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Module 4: Environmental Pollution and Water technology

Pollution

Pollution is defined as the excess discharge of any substance into the environment which affects adversely quality of environment and causing damage to humans, plants and animals.

Air pollutants can broadly classified into two types- Primary pollutants & Secondary pollutants

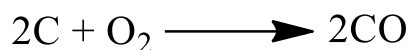
Primary air pollutants

Primary air pollutants are pollutants that are directly emitted into atmosphere through natural or human activity. Ex SO₂, NO, NO₂ and CO

Carbon monoxide

Sources:

1. Carbon monoxide is released by the partial combustion of fuel in automobiles, industries and oil refineries.



2. Tobacco smokes and domestic heat appliances are the other sources of CO
3. It is estimated that about 290million tones of CO is discharged into the atmosphere annually.
4. Leaking chimneys and furnaces; back-drafting from furnaces, gas water heaters, wood stoves, and fireplaces; gas stoves; generators and other gasoline powered equipment.

Effects:

1. Carbon monoxides causes headache visual difficulty, paralysis and even death in the human beings.
2. It reacts with the red pigments (hemoglobin) to form carboxyhemoglobin, thereby imparting the transfer of oxygen to the tissues. In other words, the presence of CO reduces the oxygen carrying capacity of blood.
3. It also lead to serious effects on the cardio- vascular system, thereby causing heart diseases.
4. At low concentrations, fatigue in healthy people and chest pain in people with heart disease.
5. At higher concentrations, impaired vision and coordination; headaches; dizziness; confusion; nausea.

Control:

1. Modification of Internal combustion engines.
2. Development of exhaust system reactors which will complete the combustion process and change the potential pollutant into more acceptable materials.
3. Development of pollution free power sources such as fuel cells to replace the natural combustion engine.
4. Development of substitute fuels for gasoline which will yield low concentration of pollutants upon combustion.

Oxides of Nitrogen

Nitric oxide (NO) and nitrogen dioxide (NO₂) are referred together as oxides of nitrogen (NO_x)

Sources:

1. Major source of oxides of nitrogen is automobile exhaust.

- Combustion of coal, oil, natural gas and gasoline.
- They are also produced naturally by lightening.
- Other sources are acid manufacture, explosive industry and acid-pickling plants.

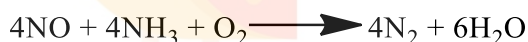
Effects:

- NO_x mainly impacts on respiratory conditions causing inflammation of the airways at high levels. Long term exposure can decrease lung function, increase the risk of respiratory conditions and increases the response to allergens. NO_x also contributes to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.
- It has unpleasant odor and leads to irritation to eyes and even lungs congestion.
- Nitrogen dioxide and hydrocarbons reacts in presence of sunlight to form smog, which limits the visibility of roads, causes eye irritation and causes difficulty in breathing leading to asthma and bronchitis.
- NO_x also reacts with other pollutants in the presence of sunlight to form ozone which can damage vegetation at high concentrations.
- NO₂ is further oxidized in the gas phase during daytime by reaction with OH

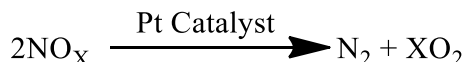


Control:

- Nitrogen oxides content in flue gases can be reduced by absorption and adsorption methods. Oxides of nitrogen can be absorbed by water hydroxides, sulphuric acid etc., the adsorbents generally used are activated carbon, silica gel, certain metal oxides etc.
- Selective catalytic reduction: in this process the ammonia is injected into the flue gas. The nitrogen oxides present in the flue gases with the ammonia present in the flue gases react with the ammonia and are converted to nitrogen and water. This reaction takes place in the presence of the catalyst at 300 to 400 °C.



- The exhaust emissions from automobiles can be controlled by installing catalytic converter in the exhaust system of the engine. Where the exhaust gas passes through the convertor oxides of nitrogen are converted into nitrogen and oxygen.

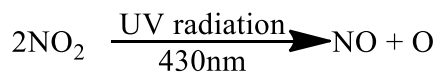


Photochemical Smog

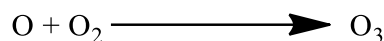
Photochemical smog (mixture of smoke and fog) was first noticed in Los Angeles in 1940s. it is caused by the action of sunlight on nitrogen oxides and unburnt hydrocarbons that are emitted into the air by internal combustion engines.

The mechanism of the formation of smog is as follows

- Nitrogen dioxide absorbs UV adiation from sunlight and decomposes into nitric oxide and atomic oxygen.



- The atomic oxygen quickly combines with molecular oxygen to give ozone.



