



**Maharaja Institute of Technology Mysore**  
**Department of Chemistry (18CHE12/22)**



**MODULE – 4 : ENVIRONMENTAL POLLUTION & WATER CHEMISTRY      10 Hours**

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**Environmental Pollution:** Air pollutants: Sources, effects and control of primary air pollutants: Carbon monoxide, Oxides of nitrogen and sulphur, hydrocarbons, Particulate matter, Carbon monoxide, Mercury and Lead. Secondary air pollutant: Ozone, Ozone depletion.

**Waste Management:** Solid waste, e-waste & biomedical waste: Sources, characteristics & disposal methods (Scientific land filling, composting, recycling and reuse)

**Water Chemistry:** Introduction, sources and impurities of water; boiler feed water, boiler troubles with disadvantages -scale and sludge formation, boiler corrosion (due to dissolved  $O_2$ ,  $CO_2$  and  $MgCl_2$ ). Sources of water pollution, Sewage, Definitions of Biological oxygen demand (BOD) and Chemical Oxygen Demand (COD), determination of COD, numerical problems on COD. Chemical analysis of water: Sulphates (gravimetry) and Fluorides (colorimetry). Sewage treatment: Primary, secondary (activated sludge) and tertiary methods. Softening of water by ion exchange process. Desalination of sea water by reverse osmosis

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**Environmental Pollution**

Pollution may be defined as the excessive discharge of undesirable substances into the environment, thereby adversely altering the natural quality of the environment and causing damage to human, plants and animals life.

Cause of Pollution:

- Uncontrolled growth of population
- Rapid urbanization
- Exploitation of nature like cutting trees
- Natural calamities like volcanic eruptions and forest fires, etc.

Types of pollution: Mainly classified into three types on the basis of the part of environment affected:

1. Air pollution
2. Water pollution
3. Land / soil pollution

**1. Air pollution:**

Air pollution may be defined as the excessive discharge of undesirable foreign substances into the atmospheric air, thereby adversely affecting the quality of air and causing damage to human, plants and animal lives. Air pollutants are classified into two major categories

- Primary air pollutants
- Secondary air pollutants

### Primary air pollutants:

The pollutants that are directly discharge /emitted into the atmosphere through natural or human activity are called primary air pollutants. Some of the primary air pollutants are:

1. Carbon monoxide
2. Oxides of nitrogen
3. Oxides of Sulphur
4. Hydrocarbons
5. Particulate matter
6. Mercury
7. Lead.

### Sources, effects and control of primary air pollutants

#### 1. Carbon monoxide

Sources: It is produced by the incomplete combustion of carbon containing fuels such as gasoline, coal, wood and from industries.



It is colorless, odorless, tasteless, non-corrosive and toxic in nature.

Effects:

- Increase in the concentration of Carbon Monoxide, reduces the oxygen transport in hemoglobin causes headache, increase risk of chest pain with heart diseases, paralysis and even death in human beings.
- It also effects impairing the transfer of oxygen to the tissues (abnormal gas exchange).
- Increase in the concentration of carbon monoxide tends to topological meteorological characteristics that exacerbate the pollution.

Control:

- Modification of internal combustion engines.
- Development of exhaust system reactors, which will complete the combustion process and change potential pollutants into more accepted materials.
- Development of substitute fuels for gasoline which will yield low concentration of air pollutants upon combustion.
- Development of pollution free power sources such as fuel cells to replace the internal combustion engine.

#### 2. Oxides of Nitrogen: Nitric Oxide (NO) and Nitrogen Dioxide (NO<sub>2</sub>) are referred together as oxides of nitrogen (NO<sub>x</sub>).

Sources:-

- When fossils fuel is burnt, di-nitrogen and di-oxygen combine to yield significant quantities of nitric oxide (NO<sub>x</sub>) and Nitrogen dioxide.  
$$N_2 + O_2 \rightarrow 2NO$$
$$2NO + O_2 \rightarrow 2NO_2$$
- It is also produce naturally by lightening.
- Other sources are acid manufacture, explosive industries and acid pickling plants.

Effects:-

- Elevated levels of nitrogen dioxide cause damage to human respiratory track. Severity of respiratory infections can cause bronchitis allergy and asthma.
- Long term exposure of high level nitrogen di-oxide can cause chronic lung diseases.
- It is unpleasant odor and leads to irritation of eyes and lungs congestion.

Control:-

Removal of nitrogen content in coal by physical cleaning (washing) before combustion is not possible, as nitrogen content of fuel is combined with organic matter of the fuels. There are several methods to reduce the oxides of nitrogen during and after combustion.

a) Removal of oxides nitrogen during combustion:

A Low NO<sub>x</sub> burner ensures the initial combustion with low oxygen concentrations, such that any gaseous nitrogen is reduced to N<sub>2</sub> without oxygen. Once initial combustion takes place further air is added to the combustion chamber to ensure complete combustion of fuel. This greatly reduces the opportunities for NO<sub>x</sub> production. Advances low NO<sub>x</sub> burners can reduce NO<sub>x</sub> concentration by up to 30%.

b) Removal of Oxides of nitrogen after combustion:

During the combustion, the emissions of NO<sub>x</sub> generated that can be reduced by treating the fuel gases. Some of the methods are

- Selective catalytic reduction (SCR): When ammonia is injected into the fuel gas, the nitrogen oxides present in the fuel gases reacts with ammonia in presence of catalyst like vanadium or tungsten oxide at low temperature of 300 C – 400 C and that are converted into nitrogen and water.



- Sorption: Treatment of fuel gas by injection of Sorbents (such as ammonia, powdered limestone, aluminum oxide or carbon) can remove NO<sub>x</sub> and other pollutants (principally Sulphur). There have been successful efforts to make sorption products a marketable commodity.

**3. Oxides of Sulphur:** Sulphur Dioxide (SO<sub>2</sub>) and Sulphur Trioxide (SO<sub>3</sub>) are referred as Oxides of Sulphur (SO<sub>x</sub>).

Sources:-

- When Sulphur containing fuel is burnt.  $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$
- It is formed by the oxidation of Sulphur dioxide under the influence of sunlight  
 $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$
- Petroleum industries, oil refineries, Sulphuric acid plants and Sulphide ore-roasting plants.

Effects:-

- Sulphur Dioxide is a gas that is poisonous to both animals and plants.
- Cardiac, pulmonary disease, eye irritation and throat problems.
- Even at low concentration of Sulphur causes respiratory diseases.

- It damages plant cells and membranes, Chlorophyll, metabolism leading to growth yield reduction.
- Corrosion of metals.
- The oxidation of SO<sub>2</sub> occurs which reacts with water to form Sulphuric acid.

Controls:-

Sulphur on coal is present in both on inorganic and organic forms. Largest amount of Sulphur is removed by crushing and washing the coal before combustion. There are several methods available to control oxides of Sulphur.

- Removal of SO<sub>3</sub> from fuel gas:
  - Absorb SO<sub>2</sub> on a suitable absorbent (Sodium Aluminate) to form a stable sulphate.
  - Absorb SO<sub>2</sub> from fuel gas and activated carbon followed by regeneration and conversion to Sulphuric acid or elemental Sulphur.
- Use of Sulphur free nuclear power to generate electricity.
- Switch to natural gas.
- The emission of SO<sub>2</sub> is controlled by using a spray dryer absorber or by passing through calcium hydroxide solution.

