Module-4

Environmental Pollution and Water Chemistry

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Introduction:

- Industrialization while bringing material benefits and comforts to the mankind has at the same time brought about deterioration in the environment.
- Besides increasing the concentration of certain material already present in the atmosphere, it has introduced in it new undesirable constituents. For instance, industrial units and various transport media constantly release into the atmosphere gases such as carbon monoxide, oxides of nitrogen and sulphur, which have a disastrous effect.
- In addition, natural causes such as earthquakes, volcanic eruptions and storms have also contributed to environmental pollution. The indiscriminate use of biotic and energy components at a rapid rate has caused further damage to the environment.

Air Pollutants:

- pollution is the presence of contaminants in atmosphere in quantities such that it is injurious to human, plant animal life and property

- The main pollutants in the atmosphere are SO2 (sulphur dioxide), CO (carbon monoxide), oxides of nitrogen, particulate matter and lead.

Carbon monoxide:

Sources:

- Oxidation of methane: Methane is formed during decay of vegetable matter. Oxidation of methane releases carbon monoxide into the atmosphere.
- Automobile exhaust- carbon monoxide is formed during the combustion of fuel such as petrol and is released into the atmosphere through the exhaust
- Incomplete combustion of fossil fuels: coal when undergoes incomplete oxidation, forms carbon monoxide and pollutes the atmosphere.

$$2C + O2 \text{ -------> } 2CO$$

- Industries: carbon monoxide is released by industries such as iron and steel and petroleum

Ill effects:

- Haemoglobin in blood can form a complex with oxygen and hence functions as carrier of oxygen. When the atmosphere is polluted with carbon monoxide, on inhalation, CO combines with the hemoglobin to form carboxy haemoglobin and hence oxygen carrying capacity of the blood decreases.
- This causes, headache, dizziness, unconsciousness.When inhaled for a long duration it may cause even death.

Control:

Using catalytic converter in automobiles.

Oxides of Nitrogen:

- Nitric oxide, nitrogen dioxide and nitrous oxide are the three main oxides of nitrogen found in the atmosphere

Sources:

The sources for the oxides of nitrogen are:

- Bacterial decomposition of nitrogenous compounds – bacteria in the soil act on the ammonium compounds present in the soil, convert them to ammonia and finally release oxides of nitrogen into the atmosphere.

  $4NH_3 + 5O_2 \text{--------} > 4NO + 6H_2O$

- Combustion during lightning – during lightning, oxygen and nitrogen in the atmosphere combine to give oxides of nitrogen.

  $N_2 + O_2 \text{------} > 2NO$

  $2NO + O_2 \text{-------} > 2NO_2$

- Industries and automobile exhaust - Air is sucked into the IC engines. At high temperatures, nitrogen and oxygen in the air combine to form nitric oxide.

  $N_2 + O_2 \text{---------} > 2NO$

  $2NO + O_2 \text{--------} > 2NO_2$

Ill effects:

- Pollution due to oxides of nitrogen affects human and plant life.
- The oxides of nitrogen combine with moisture in the atmosphere to form nitrous and nitric acid. This leads to increase in the acidity of rain water.
- Formation of photochemical smog: oxides of nitrogen combine with hydrocarbons present in the atmosphere forming peroxyacyl nitrate.
- Peoxyacyl nitrate causes injury to plants and in human beings it causes fatigue and infection of the lungs Peroxyacyl nitrate formation leads to smog (fog + smoke). Smog reduces visibility. Fading of dyes is caused in textiles .

Control:

- Using catalytic converter in automobiles.
- Catalytic converters use Pt/ Rh catalyst.in the presence of the catalysts, the oxides of nitrogen are converted to nitrogen and oxygen

Oxides of Sulphur:

Sources:

- Combustion of fossil fuels – coal and crude oil contain up to 3% sulphur.
- Roasting of ores – sulphide ores on roasting, are converted to sulphur trioxide. This, when let into the atmosphere, combines with the moisture in the atmosphere to form sulphuric acid. for example, roasting of galena , the sulphide ore of lead.

$$2PbS + 3O_2 \text{--------} > 2PbO + 2SO_2$$
$$2SO_2 + O_2 \text{ ---------} > 2SO_3$$
$$H_2O + SO_3 \text{---------} > H_2SO_4$$

- Oxidation of I H_2S – Hydrogen sulphide is formed during the decay of plants. This, on oxidation releases sulphur dioxide into the atmosphere.

$$2H_2S + 3O_2 \text{----------} > 2H_2O + 2\ SO_2$$

- Volcanic eruptions also emit sulphur dioxide.

Ill effects of SO_2:

- Sulphur dioxide pollution in the atmosphere affects causes the following damages :
- humans : it causes eye irritation, cough, lung diseases including lung cancer and asthma
- In plants: it causes damage of leaves, bleaching of chlorophyll which turns leaves brown, damage to crops and to growth of plants.
- Others: Yellowing of paper and wearing away of leather are other ill effects.

Control:

- The gases evolved during combustion of fossil fuels are passed through calcium carbonate when SO_2 is converted to calcium sulphite

$$CaCO_3 + SO_2 \text{---------} > CaSO_3 + CO_2$$

- Lime is added to coal and roasted at high temperature so that CaO formed combines with SO_2 to form calcium sulphate.

$$CaO + SO_2 + \tfrac{1}{2} O_2 \text{--------} > CaSO_4$$

Hydrocarbons:

- Hydrocarbon contamination in the environment is a very serious problem whether it comes from petroleum, pesticides or other toxic organic matter.
- Environmentalpollution caused by petroleum is of great concern because petroleumhydrocarbons are toxic to all forms of life
- Hydrocarbon vapors can cause health effects. Inhaling formaldehyde can cause irritation. It is a major contributor to eye and respiratory irritation caused by photochemical smog. ... However, hydrocarbon is not a criteria pollutant, because, it is predominant only during disasters such as photochemical smog, etc

.

Sources:

- Sources of VOC and NOx emissions include: large industry such as chemical manufacturers, and combustion sources such as power plants burning fossil fuels; small industry such as gasoline-dispensing facilities, autobody paint shops, and print shops; automobiles, trucks and buses and industries.

- Hydrocarbons Polluting the Air We Breathe. The incomplete combustion of these fuels can cause the hydrocarbons to react with nitrogen oxides (often produced from high temperatures and oxygen in excess of the amount needed to burn the fuel)

Ill effects:

- Hydrocarbons polluting the air we breathe. The incomplete combustion of these fuels can cause the hydrocarbons to react with nitrogen oxides (often produced from high temperatures and oxygen in excess of the amount needed to burn the fuel).
- The health effects of hydrocarbons have been noted in occupational exposures to tetra methyl lead, benzene, etc. Hydrocarbon vapors can cause health effects. Inhaling formaldehyde can cause irritation. It is a major contributor to eye and respiratory irritation caused by photochemical smog.

Particulate Matter:

- Particulate matters are solid or liquid suspensions in air. They are also called aerosols.
- These comprise of dust particles, ash, smoke, fumes and mist..

Sources:

- Volcanic eruptions.
- Soil erosion: wind blows away soil and the dust particles are introduced into the atmosphere.
- Industrial operations such as crushing of solid materials- solid materials are crushed, ground and powdered in industries. During these operations dust is released into the atmosphere.
- Burning of coal: The noncombustible matter in coal is left behind as ash during the combustion of coal.
- Incomplete combustion of compounds containing carbon, processing of coal, cement asbestos: These operations also release dust into the atmosphere.
- Mist – condensation of vapours, sprays etc lead to dispersion of liquids in the atmosphere thus forming mist.

