges from nuclear reactors.

They emit radiations which are harmful for living beings because they bring about changes in chromosomal DNAs and lead to genetic disorders, and diseases. These radio-nuclides are sometimes very short lived and sometimes persist for thousands of years and hence create both short time and long time hazards. These hazards are not confined to the explosion sites only because they are carried by air, water etc., by different routes to different parts of the earth and through the food chain they enter the biological processes.

Damages due to radioactive radiations include:

(*a*) Pathological damage—producing diseases leading to death also.

(*b*) Genetic damage—radiations lead to chromosomal damage to any living system causing permanent changes for generations.

(*c*) Radiations also cause loss of immunity, less enzymic activities and hence cause health problems.

Radioactive wastes can be:

(*a*) **High level wastes.** These wastes are predominantly used as fuel. They are intensely radioactive and some of them have long half-lives *e.g.,* Plutonium-239, half-life 24,000 years. Extreme precautions are to be taken to avoid such high level contamination in air, water etc.

(*b*) **Low level wastes.** These are related to nuclear energy production, wastes from uranium refineries.

Disposal of radioactive wastes

Accidents from radioactive rays have increased public concern worldwide to lead to safe disposal of these wastes. On-site storage of these wastes over short term and then final disposal for long term involve land, air and water.

1. **Ground** disposal is both cheap and easier. The wastes are either burried deep in the ground away from dwelling areas, in vacated coal-mines, in salt-heaps (salts absorb radioactive rays) inside mines. The areas for disposal should have low rainfall.

2. **Air.** Generally radioactive gases are stored in tanks, buried in the ground and finally vented to air so that there is low level of activity in the air, otherwise it may be inhaled and may enter the living system.
3. **Water.** For long term disposal ultimately the wastes are encased in non-corrosive lead, titanium or copper containers and burried deep into the ocean. It must be secured or it may affect the aquatic life, fishes and enter the food chain or enter the ground water.

Radionuclides

Radionuclides are the products of the natural decay of uranium. Uranium tailings contain a variety of radioactive atoms or radionuclides like, Ra-226, Th-230, Pb-210 etc.. Some of these have long half lives, *e.g.,* Th-230 has a half life of 80,000 years. Depending on the pH of the tailings, these nuclides become soluble and available.

The main exposure pathways for radioactivity from tailings are γ radiation, inhalation of radioactive particulates, radionuclides entering the food chain. There are more than 1000 radionuclides in the atmosphere. Both the long life and short life types of nuclides are of concern for public health problems. The table below indicates the active sites for and the half-life of different radionuclides.

Table 27.1. Some Important radionuclides and their half -lives

Radionuclide	*Target tissue*	*Half-life*
Calcium-45	Bone	165 days
Carbon-14	Whole body	5760 years
Caesium-137	Soft tissue, genital organs	27 years
Iodine-129	Thyroid	17 million years
Iodine-131	Thyroid	8 days
Plutonium-239	Bone, liver, spleen	24,400 years
Radium-226	Bone	1620 years
Strontium-90	Bone	28 years
Tritium (^3H)	Whole body	12.3 years

NOISE POLLUTION

Discomfort caused by hearing unpleasant, undesirable sound at wrong places and at wrong times is called “noise pollution”. Noise pollution is expressed in Decibel units (dB). The smallest sound unit audible and undisturbing to a healthy person having good hearing capacity is “one decibel”.

Crowded cities, mechanised transport, heavy industries, modes of entertainment cause noise pollution.

Sources of Sound Pollution

Heavy automobiles, scooters, trains, aeroplanes, horns, sirens, factories, loud speakers, radio, TV, air conditioners, generators, different functions and meetings are the different sources of noise pollution.

WHO has recommended that a person can sleep upto 35 dB noise, 75 dB is the explosive limit, 80 dB is harmful, damaging the hearing system.

Effects of Noise Pollution on Man

1. Noise pollution causes discomfort and loss of efficiency.
2. Prolonged exposure is harmful for central nervous system and affects memory.
3. Noise pollution causes increase in heart rate, damage to brain, kidney, liver.
4. Creates emotional disturbances.
5. Partial or permanent hearing loss.
6. Dilatation of pupil of eyes.
7. Creates headache.
8. Decreases working efficiency.
9. Disturbs sleep.
10. Leads to violence, tiredness, decreased colour perception, depression etc.
11. High pitched noise leads to road accidents.
12. Leads to hyper and hypoglycaemia, hypokalaemia, eosinophilia due to change in blood and body fluids.

Control of Noise Pollution

1. Noise pollution due to automobiles can be minimised by fitting silencers.
2. Setting industries away from residential areas.
3. Restricting the use of loud speakers.
4. Imposing laws to control noise.
5. Planting Ashok, Neem, Eucalyptus trees on both sides of highways, beside school, college, industrial buildings.
6. The walls of living houses, office buildings, cinema halls should be covered with sound absorbers.
7. Noise creating machinery should either be lubricated regularly or covered with insulating materials.
8. Wearing of earplugs, ear muffs for workers and others to minimise noise effects.