#### 4. Hydrocarbons:

Sources:

- Hydrocarbons are composed of hydrogen and carbon only and are formed by incomplete combustion of fuel used in automobiles and industrial exhaust.
- Methane naturally occurring hydrocarbon emitted into the atmosphere in large quantities. It is produced by bacterial through anaerobic decomposition of organic matter.



Effects:

- At high concentration, hydrocarbons are carcinogenic i.e. they cause cancer.
- They harm plants by causing aging; breakdown of tissues and shedding of leaves and flowers.
- Methane benzopyrene create narcotic effect in human beings.
- Cyclic hydrocarbons affect nervous system.
- Inhalation of vapors of benzene, toluene etc. cause irritation to the mucous membrane.

Control:

Hydrocarbons from auto exhaust can be controlled by process such as incineration, adsorption and absorption etc.



**5. Particulate Matter:** Small solid particles and liquid droplets are collectively called as particulates present in the atmosphere in a large quantity and cause serious air pollution. Its range lies between diameters of 0.0002 microns to 500 microns with lifetime vary from few seconds to several months.

Sources:

Particulates in atmosphere may be viable or non-viable.

- Viable particulate: These are bacteria, fungi, algae etc. are minute living organisms that are dispersed in atmosphere and cause plant diseases.
- Non-Viable particulate:
  - Dust:  
Main sources of dust are mines and quarries, furnaces, power plants, vehicle traffics, house cleaning dusts, natural winds, combustion operations, engine exhausts, rubber tyre abrasions and hundred other activities raise dust in the atmosphere.
  - Smoke:  
It is formed by the incomplete combustion of fuel. Smoke emission sources are locomotives, domestic wood, coal grates, industrial power plants, automobiles, incinerators and furnaces.
  - Smog:  
A mixture of smoke (from coal combustion) and fog in a suspended droplet form.
  - Asbestos: Widely used in industries for its mechanical strength and resistance to heat.

Effects:-

- Atmospheric dust causes allergic, respiratory diseases and silicosis.
- Smoke is increasingly related to incidence of cancer.
- Particulate due their small size, penetrate deep into alveoli of lungs and damage lung tissues.
- The acid and aldehyde particulate cause eye, nose and throat irritation.

Control:-

Some of the techniques to control the particulates are

- Centrifugal Cyclones – Cyclones are low cost and low maintenance, centrifugal collectors are typically used to remove particulate in the size range of 10-100 microns. But fine dust removal efficiency of cyclones is typically below 70%.
- Electrostatic precipitator - It remove the particle by using an electrostatic field to attract the particles on the electrode. Its efficiencies for well designed, well operated and well maintained systems are in the order of 99.99%.
- Filters and Dust collectors [bag house] – Collection of dust particles by passing fuel gases through a fabric that acts as a filter. They are also called a 'bag filters' or 'bag house'. The filters are made up of woven fabric, needled felt, plastic, ceramic and the Nano materials. Accumulated particles are removed by mechanical shaking, reversal of the gas flow or a stream of high-pressure air. Its efficiency is 99.9%.
- Wet scrubber – it rely on a liquid spray from a gas stream.

## **6. Mercury:**

Sources:-

- Natural sources of mercury include volcanoes, natural mercury deposit and release from the ocean.

- Man-made sources include coal combustion, waste incineration and metal processing industries.
- Other sources of mercury containing products like battery, thermometers and barometers, dental-amalgam, pharmaceutical etc.

Effects:

- Elemental and methyl mercury are toxic to the central and peripheral nervous system.
- Inhalation of mercury vapors can cause harmful effects on nervous, digestive and immune system, lungs and kidneys and may be fatal.
- Inorganic salts of mercury are corrosive to the skin, eyes and gastro-intestinal track and may induce kidney toxicity.
- Symptoms to exposure of different mercury compounds includes-tremors, insomnia, memory loss, neuro-muscular effects, headaches and cognitive.

Control:-

- Promote to use of clean energy sources that do not burn coal.
- Eliminate mercury mining and use of mercury in gold extraction. Non-mercury gold extraction must be promoted.
- Discontinue the usage of non-essential mercury containing products and implement of safe disposal.

## **7. Lead:**

Sources:

- Lead from automobile exhausts still remains in soil even today.
- Lead also comes from smelting of metal, lead acid battery manufacturing and other factories.
- Lead enters water through contact with plumbing, lead based pipes or solder that leaches lead into water through corrosion.

Effects:

- Once lead enters the body, it distributes throughout the blood and accumulates in the bones because it is similar in size  $Ca^{2+}$  and  $K^{+}$  depending on the level of exposure lead adversely affect the nervous system, kidney function, immune system and cardiovascular systems.
- Elevated levels of lead in the environment can lead to decreased growth and reproductive rates in plants and animals.
- The lead ions inhibit at least two enzymes that catalyze the bio-synthesis of hemoglobin as a result affecting the oxygen carrying capacity of the blood.
- Infants and young children are especially sensitive to even low levels of lead affect the behavioral problems and learning deficit.

Control:

- Eliminate lead contamination in drinking water by processes such as reverse osmosis, distillation and filtration using carbon filters specifically for lead removal.
- To minimize the plant absorption of lead content in agricultural soil.
- Lead smelting plants should design their storage piles in such a way that the movements of lead materials are minimized to lessen exposure to wind and air.

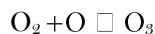
## Secondary air pollutants

The pollutants that are not directly released into the atmosphere but forms when primary pollutants react in the atmosphere are called secondary air pollutants. Examples: ground level ozone, nitric acids, and Sulphuric acids.

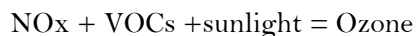
Ozone:

Sources:

Ozone in stratosphere is a product of UV radiations acting on dioxygen molecules. The UV radiations split apart molecular oxygen into free oxygen atoms. These oxygen atoms combine with the molecular oxygen to form ozone.



Ground level ozone forms when primary pollutants such as oxides of nitrogen and volatile organic compounds react with sunlight.



Effects:

- Positive at upper atmosphere: However the ozone layer beneficial, preventing the damage of UV rays reaching from the earth's surface.
- Negative effects at the ground level: ozone has very high oxidizing potential can damage mucous and respiratory tissues in animals and also affect the tissues in plants.

Control:

Control of ground level ozone can capture and treat NO<sub>x</sub> and volatile organic compounds from industries and automobile exhausts.

Ozone depletion:

Sources:

- Gradual thinning of ozone layer in the upper atmosphere caused by release of chemical compounds from industry and other human activities.
- Ozone depleting substances are chlorofluorocarbons (CFC's) and volatile organic compounds.
- CFC's are relatively stable in lower atmosphere of earth, but in stratosphere they are exposed to UV radiation and thus they breakdown to release a free chlorine atom.



