Chapter 5

QUALITY OF WATER

Meaning of pure water:

The water required for public water supply schemes should be potable or wholesome water i.e. fit for drinking purposes. It is however not essential to have physically or chemically pure water.

The presence of some minerals in water is required to give some taste to the water i.e. to make it palatable and they also assist in food assimilation. It will be difficult, time consuming and costly to have complete purification of the water.

The impurities in water are to be removed to a certain extent only so that it does not prove harmful to the public health. The term *wholesome water* is used to indicate the water which is not chemically pure, but does not contain anything harmful to the human body i.e. the water in which there are no pathogenic bacteria, no toxic substances and no excessive organic matter. Thus the wholesomeness is a must while the palatability of water is desirable.

The term *pure water* is a relative term and it has to be interpreted in relation to the use of water. The concept of pure water, potable water or wholesome water with relation to various uses of water is understood as follows:

(1) *Domestic use:* The water required for domestic consumption should possess a high degree of purity and it should be free from suspended impurities, bacteria, etc. A tolerance of small degree of hardness developed due to certain dissolved salts is however permissible. Thus the drinking water and water used in the food industry and some other industries must meet the highest standard of purity.

Following are the requirements of *potable* or *wholesome* water for domestic use:

(1) It should be clear, odourless and colourless.
(2) It should be free from harmful and disease producing bacteria.
(3) It should be free from all objectionable substances.
(4) It should be fresh and cool.
(5) It should be palatable i.e. aesthetically attractive.
(6) It should be tasty.
(7) It should not cause corrosion to the pipes and other fittings.

(2) *Civic use:* For this purpose, a large quantity of water is required to fulfil various civic purposes such as washing of roads, cleaning of sewers, etc. The nature of use of water is such that any degree of impurity can be tolerated. Hence the water containing large amount of suspended and dissolved impurities may be permitted for this purpose. But the water which is considerably mixed up with sewage and other refuse cannot be tolerated for this purpose.

(3) ***Trade or business use:*** The water required for a particular trade will depend upon nature of that trade. For instance, the water required for laundry should not be hard as it will result in more consumption of soap. Similarly the water required for bathing cattles and washing floors in case of stables may contain any type of impurities.

(4) ***Commercial or industrial use:*** The water required for this purpose should be chemically pure. The various chemical processes involved in the production make it essential to use chemically pure water. A slight amount of impurity may considerably affect the final results of the product.

The nature of water required for various factories is so variable that some of the factories install their own water supply plant to supply water to their industries. Alternatively, a city with well-developed and highly water-consuming industries should have preferably *two* systems of water supply — one supplying potable water for drinking and domestic use; and the other providing water for industry. Moscow, Paris, Hanover, Stuttgart and a number of other big cities of the world have now adopted this system in practice and in future, it may become more popular as a means to save the drinking water.

In this chapter, the various aspects related to the analysis and testing of the water quality will be briefly described.

Reasons for the analysis of water:

Following are the *reasons* or *purposes* for carrying out the analysis of water:

(1) to ascertain if the supplies maintain the required degree of purity and to find out the extent of any variations which occur;

(2) to ascertain the effect of heavy rainfalls or of long-continued drought on river waters;

(3) to ascertain the quality of the proposed supply to the new consumers;

(4) to decide that the water obtained from some additional source or sources of supply will be pure, wholesome, not too hard and free from the risk of any pollution;

(5) to decide the suitability of water for feeding boilers, hot-water pipes, etc.;

(6) to examine the effect of pumping on well waters, especially when wells are situated near the sea or an estuary;

(7) to find out the organisms responsible for the spreading of the water-borne diseases;

(8) to identify the organisms responsible for developing certain effects on water with respect to colour, odour, taste, etc.;

(9) to know the characteristics of waters at various depths of deep wells and tube wells;

(10) to know the quality of water submitted to the various purification processes;

(11) to know the quality of water used or proposed to be used for public swimming baths;

(12) to know whether water from a particular supply of water is suitable for specific purpose such as paper making, dyeing, tanning, wool washing, brewing, steam raising, etc.;

(13) to study the process of self-purification of streams and rivers;

(14) to suggest the best method of purifying, of softening or of preventing action on mains and supply pipes; etc.

Impurities in water:

It is not possible to find pure water in nature. The rain water as it drops down to the surface of earth absorbs dust and gases from the atmosphere. It is further exposed to the organic matter on the surface of earth and by the time, it reaches the source of water supply, it is found to contain various other impurities also.

For the purpose of classification, the impurities present in water may be divided into the following *three* categories:

(1) Physical impurities
(2) Chemical impurities
(3) Bacteriological impurities.

The detailed discussion on physical impurities, chemical impurities and bacteriological impurities leading respectively to physical pollution, chemical pollution and bacteriological pollution of water is given in Chapter XV of this book under the topic — types of water pollution.

Analysis of water:

In order to ascertain the quality of water, it is subjected to the various tests. These tests can be divided into the following *three* categories:

I. Physical tests
II. Chemical tests
III. Bacteriological tests.

Before we take up the discussion of various tests, it will be necessary to note the precautions which are to be taken while collecting the sample of water to be analysed. In fact, the sampling is the most important part of any analysis because the final results obtained, even from the most accurate analysis, will be misleading, if the samples on which such analysis is carried out, are not representative ones of the liquids to be tested. As a matter of fact, it will be ideal to carry out all the analysis immediately after the collection of samples and the quicker the analysis, the more representative will be the results of analysis of the liquid at the time the samples are taken. These precautions are as follows:

(1) The water should be collected in bottles, especially of white glass, having well-fitted stoppers. The bottles having holding capacity of about 2 litres of water are necessary for the chemical analysis. For bacteriological examination, the bottles with smaller holding capacities will be sufficient.

(2) The bottles should be thoroughly cleansed, filled thrice with water and thrice emptied before collecting the sample. However, it will not be necessary to carry out such process, if the sealed bottles are directly obtained from the laboratories.

(3) When the sample of water is to be collected from a pipe, the water tap should be turned on and the water should be allowed to go waste for at least *two* minutes so as to prevent the entry of impurities of the pipe in the sample of water. If the sample is to be collected for conducting a bacteriological analysis, the nozzle of the tap should be flamed and made unbearably hot and then cooled by the running water before the bottle is filled.