Ill effects:

- Decrease in visibility: Particulate matter interfere inn the transmission of light and hence affect visibility.
- Particulate matters enter the lungs causing wheezing, bronchitis, and asthma in human beings.
- In plants the particulate matter settle on the leaves blocking the stomata thereby affecting the plant growth.

Control:

- Particulate matter in the atmosphere can be controlled using Gravitational settling chambers,Centrifugal separators, Fabric filters,Wet scrubbers,Electrostatic or Cottrell separators

Lead pollutant:

Sources:

- The exhaust from automobiles which use lead tetraethyl as antiknocking agent-
- When TEL is used as antiknocking agent, lead is converted to halide and released into the atmosphere. This leads to increase in the concentration of lead in the atmosphere.
- Paint pigments: Litharge and red lead (oxides of lead) and lead chromate are used as pigments. These cause lead pollution
- Plumbing systems- lead pipes are used for plumbing and these may cause lead pollution.

Ill effects:

- Lead competes with calcium and enters the blood and bone marrow.
- The lead interferes in the manufacture of red blood corpuscles and abnormal multiplication of blood cells and thus leads to anaemia and blood cancer in human beings.
- Lead enters the blood and various organs of the body including the brain and the

Ozone depletion:

- Ozone absorbs UV radiations and is broken into atomic and molecular oxygen.

$$O_2 \xrightarrow{uv} C \longrightarrow 2O$$
$$O_3 \longrightarrow O + O_2$$

- The products formed combine again to form ozone

$$O + O_2 \longrightarrow O_3$$

- Hence a dynamic equilibrium is set up due to which the concentration of ozone in the atmosphere remains constant.
- The ozone layer protects the earth from the harmful UV radiations. If the concentration of ozone is reduced (ozone depletion), the concentration of uv radiations reaching the earth increases.
- This leads to irritation of the eyes, skin cancer and damage to immune system in human beings
- In agriculture it causes decrease in productivity.

Causes of ozone depletion

- Chlorofluorocarbons (CFCs) are used as refrigerants, aerosols and as industrial solvents.
- CFCs are noncombustible and volatile. They reach the atmosphere and are broken down into chlorine free radicals by UV radiations.

  CF2 Cl2------->uv------->C-------->*CF2 Cl + *Cl +

- The chlorine free radical brings about the degradation of ozone

  ClO3-------->*ClO + O 2

  ClO + O--------> Cl + O2

- Thus CFC reduce the concentration of ozone in the atmosphere causing ozone hole.

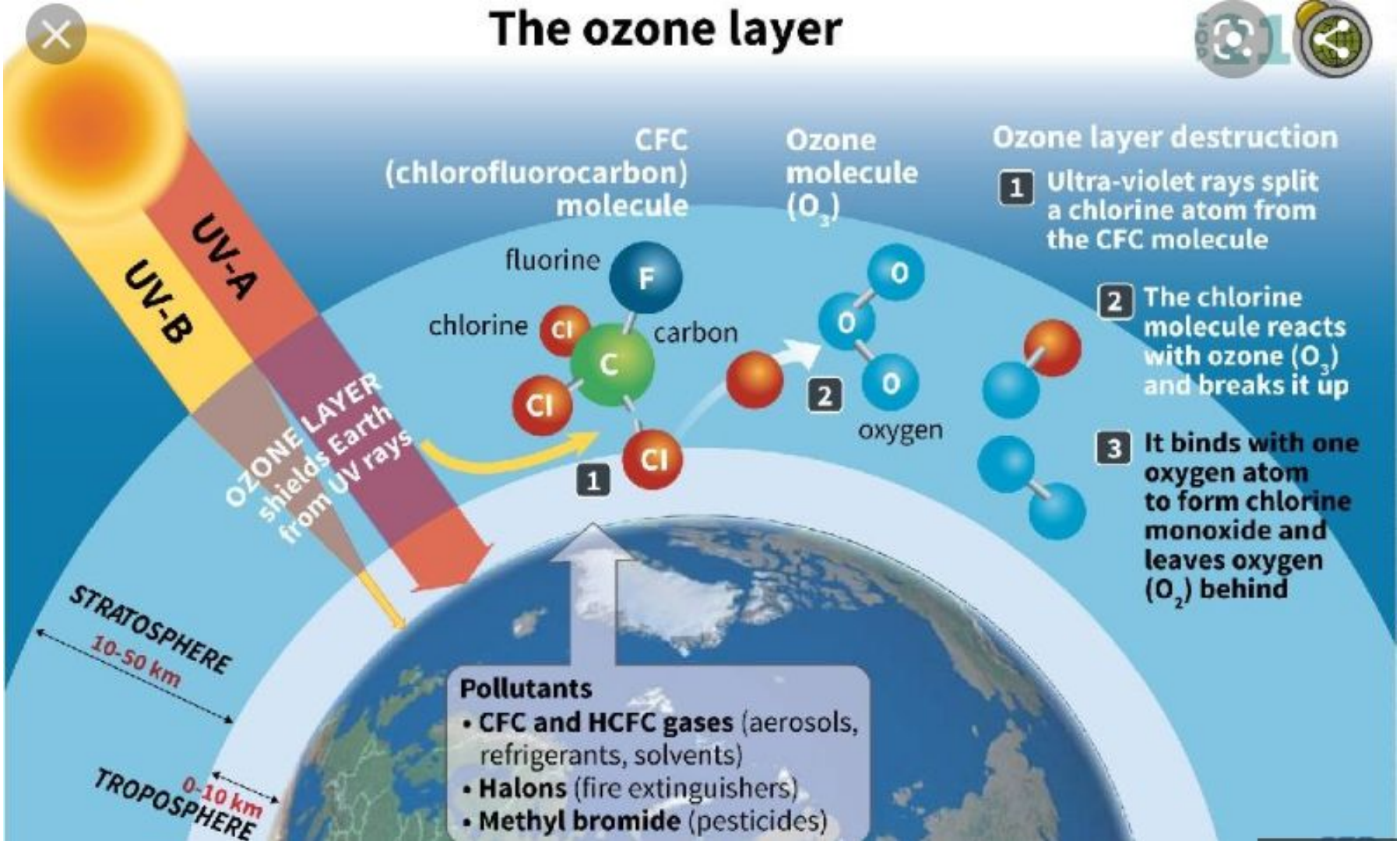
Ill effects

- Due to ozone hole, the uv radiation increases causing eye infections, skin cancer in human beings and decrease in photosynthesis in plants.
- The temperature on the earth's surface is raised and this leads to global warming.

Control of ozone depletion:

- Ozone depletion can be controlled by using hydrochlorofluorocarbons and hydrofluoroalkanes in place of CFCs. These contain more hydrogen in their molecule and undergo oxidation readily.

The ozone layer



Waste management

- Actions required to manage waste from its inception to its final disposal.This includes amongst other things collection, transport, treatment and disposal of waste together with monitoring and regulation.
- 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 forms that are industrial, biological, household, and special cases where it may pose a threat to human health
- It is produced due to human activity such as when factories extract and process raw materials. Waste management is intended to reduce adverse effects of waste on health, the environment or aesthetics.

Solid waste:

- This accounts any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations.