- The chlorine free radical react with ozone to form chlorine monoxide radicals and molecular oxygen.  

$$\text{Cl}\cdot + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$$
- The reaction of chlorine monoxide radical with atomic oxygen forms more chlorine radicals.  

$$\text{ClO} + \text{O} \rightarrow \text{Cl}\cdot + \text{O}_2$$
- The chlorine radicals are continuously regenerated resulting in the depletion of ozone layer.

Effects: With the depletion of ozone layer, UV radiations can cause: Ageing of skin, Skin cancer, Eye damage, Damages immune system, Killing of many phytoplankton's, Damage of fish productivity, Ozone chemicals can cause difficulty in breathing, chest pain, throat irritation and hamper lung functioning.

Control: Encourage growth of plants that produce oxygen, discourage deforestation. Control the release of ozone depleting substances such as CFC's.

### **Waste management**

Waste can take any form that is solid, liquid or gas and each have different methods of disposal and management. "Waste management is the collection, transport, processing or disposal managing and monitoring of waste materials. The term usually relates to materials produced by human activity and is intended to reduce adverse effect on health and the environment".

Waste hierarchy refers to the "3Rs" reduce, reuse and recycling/ recycle which classifies waste management strategies according to their desirability in terms of waste minimization. Waste can be classified as:

1. Solid waste
2. Electronic waste
3. Biomedical waste

#### **Solid waste:**

Solid waste refers to the range of garbage arising from animal and human activities that are discarded as unwanted and useless. It is generated from industrial, residential and commercial activities in a given area and may be handled in a variety of ways. As such landfills are typically classified as sanitary, municipal, construction and demolition or industrial waste sites.

#### **Sources, characteristics and disposal of solid wastes:**

1. **Sources:** Every day, tones of solid waste are disposed off at various landfill sites and recycling units'. This landfill sites produce foul smell if waste is not stored and treated properly, it can pollute the surrounding air and can seriously affect the health of human, wildlife and our environment. The following major sources are:
  - a. Residential areas and homes
  - b. Industries
  - c. Commercial establishments
  - d. Institutions
  - e. Municipal services
  - f. Manufacturing plants and sites
  - g. Constructions and demolition area
  - h. Agriculture
  - i. Characteristics:

#### **2. Generally characteristics are categorized in two ways:**

**Physical characteristics:** Density of waste (mass per unit volume  $\text{kg/m}^3$ ) and Moisture content (ratio of the weight of water to the total weight of waste) o Size distribution of materials (for separation purpose)

**Chemical characteristics:** Lipids(found in variety of waste like fats ,oils, grease etc.. suitable for energy) o Carbohydrates(found in food and yard waste), Proteins(found in food and garden waste), Natural fibers (found in paper products, food and yard waste, suitable for energy recovery), Synthetic



organic material(plastics, suitable for pyrolysis and energy recovery), Noncombustible(glass and other materials), Heating value of water (calorific value of waste).

3. **Disposal:** There are different methods of solid waste management depending on the characteristics of wastes are:

a. **Landfill:** It is the oldest method of disposal of solid waste. Garbage is most commonly dumped into a designated area usually in unusable lands in remote areas. Mainly two challenges associated with landfills;

- Seeping of solid waste into underlying soil and water, contaminating both.
- Methane emissions from waste that leads to controllable fire.

To overcome these challenges through modern and scientific landfill:

**Modern landfill:** It is designed in such a way that the bottom of the landfill is covered with an impervious liner which is usually made of several layers of thick plastic and sand. This liner protects the ground water from being contaminated because of leaching or percolation.

**Scientific landfill:** It is termed so because of its scientific design construction. Scientific landfills eliminate the risk of waste seeping underground as the base layer is constructed of 90 meters of clay, thus arresting any seepage or leakage within the landfill, on the top of the base layer, a drainage layer made of soil measuring 15 meters in length and a vegetative layer of 45 centimeters to minimize soil erosion. The presence these layers ensures that leach ate (or liquid that drains from landfill) is collected it seeps underground.

It also reduces the production of methane, since the layers soak most of the impurities in the waste disposed, methane generates slowly in ordinary landfills. Vertical wells installed in scientific landfills help extract methane regularly, and the gas then used for electricity and heat generation purpose.

b. **Incineration:** This method involves burning of solid waste at high temperature until the waste turned into ash. This method can done individuals, municipalities and even institutions. It reduces the volume of waste up to 20% or 30% of the original volume.

c. **Recovery or recycling:** Recycling or recovery 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.

d. **Energy recovery:** There are two ways of energy recovery:

- Waste to energy by combustion of waste using advanced emission control equipment. It reduces volume of solid waste up to 90% saving valuable space and they provide clean alternative fossil fuels.
- Landfill gas to energy by decomposition of waste to produce methane ,as a natural gas fuel. It can be used for alternative energy sources like production of electricity and other energy requirements, this greatly reduce power production by burning of fossil fuels.

e. **Composting:** Only biodegradable waste materials are used in composting. There are two techniques commonly used:

- Home composting: It is a proper mixture of water, oxygen, carbon and nitrogen; the microorganisms in the waste are able to break down organic matter to compost.
- Commercial level vermi-composting: It is a product or process of organic material degradation using various worms' species such as red wigglers, white worm, and earth worms. It is quick and most efficient composting method for heterogeneous mixture of waste including fast decomposing vegetable or food waste.

**f. Pyrolysis:** In this method, the solid wastes are chemically decomposed by heat without presence of oxygen under pressure at temperature up to 430 °C. The solid waste is converted into gases, solid residue and small quantity of liquid.

### **Electronic waste**

Electronic wastes are also known as e-waste. It describes the discarded electrical or electronic devices. "It is defined as the discarded equipment that are dependent on electric current or electromagnetic fields to work properly and discarded equipment used for the generation, transfer and measurement of currents. Used electronic are intended for reuse, resale, and recycling or disposal are considered e-waste. Informal processing of e-waste in developing countries can lead to adverse human health effects and environmental pollution.

Sources, Characteristics and Disposal of e-waste:

#### **1. Sources:**

- Mobilephones, laptops, printers, scanners, circuitboards, lamps, clocks, flashlight, calculators, digital/video cameras, radios, VCRs, DVD players, MP3 and CD players etc.
- Kitchen equipment
- Laboratory equipment
- Broken computer monitors and television tubes (CRTs).

**2. Characteristics:** E-waste generally characterized by analyzing the components and composition of waste.

**Hazardous components in e-waste:** Electronic waste consists of a large number of components of various sizes, shapes, some of which contain hazardous components that need to be removed by separation method. Flame retardants are widely used in to prevent plastics or delay a developing fire in electronic equipment.

**Material composition of e-waste:** It contains a mixture of various metals particularly copper, aluminum and steel attached to, covered with or mixed with various types of plastics and ceramics.

**3. Disposal:** Some of techniques for disposal are:

- Reuse: reuse of end of life electronic equipment has first priority on the management of e-waste because the usable life span of equipment is extended to a secondary market, resulting in a reduced volume of waste stream encompassing treatment.