(4) For collecting the sample of water from lake, stream, spring or well, the whole bottle with stopper closed should be suspended well under the surface of water and then only the stopper of bottle should be removed by means of a clean piece of string and the bottle is filled. Thus the entry of floating materials will be prevented in the bottle.

(5) The bottle should be held as far away from its neck as possible. In no case, the water entering the bottle should come in contact with the hand.

(6) After collecting the sample, the stopper of bottle should be well secured and the bottles containing samples of water should be labelled stating the source, date and time of collection.

I. Physical tests:

Under this category, the tests are carried out to examine water for the following:

(1) Colour
(2) Taste and odour
(3) Temperature
(4) Turbidity.

Other physical characteristics for which tests are sometimes carried out are density, electrical conductivity, radioactivity and viscosity.

(1) *Colour:* The pure water is colourless and following are the sources which contribute colour to the water:

(i) algae metabolism;
(ii) end products of degraded organic matter;
(iii) discharge of untreated and partially treated waste water from various industries like food processing, textile industry, tanneries, paper production, etc.
(iv) divalent species containing iron and manganese; etc.

The colour caused by the suspended matter is known as the *apparent colour* and the colour contributed by dissolved solids that remain after removal of suspended matter is referred to as the *true colour.*

An undesirable appearance is produced by colour in water. It spoils the clothes and affects various industrial processes. The measurement of colour in water is carried out by means of a *tintometer*. The instrument has an eye-piece with *two* holes. A slide of standard coloured water is seen through one hole and in the other hole, the slide of water to be tested is inserted. The intensity of colour in water is measured on an arbitrary scale. The unit of colour on cobalt scale is the colour produced by one milligram of platinum cobalt in litre of distilled water. The slide of standard numbers are kept ready in the laboratory. For public water supply, the number on cobalt scale should not exceed 20 and should be preferably less than 10. The measurement of water from the sample should be done within 72 hours of its collection.

It should however be remembered that the examination of colour by matching with slides of standard colours will be sufficient for most of the purposes and it is obvious that the results will be influenced by the personal factor, the conditions of lighting under which the tests are carried out, etc.

Following are the *disadvantages* of the water possessing colour:

(i) It is found that many colour bodies are colloidal in nature and they behave as adsorbents. Thus they concentrate on many trace metals and exert toxicity to the aquatic life.

(ii) The coloured water is unsuitable for certain industries like dairy production, paper making, laundering, textile, etc.

(iii) The receiving waters polluted with colour restrict the penetration of light which subsequently retard the photosynthetic reactions. It also indirectly affects the reoxygenation capacity of the receiving waters.

(iv) The true colour causing organic compounds exert a chlorine demand and hence it will increase the quantity of chlorine required for disinfection of water.

(2) *Taste and odour:* The water possesses taste and odour due to various causes and they make the water unpleasant for drinking. The test is carried out by inhaling through *two* tubes of an *osmoscope*. One tube is kept in a flask containing diluted water and the other one in a flask containing water to be tested. The taste and odour of water may also be tested by threshold number. In this method, the water to be tested is diluted with odour-free water and the mixture at which odour becomes detectable is determined. It indicates threshold number and other intensities of odour are then worked out. The results of test are greatly affected by the sensitiveness of the observer. For public water supply, the threshold number should not be more than 3.

In any event, the water to be supplied from a public water supply scheme should not contain objectionable taste and odour. The odour is expressed as disagreeable, earthy, fishy, grassy, mouldy, peaty, sweetish, etc. If an odour of chlorine or iodoform is found, it should always be recorded. The taste is expressed as brackish, saline, salty, etc. Some persons are more sensitive than others and what is called a taste is often nothing more than a sensation of roughness on the palate after the water has been swallowed.

If the taste and odour are suspected to be due to the growth of any kind, the cause may be found out by conducting microscopical and biological examinations.

(3) *Temperature:* The test for temperature of water has no practical meaning in the sense that it is not possible to give any treatment

to control the temperature in any water supply project. The temperature of water to be supplied from storage reservoir depends on the depth from which it is drawn. The desirable temperature of potable water is 10°C while temperature of 25°C is considered to be objectionable.

It should however be noted that changes in temperature of water from its source to the mains may be helpful in detecting the unsuspected source of pollution. Also the multiplication of bacteria in the waters is more rapid at higher temperature than in the waters at lower temperature. Hence, when waters with a temperature of about 15°C are collected for bacteriological analysis, they should be cooled down as quickly as possible. It should further be remembered that the air temperature at the time of taking the water sample should always be recorded.

The measurement of temperature of water is done with the help of ordinary thermometers. From the study of temperature, the characteristics of water such as density, viscosity, vapour pressure and surface tension can be determined. It also helps in determining the saturation values of solids and gases which can be dissolved in water and also the rates of chemical, biochemical and biological activity.