Sources:

- waste tires, septage, scrap metal, latex paints, furniture and toys,garbage,appliances and vehicles, oil and -freeze, empty aerosol cans, paint cans and compressed gas cylinders construction and demolition debris, asbestos.
- Residential: Residences and homes where people live are some of the major sources of solid waste, Industrial, Commercial, Institutional, Construction and Demolition Areas, Municipal services, Treatment Plants and Sites, Agriculture.

Characteristics:

- Significant changes in the density occur as waste moves from sources to disposal site, as a result of scavenging, handling, wetting, and drying by the weather and vibration during transport.

- Moisture increases the weight of the solid wastes and therefore the cost of collection and transport increases. Consequently waste should be insulated from rain or other extraneous water source
.
- These are primarily originated from the food sources rich in starch and celluloses. These readily biodegrade into carbon dioxide, water and methane. Decomposition of carbohydrates attracts the flies and rats and hence should not be left exposed for long duration.

- Proteins are the compounds containing carbon, hydrogen, nitrogen and oxygen and organic acid with amino groups. They are primarily found in food and garden wastes, but their partial decomposition result in the production of amines, which impart unpleasant odors.

- In the recent years plastics have become a significant components of solid waste, accounting for 1-10%. They are highly resistant to the biodegradation; hence their presence in the waste is objectionable. Currently much attention is given to reduce this component at disposal sites

E-waste:

Sources:

- Electronic waste, or e-waste, is a term for electronic products that have become unwanted, non-working or obsolete, and have essentially reached the end of their useful life.
  Examples:VCRs being replaced by DVD players, and DVD players being replaced by blu-ray players
- E- waste is created from anything electronic: computers, TVs, monitors, cell phones, PDAs, VCRs, CD players, fax machines, printers, etc.

Characteristics:

- Most electronics that are improperly thrown away contain some form of harmful materials such as beryllium, cadmium, mercury and lead.
- These materials might be trace elements, but when added up in volume, the threat to the environment is significant.
- Besides adding harmful elements to the environment, improper disposal of e-waste is a recycling opportunity lost.
- Almost all electronic waste contains some form of recyclable material, including plastic, glass and metals.

Biomedical waste:

- Biomedical waste is any kind of waste containing infectious (or potentially infectious) materials. Biomedical waste is generated from biological and medical sources and activities, such as the diagnosis, prevention, or treatment of diseases.

Sources:

- Human anatomical waste: (tissues, organs, body parts)
- Animal waste: (including animals used in research and waste originating from veterinary hospitals and animal houses).
- Microbiological and biotechnology waste: (including waste from lab cultures, stocks or specimens of microorganisms, live or attenuated vaccines, wastes from production of biologicals, etc.)
- Waste sharps: (used/unused needles, syringes, lancets, scalpels, blades, glass etc.)
- Discarded medicines and cytotoxic drugs.
- Soiled wastes: (items contaminated with blood and body fluids, including cotton dressings, linen, plaster casts, bedding etc.)
- Solid wastes: (wastes generated from disposable items other than waste sharps such as tubing, catheters, i.v. sets, etc.)
- Liquid waste: (waste generated from washing, cleaning, house keeping and disinfection activities including these activities in labs).
- Incineration ash: (from incineration of any biomedical waste)
- Chemical waste: (chemicals used in production of biologicals and disinfection).

SEGREGATION OF SOLID BIO-MEDICAL WASTE

NOTE:- USE ANY COLORED BIN OTHER THAN BLACK, RED, YELLOW, BLUE & WHITE FOR DISPOSAL OF GENERAL WASTE

Characteristics:

- Biomedical waste is hazardous since it has an inherent potential for dissemination of infection, both nosocomial within health care settings as well as risk of infection to persons working outside health care facilities, like waste handlers, scavenging staff and also to the general public.
- It is reported that 60% of all hospital staff sustain injuries from sharps during various procedures undertaken in health care facilities.
- Cytotoxic and chemical waste is mutagenic and / or teratogenic. Additional hazard includes recycling of disposables without being even washed

Disposal methods:

Scientific land filling:

- Solid wastes are placed in a sanitary landfill in which alternate layers of 80 cm thick refuse is covered with selected earth-fill of 20 cm thickness.
- .After 2-3 years solid waste volume shrinks by 25-30% and land is used for parks, roads and small buildings. This is the most common and cheapest cheapest method of waste disposal and is mostly employed in Indian cities.

Advantages:

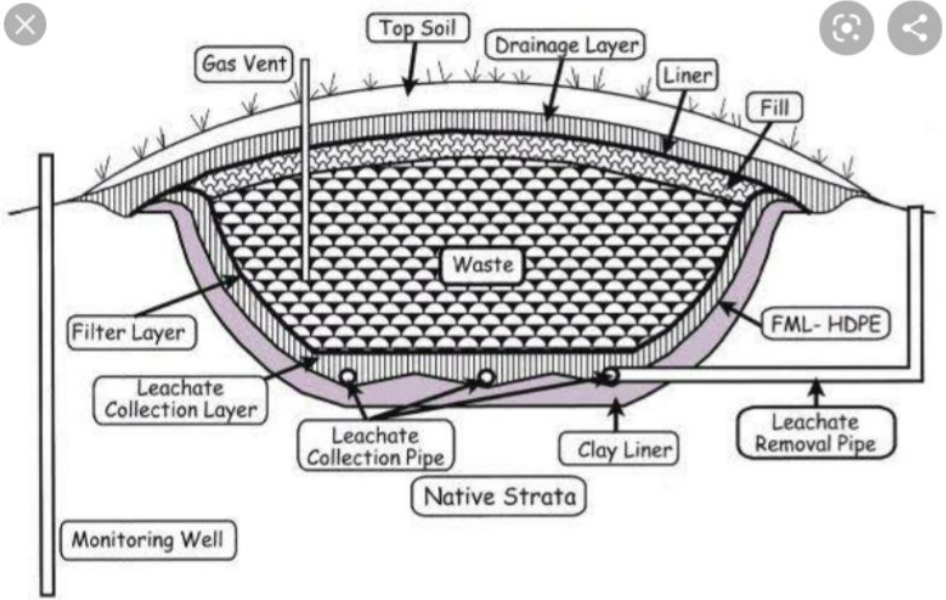
- It is simple and economical
- Segregation of wastes is not required
- Land filled areas can be reclaimed and used for other purposes
- Converts low-lying, marshy waste-land into useful areas.
- Natural resources are returned to soil and recycled.

Disadvantages:

- Large area is required
- Land availability is away from the town, transportation costs are high.
- Leads to bad odour if landfill is not properly managed.
- Land filled areas will be sources of mosquitoes and flies requiring application of insecticides and pesticides at regular intervals.
- Causes fire hazard due to formation of methane in wet weather.