- Reactive hydrocarbons combine with the hydroxyl free radicals (formed by reaction between vapor and atomic oxygen) producing carbon based radicals.



- The carbon based radical in turn combine with molecular oxygen forming peroxy radicals. The peroxy radicals oxidizes NO to NO₂ this building up a high concentration of NO₂ in the atmosphere.

The formation of photochemical smog is facilitated by the following conditions.

- Substantial vehicular traffic to emit sufficient nitrogen oxides and hydrocarbons.
- Warm and bright sunlight to catalyze several chemical and photochemical reactions.
- Very little lateral movement of air such that the reactants leading to the formation of smog get concentrated.

Control:

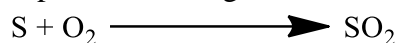
- Drive less. Walk, bike, carpool, and use public transportation whenever possible.
- Take care of cars. Getting regular tune-ups, changing oil on schedule, and inflating tires to the proper level can improve gas mileage and reduce emissions.
- Fuel up during the cooler hours of the day—night or early morning. This prevents gas fumes from heating up and producing ozone.
- Avoid products that release high levels of VOCs. For example, use low-VOC paints.
- Avoid gas-powered yard equipment, like lawn mowers. Use electric appliances instead.

Oxides of Sulphur

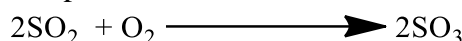
Sulphur dioxide (SO₂) and Sulphur trioxide (SO₃) are referred together as oxides of Sulphur (SO_x).

Sources:

- Thermal power plants, in which Sulphur containing coal and fuels are fired.



- Petroleum industries, oil refineries, sulphuric acid plants and sulphide ore roasting plants.
- It is formed by the oxidation of Sulphur dioxide under the influence of sunlight.

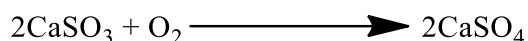
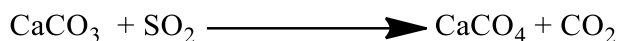


Effects:

- Cardiac, respiratory and pulmonary diseases.
- Eye irritation, throat troubles.
- Corrosion of metals.
- Damages plant cells and membranes, chlorophyll, metabolism leading to growth yield reduction.
- Even 1ppm of SO₃ in air causes breathing discomfort and irritation to the respiratory tract.

Control:

1. Removal of SO₂ from flue gas by adsorption method
 - a. Adsorb SO₂ on a suitable adsorbent (sodium aluminae) to form stable sulphates in fluidized bed at 315⁰C with subsequent regeneration.
 - b. SO₂ can be removed by passing the flue gas through a bed of adsorbers, such as activated carbon, pulverized limestone etc., which adsorb SO₂ and other gaseous pollutants.
2. The SO₂ containing flue gas is scrubbed with a slurry of calcium carbonate where SO₂ is converted into calcium sulphite. Air is then injected into the reaction mixture to oxidise CaSO₃ to CaSO₄.



3. Use of Clean Sulphur free nuclear power to generate electricity.
4. Switch to natural fuels such as biodiesel etc, from the conventional Sulphur fuels like coal and petroleum to reduce SO_x emissions.

Hydrocarbons

Sources:

1. Automobile and industrial exhaust are the major sources of hydrocarbons.
2. Methane is a naturally occurring hydrocarbon emitted into the atmosphere in large quantities it is produced by bacterial through anaerobic decomposition of organic matter.

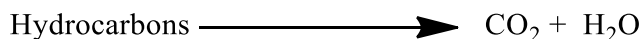


Effects:

1. Hydrocarbons at high concentration (>500ppm) have carcinogenic effect on lungs.
2. Inhalation of vapors of benzene, toluene etc., causes much irritation to the mucous membrane.
3. Cyclic hydrocarbons affect nervous system and cause loss of coordination.
4. Methane and benzo pyrene creates narcotic effect in human being.

Control:

1. Hydrocarbons from auto exhaust can be controlled by processes such as absorption, adsorption etc.



Particulate matter:

Small solid particles and liquid droplets suspended in air are collectively called as particulates. Particulates are also referred to as aerosols. These are present in atmosphere in large quantities and pose a serious air pollution.

The essential characteristic of a particulate matter is the size of the particle which is less than 100µm. particulate matter with less than 2.5µm in size are called fine particulates. These remain suspended in air for more time. Those which sizes greater than 2.5µm called coarse particulates. The coarse particles settle rapidly.

Sources:

1. **Dust:** Main sources of dust are mines and quarries, furnaces, power houses, vehicular traffics, house cleaning dusts, natural winds combustion operations, engine exhausts, crushing, grinding and blasting of solid materials loading and unloading of sand, cement, ores etc. and a hundred other activities raise dust in the atmosphere.

