UNIT 4 TREATMENT OF RAW WATER FOR DRINKING

Structure

4.1 INTRODUCTION

The drinking water should be colourless, free from suspended impurities, germs, bacteria and other dissolved impurities which are injurious to health. Therefore, drinking water is to be purified and some important stages of purification of raw water are as follows :

(a) Pretreatment

(b) Sedimentation

(c) Filtration

(d) Disinfection

(e) Desalination

In this unit, you will study about the experiments on the use of bleaching powder for disinfection, the desalination of saline water and determination of pH.

The most common application of chlorination is disinfection of drinking water to destroy microorganisms that cause diseases in humans. Chlorine is a powerful disinfectant as it produces HOCl, OCl^- and chloramines.

$$Cl_2 + H_2O \rightarrow HCl + HOCl \underset{pH<7}{\overset{pH>8}{\rightleftharpoons}} H^+ + OCl^-$$

The presence of ammonia in water leads to the formation of chloramines as follows :

$$NH_4^+ + HOCl \rightarrow NH_2Cl + H^+ + H_2O$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O$$

$$NH_2Cl + HOCl \rightarrow NCl_3 + H_2O$$

The chemical species HOCl, OCl^- are free chlorine residuals whereas chloramines are combined residuals and remain in water body for a longer period which help to kill the microorganisms even in the distribution system. The bacterial action of chlorine is mainly because of the toxic nature of the residuals and the oxidation of biomolecules by the nascent chlorine.

The process carried out to remove the common salt (NaCl) from the water body is known as desalination. The water containing dissolved salts with a peculiar salty or brackish taste is called **brackish water**. Brackish water is totally unfit for human consumption.

Objectives

After studying this unit, you should be able to

- define desalination and disinfection of water,
- define the chlorination,
- explain how chlorine acts as a powerful disinfactant,
- discuss the role of chlorination,
- explain the principle of desalination or reverse osmosis,
- define desalination,
- explain how reverse osmosis helps in desalination of brackish water,
- estimate the dosages of bleaching powder required for disinfection a certain volume of water,
- define pH, and
- explain determination of pH using pH meter.

4.2 EXPERIMENT NO. 9 : DETERMINATION OF DOSAGES OF BLEACHING POWDER REQUIRED FOR DISINFECTION OF DIFFERENT WATER SAMPLES

4.2.1 Principle

Bleaching powder is a mixture of calcium hypochlorite $Ca(OCl)_2 . 4H_2O$ and the basic chloride $[CaCl_2 . (Ca(OH)_2 . H_2O)]$ and some free slaked lime being also present. In this experiment, increasing amounts of a standard solution (solution of known concentration) of bleaching powder are added to equal volumes of different water samples taken in different containers. After allowing contact period of minimum 15 minutes, approximately 0.5 to 1 g of KI crystals are added to each container and followed by this, 3 mL of glacial acetic acid is added to each container. The reaction proceeds as shown below and iodine is liberated, i.e. disinfection is complete.

$$OCl^- + 2H^+ + 2I^- \rightarrow I_2 + H_2O + Cl^-$$

After the completion of disinfection, whatever the chlorine is present in water is the residual chlorine which is detected by the appearance of blue colour on addition of starch solution.

$$I_2 + \text{starch solution} \rightarrow \text{Blue colour}$$

4.2.2 Requirements

Apparatus	Quantity
Beaker (250 mL)	5
Glass stirrer	1
Dropper	1
Burette	1
Burette stand	1
Volumetric flask (500 mL)	1

Chemicals
Bleaching powder
Potassium iodide
Glacial acetic acid
Freshly prepared starch solution

Solution Prepared : Standard Bleaching Powder Solution

5 gm of bleaching powder is dissolved in 500 mL of distilled water in a volumetric flask.

4.2.3 Procedure

The experimental procedure involves the following steps :

(a) Take all the apparatus and chemicals to your working table.

(b) Fill the burette with standard bleaching powder solution and clamp it on the stand.

(c) Take 5 beakers of 250 mL capacity and label them as 1, 2, 3, 4 and 5.