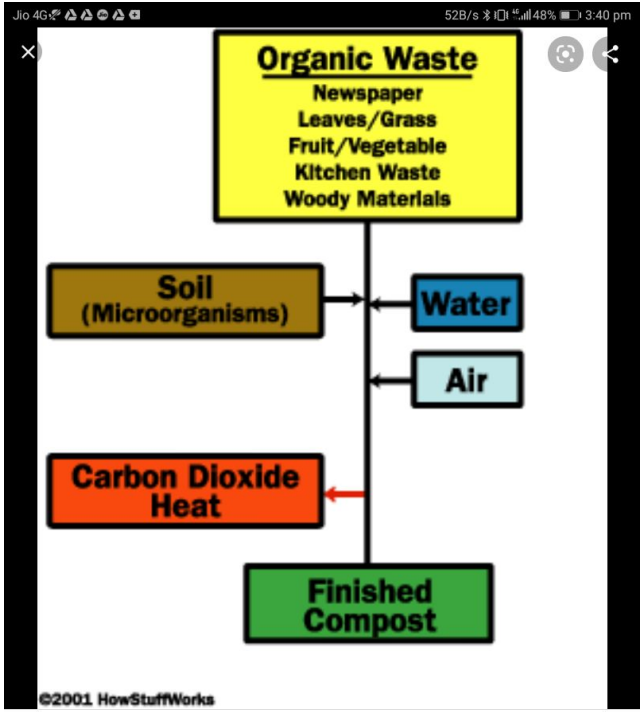
Composting:

- It is another popular method practiced in many cities in our country. In this method, bulk organic waste is converted into fertilizer by biological action.
- Separated compostable waste is dumped in underground trenches in layers of 1.5m and finally covered with earth of 20cm and left for decomposition.
- Sometimes, actinomycetes are introduced for active decomposition. Within 2 to 3 days biological action starts.
- Organic matter is destroyed by actinomycetes and lot of heat is liberated increasing the temperature of compost by 75C and the refuse is finally converted into powdery brown coloured odourless mass called humus that has a fertilizing value and can be used in agriculture.
- Humus contains lot of Nitrogen essential for plant growth apart from phosphates and other minerals.



Scientific Land filling

Composting



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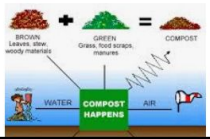


Advantages:

- Manure added to soil increases water retention and ion-exchange capacity of soil.
- This method can be used to treat several industrial solid wastes.
- Manure can be sold thereby reducing cost of disposing wastes
- Recycling can be done

Disadvantages:

- Non-consumables have to be disposed separately
- The technology has not caught-up with the farmers and hence does not have an assured market.

Recycling and reuse:

- Recycling is the process of converting waste materials into new materials and objects.
- Recycling can prevent the waste of potentially useful materials and reduce the consumption of fresh raw materials, thereby reducing: energy usage, air pollution (from incineration), and water pollution (from land filling).
- It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air fresher to breathe.
- Recycling helps protect the environment. Recycling reduces the need for extracting (mining, quarrying and logging), refining and processing raw materials.
- All of these create substantial air and water pollution. As recycling saves energy it also reduces greenhouse gas emissions, which helps to tackle climate change.

The steps involved in the process prior to recycling include

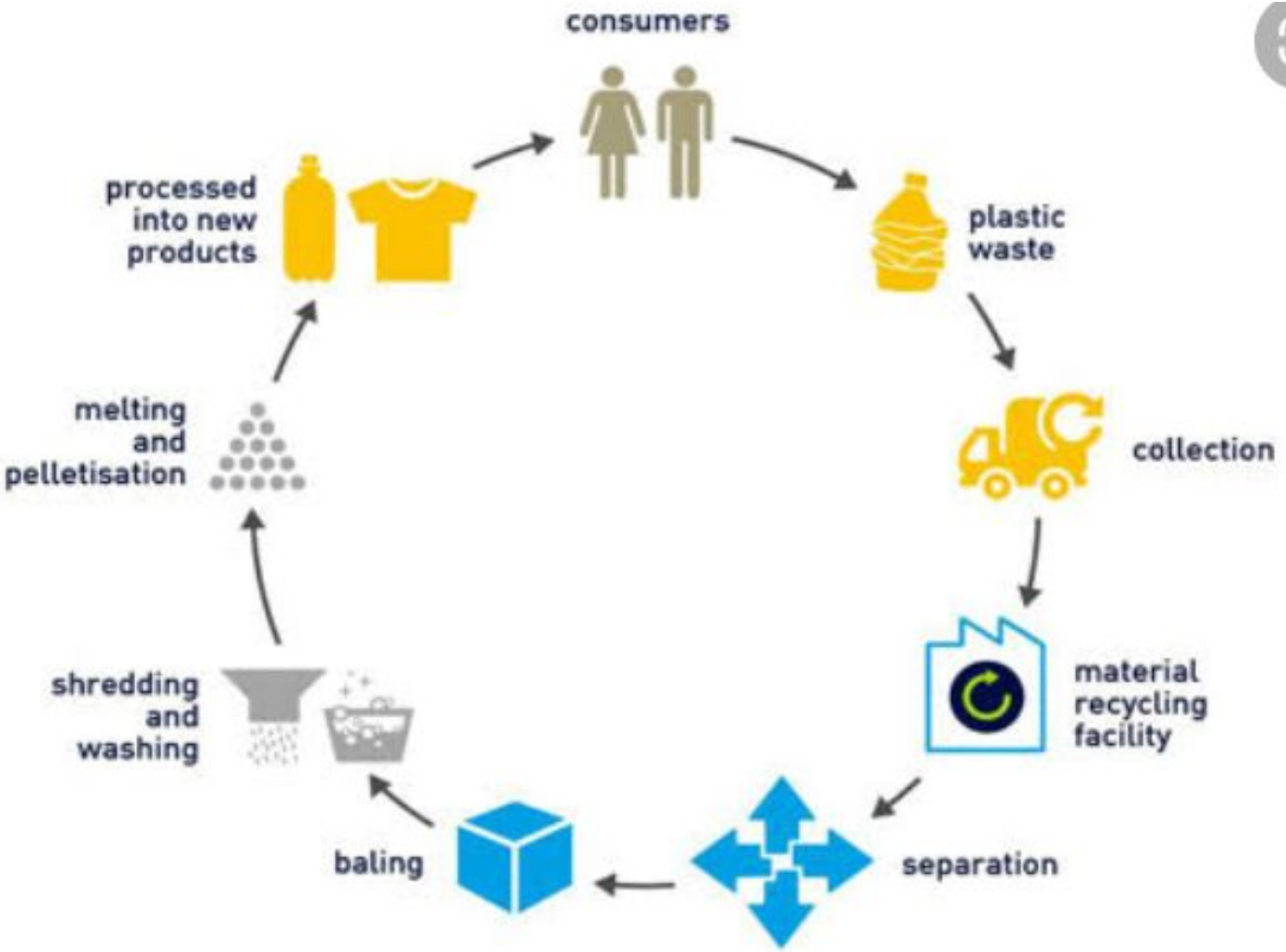
- Collection of waste from doorsteps, commercial places, etc.
- Collection of waste from community dumps.
- Collection/picking up of waste from final disposal sites.