- Re-manufacture: It is a process in which used products are cores are disassembled, cleaned, repaired or refurnished, reassembled and qualified for new equipment.
- Recycle: It can be broadly divided into the three major steps
- Dis-assembly: Selective dis-assembly, targeting by singling out hazardous or valuable components for special treatment is an indispensable process in the recycling of e-waste.
- Upgrading: Using mechanical processing /metallurgical processing to upgrade desirable materials for refining process.
- Refining: In this method, recovered metals are melted or dissolved and finally separated by using metallurgical and chemical techniques, including pyro-metallurgical and hydro-metallurgical processing.

### **Biomedical waste**

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

#### **Sources, Characteristics and Disposal of biomedical waste:**

1. **Sources:** The major sources of biomedical waste are; Hospitals, Labs, Research centers, Blood bank and Animal research.
2. **Characteristics:** It is crucial to identify the characteristics of the biomedical waste to implement an efficient treatment/disposal method.

Characteristics of biomedical waste suitable for incineration:

- Heating value (calorific value) of waste should be more than 8370 KJ/Kg.
  - Percentage of combustible matter should be above 60%.
  - Moisture content should be below 30%.
  - Characteristics for appropriate disposal
  - Infectious waste
  - Radioactive elements
  - Chemical waste
  - Pharmaceuticals waste
  - Nin –risk waste
3. **Disposal:** Disposal strategies for biomedical waste should be carefully evaluated, particularly if there is risk of toxic emissions or other hazardous consequences. The following are potential disposal methods for biomedical waste.

The following are potential disposal methods are applied:

- Incineration
- Chemical disinfection
- Microwave land filling
- Sanitary land filling

## Water Chemistry

### Q1. Explain the source of water.

#### (a) Surface water:

**1. Rain water** is probably the purest form of natural water, since it is obtained as a result of evaporation from the surface water. However, during the journey downwards through the atmosphere, it dissolves a considerable amount of industrial gases (like  $\text{CO}_2$ ,  $\text{SO}_2$ ,  $\text{NO}_2$  etc.) and suspended solid particles, both of organic and inorganic origin.

**2. River water:** Rivers are fed by rain and spring waters. Water from these sources flow over the surface of land, dissolves the soluble minerals of the soil and finally falls in rivers. River water thus contains dissolved minerals of the soil such as chlorides, sulphates, bicarbonates of sodium, calcium, magnesium and iron. River water also contains the organic matter, derived from decomposition of plants, and small particles of sand and rock in suspension. Thus, river water contains considerable amounts of dissolved as well as suspended impurities.

**3. Lake water** has a more constant chemical composition. It usually, contains much lesser amounts of dissolved minerals than even well water, but quantity of organic matter in it is quite high.

**4. Sea water** is the most impure form of natural water. Rivers join sea and throw in the impurities carried by them. Moreover, continuous evaporation of water from the surface of sea makes sea water continuously richer in dissolved impurities. Sea water contains, on an average, about 3.5% of dissolved salts, out of which 2.6% sodium chloride. Other salts present are sulphate of sodium; bicarbonates of potassium, magnesium and calcium; bromides of potassium and magnesium and a number of other compounds.

Surface water, generally contains suspended matter, which often contains the disease-producing (or pathogenic) bacteria's. Hence, such waters as such are not considered to be safe for human activities.

**(b) Underground water:** A part of the rain water, which reaches the surface of the earth, percolates into the earth. As this water journeys downwards, it comes in contact with a number of mineral salts present in the soil and dissolves some of them. Water continues its downward journey, till it meets a hard rock, when it retards upwards and it may even come in the form of spring. Spring and well water (or underground water), in general is cleaner in appearance due the filtering action of soil, but contains more of the dissolved salts. Thus water from these sources contains more hardness. Usually, underground water is of high purity.

### Q2. Discuss the types of impurities present in water with examples.

The water found in nature is never pure and contains a large number of impurities in varying amounts. The major types of impurities found in water are of the following type:

\* **Dissolved gases:** Most water contains dissolved gases such as oxygen, carbon dioxide, sulphur dioxide, ammonia and oxides of nitrogen all of which are derived from atmosphere.

\* **Dissolved solids:** Dissolved solids mainly consist of bicarbonates, chlorides and sulphates of calcium, magnesium and sodium. In addition, small amounts of nitrates, nitrites, silicates, ammonia and ferrous salts are also present.

\* **Suspended impurities:** The suspended matter may be inorganic or organic nature. The inorganic materials include particles such as sand, clay, silica, hydroxides of iron and aluminium etc. derived from erosion of soil. Some of these particles have large size and therefore settle down readily. Others are fine particles and colloidal in nature. Such particles do not settle down easily. The organic suspensions are decaying vegetable matter and due to microorganisms. These are also colloidal form. The presence of suspended matter, particularly the colloidal particles impart turbidity to water.

\* **Microscopic matter:** Many pathogenic bacteria and microorganisms are also present in water. They are main causes for the water borne diseases.

### **Q3. What is boiler feed water? Explain scale and sludge formation in boilers.**

*A boiler is a closed vessel which operates under different pressures. Water heated in boiler under pressure is transformed to steam. The water used in these types of boilers is called as boiler feed water.*

For such water all the impurities are not necessarily eliminated, and only those impurities which lead to operational troubles in boilers are eliminated or kept within the tolerable limit.

A boiler feed water should correspond with the following composition:

- Its hardness should be less than 0.2 ppm
- Its caustic alkalinity (due to hydroxyl ions) should lie between 0.15-0.45 ppm.
- Its soda alkalinity (due to sodium carbonate) should be 0.45-1.0 ppm.

**Boiler troubles/problems:** Excess of impurities if present in generally cause the following problems:

1. Scale and sludge formation
2. Priming and foaming
3. Boiler corrosion.
4. Caustic embrittlement

### **Scale and Sludge formation:**

In a boiler, water is continuously evaporated to form steam under high temperature and pressures. As boiling point of water is much lesser than that of many impurities in water get progressively

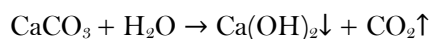
concentrated inside the boiler. This increases the concentration of dissolved salts. This leads to the formation of precipitate called scales and sludges.

**Scale:** Scales are hard deposits adhere to the inner surfaces of the boiler, which are difficult to remove and are the main sources of boiler troubles. Scales may be formed inside the boiler due to decomposition of calcium bicarbonate, deposition of calcium sulphate, hydrolysis of magnesium salts and presence of silica.

***Scale formation due to decomposition of calcium bicarbonate:***



However, scale composed of only  $\text{CaCO}_3$  is soft and is the main cause of scale formation in low-pressure boilers. But in high-pressure boilers,  $\text{CaCO}_3$  is soluble due to the formation of  $\text{Ca}(\text{OH})_2$ .

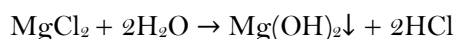


***Scale formation due to deposition of calcium sulphate:***

The solubility of  $\text{CaSO}_4$  in water decreases with increase in temperature.  $\text{CaSO}_4$  is soluble in cold water and almost insoluble in super heated water. Consequently,  $\text{CaSO}_4$  gets precipitated as hard scale on the hotter parts of the boiler. This type of scale is quite adherent and difficult to remove, even with the help of hammer and chisel.

***Scale formation due to hydrolysis of magnesium salts:***

Dissolved magnesium salts get hydrolyzed in boiler water forming magnesium hydroxide precipitate, which forms a soft type of scale.