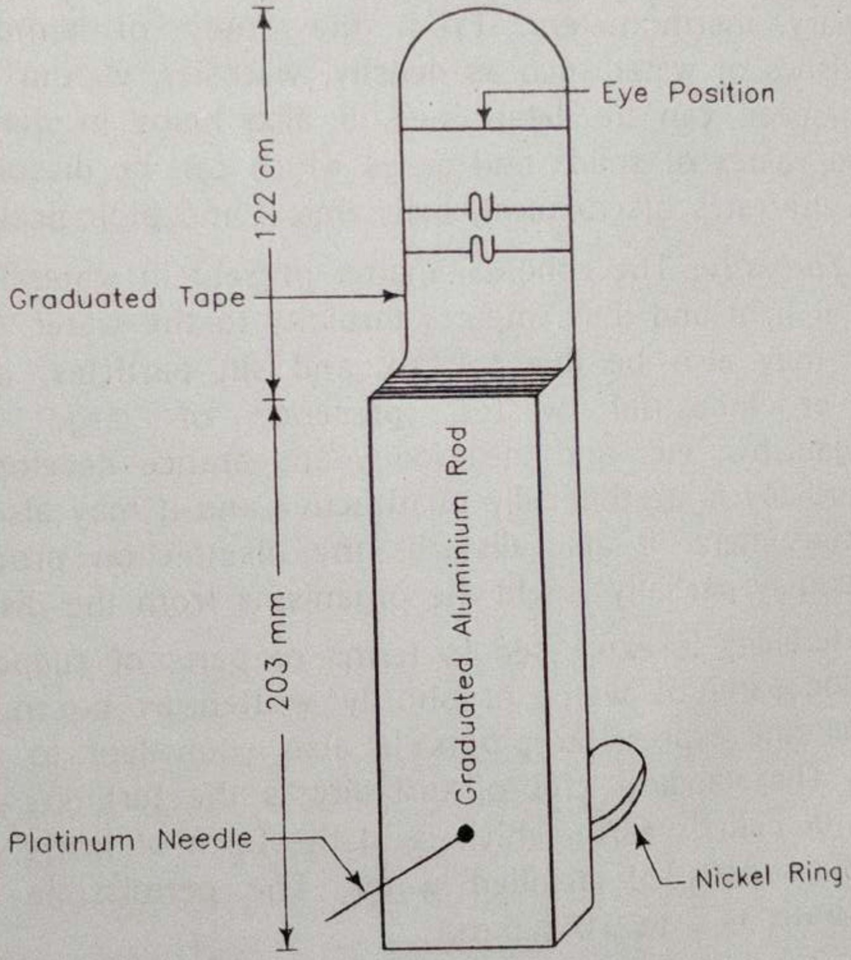
(4) *Turbidity:* The colloidal matter present in water interfers with passage of light and thus imparts turbidity to the water. The turbidity in water may also be due to clay and silt particles, discharges of sewage or industrial wastes, presence of large numbers of micro-organisms, etc. and the cloudy appearance developed in water due to turbidity is aesthetically unattractive and it may also be harmful to the consumers. It also disturbs the disinfection process because the solids may partially shield the organisms from the disinfecant.

The turbidity is expressed in terms of parts of suspended matter per million parts of water or shortly written as p.p.m. It is to be noted that the expression p.p.m. is also equivalent to mg per litre or mg/l. The standard unit of turbidity is the turbidity produced by one part of Fuller's earth which is in the form of finely divided silica in a million parts of distilled water. The permissible turbidity for drinking water is 5 to 10 p.p.m.

It should be remembered that turbidity is not a direct quantitative measurement of the suspended solids. The absorption and scattering of particles are influenced by both size and surface characteristics of the suspended material. For instance, one small pebble in a sample of water will not cause any turbidity. But if this pebble is crushed into small particles, a measurable turbidity would be developed even though the mass of pebble remains unchanged.

The measurement of turbidity in the field is done by means of a turbidity rod and it is referred to as the *visual method of turbidity measurement.* For laboratory, the various instruments known as the *turbidimeters* are found out to measure the turbidity of water, the most common being Jackson turbidimeter, Baylis turbidimeter and Nephelometric turbidimeter.

Turbidity rod: The instrument consists of a graduated aluminium rod about 203 mm long. A graduated non-stretchable tape about 122 cm long is attached at the upper end of the aluminium rod as shown in fig. 5-1. At the lower end of the aluminium rod, a screw containing platinum needle and nickel ring is inserted. The diameter of platinum needle is 1 mm and its length is 25 mm. The nickel ring is provided to insert a stick so that the instrument may be kept in vertical position. On the graduated tape, there is a mark for eye position.



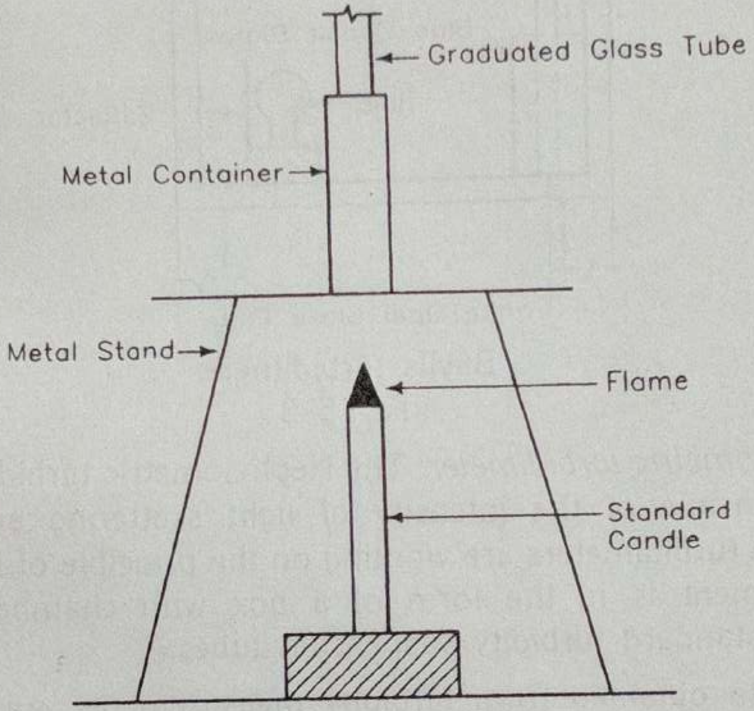
Turbidity rod

FIG. 5-1

For measuring turbidity of water, the rod is lowered in water and the depth at which the platinum wire ceases to be seen under standard light conditions is noted and corresponding reading on the bar gives the turbidity of water in p.p.m.

Jackson turbidimeter: It consists of metal stand, standard candle, metal container and graduated glass tube as shown in fig. 5-2. For measuring turbidity of water, some quantity of water is poured in the glass tube and image of candle flame is observed from the top. The depth of water in glass tube is gradually increased until the image of candle flame ceases to be seen. The corresponding reading on the glass tube indicates turbidity of water in p.p.m.