Advantages:

- Reduces the amount of waste sent to landfills and incinerators
- Conserves natural resources such as timber, water and minerals
- Increases economic security by tapping a domestic source of materials
- Prevents pollution by reducing the need to collect new raw materials
- Saves energy

Reuse of Waste:

- The next best option to reducing solid waste altogether is to reuse as many items as possible.
- Reuse can mean purchasing non-disposable items or it can mean passing an item along to another person for continued use.
- Rather than using paper towels to clean the house, you use a washable rag; and, instead of throwing out the clothes or toys your children have outgrown, you pass them along to a neighbor, charity or other social agencies.


consumers
plastic waste
collection
material recycling facility
separation
baling
shredding and washing
melting and pelletisation
processed into new products

Water Chemistry

Introduction:

Sources of water:

- **Rain Water:** Rain water includes other sources such as snow and additional types of precipitation. The precipitation that falls to the earth is a major part of the water cycle as it replenishes both surface and underground water sources.
- **Underground Water**: These are the sources of water that basically you can't see or can't access easily. The important role underground water sources play in the water cycle is that they are the primary sources for human consumption.
- These underground bodies of water are often accessed through wells and when pressure under the surface is too great, this water is pushed up and out through springs.
- **Surface Water:** Easy to see and use, surface water is easily the most abundant supply of natural water. The downside is that most of the surface water on the planet is salt water so it is not ideal for drinking for most living species.
- Surface water does play an important part in our daily lives in addition to being a source of drinking water.It is used to produce hydro-electric power as a clean energy source that is also renewable. It is supplied by precipitation, springs and ice melting from higher elevations and glaciers.

Impurities of water:

- The substances which cause pollution are called pollutants and the common pollutants which are present in water are (i) Suspended solids (ii) Organic matter,(iii) Inorganic pollutants, (iv) Oil, etc.

- Turbidity in water is mainly due to; (i) finely divided undissolved solids, clay, slit;(ii) colloidal particles and (iii) organic matters. Turbidity gives unsightly appearance. When it is used in industries, it causes problems in functioning of equipments, boilers, etc. This can be removed from water by applying proper treatments like settling, coagulation (by using alum) and filtration.

- Organic pollutants include domestic and animal sewage, biodegradable organic compounds, industrial wastes, synthetic pesticides, fungicides, herbicides, detergents, oil, grease, pathogenic microorganisms, etc. It results in rapid depletion of dissolved oxygen of water and thus such water becomes harmful for aquatic lives. Organic matter present in water can be removed by using chlorination, coagulation and ultra filtration processes.

- Inorganic pollutants consist of mineral acids, inorganic salts, finely divided metals, cyanides, sulphates, nitrates, organometallic compounds, etc.

- Oil and grease constitutes important water pollutants. These substances coat ion exchange resin, causes premature exhaustion of beds. It can be removed by coagulation with alum.

Boiler feed water:

Water used in boilers for the generation of steam is known as boiler feed water. Boilers can be used in industries as power/ energy source. Boiler feed water should correspond with the following composition.

- Its hardness should be below 0.2ppm
- Its caustic alkalinity (due to –OH) should lie in between 0.15 and 0.45 ppm
- Its soda alkanity (due to Na_2CO_3) should be 0.456 to 1ppm.
- If excess of impurities present they lead to the formation of scales, sludges, foaming , Corrosion and caustic embattlement.

Boiler troubles:

Sludge and scale formation in Boilers:

- In boilers, water is continuously evaporated to form steam. This increases the concentration of dissolved salts. Exceed their solubility product and precipitates thrown out.

Sludge formation in boilers;

- The resultant precipitate is called as scale. If it is in the form of thick adherent deposit. The precipitate is known as sludge and it is in the form of loose milky precipitate.
- Sludges are formed by substances which have greater solubility in hot water than in cold water.
  Ex: $MgCO_3$, $MgCl_2$, $CaCl_2$, $MgSO_4$ etc.
- They are collected at place, Where the flow rate is slow, they can be easily removed with a wire mesh.

Disadvantages of Sludge:

- Sludge has greater solubility in hot water than in cold water.
- They are poor conductors of heat and they tend to waste a portion of heat generated and hence decreases the efficiency of boiler. Excessive sludge formation disturbs the working of the boiler. it settles in the region of poor water circulation such as pipe connection plug opening etc.

Causes of scale and sludge formation:

- Decomposition of Calcium bicarbonate.

$$Ca(HCO3)2 \rightarrow CaCO3 + H2O + CO2$$

- $CaCO3$ is soft and it is the main cause of scale formation in low pressure boilers.In high pressure boilers $CaCO3$ is soluble due to formation of $Ca(OH)2$.

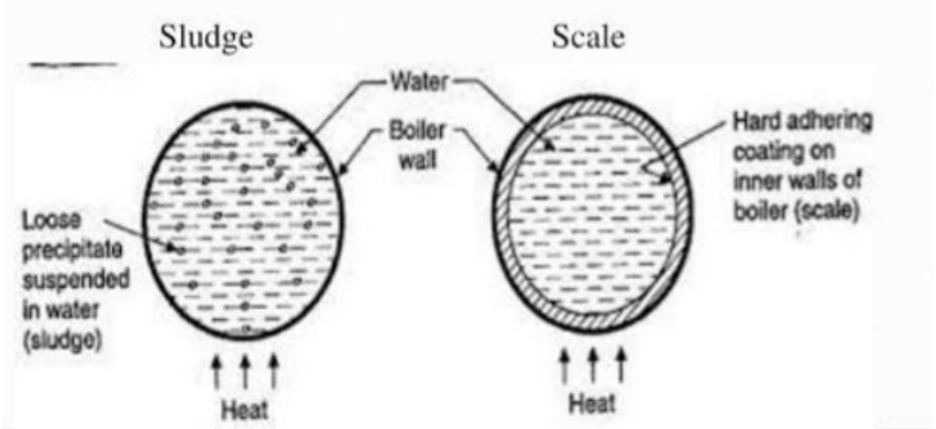
$$CaCO3 + H2O \rightarrow Ca(OH)2 + CO2$$

- In high pressure boilers, $CaSO4$, $CaSiO3$ and $MgSiO3$ are sparingly soluble in cold water.They are nearly insoluble in high temperature.

- Hydrolysis of magnesium salts.

$$MgCl2 + 2H2O \rightarrow Mg(OH)2 + 2HCl$$

- Presence of Silica: If small quantity of Silica is present it will deposit as calcium silicate or $MgSiO3$.



Boiler corrosion:

It is a process of destruction of metal under the influence of the environment by chemical or electrochemical attack. If untreated water is fed into the boiler, it often leads to corrosion of boiler metal & tubes. Boiler corrosion is a serious problem encountered in steam boiler.

Causes for boiler corrosion:

Due to dissolved oxygen

- The dissolved oxygen reacts with iron at about 350-4500C in the boiler and produces ferrous hydroxide.

  $2\ Fe + O_2 + 2\ H_2O \rightarrow 2\ Fe(OH)_2$

- Ferrous hydroxide oxidizes to ferric hydroxide by dissolved oxygen and deposits. This process repeats till all the dissolved oxygen is exhausted. The corroded parts are referred to as pits.

Due to dissolved CO2.

- Dissolved carbon dioxide release hydrogen carbonate upon interacting with water

  $H_2O + CO_2 \rightarrow H_2CO_3 \qquad H^+ + CO_3^- \rightarrow HCO_3^-$

- Further HCO_3^- may combine with Fe^{2+} giving $Fe(HCO_3)_2$ which decomposes giving $Fe(OH)_2$ and CO_2 thus continuing the process.l

  $Fe(HCO_3)_2 \rightarrow Fe(OH)_2 + 2CO_2$

Magnesium chloride:

- If it is present in boiler feed water can undergo hydrolysis producing HCl

  $MgCl_2 + H_2O \rightarrow Mg(OH)_2 + 2HCl$

- The liberated acid reacts with iron material of the boiler to form ferrous hydroxide which is converted to rust in the following way.

