

MODULE 4

Module 4

ENVIRONMENTAL POLLUTION AND WATER CHEMISTRY

Environmental pollution:

Air pollution may be broadly defined as the presence of one or more contaminants like dust, smoke, mist, odour in atmosphere which are injurious to human beings, plants and animals. Sources of air pollution can be broadly classified into natural and anthropogenic. The natural sources include volcanic eruptions, releasing poisonous gas (such as SO₂, H₂S, CO), forest fires, natural organic and inorganic decay or vegetative decay, marsh gases, deflation of sand and dust, cosmic dust, pollen grains of flowers. All these are produced naturally and released in air making it foul and injurious to health. Anthropogenic sources are manmade sources such as increase in population, deforestation, burning of fossil fuels and fires, emissions from vehicles, rapid industrialization, agricultural activities and wars.

Primary air pollutants:

Carbon Monoxide (CO):

Carbon monoxide is a colorless, odorless toxic gas.

Sources: It is released by burning of charcoal and from automobiles.

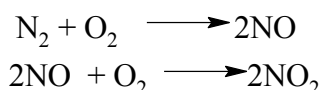
III Effects: Carbon monoxide interferes with the blood's ability to carry oxygen to brain, heart and other tissues and in particular dangerous for people having heart disease and for pregnant women which may cause stillbirths and deformed offspring. The carbon monoxide enters the lungs and combines with hemoglobin in the blood 200 times faster than oxygen to form carboxy haemoglobin. Hence human blood is deprived of oxygen. Low level of CO poisoning may lead to headache and dizziness. At high level may lead to difficulty in breathing, nausea or even death.

Control: It can be controlled by using catalytic converter, which converts toxic gases into nontoxic gas.

Oxides of Nitrogen:

Sources: Oxides of Nitrogen are produced when fossil fuel is burned especially in power plants, automobile exhaust and during lightening. These oxides of nitrogen compounds contribute to acid rain formation.

These NO_x effects plants and human health. High concentration of NO₂ effect leaves of plants and retard photosynthetic activity. A high dose of NO₂ causes internal bleeding, lung cancer, pneumonia and respiratory problems in humans.

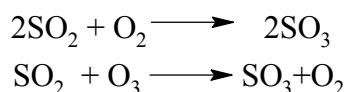


III Effects - These NO_x affects plants and human health. High concentration of NO₂ effect leaves of plants and retard photosynthetic activity. High doses of NO₂ cause internal bleeding, lung cancer, pneumonia and respiratory problems in humans.

Control - It can be controlled by using catalytic converter, which converts toxic gases into nontoxic gas.

Oxides of Sulphur:

Sources- Oxides of Sulphur are produced because of volcanic eruptions, vehicular exhaust and burning of sulphur containing fuels.



III Effects: These generate acid rain and damage plants, trees, buildings and also cause breathing problem, irritation to eyes, nose and throat.

Control - These can be controlled by using low sulphur content fuel or by using spray dryer absorber.

Hydrocarbons:

Sources: Automobiles constitute chief source of hydrocarbons. These are emitted by vehicles either as a result of evaporation or incomplete combustion of fuel.

III Effects: These are carcinogenic to lungs. They harm plants by causing aging, breakdown of tissues and shedding of leaves and flowers. Secondary pollutants produced by hydrocarbon and NO_x results in formation of photochemical smog which cause irritation to eyes, nose, throat. Hydrocarbons from vehicles can be controlled by applying techniques like incineration, absorption, adsorption and condensation.

Control: Hydrocarbons from vehicles can be controlled by applying techniques like incineration, absorption and condensation.

Particulate matter:

Sources: Particulate matter or PM is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke are large or dark enough to be seen with the naked eye. PM sources are derived from both human and natural activities. A significant portion of PM sources is generated from a variety of human (anthropogenic) activity. These types of activities include agricultural operations, industrial processes, combustion of wood and fossil fuels, construction and demolition activities, and entrainment of road dust into the air. Natural sources also contribute to the overall PM problem. These include windblown dust and wildfires.

III Effects: PM damages lungs.

Control: PM can be controlled using cyclone collectors, gravity setting chamber, filters, electrostatic precipitators and wet scrubbers.

Mercury:

Sources: Mercury is released in the course of industrial processes such as coal combustion, mercury-mining, manufacture of chlorine and caustic soda, metals processing, wastes management and incineration.

III Effects: Exposure to mercury and mercury compounds is harmful for human health, especially for foetus and children at early stages of development.

Control: Dumping Mercury in proper place.

Lead:

Sources: Lead is added to environment due to leaded gasoline, lead smelters, incineration of lead batteries, burning of lead contaminated waste oil.

III Effects: Exposure of high level of lead can cause damage of blood, brain, nerves, kidneys, reproductive organs and immune system. Low level of lead exposure can cause impaired mental functioning and development of children.

Control: The emissions of lead can be controlled using no lead in gasoline, avoiding lead smelters and using unleaded substitutes.

Secondary Air Pollutants:

Ozone: Ozone is colorless and high irritating gas.

Sources: Ozone is a secondary air pollutant and is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NO_x) and volatile organic compounds (VOC). This happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in the presence of sunlight. Ozone is harmful air pollutant at lower atmosphere and should not be confused with ozone in the upper atmosphere.