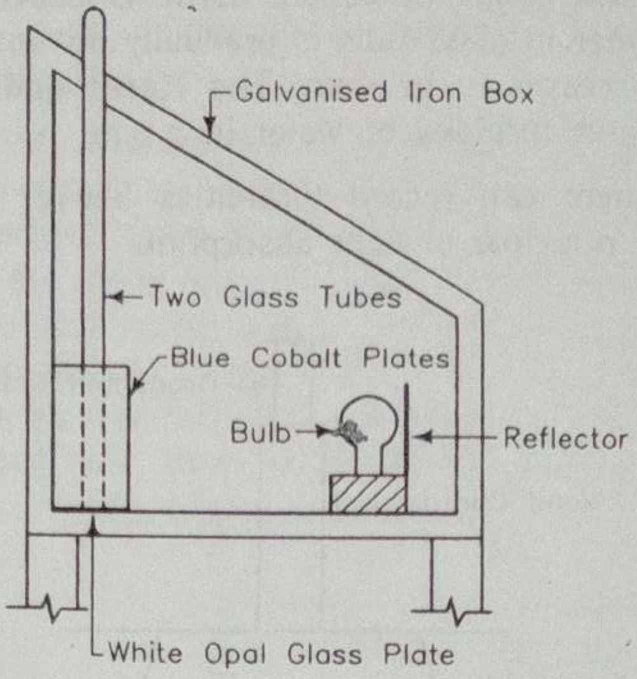
This instrument can record turbidities above 100 p.p.m. and it is based on the principle of light absorption.



Jackson turbidimeter
FIG. 5-2

Baylis turbidimeter: This instrument consists of a galvanised iron box. On one side of the box, there are *two* glass tubes and on the other side is a 250-watt bulb with reflectors as shown in fig. 5-3. The glass tubes are supported at their lower ends by a white opal glass plate and they are surrounded near their bottom portion by blue cobalt plates.

Out of *two* glass tubes, one is filled with water whose turbidity is to be determined and the other is filled with standard solution of known turbidity. The bulb is lighted and blue light from both the tubes is observed from the top. If colour of both the tubes differ, another tube of standard solution is inserted and the process is continued until colours of both the tubes are nearly same. The turbidity of standard solution then corresponds to the turbidity of sample of water. This instrument can record turbidities less than 5 p.p.m.



Baylis turbidimeter
FIG. 5-3

Nephelometric turbidimeter: The Nephelometric turbidimeter is based on the principle of the intensity of light scattering and now-a-days most of the turbidimeters are working on the principle of light scattering. The instrument is in the form of a box with chambers for sample tubes and standard turbidity suspension tubes.

The data obtained from turbidity measurements are helpful in the following ways:

(i) It assists in deciding whether turbidity interfers with the photosynthetic reaction in streams and lakes.
(ii) It gives indication of the quantity of chemicals required for day to day operations of water treatment works.
(iii) It helps in determining whether a public water supply requires before use special treatments by chemical coagulation and filtration.
(iv) The excess tubidity may seriously affect the functioning of slow sand filters.
(v) The optimum dosage of coagulants to treat the domestic and industrial waste can be determined.
(vi) The performance of water treatment plants can be evaluated.
(vii) The turbidity measurements of the filtered water are required to check the faulty filter operation.

II. Chemical tests:

Under this category, the tests are carried out to examine water for the following:

(1) Chlorides
(2) Dissolved gases
(3) Hardness
(4) Hydrogen-ion concentration (pH value)
(5) Alkalinity
(6) Acidity
(7) Metals and other chemical substances
(8) Nitrogen and its compounds
(9) Total solids.

(1) ***Chlorides:*** The chloride contents, especially of sodium chloride or salt, are worked out for a sample of water. The excess presence of sodium chloride in natural water indicates pollution of water due to sewage, minerals, edible oil mill operations, ice cream plant effluents, chemical industries, sea water intrusion in coastal regions, etc. The water has lower contents of salt than sewage due to the fact that salt consumed in food is excreted by body. For potable water, the highest desirable level of chloride content is 250 mg/litre and its maximum permissible level is 600 mg/litre.

It may be noted that there is no known evidence to show that the chlorides constitute any human health hazard. It is for this reason that the public water sources containing chlorides as much as 2000 mg/litre of water are used for domestic purposes because such water does not develop any adverse effect once the human body gets adjusted to such water.

The measurement of chloride contents is carried out as follows:

(a) 50 c.c. of sample of water is taken by pipette in a porcelain dish.
(b) *Two* or *three* drops of potassium chromate solution are added to the sample of water.
(c) The chloride contents are then determined by titrating with standard solution of silver nitrate.

The silver reacts first with all chlorides and silver chloride thus formed then reacts with potassium chromate. The silver chromate appears as reddish precipitate and the amount of silver nitrate required to produce such reddish precipitate determines the amount of chlorides present in water. The chemical reactions are as follows:

$$AgNO_3 + NaCl = AgCl + NaNO_3$$
$$2AgCl + K_2Cr_2O_7 = Ag_2Cr_2O_7 + 2\ KCl.$$

The presence of chlorides can corrode and such water cannot be used for boilers because of formation of hydrochloric acid due to presence of magnesium chloride in water. The pH value of sample of water is to be adjusted between 7 and 8 either by adding sulphuric acid or sodium hydroxide solution. Otherwise, the test results are likely to be affected.

(2) ***Dissolved gases:*** The water contains various gases from its contact with the atmosphere and ground surfaces. The usual gases are nitrogen, methane, hydrogen sulphide, carbon dioxide and oxygen. The contents of these dissolved gases in a sample of water are suitably worked out.

The nitrogen is not very important. The methane concentration is to be studied for its explosive property. The hydrogen sulphide gives disagreeable odour to the water even if its amount is very small. The carbon dioxide content indicates biological activities, causes corrosion, increases the solubility of many minerals in water and gives taste to the water.

The oxygen in the dissolved state is obtained from atmosphere and pure natural surface water is usually saturated with it. The simple test to determine the amount of dissolved oxygen present in a sample of water is to expose water for 4 hours at a temperature of 27°C with 10% acid solution of potassium permanganate. The quantity of oxygen absorbed can then be calculated. This amount, for potable water, should be about 5 to 10 p.p.m.

1.9 (3) ***Hardness:*** The term *hardness* is defined as the ability of the water to cause precipitation of insoluble calcium and magnesium salts of higher fatty acids from soap.