Control:

- As the boiler water is generally alkaline hence acid is neutralised. In case the amount of acid is more calculated quantity of alkali is added outside to prevent the corrosion

Sources of water pollution:

Main sources of water pollution are (i) Domestic and municipal sewage; (ii) Industrial waste; (iii) Agricultural waste; (iv) Radioactive materials, etc.

- **Domestic sewage** consists of human excreta, street wastes, organic substances that provide nutrition for bacteria and fungi. It is grey green or grey yellow in color and darkens with time due to decomposition, when becomes stale it develops offensive odor due to evolution of gases like NH3, H2S, etc. It is normally turbid due to the presence of suspended solids.
- A pollutant present in industrial waste water damages biological activities and kills many useful organisms. Most of the industrial wastes dissolved in water are particulate in nature and are present at the bottom of the water system. These acts as poison for the aquatic organisms. Further, toxic metals present in industrial effluents are extremely hazardous for living beings.
- **Agricultural discharge** consists of pesticides, fertilizers, insecticides, etc. In agriculture in order to increase the production and to escape the crops from various diseases, the fertilizers. Any substance or a mixture of substances which prevents, repels, destroys any pest is called a pesticide. These pollutants contaminate the water and when this is used by human being, affect the oxygen carrying capacity of hemoglobin and consequently causes suffocation and irritation to respiratory and vascular system.
- **Radioactive wastes** are mainly from atomic explosion and processing of radioactive materials near the source of water. The other sources are waste from hospitals, research laboratories, etc. The radioactive pollutants in water cause serious skin cancer, carcinoma, leukemia, DNA breakage, etc.
- Water pollution by heavy metals: Metallic elements with atomic numbers of 22 to 92 and atomic weight higher than that of sodium and with a specific gravity of more than 5.0, can cause pollution.

Biological Oxygen Demand:

- It is defined as the amount of oxygen required for the biological oxidation of the organic matter under aerobic conditions at 20°C and for a period of 3 to 5 days.

Characteristics of BOD

- It is expressed in parts per million (ppm) or mg/dm3.
- Larger the concentration of decomposable organic matter, greater is the BOD and consequently more is the nuisance value.
- Strictly aerobic conditions are required.
- Determination is slow and time consuming.

Chemical Oxygen Demand (COD)

COD is the amount of oxygen consumed in the chemical oxidation of organic and oxidisable inorganic wastes present in waste water sample in the presence of strong oxidizing agent in acid medium.

Determination of COD

Principle:

- A suitable aliquot of the sample is refluxed with a known excess of $K_2Cr_2O_7$ in sulphuric acid medium and in the presence of Ag_2SO_4 & $HgSO_4$. $K_2Cr_2O_7$ oxidizes all oxidizable impurities. Ag_2SO_4 catalyses the oxidation of straight chain organic compounds, aromatics and pyridine. Mercuric sulphate avoids the interference of Cl^- ions by forming soluble complex with them.

$$3CH_2O + K_2Cr_2O_7 + 8H_2SO_4 \longrightarrow 2K_2SO_4 + 2Cr_2(SO_4)_3 + 11H_2O + 3CO_2$$

- The amount of unconsumed $K_2Cr_2O_7$ is determined by titration with standard ferrous ammonium sulphate solution. The amount of potassium dichromate solution consumed corresponds to the COD of the sewage sample.

Procedure:

- To a measured volume of waste water sample taken in a flask, add 10 ml of 0.25 N $K_2Cr_2O_7$ solution, 1test tube dilute H_2SO_4, 1g of Ag_2SO_4 followed by 1 g of Hg_2SO_4.
- The conical flask is fixed with water condenser and the solution refluxed for 2 hours. The contents are cooled and titrated with standard ferrous ammonium sulphate solution using ferroin as an indicator till the bluish green turns sharply to reddish brown.
- Let the volume of titrant required to be a ml. Perform a blank titration taking the same amount of distilled water in place of the waste water. Let the volume required be b ml.

Calculations:-

Normality of ferrous ammonium sulphate = N
Volume of waste water sample = V ml
Volume of $K_2Cr_2O_7$ (in terms of FAS)
Required for the waste water sample = (b-a) ml
Normality of the COD of the sample = N X (b-a) X 8 / V gm. dm^{-3}

COD of the waste water sample = N X (b-a) X 8 X 1000 / V mg dm^{-3} or ppm

Significance of COD

- C.O.D is a water quality parameter for both organic and inorganic wastes (chemically oxidizable) in waste water.

- These are important in water treatment plants and industrial waste water studies. They give the pollution strength of industrial wastes.

Chemical analysis of water:

Determination of sulphate by gravimetric method:

Principle:

- This method gives the most accurate results and is the recommended procedure for sulphate concentration above 10mg/liter. The sulphate ions in the sample are precipitated by the addition of $BaCl_2$ solution to water sample, acidified with HCl and kept near the boiling point.

  $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$

- The $BaSO_4$ precipitate is filtered through Gooch crucible and weighed.

Procedure:

- Transfer 200 ml of water sample to a beaker and add Con HCl acid drop by drop until it is just acidic and add three drops in excess.
- Boil the sample to reduce the volume to 50 ml. Add hot Barium chloride solution (10%) slowly with constant stirring until all the sulphate is precipitated.
- Digest at temperature near the boiling point for a few hours, filter through Gooch crucible and wash the precipitate with hot distilled water until the washings are free from chlorides.
- Dry the precipitate and weigh as $BaSO_4$.

Calculation:
Weight of $BaSO_4$ formed = W g
233.3 g of $BaSO_4$ contains 96 g of SO_4
W g of $BaSO_4$ contains = 96 X W / 233.6 g of SO_4 = m g
Amount of SO_4 present per ppm = m X 1000 / 200 ppm of sulphate.

Determination of Fluoride by SPADNS method

Fluoride content in water is determined by colorimetric or spectrophotometric method.

Principle:

- Under acidic conditions, fluoride react with Zirconyl-SPADNS reagent and thecolor of SPADNS reagent [sodium 2-(p –sulphopheylazo)-1,8-dihydroxy 3-6 Naphthalene disulphonate] gets bleached.
- Bleaching is a function of fluoride ions and is directly proportional to the concentration of fluoride ions.
- This follows inverse of Lambertz-Beer law i.e the intensity decreases with the increase in concentration of fluoride

Procedure:-

- Prepare a series of standard solution of fluoride (NaF) in the concentration range 0 to 2 mg/liter (Take 5, 10, 15, 20, 25ml of standard NaF solution).Add 1 drop of $NaAsO_2$ solution (0.5%) to remove any residual chlorine to each of the standard solutions.
- Add 50 ml of distilled water and add 10 ml of zirconyl-SPADNS reagent in HCl to each of the standard solutions. Dilute up to the mark and mix well. Read the optical density of bleached color at 570 nm in the colorimeter against a blank without NaF solution..
- Draw a calibration curve by plotting concentration of fluoride versus absorbance.Take a suitable aliquot of water sample and repeat steps 2 and 3.Using the calibration curve, calculate the concentration of F- /liter. Knowing the volume test solution the unknown fluoride present in water is calculated.

Sewage & Sewage treatment:

- Sewage is commonly a liquid waste that is rejected after use. Sewage may be broadly classified into
- Domestic sewage: It is the waste water coming from buildings, institutions, residences etc., and contains solid wastes, organic matter, dissolved impurities and pathogenic bacteria.
- Industrial sewage: The waste water coming out of industrial establishments such as chemical plants, fertilizer industries, leather tanneries, sugar and paper industries, breweries, textile mill, oil refineries, pharmaceutical units is called an industrial sewage. Industrial sewage contains varieties of pollutants such as acids, alkalies, detergents, chemicals, zinc, lead, mercury, pesticides etc.,

Sewage treatment:

- Sewage treatment is carried out in three stages.