2. **Smoke:** formed by incomplete combustion of fuel. Smoke emission sources are rails, roads, locomotives, domestic wood, coal grates, industries power plants, open fires, incinerators, diesel engines, automobile gasoline engines, tobacco smoking.
3. **Ash:** Fly ash are major pollutants from thermal power plants where large quantities of fossil fuel like coal are burnt.
4. **Abestors:** widely used in industry for its mechanical strength and resistance to heat.

Effects:

1. Atmospheric dust causes allergic and respiratory diseases, silica dust causes silicosis, and asbestos dust causes asbestosis and also cancer.
2. Particulate due to their small size, penetrate deep into alveoli of lung and damage lung tissue.
3. The more acid and aldehyde particulates cause eye, nose and throat irritation.
4. Mercury dust causes profuse diarrhea, kidney problems, and disorder of cardiac and neurological functions.
5. Lead dust causes vomiting, bloody diarrhea and other central nervous system effects.

Control:

Many techniques are used for the control of particulate matter as shown below

1. **Centrifugal cyclones (separator):** centrifugal separators are used to remove particulates in the size range of 10-100microns (mm). But the fine dust removal efficiency of cyclones is below 70%.
2. **Electrostatic precipitators:** it removes particles by using an electrostatic field to attract the particles on to the electrodes. Collection efficiencies for well designed, well operated and well maintained systems are typically in the order of 99.9%.
3. **Filters and dust collectors (Bag Houses):** A baghouse, also known as a baghouse filter, bag filter, or fabric filter is an air pollution control device and dust collector that removes particulates or gas released from commercial processes out of the air. Power plants, steel mills, pharmaceutical producers, food manufacturers, chemical producers and other industrial companies often use baghouses to control emission of air pollutants.
4. **Control of smoke during combustion:** this can be done by the following methods.
 - a. Use of suitable fuels which do not produce much smoke.
 - b. By maintaining proper fuel air ratio.
 - c. Sufficient mixing of air and fuel.
 - d. Maintaining sufficient ignition temperature.

Mercury:

Mercury is a naturally occurring element. Its usage In the industrial manufacture are the improper effluent disposal has resulted in its contamination of soil, air and water. Mercury being volatile, spreads easily in the environment.

Sources: Mercury exist in three chemical form

- Methyl Hg
- Elemental Hg
- Mercury compounds (Organic and inorganic)

Natural sources of mercury include volcanoes, natural mercury deposit and release from the ocean. Manmade sources include coal combustion, waste incineration, metal processing industries other sources include mercury containing products. Example: Batteries, thermometers, barometers, lamps, dental amalgam (for dental filling), skin lightening products, cosmetics, pharmaceuticals.

Effects:

1. Elemental and methyl mercury are toxic to the central and peripheral nervous system. The inhalation of mercury vapors can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys.
2. The inorganic salts of mercury are corrosive to the skin, eyes and gastrointestinal tract and may induce kidney toxicity.
3. Symptoms of exposure to different mercury compounds includes memory loss, neuro muscular effects, headaches etc.
4. Exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child in utero and early in life.

Control:

1. Promote the use of clean energy sources that do not burn coal. Burning coal for power and heat is the major source of mercury.
2. Eliminate mercury mining and use of mercury in gold extraction.
3. Recover and reuse of Hg compounds in industrial waste.
4. Discontinue the use of non-essential mercury containing products such as batteries, meters, lamps, skin lightening cosmetics etc.
5. Implement safe disposal of remaining mercury containing products.

Lead:

Sources:

1. Automobile exhaust.
2. Dust and chips from old paint.
3. Lead also comes from metal smelting, lead battery manufacturing and other factories use lead.
4. Lead enters water through plumbing lead based pipes or solder that leads lead into water through corrosion.

Effects:

1. Once lead enters the body, it distributes throughout the blood and accumulates in the bones. Lead can adversely affect the nervous system, kidney function, immune system and cardiovascular system.
2. It is known that lead ions inhibit the energy that catalyze the bio synthesis of hemoglobin as a result affecting the oxygen carrying capacity of the blood.
3. It causes neurological effects in children and cardiovascular effects in adults.
4. Infants and young children are sensitive to even low levels of lead, which may contribute behavioral problems and learning difficulties.
5. Elevated levels of lead in the environment lead to decreased growth and reproductive rates in plants and animals.