THERMAL POLLUTION

The release of hot vapours from nuclear power plants, industrial effluents, nuclear reactors, coal fired power plants, hydroelectric plants raises the atmospheric temperature and causes thermal pollution. Hence due to thermal pollution the average temperature of cities are about 10°C higher than the villages. The dissolved oxygen concentration of water bodies becomes low due to rise in temperature. This in turn causes harm to fishes, aquatic plants and to aerobic aquatic microorganisms.

By the combustion of coal and petroleum products CO_2 concentration in atmosphere increases which results increased temperature of the earth and green-house effect.

Highlights:

(*i*) **Sources of water pollution**

- Domestic sewage
- Industrial effluents
- Agricultural discharges containing pesticides etc.
- Oils, greases from automobiles, machines.
- Radioactive wastes.

(*ii*) **Municipal sewage treatment**

1. Preliminary mechanical filtration
2. Settling in sedimentation tanks
3. Biological treatment

(*a*) Aerobic process involving (*i*) Trickling filters, (*ii*) Oxidation ponds, and (*iii*) Activated sludge process

(*b*) Anaerobic process.

(*iii*) **Other types of pollution**

- Soil or Land Pollution
- Radioactive Pollution
- Noise Pollution
- Thermal Pollution

(*iv*) **BOD**

- Biological oxygen demand is the amount of free O_2 in mg required for the biological oxidation of the organic matter present in 1 litre of sewage.

(*v*) **COD**

- Chemical oxygen demand is a measure of oxidisable impurities present in sewage.

SHORT QUESTIONS AND ANSWERS

Q. 1. What is Pollution?

Ans. See text page no. 571.

Q. 2. What are the principal causes of pollution?

Ans. (*i*) Population explosion.

(*ii*) Rapid urbanization.

(*iii*) Rapid industrialization.

(*iv*) Deforestation.

(*v*) Natural disasters.

Q. 3. What are the undesirable effects of excess of oxides of sulfur in the atmosphere?

Ans. See text page no. 572.

Q. 4. What is acid rain?

Ans. The oxides of sulfur and nitrogen formed due to air pollution dissolve in the moisture present in the atmosphere to form the corresponding acids, which fall with the rain slowly on earth and lowers the pH of the rain water below pH = 5.

Q. 5. What is green-house effect?

Ans. Gases such as CO_2, CH_4, NO etc., do not allow the radiating infrared rays from the earth's surface to pass through thereby increasing the atmospheric temperature of the earth which is called green-house effect. This leads to about 0.05°C rise of temperature per year.

Q. 6. What is the importance of ozone layer?

Ans. Ozone at an elevation of 30 km from the earth's surface absorbs the most harmful UV radiation coming from the sun and thereby protects the living beings on earth.

Q. 7. What are the causes of 'ozone hole'?

Ans. Chlorofluorocarbons coming out from the exhaust of the supersonic jets and from the refrigerators, aerosols etc., lead to the breakdown of ozone into oxygen by a chain reaction and cause the depletion and thereby formation of ozone hole over Antarctica.

Q. 8. What is photochemical smog? Mention its effects.

Ans. See text page no. 575.

Q. 9. What are effects of particulate matter on human?

Ans. Presence of excessive particulate matter in air leads to allergy and respiratory diseases in human. The two most common diseases taking place are bronchial asthma and lung cancer.

Q. 10. What is sewage?

Ans. The liquid waste, which includes human and household waters, industrial wastes, street washing ground wastes containing mainly water and other organic and inorganic matters is called sewage.

Q. 11. What is BOD?

Ans. The amount of free oxygen in mg required for the biological oxidation of the organic matter present in 1 litre of sewage is called its biological oxygen demand (BOD).

Q. 12. What is COD?

Ans. Chemical oxygen demand (COD) is a measure of oxidisable impurities present in sewage.

Q. 13. What is the importance of BOD or COD measurement?

Ans. BOD or COD is very important in sewage treatment since it indicates the amount of oxidisable organic matter present in the sewage. Hence greater the value of BOD, higher is the pollution level of the sewage.

Q. 14. What is 'water table' and how does it fall?

Ans. The depth in the soil below which soil is filled with bed of water only.

The water table falls when the rate of pumping out of water is greater than the rate of rainwater percolation.

Q. 15. How is reforestation important in controlling atmospheric pollution?

Ans. Plants utilize the CO_2 of air for their photosynthesis and give out O_2 in the air, thereby reducing the load of CO_2 in air and enriching it with O_2.

Moreover, air flowing through the trees in the forests slows down leading to deposition of particulate matters carried by the air.

Q. 16. How can we decrease the lead pollution due to automobiles?

Ans. Lead pollution due to the automobiles can be decreased by using unleaded petrol as fuel.

Q. 17. What is eutrophication?

Ans. Algae in rivers, lakes multiply rapidly by fertilizers from farmland or by nutrients from sewage. Thus formed thick layers of algae block out the light to plants growing below the surface so that they can no more produce oxygen, and aquatic life becomes endangered. The phenomenon is known as eutrophication.