III Effects: Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and lung infection. Ozone present in the troposphere is also called as bad ozone. It is also a green house gas and major constituent of the urban smog.

Ozone depletion:

Ozone is a colourless gas which is found in the stratosphere of our upper atmosphere. The layer of ozone gas protects us from the harmful ultraviolet radiations of the sun. The ozone layer absorbs these harmful radiations and thus prevents these rays from entering the earth's atmosphere.

Sources: Ozone layer depletion, is simply the wearing out (reduction) of the amount of ozone in the stratosphere. Industries that manufacture insulating foams, solvents, soaps, Air

Conditioners, Refrigerators use chlorofluorocarbons (CFCs). These substances are heavier than air, but over a period of time they are carried high into the stratosphere by wind action. Depletion begins when CFC's get into the stratosphere. Ultra violet radiation from the sun breaks up these CFCs. The breaking up action releases Chlorine atoms. Chlorine atoms react with Ozone, starting a chemical cycle that destroys the good ozone in that area. One chlorine atom can break apart more than 100,000 ozone molecules.

III Effects: Ozone layer depletion may lead to skin cancer, aging of skin, damage to eyes and immune system.

Control: Ozone layer depletion can be prevented by avoiding (CFC & Hydrofluorocarbons) ozone depleted products.

Waste Management:

Solid waste:

It is defined as any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, discarded material including solid, semi solid liquid from an industrial, commercial, mining and agricultural operations and from community activities.

Sources:

Residential	Garbage, Food waste, paper, cardboard, plastic, textiles, leather, wood, glass, metal, yard waste, ash, tyres, batteries, old mattresses, used oil, etc
Industrial	Packaging material, construction and demolition material, hazardous wastes, ash, wood, steel, concrete, etc.
Commercial	Paper, card board, wood, food waste, glass, metal, hazardous waste, plastics, etc.
Institutional	Glass, rubber waste, plastics, food wastes, wood, paper, metals, cardboard materials, electronics as well as various hazardous wastes.
Construction and Demolition Areas	Steel materials, concrete, wood, plastics, rubber, copper wires, dirt and glass.

Physical Characteristics: This involves identification of individual component and analysis of particle size, moisture content and density.

Chemical Characteristics:

- It involves proximate analysis which consists of test such as moisture content, volatile combustible matter, fixed carbon and ash determination. It also involves fusion point of ash, ultimate analysis of solid component and energy content of solid component.

- It includes biodegradability of organic waste components, production of odours and breeding of flies.

Disposal methods:

1. **Scientific land filling:** A scientific landfill is constructed as a sustainable space for waste disposal and treatment of municipal solid waste. It ensures complete control over gas developed in the landfill and leachate (water that has infiltrated through a solid and leached out) as well as limited access of vectors such as rodents and flies to the waste.

- Simple, cheap, and effective method
- A deep trench (3 to 5 m) is excavated
- Refuse is laid in layers
- Layers are compacted with some mechanical equipment and covered with earth, leveled, and compacted
- With time, the fill would settle
- Microorganisms act on the organic matter and degrade them
- Decomposition is similar to that in composting
- Facultative bacteria hydrolyze complex organic matter into simpler water soluble organics
- These diffuse through the soil where fungi and other bacteria convert them to carbon dioxide and water under aerobic conditions
- Aerobic methanogenic bacteria utilize the methane generated and the rest diffuses into the atmosphere
- Too much refuse shall not be buried – fire hazard
- Moisture content – not less than 60% for good biodegradation
- Temperature in the initial stages of decomposition – as high as 70 degree C – then drops
- Reclaimed areas may be used for other uses
- Bottom of the trench is lined with impervious material to prevent the leachate from contaminating groundwater
- A well designed and laid out leachate collection mechanism is to be provided
- Leachate so collected is treated and then disposed off

2. Composting

- Similar to scientific landfilling
- Yields a stable end product – good soil conditioner and may be used as a base for fertilizers
- Popular in developing countries
- Decomposable organic matter is separated and composted

Methods: There are 2 methods of composting.

a. Open window composting

- Refuse is placed in piles, about 1.5m high and 2.5m wide at about 60% moisture content
- Heat build up in the refuse piles due to biological activity – temperature rises to about 70°C
- Pile is turned up for cooling and aeration to avoid anaerobic conditions
- Moisture content is adjusted to about 60%
- Piled again – temperature rises to about 70°C
- The above operations are repeated
- After a few days (~ 7 to 10 weeks) temperature drops to atmospheric temperature – indication of stabilization of compost

b. Mechanical composting

- Process of stabilization is expedited by mechanical devices of turning the compost
- Compost is stabilized in about 1 to 2 weeks
- To enrich compost – night soil, cow dung etc. are added to the refuse
- Usually done in compost pits
- Arrangements for draining of excess moisture are provided at the base of the pit
- At the bottom of the pit, a layer of ash, ground limestone, or loamy soil is placed – to neutralize acidity in the compost material and providing an alkaline medium for microorganisms
- The pit is filled by alternate layers of refuse (laid in layers of depth 30 – 40 cm) and night soil or cow dung (laid over it in a thin layer)
- Material is turned every 5 days or so
- After ~ 30 days – it is ready for use

3. Recycling and Reuse:

Recycling involves the collection of used and discarded materials, processing these materials and making them into new products. It reduces the amount of waste that is thrown into the community dustbins thereby making the environment cleaner and the air fresher to breathe.