Control:

1. Lead smelting plants should design their storage pipes in such a way that movements of lead materials are minimized to exposure of wind and air.
2. Eliminate lead contamination in drinking water by processes such as reverse osmosis distillation and filtration using carbon filters specially manufactured for lead removal.
3. Minimize plant absorption of lead by adding organic matters like composted leaves and lead will bind with organic matter.

Secondary air pollutants:

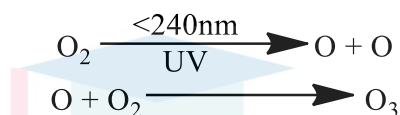
Secondary pollutants are pollutants which form in the atmosphere. These pollutants are not emitted directly from a source (like vehicles or power plants). Instead, they form as a result of the pollutants emitted from these sources reacting with molecules in the atmosphere. Pollutants that are emitted into the environment from a source are called primary pollutants.

Ozone

Ozone is a molecule of oxygen with the formula O_3 . It is found in the atmosphere, however the location of it is crucial: near the ground it can be harmful to humans, yet high in the atmosphere it is vital in protecting the Earth from harmful ultraviolet radiation. Therefore its use in conversation can be ambiguous:

Sources:

1. Ozone or trioxygen, is an inorganic molecule with the chemical formula O_3 . It is produced in the upper layer about 20km above the earth surface in the atmosphere.



2. Ground level ozone forms when primary pollutants such as oxides of nitrogen (NO_x) and volatile organic compounds (VOC's) react with sunlight.



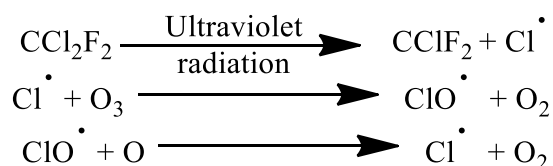
3. Ozone is a powerful oxidant produced and used in many industries and consumer application related to oxidation.

Ozone depletion

Gradual thinning of earth's ozone (ozone depletion) in the upper atmosphere caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and other human activities.

A combination of low temperatures, elevated chlorine and bromine concentrations in the upper stratosphere are responsible for the destruction of ozone.

Ozone depletion is mainly due to CFC's (chloro fluoro carbon) which is relatively stable in the lower atmosphere of the earth, but in the stratosphere they are exposed to ultraviolet radiation and thus they break down to release a free chlorine atoms. Each atom of the chlorine, is capable of attacking several ozone molecules as shown in the below equation.



The third reaction regenerates chlorine free radical, which again reacts with ozone and the ozone depletion process is continuous resulting in depletion of the ozone layer.

Certificates

Effects of Ozone

1. Positive effect at upper atmosphere.

However the ozone layer (a portion of the stratosphere with a higher concentration of ozone from two to eight ppm) is beneficial, it is preventing from ultraviolet light from reaching the earth's surface, to the benefit of both plants and animals.

2. Negative effects at ground level.

Ozone has very high oxidizing potential, can damage mucous and respiratory tissues in animals and also tissues in plants.

Waste Management

Waste can take any form that is solid, liquid or gas and each have different methods of disposal and management. Waste management normally deals with all types of waste whether it was created in industries, biological, household and any other cases where it may pose a threat to human health.

Waste management includes collection, transport treatment and disposal of waste.

Solid waste

Solid waste refers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless. Solid waste is generated from industrial, residential and commercial activities in a given area and may be handled in a variety of ways.

Sources of solid waste.

The solid waste comes from homes, offices, industries and various agricultural related activities. The following are the major sources of solid waste.

1. Residential areas and homes.
2. Industries
3. Commercial establishments
4. Institutions
5. Municipal services
6. Manufacturing plants and sites.

Characteristics of solid waste: Characteristics of solid waste are important for selecting a suitable disposal technique.

i. Physical characteristics

- a. Density of waste (mass per unit volume)
- b. Moisture content in wet waste (weight of water to the total weight of waste).
- c. Size distribution of materials (for separation purpose).

ii. Chemical Characteristics

If solid wastes are to be used as fuel or are used for any other purpose, we must know the chemical characteristics of the waste such as,

- a. Lipid (found in variety of wastes, suitable for energy recovery)
- b. Carbohydrate content (formed in food and yard wastes)
- c. Proteins (found in food and garden wastes)
- d. Natural fibers (found in paper products, food and yard wastes, suitable for energy recovery)
- e. Synthetic organic material (plastics, suitable for pyrolysis and energy conversions)
- f. Non-combustibles (glass and other materials)
- g. Heating value of waste (or calorific value of waste)

Disposal methods of solid waste

1. Scientific land filling

Scientific landfills eliminate the risk of waste seeping underground as the base layer is constructed of 90meters of clay, thus arresting any seepage or leakage within the landfill. On top of the base layer, a drainage layer made of soil, measuring 15meters in length and a vegetative layer of 45cm to minimize soil erosion.