The hardness or soap-destroying power of a water is of *two* types — temporary hardness and permanent hardness.

The *temporary hardness* is also known as the *carbonate hardness* and it is mainly due to the presence of bicarbonates of calcium and magnesium. It can be removed by boiling or by adding lime to the water.

The *permanent hardness* is also known as the *non-carbonate hardness* and it is due to the presence of sulphates, chlorides and nitrates of calcium and magnesium. It cannot be removed by simply boiling the water. It requires special treatment of water softening.

Thus the hardness of water is divided into the following *two* forms:

(1) Carbonate hardness—metals associated with HCO_3^-

(2) Non-carbonate hardness—metals associated with SO_4^{--}, Cl^- and NO_3^-.

Now, most of the natural alkalinity in waters is due to HCO_3^- which is produced by the action of ground water on limestone or chalk as shown by the following equation:

$$\underset{\text{(Insoluble)}}{CaCO_3} + \underset{\text{(From soil bacteria)}}{H_2O + CO_2} \longrightarrow \underset{\text{(Soluble)}}{Ca(HCO_3)_2}$$

Thus we get the following relation:

Total hardness = Carbonate hardness or alkalinity + Non-carbonate hardness

or T.H. = C.H. + N.C.H.

Following *two* rules should be remembered in this connection:

(1) When alkalinity < T.H., then

C.H. = Alkalinity

(2) When alkalinity $\geq$ T.H., then

C.H. = T.H.

The excess hardness of water is undesirable because of various reasons such as it causes more consumption of soap, affects the working of dyeing system, provides scales on boilers, causes corrosion and incrustation of pipes, makes food tasteless, etc.

The hardness is expressed as per Clark's scale in terms of degree of hardness. Thus one grain of $CaCO_3$ dissolved in one gallon of water will produce one degree of hardness.

Now, 7000 grains = 0.4536 kg = 453600 mg

One grain = 64.8 mg

One gallon (imperial) = 4.546 litres.

Hence one degree of hardness will be equivalent to $\frac{64.8}{4.546} = 14.254$, say 14.3 milligrams of calcium carbonate in a litre of water. The expression p.p.m. is used to mean mg per litre and in that case, one degree of hardness will be equal to 14.3 p.p.m. It is found that each degree of hardness causes wastage of about 0.60 gram of soap.

The hardness is usually measured by the soap solution test. The standard soap solution is added in the sample of water. It is then vigorously shaken for about *five* minutes and the formation of lather is observed. The difference between the total amount of soap solution and the lather factor indicates the hardness of water.

The water, having hardness of about 5 degrees, is reasonably soft water and a very soft water is tasteless. Hence, for potable water, the hardness should preferably be more than 5 degrees but less than 8 degrees or so.

For the purpose of convenience, a tentative scale of hardness may be framed as shown in table 5-1.

TABLE 5-1
SCALE OF HARDNESS

No.	Nature of water	Hardness in degrees
1	Extremely soft	1
2	Very soft	2
3	Soft	3
4	Moderately soft	6
5	Moderately hard	7
6	Hard	9
7	Very hard	11
8	Excessively hard	15
9	Too hard for use	17

The hardness is normally expressed in terms of calcium carbonate. Now the chemical analyses for individual ions are usually given in terms of that ion. It will thus be necessary to convert the analytical results to the common denominator.

$$\text{Hardness in mg/l as } CaCO_3 = M^{++}\,(\text{mg/l}) \times \frac{\text{equivalent wt. of } CaCO_3}{\text{equivalent wt. of } M^{++}}$$

where M represents any ion or radical.

$$\text{Now,} \quad \text{Equivalent weight} = \frac{\text{Molecular weight}}{X}$$

where $X =$ for acids, the number of moles of H^{++} obtainable from 1 mole of acid

$X =$ for bases, the number of moles of H^{++} with which 1 mole of base will react.

$$\text{Thus, Equivalent weight of } CaCO_3 = \frac{(40 + 12 + 3 \times 16)}{2} = 50.$$

For solving problems on hardness, the following facts should be noted:

(1) The alkalinity will be caused by positively charged Ca^{++}, Mg^{++} and Sr^{++} ions and negatively charged CO_3^{--}, and HCO_3^{-} ions only. The readings of other metals should be ignored.

(2) The equivalent weights of Ca^{++}, Mg^{++} and Sr^{++} will be respectively as follows:

$$\begin{aligned} Ca &= 40/2 = 20; \\ Mg &= 24.4/2 = 12.2; \text{ and} \\ Sr &= 87.6/2 = 43.8. \end{aligned}$$

(3) For measuring alkalinity, the reading of only CO_3^{--} or HCO_3^{-} will be required and expressed as percentage, they can be found out from the following relations:

$$\left.\begin{matrix}\text{Total alkalinity} \\ \text{as } HCO_3 \text{ in mg/l}\end{matrix}\right\} = \left\{\begin{matrix}\text{Bicarbonate alkalinity} \\ \text{in mg/l}\end{matrix}\right\} \times 1.22$$

$$\left.\begin{matrix}\text{Total alkalinity} \\ \text{as } CO_3 \text{ in mg/l}\end{matrix}\right\} = \left\{\begin{matrix}\text{Carbonate alkalinity} \\ \text{in mg/l}\end{matrix}\right\} \times 0.60$$

$$\begin{bmatrix}\text{Molecular wt of } HCO_3 = (1 + 12 + 3 \times 16) = 61 \\ \text{Molecular wt of } CO_3 = (12 + 3 \times 16) = 60\end{bmatrix}$$

Problem 5-1.

The analysis of water from a bore shows the following results in mg/l:

$Ca = 60$, $Mg = 48$, $Na = 103.5$, $K = 19.5$
$HCO_3 = 244$, $SO_4 = 220.8$, $Cl = 78.1$.

Find out the total hardness, carbonate hardness and non-carbonate hardness.