(d) In each beaker, take equal volume of water sample, say, 100 mL and arrange them in a row.

(e) From the burette, transfer 1, 2, 3, 4 and 5 mL of the standard bleaching powder solution to the breakers 1 to 5, respectively.

(f) Stir thoroughly the beakers and allow to stand for a minimum period of 15 minutes as contact period.

(g) Then add 0.5 g of KI and 3 mL of glacial acetic acid to each beaker followed by 3 to 4 drops of freshly prepared starch solution.

(h) Stir the solution and look for the development of blue colour.

(i) If none of the beaker develops blue colour then throw the contents and wash the beaker thoroughly.

(j) Again start the experiment from the beginning but this time increase the dosages of bleaching powder solution as 6, 7, 8, 9 and 10 mL of solution to each of the beakers from 1 to 5, respectively.

(k) In a similar way, repeat the experiment till you get the blue colour and note the minimum volume (in mL) of bleaching powder solution with which the blue colour develops (Table 4.1).

4.2.4 Observations

Volume of water sample taken = . . . mL

Concentration of bleaching powder solution used = 5g/500 mL = 1g/100 mL

Contact period = . . . minutes = 15 minutes

Temperature of experiment = . . . ^{o}C

Table 4.1 : Dosages of Bleaching Powder Solution Required for Disinfection of Water

Sl. No.	Volume of Bleaching Powder Solution (in mL)	Appearance of Blue Colour	Minimum mL for Producing Blue Colour
1	1	No	
2	2	No	4 mL (for example) (say *n* mL)
3	3	No	
4	4	Yes	
5	5	Yes	

4.2.5 Calculations

'*n*' mL of bleaching powder solution disinfected = 100 mL of water sample

1 mL of bleaching powder (B. P.) solution disinfected $= \frac{100}{n}$ mL of water sample

100 mL of B. P. solution disinfected $= \frac{100 \times 100}{n}$ mL of water sample.

$= \frac{10}{n}$ litres of water sample.

Now, $\frac{10}{n}$ litres of water sample required = 100 mL = 1 g bleaching powder

($\because$ 5 gm/500 mL)

1 litres of water sample required $= \frac{10}{n} \times$ 1 g of bleaching powder

10^3 (say) litres of water sample required $= \frac{10}{n} \times 10^3 \times 1\text{ g}$ of B. P. = 100 *n* g of B. P.

In this case, for example, *n* = 4.

Then, 100 × 4 g = 400 g of B. P.

4.2.6 Result

The dosages required for disinfection of . . . litre volume of water = . . . gm (or kg).

SAQ 1

(a) What is chlorination? Why chlorination is an important method for the purification of drinking water?

(b) What is bleaching powder? Write the chemical composition of bleaching powder.

4.3 EXPERIMENT NO. 10 : DESALINATION OF SALINE OR BRACKISH WATER (BY REVERSE OSMOSIS PROCESS)

The processes for separating common salts (NaCl) from water in potables water treatment include distillation, reverse osmosis and electrodialysis. Distillation and reverse osmosis are the common methods for desalination.

4.3.1 Principle

The basic principle of reverse osmosis process involves manipulation of the osmotic pressure of a solution. Reverse osmosis process is employed to separate the pure water from its pollutants by using a membrane filter. This is also called as *hyperfiltration* or *superfiltration*. In this method, the high pressure is applied to the water to force out the liquid through a semi-permeable membrane leaving behind the dissolved solids (Figure 4.1).

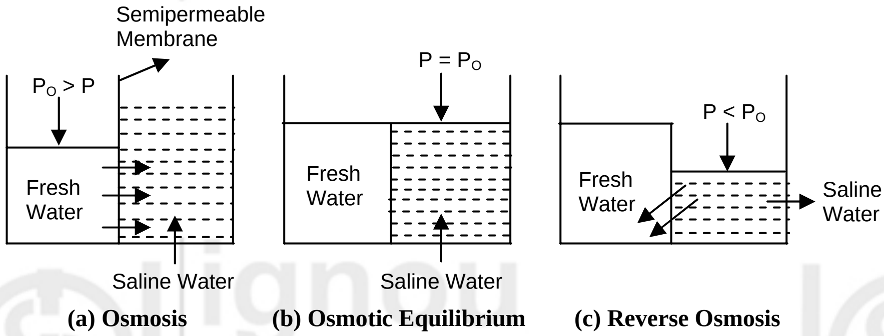

Figure 4.1 : The Process of Reverse Osmosis

The rate of water transfer depends primarily on the difference in salt concentration between the solutions, characteristics of the membrane, and magnitude of the applied pressure. The ideal range of Reverse Osmosis Pressure is of 600 to 800 Psi.