Scientific landfills also reduce the production of methane. Vertical wells installed in scientific landfills help extract methane, regularly and the gas can then be used for electricity and heat generation purposes.

2. Composting

Due to lack of adequate space for landfills, biodegradable wastes are allowed to decompose in a medium, designed for the purpose, only biodegradable waste materials are used in composting. Good quality of environmentally friendly manure is formed from the compost and can be used for agricultural purposes.

3. Recycling and reuse

Recycling of resources is the process of taking useful but discarded items for next use. The process aims at reducing energy loss, consumption of new material and reduction of landfills.

E-waste

The term e-waste refers to electronic waste which include discarded computers, batteries, TV's, mobile phones, radios, fluorescent bulbs and electronic appliances. Only discarded electronic materials which have reached the end of life are considered as e-waste. E-waste is regarded as one of the world's fastest growing waste stream.

All electronic materials contain hazardous substances including toxic metals, inappropriate processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution.

Sources of e-waste

1. TV's, Computer monitors, laptops, mobile phones, printers, scanners, keyboards, mouse, cables, circuit boards, lamps, clocks, flashlights, calculators, phones, digital/video cameras, radios, VCR's, DVD players, MP3 and CD Players.
2. Kitchen equipment's (toasters, coffee makers, microwave ovens etc.)
3. Laboratory equipment's (hot plates, microscopes, calorimeters etc.,)
4. Broken computers, monitors, television tubes etc.

Characteristics of e-waste

Understanding the characteristics of e-waste is essential to select a safe and efficient disposal method, e-waste is generally characterized by analyzing the components and composition of waste.

i. Hazardous components in e-waste

Electronic waste consist of a large number of components of various sizes and shapes, some of which contain hazardous components that need to be removed for separate treatment. Need to be removed for separate treatment.

ii. Material composition of e-waste

Electronic waste contains a mixture of various metals, particularly copper, aluminum and steel, attached to, covered with or mixed with various types of plastics and ceramics.

Disposal of e-waste

a. Landfilling

This is the most common methodology of e-waste disposal. Soil is excavated and trenches are made for burying the e-waste in it. However, landfilling is not an environmentally sound process for disposing off the e-waste as toxic substances like cadmium, lead and mercury are released inside the soil and ground water.

b. Recycling of e-waste

Mobile phones, monitors, CPU's, Floppy drives, laptops, keyboards, cables and connecting wires can be re-utilized with the help of the recycling process. It involves dismantling of the electronic device,

separation of the parts having hazardous substances like printed circuit boards etc. and then recovery of the precious metals like copper, gold or lead can be done with the help of a e-waste recycling.

c. Reuse

This is the most desirable e-waste recycling process where with slight modifications the mobile phones, computers, laptops, printers can be reused or given as second hand product. The old electronic equipment can also be donated in the various charity programs and thus helping the person in need.

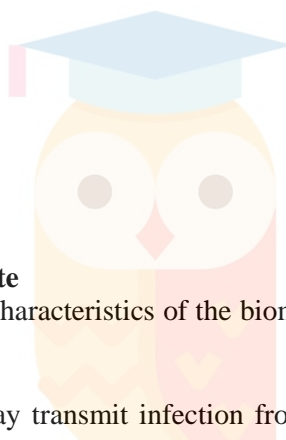
Biomedical waste

Biomedical waste also known as infectious waste or medical waste also known as infectious waste or medical waste, is defined as a waste generated during the diagnosis, testing, treatment, research or production of biological products for human or animals.

It includes solid waste, disposables, anatomic waste, cultures, discarded medicines, chemical wastes etc. these are in the form of disposable syringes, tissues, swabs, bandages, body fluids, human excreta etc.,

Sources of biomedical waste

1. Hospitals
2. Clinics
3. Labs
4. Research Centers
5. Animal research
6. Blood banks
7. Nursing homes.



Characteristics of biomedical waste

It is crucial to identify the characteristics of the biomedical waste to implement an efficient treatment or disposal method.

1. Infectious waste: waste that may transmit infection from virus, bacterial, parasites to human. I.e. Lab cultures, tissues, body parts, body fluids, needles, knives etc.
2. Radioactive: Unused liquid in radiotherapy or lab research, contaminated glassware etc.
3. Chemical waste: expired lab reagents, disinfectants etc.
4. Pharmaceutical waste: expired and contaminated medicines.