Solution:

$$\begin{aligned}\text{Total hardness} &= (60 \times 50/20 + 48 \times 50/12.2) \\ &= (150 + 196.72) = 346.72 \text{ mg/l as } CaCO_3.\end{aligned}$$

$$\left.\begin{matrix}\text{Total alkalinity} \\ \text{as } HCO_3 \text{ in mg/l}\end{matrix}\right\} = \left\{\begin{matrix}\text{Bicarbonate alkalinity} \\ \text{in mg/l}\end{matrix}\right\} \times 1.22$$

$$\therefore \quad 244 = \text{Bicarbonate alkalinity} \times 1.22$$

$$\therefore \text{Bicarbonate alkalinity} = 244/1.22 = 200 \text{ mg/l.}$$

In this case,

$$\text{Alkalinity} < \text{T.H.}$$

$$\therefore \quad \text{C.H.} = \text{Alkalinity} = 200 \text{ mg/l.}$$

Then,

$$\begin{aligned}\text{N.C.H.} &= \text{T.H.} - \text{C.H.} \\ &= (346.72 - 200) = 146.72 \text{ mg/l.}\end{aligned}$$

Problem 5-2.

The analysis of a sample of water shows the following results in mg/l:

Na = 20 Cl = 40
K = 30 HCO_3 = 67
Ca = 5 SO_4 = 5
Mg = 10 NO_3 = 10

The concentration of stroncium (Sr) is equivalent to a hardness of 2.29 mg/l and the carbonate alkalinity in this water is zero. Calculate the total hardness, carbonate hardness and non-carbonate hardness in mg/l as $CaCO_3$.

Solution:

$$\text{Total hardness} = \frac{Ca^{++} \times 50}{20} + \frac{Mg^{++} \times 50}{12.2} + 2.29$$

$$= \frac{5 \times 50}{20} + \frac{10 \times 50}{12.2} + 2.29$$

$$= (12.5 + 40.98 + 2.29)$$

$$= 55.77 \text{ mg/l as } CaCO_3.$$

$$\text{Bicarbonate alkalinity} = 67/1.22 = 54.92 \text{ mg/l as } CaCO_3.$$

In this case,

$$\text{Alkalinity} < \text{T.H.}$$

$$\therefore \quad \text{C.H.} = \text{Alkalinity} = 54.92 \text{ mg/l as } CaCO_3.$$

Then,

$$\text{N.C.H.} = \text{T.H.} - \text{C.H.}$$

$$= (55.77 - 54.92) = 0.85 \text{ mg/l as } CaCO_3.$$

Problem 5-3.

The results obtained from a sample of water are as follows in mg/l:

Na = 20 Sr = 2
K = 30 Cl = 40
Ca = 6 HCO_3 = 72
Mg = 11 SO_4 = 5

Find out T.H., C.H. and N.C.H. in mg/l as $CaCO_3$.

Solution:

$$\text{Total hardness} = (6 \times 50)/20 + (11 \times 50)/12.2 + (2 \times 50)/43.8$$

$$= (15 + 45.08 + 2.28)$$

$$= 62.36 \text{ mg/l as } CaCO_3.$$

Bicarbonate alkalinity = 72/1.22 = 59.02 mg/l as $CaCO_3$.

In this case,

Alkalinity < T.H.

$\therefore$ C.H. = Alkalinity = 59.02 mg/l as $CaCO_3$.

Then, N.C.H. = T.H. − C.H. = (62.36 − 59.02)

= 3.34 mg/l as $CaCO_3$.

Problem 5-4.

The total hardness value obtained from the complete analysis of a water sample is found to be 116 mg/l. The analysis further shows that the concentrations of all the *three* principal cations causing hardness are numerically the same. If the value of C.H. is 58 mg/l, calculate the following:

(1) the value of N.C.H.;
(2) the concentrations of principal cations; and
(3) the value of total alkalinity in mg/l.

Solution:

T.H. = C.H. + N.C.H.

In the given problem,

T.H. = 116 mg/l and C.H. = 58 mg/l.

$\therefore$ 116 = 58 + N.C.H.

$\therefore$ N.C.H. = (116 − 58) = 58 mg/l as $CaCO_3$.

Let P = Concentration of principal cations.

Then, T.H. = (P × 50)/20 + (P × 50)/12.2 + (P × 50)/43.8

$\therefore$ 116 = P (2.5 + 4.1 + 1.14)

$\therefore$ P = 116/7.74 = 14.99, say 15 mg/l

$\therefore$ Concentrations of Ca^{++}, Mg^{++} and Sr^{++} are 15 mg/l.

In this case,

Alkalinity < T.H.

$\therefore$ Total alkalinity = C.H. = 58 mg/l as $CaCO_3$.

---

(4) ***Hydrogen-ion concentration (pH value)***: The acidity or alkalinity of water is measured in terms of its pH value or H-ion concentration.

The pure water (H_2O) consists of positively charged hydrogen or H-ions combined with negatively charged hydroxyl or OH-ions. But the process of dissociation takes place in pure water and hence it contains some uncombined positively charged H-ions and some uncombined negatively charged OH-ions. The water becomes acidic when positively charged H-ions are in excess than negatively charged OH-ions and it becomes alkaline when reverse is the case. For neutral water, the concentrations of H-ions and OH-ions are equal.

The water will dissociate into hydrogen and hydroxyl ions as follows:

$$H_2O \rightleftharpoons H^+ + OH^- \ldots\ldots\ldots\ldots \tag{1}$$

Now, applying the law of mass action to equation (1), we get

$$K = \frac{[H^+][OH^-]}{H_2O} \ldots\ldots\ldots\ldots \tag{2}$$

The brackets indicate concentration of the constituents in moles/litre. A *mole* is the molecular weight in g. Since the concentration of water in a dilute aqueous system is essentially constant, it can be expressed as follows:

$$K_w = [H^+][OH^-] \ldots\ldots\ldots\ldots \tag{3}$$

where K_w = ionization constant or ion product of water.

