UNIT - I / WATER AND ITS TREATMENT

1.1 INTRODUCTION

Water is the most important compound essential for the survival of all living organisms. About 80% of the earth's surface is covered by water. Besides being a supporter of life, water plays a unique role in industries. Water is used in the power generation industry for the production of the electric current through steam generation. It is also used as a coolant in nuclear power plants and chemicals plants. Water is widely used in other fields such as production of steel, atomic energy, textiles, irrigation, etc.

The process of removing of all types of impurities from water and making it fit for domestic or industrial purposes is called water technology or water treatment.

SOURCES OF WATER

The main sources of water are

- Rain Water
- Surface water
- Underground water
- Sea water

Characteristics of water

Some of the essential qualities of drinking water as per WHO (World Health Organization) and ICMR (Indian Council of Medical Research) are given as below;

1. Water should be,

- clear, colourless and odourless
- cool and have pleasant taste
- free from harmful bacteria and suspended impurities
- free from dissolved gases such as CO_2, NH_3, H_2S, and poisonous heavy metals like Pb, As, Mn, etc.

2. Water should have dissolved oxygen.

3. Chloride content should be less than 250 ppm.

4. Hardness should be less than 500 ppm.

5. TDS (Total Dissolved Solids) content should be less than 500 ppm.

6. Fluoride content should be less than 1.5 ppm.

7. pH should range between 6.5 – 8.5

Impurities in Water

The common impurities present in natural waters may be classified as follows.

1. **Dissolved minerals** – mostly comprise of carbonates, bicarbonates, sulphates and chlorides of calcium, magnesium, sodium and potassium.
2. **Dissolved gases** – mostly air and carbon dioxide.
3. **Suspended matter** – mostly mineral matter, giving turbid or muddy water. Organic matter may also be present.
4. **Microscopic matter** – consists mostly of plant and bacterial life giving colour, taste and odour.

In general, the removal of impurities from water of classes 1, 2 and 3 form the chief problem for industrial usage, and 3 and 4 for municipal supplies.

1.2 WATER QUALITY PARAMETERS

The demand for pure water is growing day by day and it is very important to decide the quality of water. Water quality determines the 'goodness' of water for particular purposes. The water used for domestic and industrial purposes should be free from toxic substances and pathogenic organisms. The following are some of the parameters which determine the quality of water.

S.No.	Water Quality Parameters	Maximum acceptable limit
1.	Colour	15 TCU (True colour unit).
2.	Odour	Odourless
3.	Turbidity	less than 5 NTU (Nephthalometric turbidity unit)
4.	pH	6.5 – 8.5.
5.	Hardness	350 ppm.
6.	Alkalinity	300ppm.
7.	TDS	300mg/L.
8.	COD	250mg/L
9.	BOD	30mg/L
10.	Fluoride	0.7-1.5ppm
11.	Arsenic	0.01mg/L

1. Colour:

- Pure water should be absolutely colourless. Therefore any types of colour appearance in water indicates water pollution.
- Natural water is often coloured due to the degradation of organic matter or untreated discharge from textile, dying, wood pulp, leather industries.
- If colour is due to **suspended material**, it is called as **apparent colour.** Colour given by **dissolved material** that remains even after removal of suspended material is called **true colour or real colour**.

- The guideline value (maximum acceptable level) for colour of drinking water is 15 TCU (True colour unit).

2. **Taste and odour:**

- Pure water is always tasteless and odourless. Therefore if any taste and odour is present, it indicates water pollution.
- Bitter taste – due to presence of iron, aluminium, manganese, sulphate or excess lime.
- Soapy taste – presence of large quantities of sodium bicarbonate.
- Brackish taste – presence of unusual amount of dissolved salts.
- Palatable taste – presence of dissolved gases(CO_2) and minerals (like nitrates)
- Disagreeable odour – due to the presence of living organisms and decaying vegetable matter.