***Disadvantages of scale formation:***

- Wastage of fuel
- Lowering of boiler safety
- Decrease in boiler efficiency
- Danger of boiler explosion
- Distortion of boiler material (Bagging)

***Removal of scale:***

- Soft scales are removed with the help of wire brush or scrappr
- Brittle or hard scles can be removed by giving thermal shocks

- By dissolving scales in certain chemicals and hence can be removed along with water. For example,  $\text{CaCO}_3$  scales can be dissolved by using 5-10% HCl. Similarly EDTA can also be used to dissolve the salts of Ca, with which it forms soluble complexes.

*Prevention of scale formation:* Scale formation can be minimized by subjecting boiler feed water to certain treatments namely

- Water softening techniques like carbonate conditioning, phosphate conditioning, calgon conditioning and colloidal conditioning internal treatment of water
- Lime soda process, Zeolite process & Ion exchange process--external treatment of water

**Sludge:** Sludge is a soft, loose and slimy precipitate formed in the cooler, less turbulent parts of the boilers and in the distribution pipes of the boilers. Sludges are formed by substances which have greater solubilities in hot water than in cold water, *e.g.*,  $\text{MgCO}_3$ ,  $\text{MgCl}_2$ ,  $\text{CaCl}_2$ ,  $\text{MgSO}_4$  etc. Sludge can be easily removed (scrapped off). If sludges are not removed frequently, it settles down to form scales.

Disadvantages of sludge formation:

- Sludges are poor conductors of heat, so they tend to utilize more heat. The boilers will have to be heated to higher temperatures in order to maintain the uniform supply of heat.
- Sludge formation decreases the efficiency of boilers.
- The formation of sludges slows down the water circulation as it settles in the regions such as pipe connections, plug openings etc.

Prevention of sludge formation:

- By using softened water
- By frequent blow-down operations

Methods of cleaning sludge

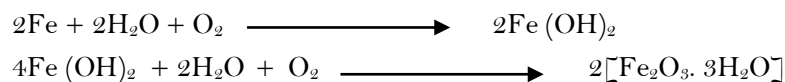
- Using soft water for boiler operations
- Removing concentrated salty water time to time so that deposition of sludge is prevented.

### Q5. Explain boiler corrosion.

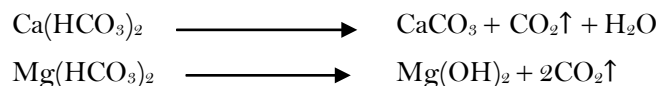
The process of degradation of the boiler surface by the attack of boiler feed water is called as boiler corrosion. The mineral acids and dissolved gases like oxygen and carbon dioxide present in the boiler feed water cause boiler corrosion.

#### Reactions causing boiler corrosion

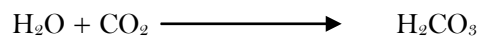
1. **Due to presence dissolved oxygen:** Natural water usually contains 8- 9 ppm of dissolved oxygen. Generally oxygen level of more than 7 ppm present in boiler feed water cause boiler corrosion. The dissolved oxygen present in boiler feed water can attack boiler surface and produce rust as follows:



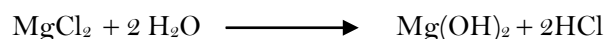
2. **Due to presence of CO<sub>2</sub>:** Carbon dioxide is present in the boiler water either from air or due to the presence of residual temporary hardness.



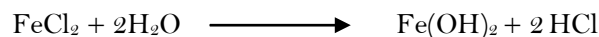
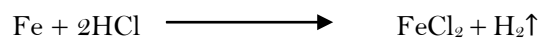
This carbon dioxide dissolves in water to produce carbonic acid, which is slightly acidic in nature and hence cause corrosion.



3. **Due to presence of MgCl<sub>2</sub>:** Corrosion also occurs when the pH drops below 8.5 due to acidic nature of feed water. Under this condition, acid may be formed due to the presence of magnesium compounds in feed water.



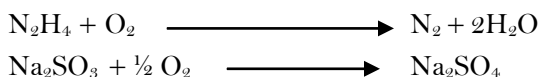
The resultant acid then attacks the boiler to form rust.



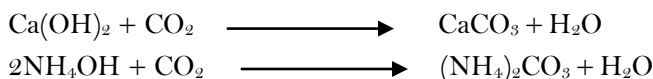
### Controlling of boiler corrosion:

Boiler corrosion can be controlled by reducing the quantities of oxygen, carbon dioxide and any acid from the feed water. This can be achieved by the following ways,

**By removing oxygen:** Dissolved oxygen is first removed by vacuum degasifiers. The remaining trace of oxygen are chemically removed by using oxygen scavengers like hydrazine and sodium sulphite



**By removing carbon dioxide:** Mechanical removal of carbon dioxide can be done by deaeration. Chemical removal of carbon dioxide can be done by treating with lime or ammonium hydroxide.



Finally, acidic impurities if there any, can be removed by treating with alkaline agents like ammonium hydroxide.

### Q7. Define BOD (Biological oxygen demand) and COD (Chemical oxygen demand).

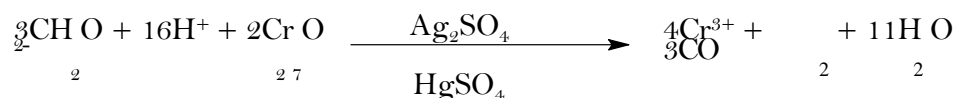
BOD (Biological oxygen demand) is defined as “the amount of dissolved oxygen consumed by the micro organisms to oxidize the biologically oxidizable impurities present in 1 liter of water over the period of 5 days at 20 °C”.



COD (Chemical oxygen demand) is defined as “the amount of oxygen required to oxidize all oxidizable impurities present in 1 liter of waste water using a strong oxidizing agent such as acidified  $K_2Cr_2O_7$ ”. COD values are expressed in  $mgdm^{-3}$ .

**Q8. Explain the experimental method for the determination of COD of waste water.**

**Principle:** The principle of the method is the oxidation of organic matter using chemical oxidizing agents such as acidified potassium dichromate in the presence of a catalyst such as silver sulphate (which catalyzes the oxidation of organic matter) and mercuric sulphate (which forms a complex with chloride ions present in water thus preventing its interference). A typical reaction representing the oxidation of organic matter is given below.



**Procedure:**

**Back Titration:** A known volume (25 ml,  $V_s$ ) of the waste water (sewage) is pipetted out into a round bottomed flask. A known excess of  $K_2Cr_2O_7$  (25 ml) is pipetted into the same flask along with one test tube full of  $H_2SO_4$  containing  $HgSO_4$  and  $Ag_2SO_4$ . The content of the flask is refluxed for 2 hours. The contents are cooled and transferred into a conical flask. Five drops of ferroin indicator is added to it and titrated against standard FAS solution taken in the burette till the colour changes from blue green to reddish brown. Let the volume of titrant required be ' $V_{Back}$ ' ml.

**Blank Titration:** A blank titration is performed by taking the same amount of distilled water in place of waste water. Let the volume required for blank titration is ' $V_{Blank}$ ' ml.