It is found by various experiments that K is approximately equal to 1×10^{-14} at a temperature of 25°C. The equation (3) can be used to calculate the hydrogen-ion concentration when the hydroxyl-ion concentration is known and vice versa. Thus a litre of pure water at 25°C contains:

$$10^{-7} \text{ g of H-ion} \times 10^{-7} \text{ g of OH-ion} = 10^{-14} \ldots\ldots\ldots\ldots \tag{4}$$

It is universally acknowledged to express H-ion concentration in terms of logarithm of its reciprocal and thus pH value of water by definition can be expressed as follows:

$$pH = -\log_{10}[H^+] = \frac{1}{\log_{10}[H^+]} \ldots\ldots\ldots\ldots \tag{5}$$

Similarly pOH value of water by definition can be expressed as follows:

$$pOH = -\log_{10}[OH^-] = \frac{1}{\log_{10}[OH^-]} \ldots\ldots\ldots\ldots \tag{6}$$

Now as per equation (3),

$$[H^+] \times [OH^-] = 10^{-14}$$

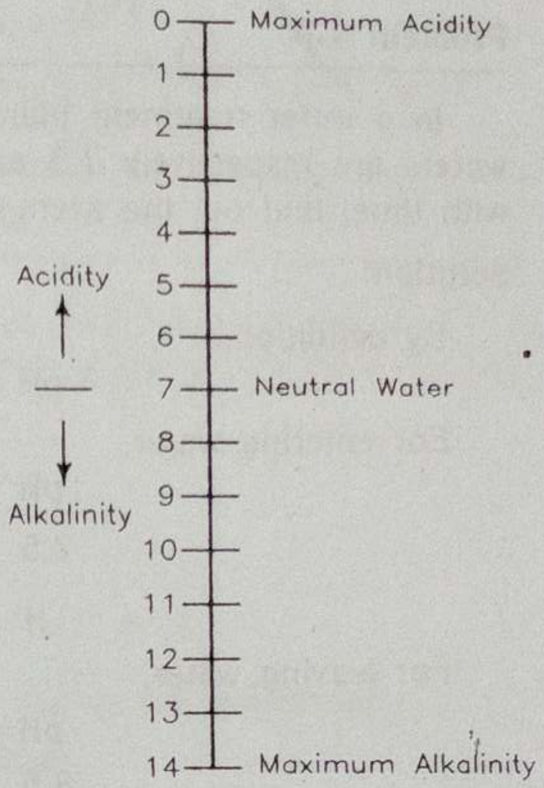
$$\therefore \left(\frac{pH}{-\log_{10}}\right) \times \left(\frac{pOH}{-\log_{10}}\right) = 10^{-14}$$

$$\therefore \log_{10} (pH + pOH) = 10^{-14}$$

$$\therefore pH + pOH = 14 \ldots\ldots\ldots\ldots \tag{7}$$

With the above relation of pH and pOH, it has become a practice to refer only H-ion concentration in water. The term *pH index* is used to indicate the reactivity of water with respect to alkalinity or acidity and it is expressed quantitatively by concentration of the hydrogen-ions.

Fig. 5-4 shows pH-scale. A neutral water has pH value of 7. As pH value becomes less, the water becomes acidic and when pH value is zero, it indicates maximum acidity. Similarly the water becomes alkaline as pH values increase and maximum alkalinity is indicated when pH value is equal to 14.



pH-scale
FIG. 5-4

It is desirable to maintain pH value of water very close to 7. The acidic water causes tuberculation and the alkaline water causes incrustation. For potable water, the pH value should be between 6.50 and 8.50 and it is found that if this range is maintained, there is no direct effect on healh of human beings. If pH value of water is below 4, it will produce a sour taste and if it is more than 8.50, it will impart a bitter taste. The higher values of pH induces the formation of trihxlomethanes which are responsible for causing cancer in human beings. The lower values of pH starts corrosion in pipes and thereby the toxic metals like Zn, Pb, Cu, etc., are released.

Following are the *two* methods which are employed to measure the pH value of water:

(i) Electrometric method
(ii) Colourimetric method.

(i) *Electrometric method:* In this method, the potentiometer is used to measure the electrical pressure exerted by positively charged H-ions. The pH value is then correspondingly expressed.

(ii) *Colourimetric method:* In this method, the chemical reagents or indicators are added in water and the colour produced is compared with standard colours of known pH values. A set of sealed tubes containing coloured waters of known pH values is kept in the laboratory for ready reference. This test is simple and hence it is commonly carried out in the public health laboratories. The usual indicators are Benzol yellow, Methyl red, Bromphenol blue, etc. for acidic range and Thymol blue, Phenol red, Tolyl red, etc. for alkaline range.

Problem 5.5.

In a water treatment plant, the pH values of entering and leaving waters are respectively 7.5 and 8.5. Assuming linear variation of pH with time, find out the average pH value of water.

Solution:

By definition,

$$\text{pH} = -\log_{10}\text{H}$$

For entering water,

$$\text{pH} = 7.5$$

$$\therefore \quad 7.5 = -\log_{10}\text{H}$$

$$\therefore \quad \text{H} = 10^{-7.5}$$

For leaving water,

$$\text{pH} = 8.5$$

$$\therefore \quad 8.5 = -\log_{10}\text{H}$$

$$\therefore \quad \text{H} = 10^{-8.5}$$

$$\therefore \quad \text{Average value of H} = \frac{10^{-7.5} + 10^{-8.5}}{2}$$

$$= 10^{-8.5}\left[\frac{10 + 1}{2}\right] = 5.50 \times 10^{-8.5}$$

$$\therefore \text{ Average pH value of water} = -\log_{10}\text{H}$$

$$= -\log_{10}\left(5.50 \times 10^{-8.5}\right)$$

$$= (8.50 - 0.7404) = 7.7596.$$

Problem 5-6.

Calculate pH and OH values of freshly prepared distilled water.

Solution:

As per equation (3),

$$[\text{H}^+] \times [\text{OH}^-] = 10^{-14} \text{ mole/l}$$

In freshly distilled water, the concentrations of both the ions will be the same say, C moles/litre.

Then, $C \times C = 10^{-14}$

$\therefore$ $C = 10^{-7}$

i.e. $[H^+] = 10^{-7}$ and $[OH^-] = 10^{-7}$

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

$= -\log_{10}[10^{-7}] = -[-7] = 7$

Similarly $pOH = 7.$

Problem 5-7.