The steps involved in the process prior to recycling include

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

Waste recycling has some significant advantages. It

- Leads to less utilization of raw materials.
- Reduces environmental impacts arising from waste treatment and disposal.

- Makes the surroundings cleaner and healthier.
- Saves on landfill space.
- Saves money.
- Reduces the amount of energy required to manufacture new products.

In fact recycling can prevent the creation of waste at the source.

E waste: E-waste refers to the generation of waste from the engineering world which is dominated by the use of electronic /electrical devices and equipment.

Sources of E-Waste: E-waste sources can be numerous. Electronic appliances like personal computers, DVD players, laptops, television sets, mobile phones, mp3 players, etc.

House hold appliances like washing machines, vacuum cleaners, toasters, drying machines, refrigerators, irons, air conditioners, coffee machines and related items.

Lighting fixtures and appliances such as sodium lamps, fluorescent tubes, sewing machines, surveillance equipments, lawn mowers, coin slot machines and even electronic toy products also form e-wastes.

Characteristics:

- E-waste consists of toxic metal like Hg, Pb, Cd, Cr which produces toxins.
- They are the sources of carcinogens like polychlorinated biphenyls, dioxins.
- They cause several health problems to all those who directly involve with the e-waste processing, as they contain radioactive isotopes. Health risks range from kidney disease and brain damage to genetic mutations.
- When e-waste sits in a typical landfill, for example, water flows through the landfill and picks up trace elements from these dangerous minerals. Eventually the contaminated landfill water, called “leachate,” gets through layers of natural and manufactured landfill liner and other protection. When it reaches natural groundwater, it introduces lethal toxicity.

Disposal methods:

Recycling and Reusing:

E-waste is a dangerous material to dispose of improperly and irresponsibly due to toxic heavy metals such as mercury and lead and corrosive chemicals. Recycling e-waste often leads to illegal overseas shipping and dumping. Devices get left in a huge pit or burned. The safest and most responsible disposal for your e-waste is at a designated e-waste drop off location.

Reusing is always better than recycling. If your electronics still have life left, you can reduce e-waste pollution and share technology with people who wouldn't otherwise have access to it.

The steps to be followed to manage e-waste:

- Upgrade your computer instead of simply replacing it

- Take out the batteries from your gadgets before getting rid of them
- Give Your Electronic Waste to a Certified E-Waste Recycler
- Sell Off Your Outdated Technology
- Donate Your Outdated Technology
- Safeguard Both the Environment and Your Sensitive Information

Biomedical Waste:

Medical care is vital for our life and health, but the waste generated from medical activities represents a real problem of living nature and human world. Improper management of waste generated in health care facilities causes a direct health impact on the community, the health care workers and on the environment. Every day, relatively large amount of potentially infectious and hazardous waste are generated in the health care hospitals and facilities around the world. Indiscriminate disposal of BMW or hospital waste and exposure to such waste possess serious threat to environment and to human health that requires specific treatment and management prior to its final disposal.

Any waste which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biological is called biomedical waste.

Sources: Hospitals / dispensaries, Primary health centers, Medical colleges and research centers, Veterinary colleges and animal research centers, Blood banks/mortuaries/autopsy centers, Biotechnology institutions, Production units, Blood donation camps, Physicians / dentists' clinics, Animal houses/slaughter houses, Acupuncturists/psychiatric clinics/cosmetic piercing, Vaccination centers, etc.

Characteristics:

Proper disposal of biomedical waste is of paramount importance because of its infectious and hazardous characteristics. Improper disposal can result in the following:

- Injuries from sharps to all categories of health care personnel and waste handlers.
- Increase risk of infections to medical, nursing and other hospital staff.
- Poor infection control can lead to infections in patients namely **HIV, Hepatitis B & C**.
- Increase in risk associated with hazardous chemicals and drugs being handled by persons handling wastes.
- Poor waste management encourages unscrupulous persons to recycle disposables and disposed drugs for repacking and reselling.
- Development of resistant strains of microorganisms.

Disposal methods:**Stage 1: Collection and Segregation**

The best practice for medical waste collection is at the point of generation. This approach reduces the risk of the waste spilling on its way from the generation site to the collection container. **For segregation purposes, bio-medical waste is traditionally classified into these 8 categories:**

- General waste: paperwork, food waste, packaging materials, etc.
- Radioactive waste: contaminated glassware and other waste from radiotherapy or lab research
- Pharmaceutical waste: unused, expired or contaminated medications
- Sharps: scalpels, needles, scissors, etc.
- Pathological waste: organs, tissues and body parts
- Infectious waste: items capable of transmitting an infection
- Chemical waste: cleaning agents, lab reagents and similar chemicals
- Pressurized containers: cylinders containing pressurized gas

Using the Right Containers

Use of the right collection containers based on the type of waste is crucial. Placing the wrong item in the wrong container may not only hinder safe disposal, but also pose risk of contaminating the environment or infecting staff or patients.

Stage 2: Storage and Transportation

Upon segregation, it is determined which waste is being picked up and disposed of through a medical waste removal vendor and which waste is reusable or can be disposed of on site. Storage areas should be chosen carefully and should be inaccessible to the general public.