3. **Turbidity:**

- Turbidity is a measure of the ability of light to pass through water.
- It is due the presence of finely divided, insoluble impurities that are suspended in water.
- Turbidity is measured in Nephelometric Turbidity Units (NTU's).
- High turbidity affects submerged plants by preventing sufficient light from reaching them for photosynthesis.
- High turbidity also has the capacity to significantly increase water temperature.
- Drinking water should have turbidity less than 5 NTU (Nephthalometric turbidity unit)

4. Total dissolved solid (TDS):

- If water is filtered to remove suspended solids, the remaining solid in water indicates total dissolved solids.
- Dissolved solid may be organic (animal or plants waste) or inorganic compounds (carbonate, sulphate, bicarbonate etc.). These compounds give variety of effects like hardness, taste, odour etc. depending on nature of dissolved solid.
- If the dissolved solid in water exceeds 300 mg/lit, it adversely affects living organisms as well as industrial products.

5. pH

- pH is a measure of the acidity or alkalinity of water. pH is given by the formula,

$$pH = -\log_{10}[H^+]$$

- The pH scale ranges from 0 to 14.

Acidic range: 0 to 6.9

Neutral: 7

Alkaline range: 7.1 to 14

- A pH range of 6.5 – 8.5 is optimal for freshwater.
- A range of 8 – 9 is optimal for estuarine and sea water.
- Range of pH for consumable water is 6.5 – 7.5.

6. **Hardness:**
   - Hardness is the "**characteristic property of water which prevents the lathering of soap".**
   - This is due to the presence of certain salts of calcium, magnesium and other heavy metals dissolved in water.

How to detect hardness?

When a sample of water is treated with soap solution, if it does not produce lather, but forms a white scum or precipitate, the water contains hardness.

This is due to the formation of insoluble soaps of calcium and magnesium.

$$2C_{17}H_{35}COONa + CaCl_2 \rightarrow (C_{17}H_{35}COO)_2Ca \downarrow + 2\,NaCl$$

(sodium stearate) (hardness causing substance) Calcium stearate (insoluble soap)

TYPES OF HARDNESS

- Hardness is classified into two types based on dissolved salts present in water.

  They are: Temporary Hardness (or) Carbonate Hardness (CH)

  Permanent Hardness (or) Non-Carbonate Hardness (NCH)

TEMPORARY HARDNESS

Temporary Hardness is due to the presence of dissolved bicarbonates of calcium and magnesium. Thus the salts responsible for temporary hardness are $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. Temporary hardness is otherwise known as Carbonate Hardness (or) Alkaline Hardness.

Temporary Hardness can be removed by following two processes:

- Boiling of water
- Adding lime (CaO)

The above two processes convert the bicarbonates into insoluble carbonates and hydroxides, these are removed by filtering.

PERMANENT HARDNESS

Permanent hardness is due to the presence of dissolved chlorides and sulphates of calcium and magnesium. The salts responsible for permanent hardness are $CaCl_2$, $MgCl_2$, $CaSO_4$ and $MgSO_4$. Permanent hardness cannot be removed by boiling. It can be removed by the following two processes:

- Lime – soda process
- Zeolite process

Permanent Hardness is otherwise known as Non-Carbonate Hardness (NCH) (or) Non – alkaline Hardness.

TOTAL HARDNESS

Total hardness = Temporary Hardness + Permanent Hardness

Classification Of water based on hardness

On the basis of hardness, water can be classified into two types:

- Hard Water
- Soft Water

HARD WATER

Water which does not produce lather easily with soap solution, but forms a white precipitate, is called **hard water**. **It contains dissolved salts of calcium and magnesium**.

SOFT WATER

Water which lathers easily with soap solution, is called **soft water**. I**t does not contain dissolved calcium and magnesium salts.**

7. Alkalinity

- Alkalinity is a measurement of dissolved alkaline substances in water (higher than 7.0 pH). It is generally termed as basicity of water.
- It is the ability of water to neutralize acid.
- It is due to the presence of soluble hydroxide, carbonate and bicarbonate ions.
- It also may be due to the dissolution of phosphates, limestone, and borates in water sources.

There are three primary types:

1. Hydroxide alkalinity – due to (OH^-) ions
2. Carbonate alkalinity - due to (CO_3^{2-}) ions
3. Bicarbonate alkalinity - due to (HCO_3^-) ions

Significance

Higher alkalinity levels in surface waters will buffer acid rain and other acid wastes and prevent pH changes that are harmful to aquatic life.