Calculations:

$$COD = \frac{N_{FAS} \times (V_{Blank} - V_{Back}) \times 8}{V_s \times 1000} \times 10^6 \text{ ppm}$$

**Q9. Explain the determination of sulphates by gravimetric method.**

**Principle:** Gravimetry is a technique in which the amount of analyte in a sample is determined by converting (or precipitating) the analyte to some product. In this case, sulphate ions in the water sample are qualitatively precipitated as  $BaSO_4$  by treating with  $BaCl_2$  solution containing HCl. Precipitate  $BaSO_4$ , is separated by filtration, dried and weighed.



**Procedure:** Take 200ml of water sample in a beaker, heat it to boiling and add one test tube of HCl and heat the solution to near boiling. To the hot solution add one test tube of BaCl<sub>2</sub> solution slowly with constant stirring. Digest the solution on a water bath for about 30min. Check for the completion of precipitation, allow it to stand for 1 hour and filter through ash-less Whatman filter paper, Transfer the filter paper contacting barium sulphate precipitate into previously dried and weighed silica crucible (W<sub>1</sub>) and burn it in an electrical burner. Once the filter paper is burnt off, transfer the crucible to a dessicator for cooling. After cooling, note the weight (W<sub>2</sub>) of crucible. The difference in weight (W<sub>2</sub> – W<sub>1</sub>) is equal to the amount of barium sulphate precipitated from the sample. Calculate the amount of sulphate using the following formula.

Calculations:

233.33 g of BaSO<sub>4</sub> contains 96g of sulphate

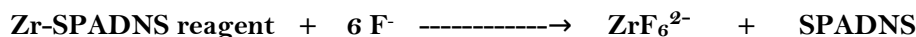
$$(W_1 - W_2) \text{ g of BaSO}_4 \text{ contains } = \frac{(W_1 - W_2) \times 96 \times 1000}{233.22} = 'a' \text{ mg of sulphate}$$

i.e., 200ml of water sample contains 'a' mg of sulphate

1000ml of water sample contains  $1000 \times a / 200$  mg of sulphate

#### Q10. Explain the determination of fluoride by SPADNS method using colorimetry.

**Principle:** Under acidic conditions, fluorides react with zirconium dyes (such as SPADNS: sodium 2-p-sulphophenyl azo-1,8-dihydroxy-3, 6-naphthalein disulphonate) to form a colourless complex and another dye. The dye becomes progressively lighter as fluoride concentration increases.



Reddish

Colourless

Yellow

#### Procedure:

1. Prepare a blank solution by adding 10ml acid zirconyl-SPADNS reagent to 100 ml distilled water, Use this solution to set ZERO in the colorimeter at 570nm.
2. Transfer exactly 5, 10, 15, 20 and 25 ml stock solution of fluoride of 10ppm into 50 ml volumetric flasks.
3. Add 10 ml Zr-SPADNS reagent to each of the flask dilute up to the mark and mix well the solution and measure the absorbance at 570nm against the blank reagent.
4. Draw calibration curve by plotting concentration versus absorbance.
5. Take suitable aliquot of water sample and add repeat step 3.
6. Using the calibration curve, calculate the concentration of F<sup>-</sup> ions in the sample.

**Q11. Define sewage. Mention sewage characteristics.**

Sewage is a liquid waste which include industrial wastes, household wastes etc; Sewage waste when it is fresh, slightly green in colour but later it becomes dark brown.

**Characteristics of Sewage:**

Fresh sewage is odorless but when it becomes stale it produces smell due to release of gases like hydrogen sulphide ( $\text{H}_2\text{S}$ ), Phosphine ( $\text{PH}_3$ ) ammonia ( $\text{NH}_3$ ) etc. Sewage water is normally turbid and has the temperature is slightly higher than the temperature of ordinary water.

It contains both organic and inorganic impurities, also contains pathogenic and nonpathogenic bacteria. There are two types of non pathogenic bacteria.

**Aerobic:** - which live and grow on free oxygen and dissolved oxygen, which acts as a catalyst for oxidation of fresh sewage. Products of oxidation are nitrites, nitrates, sulphites, and sulphates etc. which do not produce any offensive smell.

**Anaerobic:** - which lives and grows in absence of free oxygen. When dissolved oxygen content in water decreases below a particular value, anaerobic bacteria tries to decompose organic compounds in water and produce methane  $\text{CH}_4$ ,  $\text{H}_2\text{S}$ ,  $\text{PH}_3$  etc responsible for offensive smell.

**Q10. Write a note on primary treatment of sewage water (physical method). Mention the objectives of sewage treatment.**

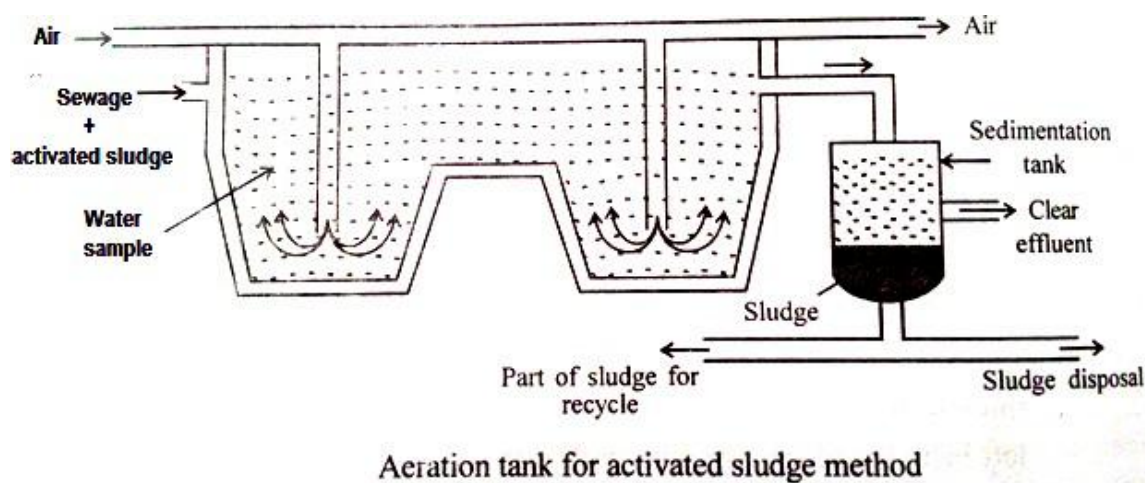
**Primary treatment:** It is to remove suspended and floating solids from sewage.

1. **Screening:** Sewage is made pass through bar screens/mesh screens to remove suspended & coarse particles.
2. **Slit & grit removal:** Sewage is slowly passed through the grit chamber- heavier sand and broken glass settle down by gravity.
3. **Removal of oil & grease:** Sewage is kept in skimming tank & compressed air is blown through it. Oil & grease form froth and float on the surface it is skimmed off.
4. **Sedimentation:** Sewage is sent to large tanks, called primary clarifiers or primary sedimentation tanks where fine particles settles and non settleable particles are removed by the addition of coagulating agents like alum, ferrous sulphate

**Q11. Explain the Activated sludge method (Secondary/Biological treatment) of sewage water.**

It is designed to degrade the biological content of the sewage derived from human waste, food waste, soaps & detergents. Activated sludge is a thick greasy mud containing aerobic bacteria. Activated sludge containing micro organisms is sprayed over sewage water and it is made to live on organic waste present in water. This is followed by bubbling air from centre of tank in order to have maximum contact between organic waste and bacteria in the presence of air or oxygen and also sunlight. During aerobic oxidation several organic reactions takes place. Carbon of organic matter is converted carbon dioxide,

nitrogen to ammonia and finally to nitrites and nitrates. The sludge formed is filtered, dried and used as a fertilizer; a part of sludge can be further used for treatment.