Stage 3: Treatment and Disposal

There are different ways medical waste can be treated and decontaminated. Incineration is a common approach that can be used on site or off site to both treat and dispose of waste at the same time. However, you can also decontaminate waste with thermal processing (autoclaving), irradiative, chemical or biological (enzyme) treatments. Chemical treatment is often used to decontaminate liquid waste, so that it can be disposed of locally. The rest of the methods can be used to decontaminate waste before it can be land-filled.

WATER CHEMISTRY:

Sources of water are classified as

1. **Surface water**
2. **Underground water.**

Surface water is classified into

1. Rain water: Supposed to be the purest form, but contains gases, suspended solids, etc.
2. River water: Contains Cl^- , SO_4^{2-} , bicarbonates of Na, Ca, Mg, Fe, organic matter, etc.
3. Lake water: Contains organic matter.
4. Sea water: The most impure form of natural water contains 3.5% of dissolved salts, like NaCl, sulphates of Na, bicarbonates of K, Mg & Ca, KBr, MgBr, etc.

Underground water includes spring & well water, clean due to filtering action of soil, contains some dissolved salts.

Impurities in water: Impurities of water depend on the source. The major types are,

1. **Dissolved gases:** CO_2 & O_2 are the dissolved gases. Water may also contain NH_3 & S-compounds like H_2S which gives foul smell to water.
2. **Dissolved solids:** The soluble salts of Ca, Mg, Na, oxides of Mn, Fe, Pb, Arsenic, etc.
3. **Suspended Impurities:** Solid particles can be removed by filtration or settling. There are 2 types.
 - a. **Organic Impurities:** Wood pieces, particles of dead animals, leaf, fishes, bacteria, algae, protozoa, etc., impart turbidity to water.
 - b. **Inorganic Impurities:** Clay, silica, oxides of Fe, Mn, etc.
4. **Microscopic matter:** Pathogenic bacteria & micro organisms cause water borne diseases.

Boiler feed water:

A boiler is a closed vessel in which water under pressure is transformed into steam by the application of heat. The water used in boilers is called boiler feed water. The steam generated should be pure and uncontaminated and is used for purposes like power generation, sterilization, drying, process heating, etc.

Boiler troubles:

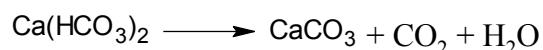
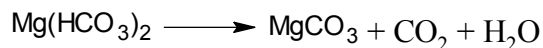
The impurities present in boiler feed water bring problems to boiler and reduce its efficiency. The major boiler problems are 1. Scale and sludge formation, 2. Priming and foaming, 3. Boiler corrosion.

1. Scale and sludge formation: During production of steam, water is heated under high pressure to high temperature, which causes the water to evaporate. Hence the impurities present in water get highly concentrated. When they reach a saturation level, they get precipitated in the form of an adherent deposit, termed as **scale**, or a loose silky precipitate, called **sludge**.

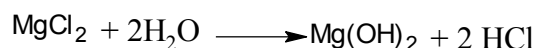
Causes for scale formation:

These deposits stick to the inner wall of the boiler and are difficult to remove. The various dissolved salts of water contributing for scale formation are CaSO_4 , $\text{Ca}(\text{HCO}_3)_2$, $\text{Mg}(\text{HCO}_3)_2$, MgCl_2 and silica.

- CaSO_4 is soluble in water but as the temperature increases, its solubility decreases. Hence at very high pressure and temperature, it gets precipitated and deposits on the walls of the boiler.
- If bicarbonates are present as impurities, they precipitate as their highly insoluble carbonates.



- Magnesium salts present in dissolved form in water get precipitated as their hydroxides at high temperature.



- Impurities in water in the form of silicates of Ca and Mg are slightly soluble in normal water but highly insoluble in hot water, and they precipitate and deposit as scale.

Disadvantages of scale formation:

- **Danger of scale formation:** Scales form a coating on the inner walls of the boiler. When the boiler is heated, the metal gets heated up faster than the scales. The metal takes up heat and expands, while the scales do not expand much. Hence the scales crack, water enters through the cracks and comes in contact with the hot metal and immediately forms steam. This steam exerts a pressure on the boiler walls, which may crack under pressure and burst.
- **Lowering of boiler efficiency:** Boiler parts may get choked by deposition of scales, thus lowering the efficiency of boilers.
- **Wastage of fuel:** Scales being insulators do not conduct heat to the boiler water. Thus there is wastage of fuel.
- **Increase in cleaning expenses:** Scales need to be cleaned often; hence the cleaning expense is major.

Causes for sludge formation: Sludge is a loose accumulation of suspended solids, found in the colder and less turbulent sections of the boiler and in the distribution pipes. It is formed by substances that have greater solubility in hot water than in cold water, like MgCl_2 , MgCO_3 , MgSO_4 , CaCl_2 , etc. if sludge is not removed periodically, it may settle down to form scales.

Disadvantages of sludge formation:

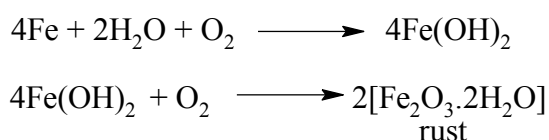
- Colder parts of the boiler and distribution lines may get plugged by sludge.
- Waste of fuel, as sludge is a bad conductor of heat.
- Sludge lowers the boiler efficiency.
- Sludge causes an increase in cleaning expenses.