8. Chemical Oxygen Demand (COD)

Chemistry Oxygen Demand is the amount of oxygen required to oxidise the organic matter and oxidisable inorganic matter present in a water sample under acidic conditions.

Significance of COD:

It is a measure of both the biologically oxidisable & biologically inert organic matter.

1. Higher COD levels mean a greater amount of oxidisable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is harmful to higher aquatic life forms.

9. Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand is the quantity of oxygen required by the microorganisms for the biological oxidation of organic matter present in waste water under standard experimental conditions. It is calculated over five days at a specific temperature of 20°C.

Significance of BOD:

1. It represents the quantity of oxygen which is consumed during the decomposition of organic materials, by microorganisms.
2. The BOD therefore provides information on the biologically-convertible proportion of the organic content of a sample of water.
3. BOD of water is essentially important for understanding the polluting potential of the water.
4. The more the BOD levels in a water body, the more polluting potential it has. It is used as an index in sewage or wastewater treatment plants.

10. Fluoride

- Fluoride is a naturally occurring mineral, present in in soil, groundwater and oceans.
- It helps prevent cavities in children and adults by making the outer surface of the teeth (enamel) more resistant to the acid attacks that cause tooth decay.
- It is also produced synthetically for use in drinking water, toothpaste, mouthwashes and various chemical products.

Significance of fluoride

- Fluoride comes from fluorine, which is a common, natural, and abundant element.
- Adding fluoride to the water supply reduces the incidence of tooth decay.
- Fluoride protects teeth from decay by demineralization and remineralisation.
- Too much fluoride can lead to dental fluorosis or skeletal fluorosis, which can damage bones and joints.
- A fluoride content of 1.5ppm is now considered best for dental health.
- A concentration above 1.5ppm is hazardous.

11. Arsenic

- Arsenic is an element that occurs naturally in rocks and soil and is used for a variety of purposes within industry and agriculture.

- It is also a by-product of copper smelting, mining, and coal burning.
- Arsenic can combine with other elements to make chemicals used to preserve wood and to kill insects on cotton and other agricultural crops.

Arsenic in water:

- Arsenic can enter the water supply from natural deposits in the earth or from industrial and agricultural pollution.
- Arsenic remains in the environment for a long time.
- Arsenic is removed from the air by rain, snow, and gradual settling.
- Once arsenic enters the soil or surface water, it can slowly enter ground water.

Arsenic toxicity:

- Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions.
- It has also been associated with cardiovascular disease and diabetes.
- Exposure to high levels of arsenic may cause stomach pain, vomiting, diarrhoea and impaired nerve function.
- Exposure to amounts of arsenic can be fatal.

1.3 Municipal water treatment / Potable water treatment

Municipal water / Potable water

Municipal water is tap water that is sent to various industries and homes through underground pipes. This water is fully treated and processed and is safe for domestic and drinking purposes.

Municipal water supply

A public water supply system or water supply network including water treatment facilities, water storage facilities (reservoirs, water tanks and water towers) and a pipe network for distributing the treated water to customers including residential, industrial, commercial or institutional establishments.