Primary treatment: -

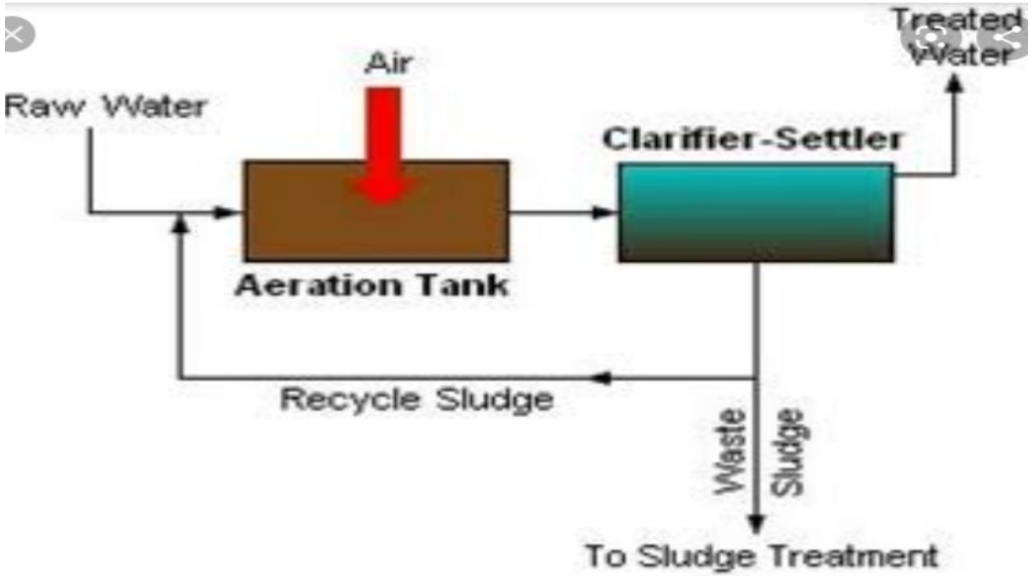
- Sewage contains floating, suspended and colloidal solids. In order to remove the coarse, suspended and floating matter, the sewage is passed through screens.
- Then it is passed through grid chambers (shallow rectangular tanks) when the grit (sand, broken glass etc.,) settled down.
- Then the waste water is passed in to sedimentation tank where the finely divided solids settle down. The sedimentation of colloidal particles is done by coagulation by treatment with coagulating agents like alum $FeCl_3$ etc

Secondary treatment :-

- (Activated sludge process) the sewage after primary treatment is subjected to secondary treatment. The most important process for secondary treatment is the activated sludge process.
- In this process the waste water from primary treatment is fed into a large tank containing activated sludge (the sludge that is biologically active and contains a large number of aerobic bacteria).
- It is then aerated and agitated for 4 to 10 hours, during which the organic wastes undergoes oxidation in the presence of oxygen and bacteria to form CO_2 & H_2O.

  Organic matter + O_2----------> CO_2 + H_2O + Biomass
- The sludge formed is allowed to settle, a part of it is recycled while the remaining is used as a fertilizer. The effluent is disposed off.

Diagram:



Tertiary treatment:

- The effluent coming from secondary treatment contains high concentration of phosphates, metal ions, and colloidal impurities. The tertiary treatment is carried out for further purification.
- The phosphates are removed by lime in the form of insoluble Ca3(PO4)2.
- The metal ions are removed by adding sulphide ions removed as metal sulphides.
- The colloidal impurities are removed by adding a coagulant such as alum.
- Pathogenic bacteria are destroyed by chlorination.

Softening of Water by Ion exchange process:

- The process of removal of all the associated ions from water by the application of ion exchange resin is known as demineralization of water.

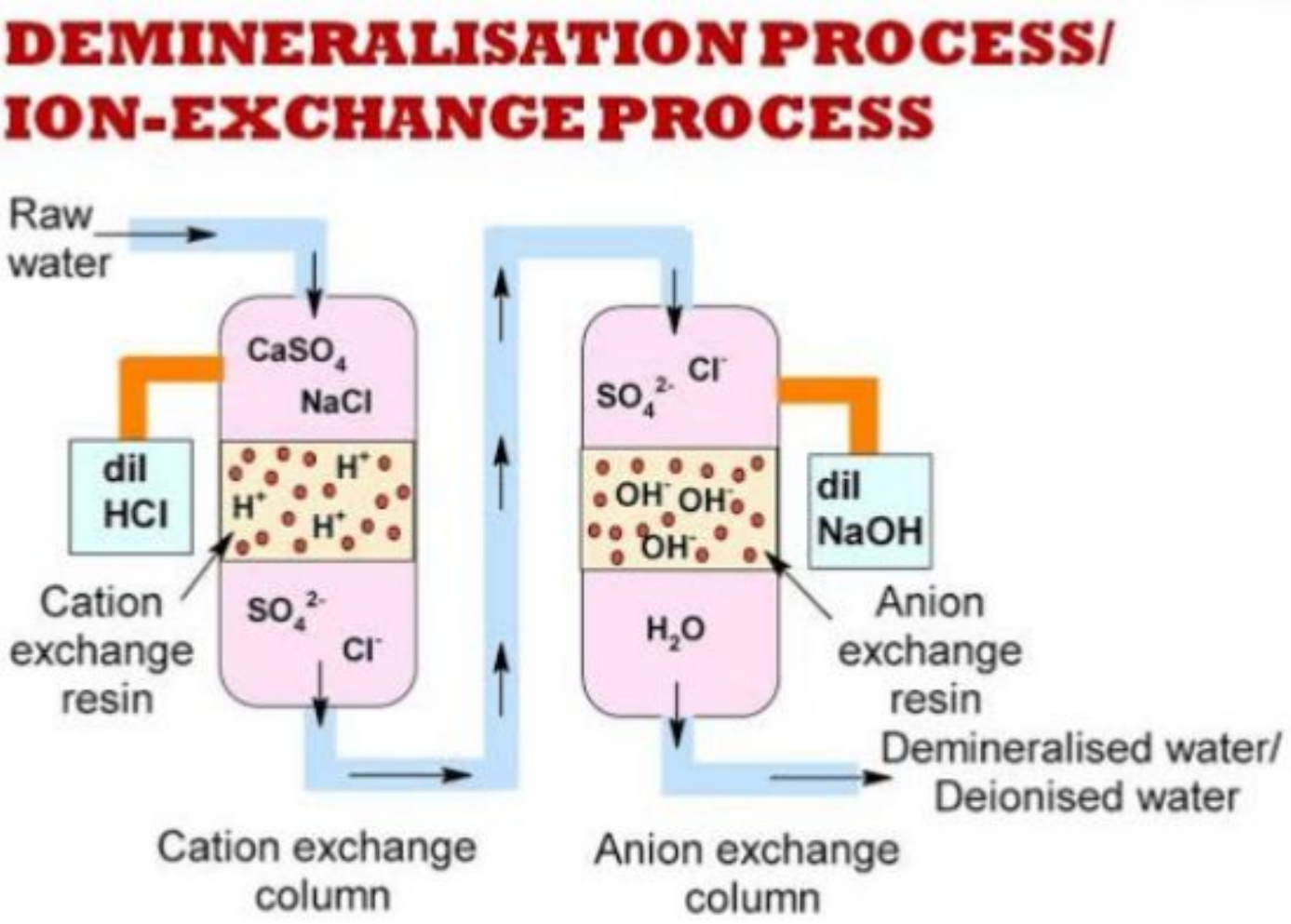
Principle of ion exchange process:

- In ion exchange process the impure water is passed through cation & anion exchange resin. Cation exchange resin is capable of exchanging cations present in water for H+ ions, i.e., when the water passes through the cation exchanger, the cation present in the water as impurities are retained by the resin & H+ ions are released into water. Anion exchange resin is capable of exchanging anions present in water for OH- ions, i.e., when water passes through the anion exchanger, the anions present in the water as impurities are retained by the resin & OH- ions are released into water.