Prevention Methods:

The scale and sludge formation is mainly due to the presence of salts of Calcium and Magnesium ions. Therefore, the scale & sludge formation in boilers can be prevented by eliminating these metal ions from boiler feed water. Hence boiler feed water is subjected to suitable treatments like ion exchange process, desalination, etc.

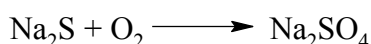
Boiler corrosion: Boiler corrosion is a decay process in which the boiler surface gets degraded by the attack of feed water. It is caused due to the presence of dissolved gases such as oxygen and CO₂ in the boiler feed water.

Raw water has about 8-9 ppm of dissolved oxygen. Oxygen levels of more than 7 ppm causes boiler corrosion. The dissolved oxygen can attack the iron in the boiler and produce rust.



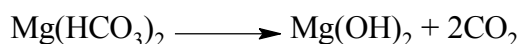
The boiler corrosion caused by the presence of dissolved oxygen can be prevented by eliminating oxygen from boiler feed water. The dissolved oxygen is removed by chemical treatment or mechanical de-aeration.

Chemical treatment: Addition of reducing agents to boiler water removes dissolved oxygen.

**Mechanical de-aeration:**

Dissolved oxygen can also be removed by mechanical method. The water is made to trickle through a series of perforated hot plates fitted in a large chamber called de-aerator. The de-aerator is heated externally and connected to a vacuum pump to remove oxygen.

Dissolved CO₂ is found in the boiler water either from air or due to the presence of residual temporary hardness.

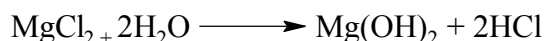


It dissolves in water to produce carbonic acid, which is slightly acidic and corrosive in nature.

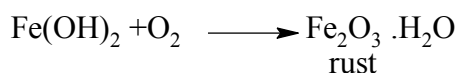
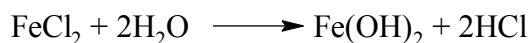
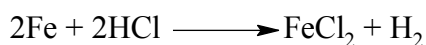


Carbon dioxide can be eliminated from boiler water by the addition of calculated amount of ammonia.

If **magnesium chloride** is present in boiler feed water, on hydrolysis it produces HCl.



HCl produced reacts with iron materials of the boiler to form ferrous hydroxide, which on oxidation forms rust.



Presence of residual alkali in the boiler water may lead to caustic embrittlement at the stressed regions of the boiler. Hence to avoid boiler problems, it is desirable to treat the boiler feed water before feeding to boilers.

Sources of water pollution:

Direct sources include effluent outfalls from factories, refineries, waste treatment plants etc. that emit fluids of varying quality directly into urban water supplies.

Indirect sources include contaminants that enter the water supply from soils/groundwater systems and from the atmosphere via rain water. Soils and groundwater contain the residue of human agricultural practices (fertilizers, pesticides, etc..) and improperly disposed of industrial wastes. Atmospheric contaminants are also derived from human practices (such as gaseous emissions from automobiles, factories and even bakeries).

Biological oxygen demand (BOD):

It is defined as the amount of oxygen required for biological oxidation of organic matter present in one litre of waste water at 20°C over a period of 5 days. The unit of BOD is mg/dm³ or ppm.

It indicates the amount of decomposable organic matter present in sewage.

Chemical oxygen demand (COD):

COD is defined as the amount of oxygen required to oxidize the total oxidizable impurities present in one litre of sewage water using strong oxidizing agent like acidified K₂Cr₂O₇.

It is represented in mg/dm³ or ppm. COD value is always greater than BOD, since COD includes both biologically oxidizable & non oxidizable impurities.

Determination of COD

Principle: A known volume of sewage sample is refluxed with a known excess of potassium dichromate in H₂SO₄ medium and in the presence of Ag₂SO₄ and HgSO₄. Potassium dichromate oxidizes all oxidizable impurities. Silver sulphate catalyses the oxidation of straight chain organic compounds, aromatics & pyridine. Mercuric sulphate removes chloride ions by forming

a precipitate with them. The unconsumed potassium dichromate is determined by titration with standard ferrous ammonium sulphate solution. The amount of potassium dichromate consumed corresponds to the COD of the sample.

Procedure:

A known volume of sewage water is taken in a conical flask. 1g of HgSO_4 and 1g of Ag_2SO_4 are added; a known volume of potassium dichromate solution is also added & acidified with sulphuric acid. The conical flask is fixed with a water condenser and the solution is refluxed for 2 hours. The contents are cooled and titrated with standard ferrous ammonium sulphate solution using ferroin indicator, till the color changes from bluish green to reddish brown.

Blank titration: The above procedure is repeated by taking same volume of distilled water in place of sewage water.