4.3.2 Requirements

Apparatus : Reverse Osmosis Cell **Chemical :** Water Sample (Saline)

The other apparatus and chemicals will be the same as per the experiment of water for testing chloride content.

4.3.3 Procedure

The experimental procedure involves the following steps :

(a) Carry out the experiment for chloride content in water sample in the same way as done in Experiment No. 8 (Unit 3) before feeding the water sample to reverse osmosis cell.

Sodium Chloride vs Silver Nitrate Solution

Sl. No.	Volume of NaCl (in mL)	Burette Reading (in mL)		Volume of $AgNO_3$ Salt (in mL) (Final – Initial)
		Initial	Final	
1	25			
2	25			
3	25			

(b) The semi-permeable membrane (polymethacrylate, polyamide polymer or polysulphone) is put into place.

(c) A given volume of saline water (water sample), say 2 litre, is fed into the reverse osmosis cell.

(d) Increase the reverse osmotic pressure slowly till the water from the saline water side will come across to the fresh water side.

(e) Carry out the process by increasing the reverse osmotic pressure at the rate of 10 to 20 Psi per minute. This process should be carried out till the maximum volume of fresh water is obtained.

(f) The fresh water will be collected and subjected to chloride content in water test in same way, as in (a) above.

Water Test Sample vs Silver Nitrate Solution

Sl. No.	Volume of Water Test Sample (in mL)	Burette Reading (in mL)		Volume of $AgNO_3$ Salt (in mL) (Final – Initial)
		Initial	Final	
1	25			
2	25			
3	25			

4.3.4 Calculations

Chloride content in water sample before reverse osmosis = . . . g L^{-1} (say *X*)

Chloride content in water sample (fresh) after reverse osmosis = . . . g L^{-1} (say *Y*)

The percentage of chloride content has been reduced by this process

$$= \frac{X - Y}{X} \times 100 = \ldots \% \text{ removed}$$

4.3.5 Result

In this desalination process (RO) the salinity has been reduced to = . . . %.

SAQ 2

What is the basic principle of Reverse Osmosis?

4.4 EXPERMINET NO. 11 : DETERMINATION OF pH OF THE SOLUTION USING pH METRE

4.4.1 Principle

The degree of acidity or alkalinity of a solution is expressed by using pH scale. Sorensen expressed the concentration of H^+ ions in solution in terms of a series of numbers between 0 and 14, called pH which can be defined as the negative logarithm of hydrogen ion concentration. The concentration is expressed in molarity so the pH value also expressed in molarity. Mathematically,

$$pH = -\log [H^+] \quad \text{or} -\log C_{H^+}$$

For pure water $\quad H_2O \rightleftharpoons H^+ + OH^-$

$$C_{H^+} = C_{OH^-}$$

$$K_W = C_{H^+} + C_{OH^-} \quad (\because K_W = \text{Ionic produce of water})$$

At 25°C, $\quad K_W = 10^{-14}$

So, $\quad C_{H^+} = C_{OH^-} = 10^{-7} \text{ gm ion } L^{-1}$

or $$pH = -\log_{10} 10^{-7} = 7$$

Therefore, pH value is (i) 7 for a neutral solution, (ii) less than 7 for an acidic solution and (iii) more than 7 for an alkaline solution.

In this experiment, you will determine the pH of a solution using pH metre (Figure 4.2).