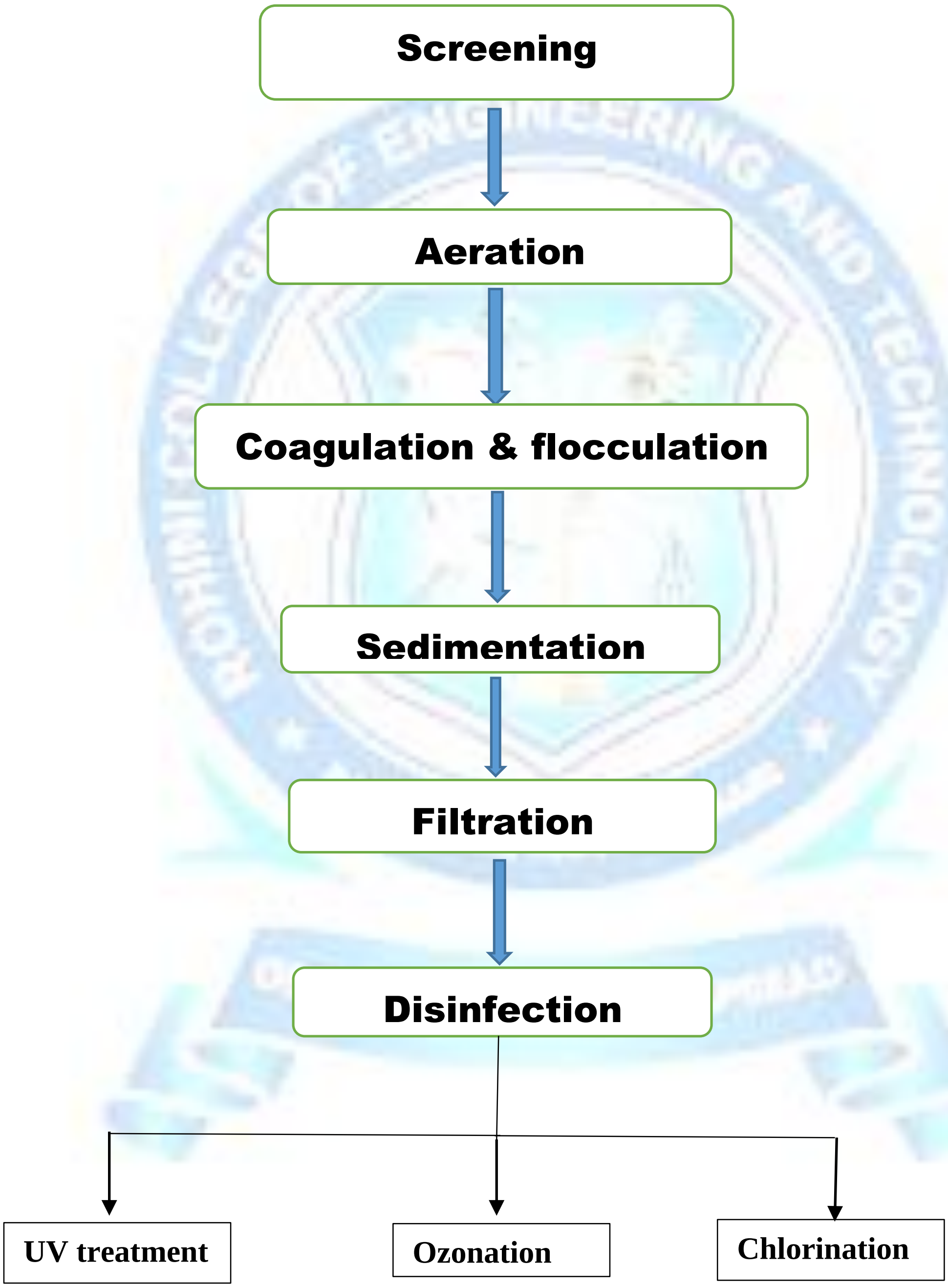
Municipal water treatment

Water treatment *is the process of removing all physical, chemical or biological impurities that are potentially harmful for human and domestic use. This treatment helps to produce safe, palatable, clear, colourless and odourless water.*

The need for municipal water treatment

In urban areas, there is large demand for water. As the urban population is increasing, there is a need to find new sources to meet the growing demand. If groundwater is available this can often be used with minimal treatment but any surface water source will need to be treated to make it safe. For towns and cities, the water supply is then best provided by large mechanized water treatment plants that draw water from a large river or reservoir, using pumps. The treated water is then distributed by pipelines.

Stages of municipal water treatment



1. **Screening**
   - It is the process of using screens to remove floating and suspended solids that are present in the flowing water.
   - The floating materials include leaves, twigs, paper, rags and other debris.

- There are coarse and fine screens.
- Suspended matter as small as algae and plankton (microscopic organisms that float in water) can be trapped by using fine screens.

2. Aeration

- After screening, the water is aerated (supplied with air).
- This helps to expel soluble gases such as CO_2 and H_2S and any gaseous organic compounds that might give an undesirable taste to water.