Characteristics of bio-medical waste suitable for incineration

1. Heating Value (or calorific value) of waste should be more than 8370kj/kg.
2. Moisture content should be below 30%.

Disposal of biomedical waste by landfilling

Sanitary landfills: (The use of landfill for biomedical waste). It should not be dumped in open spaces as it leads to acute pollution problems, fires, higher rise of disease transmission, sanitary landfills are safer over open dumps.

Water Technology

Introduction Boiler feed water:

Water is used in boilers for generating steam for industries and power plants. The hardness of boiler feed water should be below 0.2ppm, alkalinity due to OH^- should be below 0.45ppm and due to CO_3^{2-} should be below 1 ppm. If excess impurities are present in the boiler feed water, they lead to formation of scales, sludge, priming, foaming, corrosion and caustic embrittlement.

Scale and Sludge formation:

During production of steam, water is heated continuously under pressure in boiler. The evaporation of water increases the concentration of dissolved salts which precipitates on reaching saturation level.

The precipitate adheres on the wall of boiler strongly called scale; the deposit is so hard such that removal of scale is difficult.

If the precipitate formed is loose, non-adherent and suspended then it is called sludge.

Causes for scale formation: When water is heated to generate steam, water is evaporated leaving behind the salts which stick to the walls of the boilers. This process continuously occurs in boiler leading to the formation of hard, insoluble coating (Scale formation).

- **CaSO_4** is soluble in cold water but as the temperature increases its solubility decreases. Therefore at high temperature and pressure it gets precipitated and deposit as scale.
- **Decomposition of Bicarbonates** if bicarbonates are present as impurities they precipitate as insoluble carbonates.



- **Hydrolysis of salts of Magnesium:** Magnesium salts present in dissolved water form insoluble hydroxides at high temperature.



Causes for sludge formation: Sludge is formed by the impurities in water which are soluble in hot condition & less soluble/not soluble in cold condition. If sludge is not removed periodically, then it forms scale.

Disadvantage of scale & Sludge formation:

- **Wastage of Fuel:** Scale formed is bad conductor of heat thus need excess of heat for steam production.
- **Danger of Explosion:** Boiler may get exploded due to excess pressure.
- **Reduces efficiency:** Boiler parts get choked, & reduces the efficiency of boiler.
- **Increase in cleaning expenses:** In order to retain the efficiency of the boiler, it has to be cleaned periodically to remove scale.

Priming and foaming:

Priming: During rapid boiling of water, the steam formed will carry droplets of water known as wet steam. These droplets of water have dissolved salts in it, *"The process of carrying water droplets along with steam is called as priming"*.

Disadvantages of Priming:

- Wet steam reduces the heating ability of steam.
- Dissolved salts in wet steam deposits on turbine blades leading to corrosion.

- Dissolved salts in wet steam leave salt particles on engine valves thereby reducing its life.

Foaming: *“The process of formation of persistent bubbles on the surface of boiler water is called foaming”.* It is caused due to the presence of oils, fats, alkalis etc.

Disadvantages of Priming:

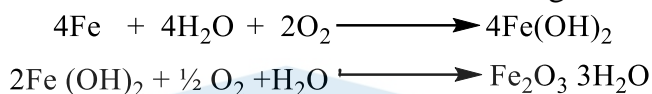
- The rupture of bubbles leads to spraying of dissolved salts on boiler parts which forms scales.
- Due to foaming it is difficult to maintain boiler pressure.
- The steam produced will also be a wet steam.

Boiler Corrosion:

The major chemical composition of boiler is iron. *“The decay of boiler material due to presence of impurities in boiler feed water is called boiler corrosion”.*

Corrosion due to dissolved oxygen:

DO content of raw water is normally between 8-9ppm. When it is heated at high pressure the free oxygen gas is evolved which attack on boiler material through the reactions below.



Corrosion due to dissolved carbon dioxide:

The CO_2 may get dissolved in boiler water either from air or from decomposition of salts and produce carbonic acid. This carbonic acid is slightly acidic and corrosive in nature.



Corrosion due to MgCl_2 :

Due to the presence of salt like MgCl_2 in boiler feed water, the pH value drops below 8.5, because of the following reaction.



The acid formed will attack boiler parts and causes corrosion.



Biological Oxygen Demand

“BOD is defined as the amount of oxygen required for the biological oxidation of organic matter under aerobic conditions at 20°C for the period of five days”.

Chemical Oxygen Demand

“COD is defined as the amount of oxygen required for the complete chemical oxidation of total oxidizable impurities present in water with strong oxidizing agent in acidic medium”.