Process

- The raw water is first passed through the column containing cation exchanger resin, in which the cations present in water are retained & H+ ions are released into water. The water coming out of the cation exchanger is acidic. The water coming from cation exchange column is then passed through the anion exchanger column. The column retains the anions present in water & releases OH- ions.
  As cations are replaced by H+ ions & anions by OH-, net effect is introduction of water in place of metal salts present in water.

Diagram:


DEMINERALISATION PROCESS/
ION-EXCHANGE PROCESS
Raw water
$CaSO_4$
NaCl
dil HCl
H^+
H^+
H^+
H^+
Cation exchange resin
SO_4^{2-}
Cl^-
Cation exchange column
SO_4^{2-}
Cl^-
OH^- OH^-
OH^-
dil NaOH
H_2O
Anion exchange resin
Demineralised water/ Deionised water
Anion exchange column

Desalination or desalting of sea water:

- The process of removal of dissolved salts from sea water to the extent, that water becomes usable known as desalination.
- Methods of Desalination or desalting of sea water: There are three important method of purification of water. Multistage flash evaporation ,Electro dialysis ,Reverse osmosis

Reverse osmosis:-

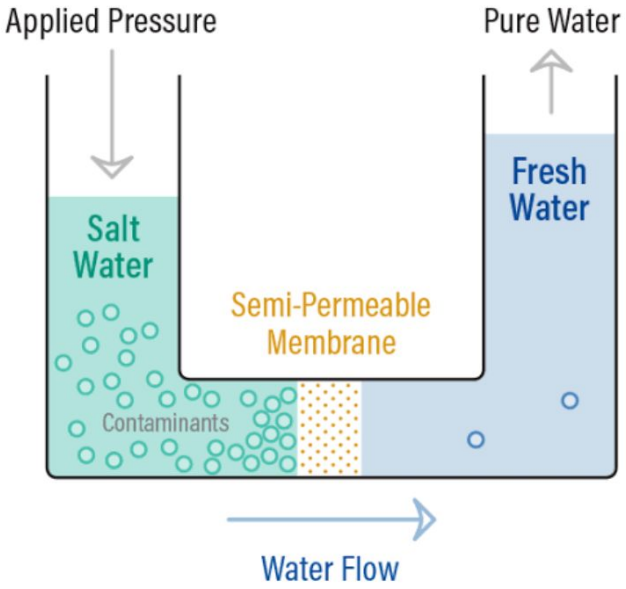
Principle:

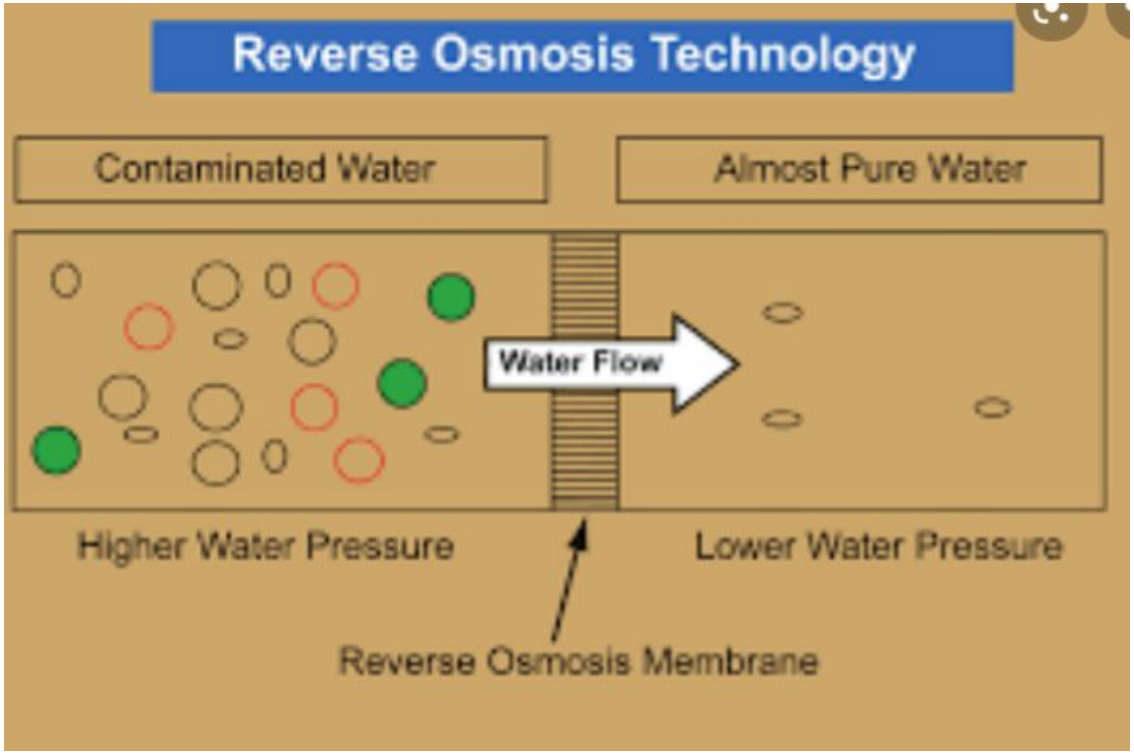
- In reverse osmosis process, the water is separated from dissolved salts by means of a membrane which permits the passage of water through it but not salts. If such a membrane is placed between the brine & pure water, water has tendency to flow through the membrane into the brine due to osmotic pressure.
- This natural process may be reversed by applying a pressure on the brine side higher side than that of osmotic pressure, when fresh water tends to flow from brine into fresh water. The process which reverses the natural spontaneous osmosis is called reverse osmosis.

Process:

- A reverse osmosis unit consisting of series of tubes made up of porous material is lined on the inside with extremely thin film of cellulose acetate semi permeable membrane. These tubes are arranged in parallel array in fresh water.
- Barkish water is pumped continuously at high pressure (>25atm) through these tubes. Water flow from barkish water into fresh water. The flow of water is proportional to applied pressure which in turn depends on the characteristics of the film. The film may rupture under excessive pressure.
- Further, greater the number of tubes, larger is the surface area & hence, more production of fresh water. Concentrated brine & fresh water are withdrawn through their respective outlets.

Diagram:


Applied Pressure
Pure Water
Salt Water
Fresh Water
Semi-Permeable Membrane
Contaminants
Water Flow


Reverse Osmosis Technology
Contaminated Water
Almost Pure Water
Water Flow
Higher Water Pressure
Lower Water Pressure
Reverse Osmosis Membrane