**Q12. Write a note on tertiary treatment of sewage water (chemical method).**

Tertiary treatment provides a final stage to raise the effluent quality to the required standard, before it is discharged to the river, sea, lake and ground.

1. Removal of dissolved salts: done by adding lime—a precipitate of calcium salt is formed.
2. Degasification: dissolved gases are removed by trickling the water through a tall tower—due to hot condition and large surface area, liberation of dissolved gases take place.
3. Disinfection: To remove pathogenic bacteria—by passing  $\text{Cl}_2$  gas/ozone/UV light.

**Q3. Define the following terms:**

**i. Potable water:** Water that is fit for human consumption and meets the stringent microbiological and chemical standards of quality to prevent waterborne diseases and health risks from toxic chemicals is called potable water.

**ii. Desalination of brackish water (salt water):** The process of removal of dissolved salts from sea water (brackish water) to the extent, that water becomes usable is described as “desalination or desalting”.

**iii. Softening of water:** The process of removal of calcium, magnesium, iron salts and other metallic ions (which form insoluble metallic soaps) from water is called softening of water.

**Q13. Explain demineralization of water (Ion exchange/Deionisation) used for water softening process.**

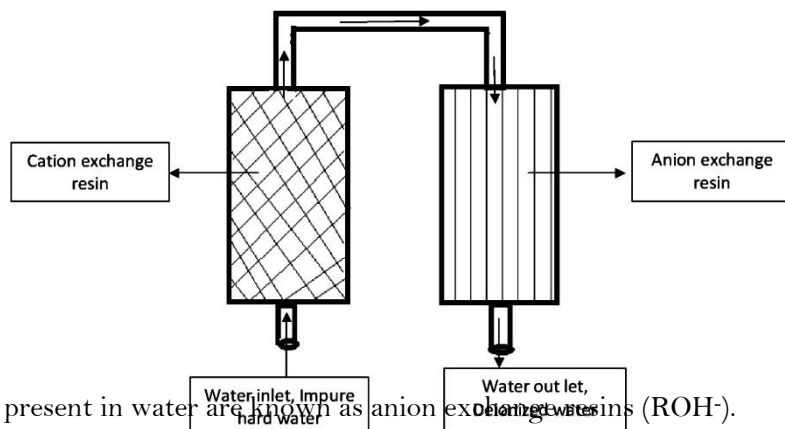
The process of complete removal of all ions present in water is called demineralization and is achieved by using ion exchange resins (polymer material). The functional groups attached to the resin may be acidic or basic and hence resins

can be classified as cation exchange resins and anion exchange resins.

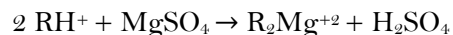
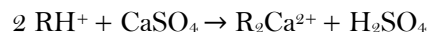
The resins containing acidic groups which are capable exchanging  $H^+$  (or  $Na^+$ ) ions for cations ( $Ca^{2+}$  or  $Mg^{2+}$ ) present in water are known as cation exchange resins ( $RH^+$ ).

The resins containing basic groups which are capable

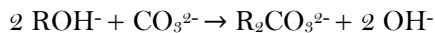
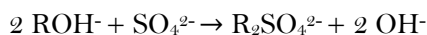
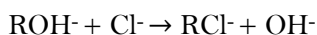
exchanging  $OH^-$  for anions ( $Cl^-$ ,  $SO_4^{2-}$ ) present in water are known as anion exchange resins ( $ROH^-$ ).



**Process:** The ion exchange unit consists two tanks. Cation exchange resins and anion exchange resins are placed in first and second tank respectively. First, hard water is made to pass through cation exchange resin which exchanges its  $H^+$  for  $Ca^{+2}$  and  $Mg^{+2}$  ions in water as follows (examples):



The anions originally associated with  $Ca^{+2}$  and  $Mg^{+2}$  are now associated with  $H^+$  ions. Thus water after passing through cation exchange is free of  $Ca^{+2}$  and  $Mg^{+2}$  ions. This water (passing out from the cation exchange tank) is then passed through another tank having anion exchange resin. Here the anions like  $SO_4^{2-}$ ,  $Cl^-$  etc present in water are exchanged for  $OH^-$  ions of the resin as follows (examples):



The water coming out of the anion exchanger is completely free from cations and anions responsible for hardness. It is known as deionised water or demineralised water. It is as pure as distilled water.

**Regeneration:**

When the resins are exhausted and lose their capacity to exchange ions, they are regenerated. The process of regeneration is the reversal of the reaction taking place for ion exchange. The cation exchange

resin is regenerated by passing a solution of dilute HCl or H<sub>2</sub>SO<sub>4</sub>. Similarly, anion exchange resin is washed with ammonium or sodium hydroxide solutions.

*Advantages:*

- Highly acidic or alkaline water can be softened
- Water of very low hardness is produced.
- Anions as well as cations are removed thereby problems like caustic embrittlement and boiler corrosion reduced when treated water is used as boiler feed water.

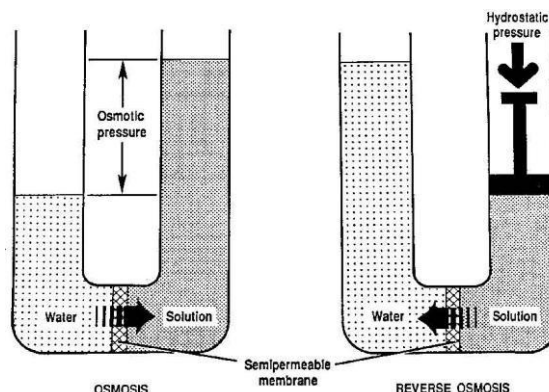
*Disadvantages:*

- The equipment is costly
- Costly chemicals are required for regeneration of ion exchange resins.
- Turbid water decreases the efficiency of the process.

**Q14. Discuss the desalination of sea water by reverse osmosis.**

**Principle:** When two solutions of unequal concentrations are separated by a semi-permeable membrane (which selectively does not permit the passage of dissolved solute particles, i.e., molecules, ions, etc.), flow of solvent takes place from dilute to concentrated sides (solvent rich side to solute rich side), due to osmosis. If, however, a hydrostatic pressure in excess of osmotic pressure is applied on the concentrated side, the solvent flow reverses, i.e., solvent is forced

to move from concentrated side to dilute (solute rich side to solvent rich side) across the membrane. This is the principle of reverse osmosis. Thus, in reverse osmosis (R.O) methods, pure solvent (water) is separated from its contaminants rather than removing contaminants from the water. This membrane filtration is sometimes also called “super-filtration” or hyper-filtration”.