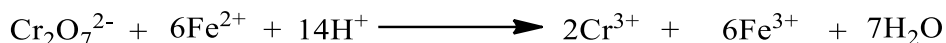
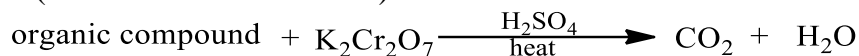
This is expressed in terms of milligrams of oxygen

Experiment: Back titration: Pipette out 25 ml (V) of water sample and 25cm^3 $\text{K}_2\text{Cr}_2\text{O}_7$ solutions into 250cm^3 conical flask. Add 20cm^3 of 1:1 H_2SO_4 containing silver sulphate with constant stirring. Boil the mixture for half an hour and cool. Add 2 drops of ferroin indicator and titrate against std. Ferrous ammonium sulphate solution till the solution turns from blue green to reddish brown. Note down the volume of FAS required to react with remaining $\text{K}_2\text{Cr}_2\text{O}_7$ (Back titration = A ml). Repeat the titration for agreeing values.

Blank titration: Pipette out 25cm^3 of standard potassium dichromate solution. Add 20cm^3 of dilute 1:1 sulphuric acid followed by 2-3 drops of ferroin indicator. Titrate against standard FAS

solution till the color turns from blue - green to reddish brown. Note down the volume of FAS solution added (Blank titre value = B ml)

Reactions



5.7.3 Calculations:

Normality of Standard FAS solution _____ N

$$\text{COD of a sample} = \frac{N(B - A)}{V} \times 8 \times 1000 \text{ mg/lit}$$

Sewage Treatment.

The treatment of domestic sewage water is carried out in 2 or 3 stages.

Primary Treatment.

Course solids in sewage water are removed by passing through racks, screens, grid chambers & skimming tanks. Then the water is passed into sedimentation tank and allowed to settle. The nonsettleable solids are removed by coagulation by treating with coagulating agents like alum, ferric chloride or lime.

Secondary treatment.(Activated sludge process).

After the primary treatment water is allowed to flow into large tanks and sprayed with activated sludge containing microorganisms as shown in figure 5.1 . Air is passed vigorously from the center of the tank in order to bring good contact between the organic wastes & bacteria in presence of air & sunlight. The microorganisms oxidize the organic wastes in the water effectively. Finally sludge is removed by settling or filtration. The activated sludge process operates at 90-95 percent efficiency of BOD treatment.

Tertiary treatment.

It is the chemical method for the removal of dissolved impurities and microorganisms.

- Treatment with lime for the removal of phosphates as insoluble calcium phosphate.
- Treatment with sulphide ions for the removal of heavy metal ions as insoluble sulphides.
- Treatment with activated charcoal to adsorb remaining organic compounds.
- Treatment with alum to remove the colloidal impurities.

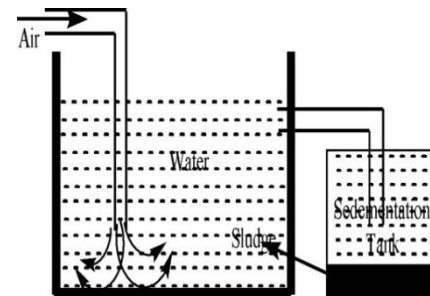
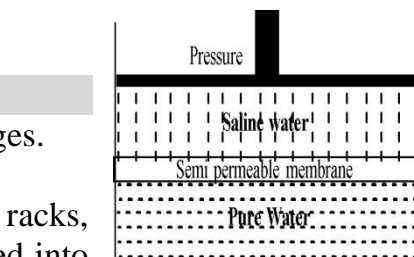
Potable water: Water that meets the stringent microbiological & chemical standards of quality for human consumption is called potable water.

Desalination:

The process of partial or complete demineralization of saline water is referred to desalination.

Methods of desalination.

Reverse Osmosis: The process of osmosis can be reversed by applying pressure called reverse osmosis. This process is carried out in Reverse osmosis (RO) cell where saline water is separated from fresh water through semipermeable membrane. A pressure of about $15\text{--}40 \text{ kg/cm}^2$ is applied on saline water, as a result of reverse osmosis fresh water moves down and gets collected from outlet at the bottom of the cell. Schematic diagram of Reverse osmosis is as shown in figure



5.9.3 Softening of water: Ion Exchange Process:

In this method all the ions in water are removed, hence it is also called demineralization process.

Ion exchange resins are insoluble, cross linked long chain organic polymers, containing microporous structure with functional groups for exchange of ions. Depending on functional group attached to resins they are classified into Schematic diagram for Ion exchange process is as shown in figure.