Calculation:

Volume of waste water sample = V ml

Volume of standard FAS consumed in sample titration = A ml

Volume of standard FAS consumed in blank titration = B ml

Normality of FAS solution = N

Hence amount of $\text{K}_2\text{Cr}_2\text{O}_7$ consumed for the oxidation in terms of FAS solution = (B – A) ml

$$\begin{aligned} \text{Therefore Normality of water sample} &= \frac{N \times (B-A)}{V} \quad \left[\begin{array}{l} N_1 \times V_1 = N_2 \times V_2 \\ \text{i.e, } N_1 \times V = N \times (B-A) \end{array} \right] \\ &= \frac{N \times (B-A) \times 8}{V} \text{ g / dm}^3 \end{aligned}$$

$$\text{i.e, COD of the sample} = \frac{N \times (B-A) \times 8 \times 1000}{V} \text{ mg / dm}^3$$

Problems:

Chemical analysis of water:

Determination of sulphate by gravimetric method:

Principle:

The sulphate ions in the water sample are precipitated by the addition of barium chloride solution to water sample acidified with hydrochloric acid and kept near the boiling point.



The BaSO_4 precipitate is filtered through Gooch crucible and weighed.

In alkaline water near the boiling temperature BaCO_3 may precipitate and to avoid this, the water sample is acidified. The precipitate of BaSO_4 is highly insoluble and it has the tendency to

form in a colloidal condition which cannot be removed by ordinary filtration process. To convert the colloidal form of BaSO_4 to crystalline form the precipitate is digested for few hours near the boiling point.

Procedure:

200ml of water sample is transferred to a beaker and concentrated hydrochloric acid is added drop wise until it is just acidic. Three drops of hydrochloric acid is added in excess. Water sample is boiled and the volume is reduced to 50ml. Hot barium chloride solution is slowly added with constant stirring until all the sulphate precipitates. It is then digested at temperatures near the boiling point for a few hours and filtered through a Gooch crucible. The precipitate is washed with hot distilled water until the washings are free from chlorides. The precipitate is dried and weighed as BaSO_4 .

Calculation:

Weight of $\text{BaSO}_4 = W \text{ g}$

233.3g of BaSO_4 contains 96.0g of SO_4^{2-}

$$W \text{ g of } \text{BaSO}_4 \text{ contains } \frac{96 \times W}{233.3} \text{ g of } \text{SO}_4^{2-} = 'm' \text{ g}$$

$$\text{Amount of sulphate present in a litre of water sample} = \frac{'m' \times 1000}{200} \text{ mg / L}$$

Determination of fluoride by Colorimetric method:

Principle

Under acidic conditions fluoride reacts with complex of zirconium with an organic reagent SPADNS [sodium-2-(parasulphophenylazo)-1,8-dihydroxy-3,6-naphthalene disulphonate] and dissociates a portion of it into a colorless anion $[\text{ZrF}_6]^{2-}$ and the reagent.

As the amount of fluoride is increased, the color produced by Zr-SPADNS complex becomes lighter. A calibration curve is obtained by treating a series of standard solutions of fluoride with the complex, measuring the absorbance and by plotting absorbance verses concentration of fluoride.

By measuring the absorbance of the sample after treating with the reagent complex, the amount of fluoride present in the sample of water can be determined. The interfering ions are removed by distillation.

Procedure:

Preparation of the reagent:

950 mg of SPADNS is dissolved in distilled water and is diluted to 500ml. 133 mg of Zirconyl chloride octahydrate ($\text{ZrCl}_2 \cdot 8\text{H}_2\text{O}$) is dissolved in 25 ml of distilled water and 350ml of

concentrated HCl is added and diluted to 500ml with distilled water. Equal volumes of SPADNS solution and Zirconyl acid reagent are mixed.

Preparation of calibration curve:

0.221g of anhydrous sodium fluoride is dissolved in water and diluted to 1 litre. 1, 2, 3....8 ml of this solution is pipetted out into 50 ml standard flasks. 10 ml of Zirconyl – SPADNS reagent is added to all the standard flasks, made up to the mark with distilled water and shaken well.

A reference solution is prepared by adding 10 ml of SPADNS solution to 100 ml distilled water to which HCl solution is added. This solution is used to set zero in the colorimeter at 570 nm. The absorbance of the standard solutions is measured at 570 nm wavelength. A calibration curve of absorbance verses concentration is plotted.

A known volume of water sample is pipetted out into a 50 ml standard flask. 10 ml of Zirconyl – SPADNS reagent is added to it, made up to the mark and shaken well. The absorbance is measured as before. From the calibration curve concentration of fluoride in the test solution can be determined.

Sewage treatment:

The domestic sewage contains biologically oxidizable impurities, pathogenic bacteria, color and smell. If it is discharged into water body, it gets contaminated causing

- Decrease in dissolved oxygen, destroying fish and other aquatic life.
- Color & smell
- Water borne diseases.

The domestic sewage therefore needs proper treatment before it is discharged. The treatment involves three steps.