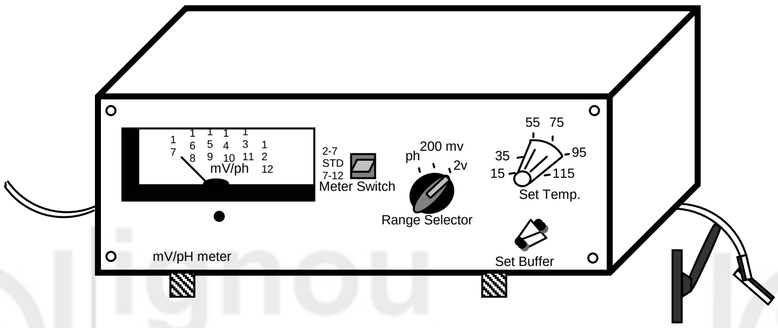

Figure 4.2 : pH Metre

4.4.2 Description of pH Metre

Power Switch

This is located in the back panel of the instrument, which turns the instrument OFF/ON. When the switch is in ON position, the indicator light will glow.

Range Selector

This switch may be put on three positions marked pH, 200 mV and 2V. The selector brings into the circuit either pH scale or 200 mV or 2 V scale.

Meter Switch

This is a sliding switch with three positions. The middle position serves as a stand by position. For pH measurement, the switch chooses the appropriate range (7-2 or 7-12).

Set Temperature

You will have to adjust the pH meter temperature according to that of the solution.

Set Zero

For pH measurement, it should be used to set the meter at the pH of the solution in the indicator cell.

Set Slope

There are two such knobs which can be used to read pH value at the appropriate range, i.e. 7-2 or 7-12.

Cell Connection

In this experiment, you will use direct reading type pH meter where the emf of the cell containing the glass electrode was impressed upon a high resistance and current flowing in the resistance was then amplified and applied to a sensitive moving coil meter. The moving coil was calibrated in millivolts and hence the cell emf was directly recorded.

4.4.3 Requirements

Apparatus	Quantity	Chemicals
PH meter with glass electrode	1	Testing solution say acetic acid

Beakers	3	Distilled water Buffer solution of pH 4 Buffer solution of pH 7

Solutions Provided

Buffer Solution of pH 4

The requisite buffer solution may be prepared by dissolving a buffer tablet of pH 4 in a 100 mL distilled water in a volumetric flask. Or, it is prepared by dissolving 10.21 g of the potassium hydrogen phthalate in 100 mL of distilled water.

Buffer Solution of pH 7

It is also prepared by dissolving the buffer tablet of pH 7 in 100 mL distilled water or by dissolving 3.40 g of potassium dihydrogen phosphate (KH_2PO_4) and 3.55 g of disodium hydrogen phosphate (Na_2HPO_4) in 1000 mL distilled water.

4.4.4 Procedure

The experiment procedure involves the following steps :

(a) Switch on the instrument and allow it to warm up for 10 minutes.

(b) Set the selector on the pH mode and the meter switch on 7.2 position.

(c) Set the control to the measured temperature of the solution.

(d) Use the set zero control to set the meter reading to 7.0 and slide the meter switch to standby position.

(e) Wash the electrode with distilled water and insert it into a 100 mL beaker containing 20 mL of pH 4.0 buffer solution.

(f) Carefully adjust the set buffer control until the meter reading coincides with the known pH 4 of the buffer solution.

(g) The electrode is taken out and washed with distilled water. Again, it is inserted into 2^{nd} beaker containing buffer solution of pH 7. If the meter reading does not agree exactly with the known pH (7) of the 2^{nd} buffer solution, then adjust the 'slope' control to achieve the same. Repeat this to get satisfactory calibration value.

(h) Then the electrode is taken out of the buffer solution and washed with distilled water. It is inserted into the beaker containing test solution (Acetic acid). Read and record the pH value (Table 4.1) of the solution after setting the selector switch to the pH range. Repeat it 3 to 5 times to get a constant pH value of the solution.

4.4.5 Observations and Calculation

Table 4.1 : pH Value of the Solution

Sl. No.	pH Value
1	
2	
3	

4.4.6 Result

The pH value of the given solution = ...

SAQ 3

Define pH. What is the total range of pH values?