5.9.3.1 Cation Exchange resins: The resins having functional groups such as $-\text{SO}_3\text{H}$, COOH etc., groups are called cation exchange resins. These are capable of exchanging H^+ Ions with cations present in water.

5.9.3.2 Anion exchange resins: The resins having functional groups such as Quarternary ammonium groups etc., with hydroxide salts called as anion exchange resins. These are capable of exchanging OH^- Ions with anions present in water.

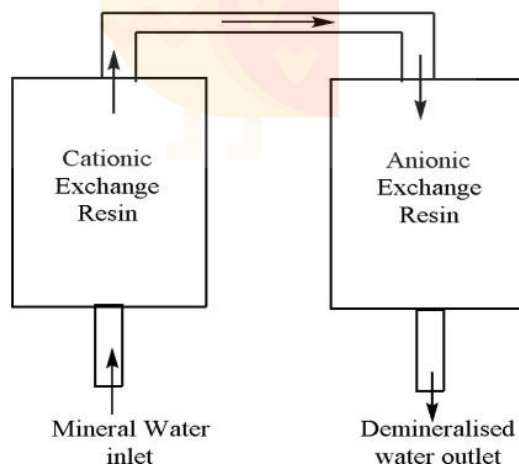
Ion exchange resin consist of two main compartment cation and anion exchange resins, water sample with high mineral is first allowed to pass through cation exchange resin, which exchanges all the cations present in water by H^+ . Thereafter it is passed through anion exchange resins which exchanges all the anions present in water. Water free from minerals is collected.



Regeneration Process:

Cationic resin regenerated by passing hydrochloric acid

Anionic resin regenerated by passing Sodium hydroxide



Determination of Fluoride in water sample SPADNS colorimetric method

Principle: The SPADNS colorimetric method is based on the reaction between fluoride and a zirconium-dye lake. Fluoride reacts with the dye lake, dissociating a portion of it into a colorless complex anion (ZrF_6^{2-}), and the dye. As the amount of fluoride increases, the color produced becomes progressively lighter.

Procedure:

Preparation of mixed acid – zirconyl - SPADNS reagent

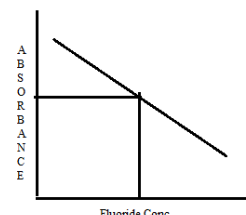
Principle: The method involves precipitation of sulphates in a known volume of water sample by adding $BaCl_2$ to form $BaSO_4$ as insoluble complex. The precipitate is filtered and the amount of sulphate is determined gravimetrically in terms of one liter of sample.

Procedure:

- Dissolve 0.95g of SPADNS sodium (2-(parasulfophenylazo) 1,8-dihydroxy 3,6-naphthalene disulfonate) in distilled water and dilute to 500 mL
- Dissolve 0.13g of zirconyl chloride octahydrate in 25 mL distilled water, add 350 mL conc HCl and dilute to 500 mL with distilled water
- Mix both the solution equi-volume when required.

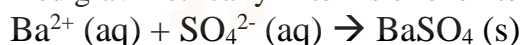
Draw out 10, 20, 30, 40 & 50 cm³ of 100 ppm Stock Fluoride solution into 5 separate 100ml volumetric flasks. Add 10.00 mL mixed acid – zirconyl - SPADNS reagent, to each standard and mix well. Dilute the flasks up to the mark and mix well. Blank is prepared in the same manner without fluoride solution

Measure the absorbance at 570nm (λ_{max}) of each of these solutions against blank solution. Plot a graph of volume of Fluoride Vs decrease in absorbance. The concentration of fluoride in water is determined by following the same procedure.



Determination of sulphate in water by gravimetric method

Principle: The method involves precipitation of sulphates in a known volume of water sample by adding $BaCl_2$ in acidified condition to form $BaSO_4$ as insoluble complex. The precipitate is filtered and the amount of sulphate is determined gravimetrically in terms of one liter of sample.



Procedure:

Take 200ml of the water sample, add 2ml conc. HCl in it, heat the solution on hot plate to near boiling, and add 10ml of 0.5M $BaCl_2$ to the hot sample with continuous stirring. The sulphate in water precipitates as $BaSO_4$. Filter the ppt using wattman filter paper. Wash the precipitate several times with distilled water. Transfer the filterpaper along with precipitate to a previously weighed crucible and place the crucible in furnace till the filter paper burns completely. Remove the crucible and allow it to cool to room temperature. Note down the weight of the crucible. Sulphate in water is calculated using the formula

$$SO_4 \text{ in mg/l} = \frac{\text{mg of } BaSO_4 \times 96.06 \times 1000}{\text{ml of water} \times 233.4}$$