- Primary treatment
- Secondary treatment
- Tertiary treatment

1. Primary treatment: It involves four steps.

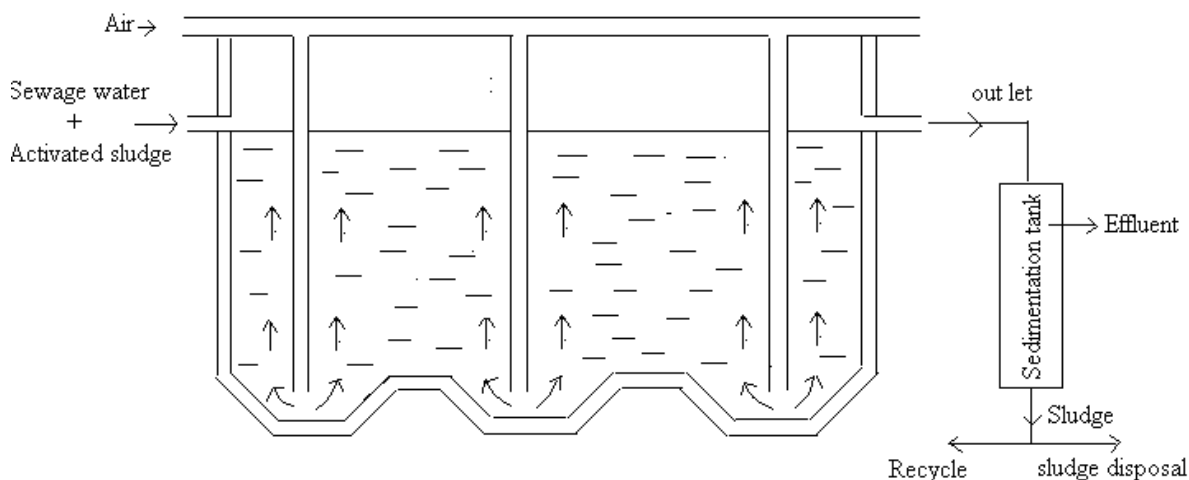
a. Screening: It is a process in which large suspended & floating matter is removed by passing water through mesh screens.

b. Silt and grit removal: The sewage is passed through grit chambers, where silt (clay) & grit (sand, broken glass) particles settle down at the bottom.

c. Removal of oil & grease: Sewage is passed through large skimming tanks, where compressed air is blown through it. Oil & grease form foam, floats on surface, which is skimmed off.

d. Sedimentation process: It removes fine suspended impurities. Sewage water is passed through sedimentation tanks where coagulants like alum, ferrous sulphate etc. are added, which help in easy settlement of finely suspended particles.

2. Secondary treatment (Biological treatment) by activated sludge process:

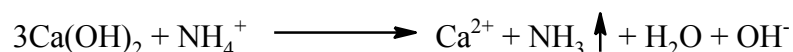
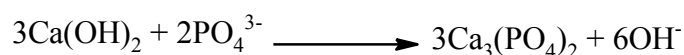


Activated sludge process is a biological process, in which the sedimented sewage water is mixed with proper quantity of activated sludge containing large number of aerobic bacteria and other microorganisms. The mixture is sent to the aeration tank, in which the mixture is exposed to air and agitated for several hours. During this process the microorganisms and aerobic bacteria oxidize the organic matter into nitrates, nitrites, sulphates, and phosphates etc. which do not produce any offensive smell. After the process is complete the effluent is sent to a sedimentation tank where sludge settles down and water free from organic matter is removed. This water is chlorinated to remove bacteria and discharged into lakes, streams, rivers and sea. A part of the sludge is reused and the rest is used as fertilizer.

3. Tertiary treatment:

Further purification of waste water is done by this process, which involves 5 steps.

a. Removal of phosphate: The phosphates are removed by adding Ca(OH)_2 at pH of 10-11. At this pH ammonium salts are converted into ammonia.



b. Coagulation and sedimentation: The suspended particles are removed by adding coagulants like alum, ferrous sulphate etc. A precipitate of Al(OH)_3 or Fe(OH)_2 is formed, settles down & separated.

c. Filtration: Water is passed through sand filter beds to remove last traces of suspended matter.

d. Degasification: The degasifier consists of a large tower fitted with a number of perforated plates. Water is allowed to trickle down through these plates. Large surface area and higher temperature promote removal of dissolved gases like NH_3 , CO_2 , H_2S etc.

e. Disinfection: The pathogenic bacteria are destroyed by adding disinfectants like chlorine.

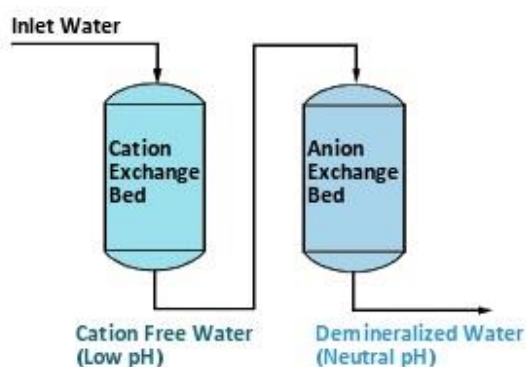


HOCl attacks bacteria and kills them. The final composition of treated waste water is $\text{BOD} < 1\text{ppm}$, $\text{NH}_4^+ < 1\text{ppm}$, $\text{PO}_4^{3-} < 1\text{ppm}$. The treated water has high clarity, free from odour, low BOD, and therefore it is nearly equivalent to drinking water and can be recycled.

Softening of water by ion exchange process:

Ion exchange process is the process of softening of water by exchanging the harmful ions of water with harmless ions from an ion exchange resin. The process is also called demineralization of water.

Ion exchange resins are high molecular weight, cross-linked polymers with a porous structure. The ion exchange properties arise due to the presence of acidic (sulphonic or carbonyl) or basic (substituted amino group) functional groups present attached to the polymeric chains. The acidic groups exchange their H^+ ions for cations (Ca^{+2} , Mg^{+2}) present in water and are known as cation exchange resins. The basic groups exchange OH^- for anions present in water and are known as anion exchange resins. The H^+ and OH^- ions released combine to form demineralised water.