**Problems on COD:**

**1).** 25ml of a sewage water sample was refluxed with 10 ml of 0.25N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution in presence of dil.H<sub>2</sub>SO<sub>4</sub>. The unreacted dichromate required 5.5 ml of 0.1N FAS solution. 10 ml of the same K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution and 25 ml distilled water under the same conditions as the sample required 26.0 ml of FAS of 0.1N. Calculate the COD of the sample.

$$\begin{aligned}
 \text{COD} &= N_{\text{FAS}} \times (V_{\text{Blank}} - V_{\text{Back}}) \times 8 \times 10^6 / V_{\text{waste water}} \times 1000 \\
 &= 0.1 \times (26 - 5.5) \times 8000 / 25 \\
 &= 656 \text{ mg/dm}^3
 \end{aligned}$$

2). In a COD experiment, 29.5 cm<sup>3</sup> and 20 cm<sup>3</sup> of 0.025N FAS solution were required for blank and sample titration respectively. The volume of test sample used is 25 cm<sup>3</sup>. Calculate the COD of the sample solution.

$$\begin{aligned}\text{COD} &= N_{\text{FAS}} \times (V_{\text{Blank}} - V_{\text{Back}}) \times 8 \times 10^6 / V_{\text{waste water}} \times 1000 \\ &= 0.025 \times (29.5 - 20) \times 8000 / 25 \\ &= 76 \text{ mg/dm}^3\end{aligned}$$

3). In a COD experiment, 28.1 cm<sup>3</sup> and 14 cm<sup>3</sup> of 0.05N FAS solution were required for blank and sample titration respectively. The volume of test sample used is 25 cm<sup>3</sup>. Calculate the COD of the sample solution. (Ans-225.6 mg/dm<sup>3</sup>).

4). 20 ml of sewage for COD is reacted with 25 ml of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution and unreacted K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> requires 9.0 ml of N/4 FAS solution. Under similar conditions, in blank titration 15.0 ml of FAS is used up. Calculate the COD of the sample. (Ans- 600 mg/dm<sup>3</sup>).

5). In a COD experiment, 30 cm<sup>3</sup> of an effluent sample required 9.8 cm<sup>3</sup> of 0.001M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution for oxidation. Calculate the COD of the sample.

Solution: (i) Evaluate the oxygen equivalent

1000 cm<sup>3</sup> of 1M solution of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to* 3 equivalent of oxygen. = 3 × 16 g of oxygen.

Therefore 9.8 cm<sup>3</sup> of 0.001M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to*

$$\begin{aligned}&9.8 \text{ cm}^3 \times 0.001\text{M} \times 3 \times 16 \text{ g} / 1000 \text{ cm}^3 \times 1 \\ &= 0.0004704 \text{ g of oxygen.} \\ &= 0.4704 \text{ mg of oxygen.}\end{aligned}$$

(ii) To evaluate COD value

30 cm<sup>3</sup> of effluent is *equivalent to* 0.4704 mg of oxygen. Therefore

1000 cm<sup>3</sup> of effluent is *equivalent to*

$$\begin{aligned}&1000\text{cm}^3 \times 0.4704 \text{ mg} / 30 \text{ cm}^3 \\ &= 15.68 \text{ mg of oxygen.}\end{aligned}$$

Therefore COD of effluent = 15.68 mg/dm<sup>3</sup>.

**6). Calculate the COD of the effluent sample when 25 cm<sup>3</sup> of an effluent sample required 8.3 cm<sup>3</sup> of 0.001M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution for complete oxidation (Ans- 15.93 mg/dm<sup>3</sup>).**

1000 cm<sup>3</sup> of 1M solution of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to* 3 equivalent of oxygen.

$$= 3 \times 16 \text{ g of oxygen.}$$

Therefore 8.3 cm<sup>3</sup> of 0.001M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to*

$$= 8.3 \text{ cm}^3 \times 0.001\text{M} \times 3 \times 16 \text{ g} / 1000 \text{ cm}^3 \times 1$$

$$= 0.0003984\text{g of oxygen.}$$

$$= 0.3984\text{mg of oxygen.}$$

(ii) To evaluate COD value

25 cm<sup>3</sup> of effluent is *equivalent to* 0.3984 mg of oxygen. Therefore

1000 cm<sup>3</sup> of effluent is *equivalent to*

$$1000\text{cm}^3 \times 0.3984 \text{ mg} / 25 \text{ cm}^3$$

$$= 15.936 \text{ mg of oxygen.}$$

Therefore COD of effluent = 15.936mg/dm<sup>3</sup>.

**7). Calculate the COD of the effluent sample when 25 cm<sup>3</sup> of an effluent sample required 10.5 cm<sup>3</sup> of 0.005M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution for complete oxidation.**

Alternative method : C.O.D = N<sub>dichromate</sub> X V<sub>dichromate</sub> X 8 x 10<sup>6</sup> / V<sub>waste water</sub> X 1000

$$1\text{M K}_2\text{Cr}_2\text{O}_7 = 6 \text{ N K}_2\text{Cr}_2\text{O}_7$$

$$0.005 \text{ M K}_2\text{Cr}_2\text{O}_7 = 6 \times 0.005 \text{ N K}_2\text{Cr}_2\text{O}_7$$

$$\text{C.O.D} = 6 \times 0.005 \times 10.5 \times 8 \times 10^6 / 25 \times 1000$$

$$= 100.8 \text{ ppm}$$

**8). 25 cm<sup>3</sup> of an industrial effluent when subjected to COD test required 22.5 cm<sup>3</sup> of 0.5N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution for complete oxidation. Calculate the COD of the sample.**

Solution:

1000 cm<sup>3</sup> of 1N solution of K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to* = 8g of oxygen.

Therefore 22.5 cm<sup>3</sup> of 0.5M K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> *equivalent to*



$$\begin{aligned}
 & 22.5 \text{ cm}^3 \times 0.5\text{M} \times 8 \text{ g} / 1000 \text{ cm}^3 \times 1 \\
 & = 0.090\text{g of oxygen.} \\
 & = 90\text{mg of oxygen.}
 \end{aligned}$$

(ii) To evaluate COD value

25 cm<sup>3</sup> of effluent is *equivalent to* 90 mg of oxygen.

Therefore 1000 cm<sup>3</sup> of effluent is *equivalent to*

$$\begin{aligned}
 & 1000\text{cm}^3 \times 90\text{mg} / 25 \text{ cm}^3 \\
 & = 3600 \text{ mg of oxygen.}
 \end{aligned}$$

Therefore COD of effluent = 3600 mg/dm<sup>3</sup>.

**9). 25 cm<sup>3</sup> of an industrial effluent consumed 5 cm<sup>3</sup> of 0.5N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> solution for oxidation. Calculate the COD of the sample.**

$$\begin{aligned}
 \text{C.O.D} &= N_{\text{dichromate}} \times V_{\text{dichromate}} \times 8 \times 10^6 / V_{\text{waste water}} \times 1000 \\
 &= 0.5 \times 5 \times 8 \times 10^6 / 25 \times 1000 = 800 \text{ mg}
 \end{aligned}$$