3. Coagulation and flocculation

Coagulation

- After aeration, **coagulation** takes place, to remove the fine particles (less than 1 µm in size) that are suspended in the water.
- A **coagulant** (with a positive electrical charge) is added to water, (this neutralises the negative electrical charge of the fine particles). the fine particles come together, forming soft, fluffy particles called 'flocs'.
- Two commonly used coagulants are aluminium sulphate and ferric chloride.

Flocculation.

- Here the water is gently stirred in a flocculation basin and the flocs come into contact with each other to form larger flocs.
- Chemicals called flocculants are added to enhance the process.
- Organic polymers called polyelectrolytes can be used as flocculants.

4. Sedimentation

- The water (after coagulation and flocculation) is kept in the tank for 2-6 hours for sedimentation to take place.
- The material accumulated at the bottom of the tank is called sludge; this is removed for disposal.

5. Filtration

Filtration is the process where solids are separated from a liquid by passing the water through beds of sand and gravel.

6. Disinfection/sterilization

- The process of removal, or killing of pathogenic microorganisms is called disinfection. It is otherwise termed as sterilization.
- The three main methods of disinfection are UV treatment, Ozonation and chlorination.

a) UV treatment

- UV rays produced from the mercury vapour lamp has strong germicidal ability.
- UV rays can break the chemical bonds and kill microbes.

b) Ozonation / Ozonisation

- Ozone is a form of oxygen (O_2) with the molecular formula O_3.
- It is a powerful oxidant and one of the most powerful disinfectants available in water treatment.
- Ozone is effective in removing colour, organic chemicals and odour causing contaminants in wastewater.

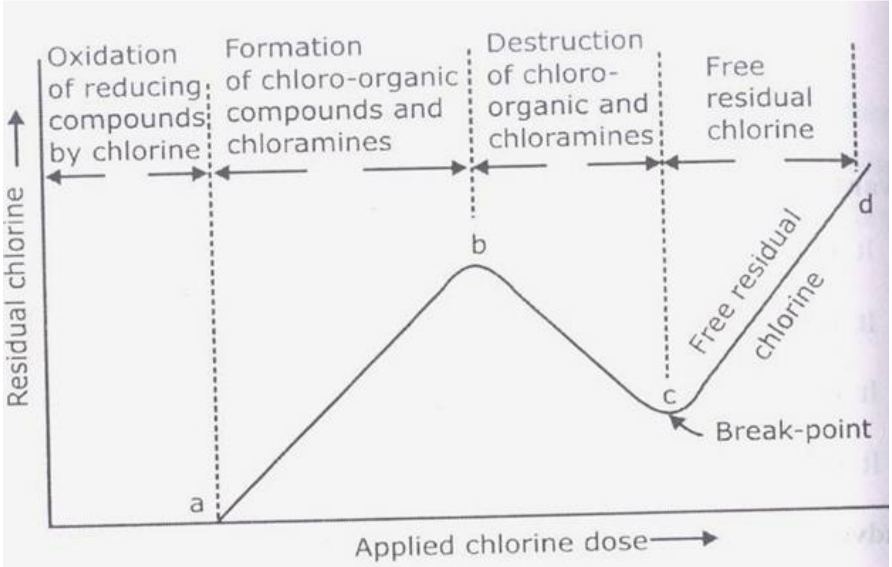
c) Chlorination

- The most commonly used disinfectant is chlorine.
- It can be used in the form of a liquid (such as sodium hypochlorite, NaOCl) or as chlorine gas.
- It is relatively cheap, and simple to use.

Breakpoint chlorination

When sufficient quantity of chlorine is added to water it oxidises all organic and inorganic impurities in water.

Break point is a point where all the impurities present in the water such as reducing compounds, organic compounds and ammonia are oxidised by chlorine and the chlorine further added acts as a disinfectant to kill the pathogens.



Advantages of break point chlorination: (Significance)

i) It is used to remove Bacteria, Ammonia, Organic impurity (sewage) Inorganic salt impurities (Effluents, H_2S, Fe salts) from water.

ii) It prevents the growth of any weeds in water.