In the process, the cation and anion exchange resins are packed in separate columns. The water is first passed through the cation exchange resin where cations like Ca^{+2} , Mg^{+2} are exchanged with H^+ . It is then passed through anion exchange resin where ions like SO_4^{-2} , Cl^- etc. are exchanged with OH^- . The sequence of water flow is important and cation exchange resin needs to be used first. This is because if water is first passed through anion exchange resin, alkali is produced which can harm the cation exchange resin in the subsequent step. When resins are exhausted and lose their capacity to exchange H^+ and OH^- ions, they are regenerated. The exhausted cation exchange column is regenerated by passing a solution of dilute HCl or H_2SO_4 .

and then washing with deionized water. Similarly, anion exchange resins are regenerated by passing a solution of ammonium hydroxide or sodium hydroxide and then washing with deionized water.

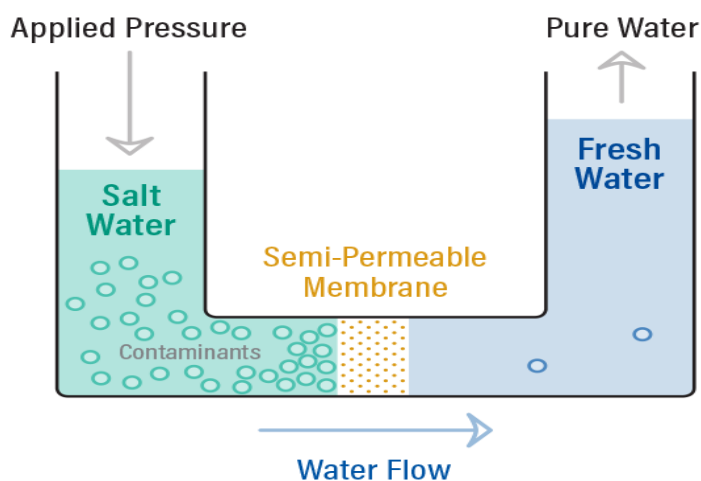
Desalination of sea water by Reverse osmosis:

When a semi permeable membrane is placed between brine and pure water, water has a natural 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 than that of osmotic pressure so that fresh water tends to flow from brine into fresh water side. This process is called reverse osmosis.

Process: Tubes made up of porous material with thin film of cellulose acetate semi permeable membrane are arranged parallel to each other in fresh water as shown in the figure.

Salt water is pumped continuously at high pressure through these tubes. Water flows from salt water into fresh water. The flow of water depends on the applied pressure and on the characteristics of the film. The film may rupture under excessive pressure. If the osmosis unit consists of many tubes with larger surface area, more fresh water is produced. Concentrated brine and fresh water are withdrawn through their respective outlets.

Reverse Osmosis



Advantages:

- Process is simple & continuous.
- No phase changes.
- Needs extremely low energy.

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Associate Professor
Dept. of Chemistry
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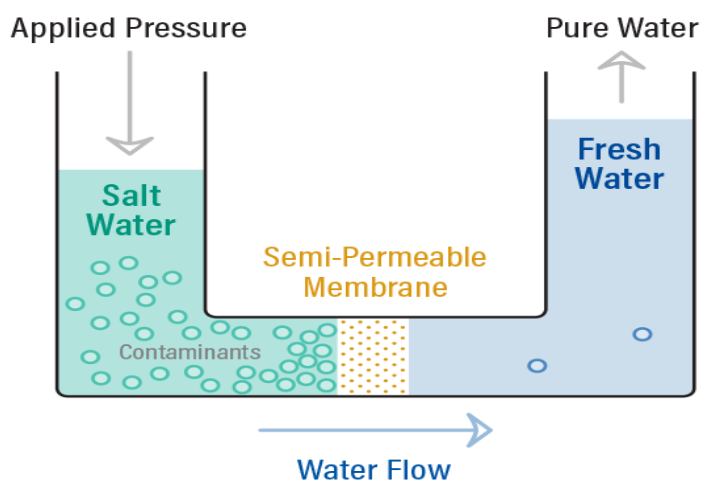
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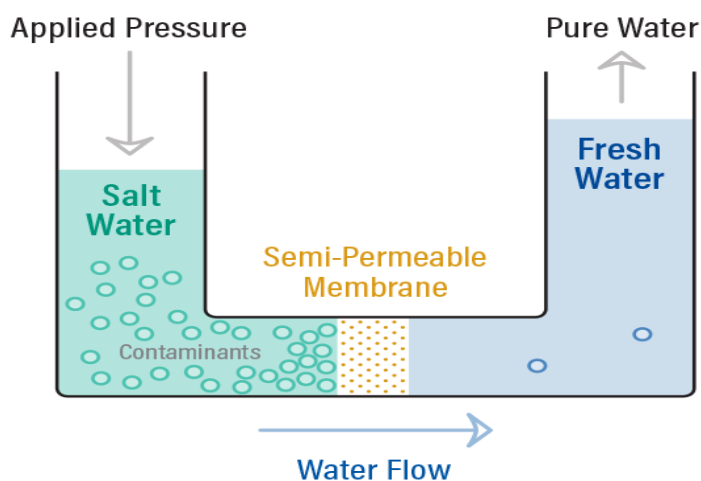
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