A factory discharges 50 m^3/day of waste having pH = 11. If the waste contains KOH only, find out the quantity of KOH in kg/day.

Solution:

$$pH + pOH = 14$$

$$\therefore \quad 11 + pOH = 14$$

$$\therefore \quad pOH = 14 - 11 = 3.$$

Thus the concentration of hydoxycl ion in the given water is 10^{-3} moles/litre i.e. $[OH^-] = 10^{-3}$ moles/litre.

The molecular weight of KOH in 1 litre solution works out to

$$(39 + 16 + 1) = 56 \text{ g.}$$

$$\therefore \quad \text{KOH in g/litre} = 56 \times 10^{-3}$$

$$\therefore \quad \text{KOH in kg/litre} = 56 \times 10^{-6}$$

Now, Discharge = Q = 50 m^3/day = 50 × 10^3 litres/day.

Quantity of KOH in given waste = $(56 \times 10^{-6} \times 50 \times 10^3)$ kg/day

= 2.80 kg/day.

Problem 5-8.

Calculate the pH of 1000 mg/l of $Ca(OH)_2$.

Solution:

The molecular weight of $Ca(OH)_2$ works out to $[40 + 2\,(16+1)]$

= 74 g/l.

Now, 74 g/litre contains 2 moles of $[OH^-]$,

$\therefore$ 1 g/litre contains $\frac{2}{74}$ moles of $[OH^-]$

Thus,
$$[OH^-] = \frac{2}{74}$$

$$\therefore \quad pOH = -\log_{10} [OH^-]$$
$$= -\log_{10} [2/74]$$
$$= -\log_{10} [0.027] = 1.5686.$$

Now,
$$pH + pOH = 14$$
$$\therefore \quad pH = 14 - pOH = (14 - 1.5686)$$
$$= 12.4314$$

$\therefore$ pH of 1000 mg/l i.e. 1 g/l of $Ca(OH)_2$ = 12.4314.

Problem 5-9.

Find out the pH of the following mixture:

	Volume	pH
Solution A ..	500 ml	6
Solution B ..	500 ml	5

Solution:

As the volume of both the solutions in the mixture i.e. A and B is the same, the morality of the mixture will be half in 1000 ml.

pH of A = 6 i.e. $[H^+]$ of A = 10^{-6} mole/litre

pH of B = 5 i.e. $[H^+]$ of B = 10^{-6} mole/litre

$$\text{pH of new mixture} = \left(\frac{1}{2} \times 10^{-6}\right) + \left(\frac{1}{2} \times 10^{-5}\right)$$
$$= (0.5 \times 10^{-6}) + (5 \times 10^{-6})$$
$$= 5.5 \times 10^{-6} \text{ mole/litre}$$

$$\therefore \quad \text{pH of new mixture} = -\log_{10} [H^+]$$
$$= -\log_{10}(5.5 \times 10^{-6})$$
$$= (-0.7404 + 6)$$
$$= 5.2596.$$

Problem 5-10.

Find out the pH of the mixture which will be formed by mixing the following *two* volumes:

	Volume	pH
Solution A ..	100 ml	6
Solution B ..	900 ml	5

Solution:

In this case, the volumes of A and B are not the same in 1000 ml mixture.

$$\text{pH of A} = 6 \text{ i.e. } [H^+] \text{ of A} = 10^{-6} \text{ mole/litre}$$

$$\text{pH of B} = 5 \text{ i.e. } [H^+] \text{ of B} = 10^{-5} \text{ mole/litre}$$

For solution A:

The volume of solution A is 100 ml and concentration of $[H^+]$ is 10^{-6} mole/litre i.e. 10^{-6} moles per 1000 ml.

$$\therefore \text{Concentration of } [H^+] \text{ in 100 ml} = 10^{-6} \times \frac{100}{1000}$$

$$\therefore \quad [H^+]_A = 10^{-7} \text{ mole/litre.}$$

For solution B:

The volume of solution B is 900 ml and concentration of $[H^+]$ is 10^{-5} mole/litre i.e. 10^{-5} moles per 1000 ml.

$$\therefore \text{Concentration of } [H^+] \text{ in 900 ml} = 10^{-5} \times \frac{900}{1000}$$

$$\therefore \quad [H^+]_B = 9 \times 10^{-6} \text{ mole/litre.}$$

$$\begin{aligned} \text{Concentration of } [H^+] \text{ in mixture} &= [H^+]_A + [H^+]_B \\ &= [10^{-7}] + [9 \times 10^{-6}] \\ &= (0.1 \times 10^{-6}) + (9 \times 10^{-6}) \\ &= 9.1 \times 10^{-6} \text{ mole/litre} \end{aligned}$$

$$\begin{aligned} \therefore \quad \text{pH} &= -\log_{10} (9.1 \times 10^{-6}) \\ &= (-0.959 + 6) = 5.041. \end{aligned}$$

Problem 5-11.

There are *three* samples *X*, *Y* and *Z* of water having pH values of 4.5, 5.5 and 6.5 respectively. Calculate how many times *X* is acidic than *Z*.

Solution:

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

Sample *X*:

$$\text{pH} = 4.5$$

$$\therefore \quad 4.5 = -\log_{10} [H^+]$$

$$\therefore \quad [H^+] = 10^{-4.5} \text{ mole/litre.}$$

Sample *Z*:

$$\text{pH} = 6.5$$

$$\therefore \quad 6.5 = -\log_{10} [\text{H}^+]$$

$$\therefore \quad [\text{H}^+] = 10^{-6.5} \text{ mole/litre.}$$

$$\therefore \quad \frac{\text{Concentration of } [\text{H}^+] \text{ ion in } X}{\text{Concentration of } [\text{H}^+] \text{ ion in } Z} = \frac{10^{-4.5}}{10^{-6.5}} = 100$$

Thus sample *X* is 100 times acidic than sample *Z*.

Problem 5-12.

What would be the pH of a solution containing 1.70×10^{-8} g of hydroxide per litre? Assume molecular weight of OH as 17 g.

Solution:

$$[\text{OH}^-] = \frac{17 \times 10^{-9}}{17} = 10^{-9} \text{ mole/l}$$

$$\therefore \quad \text{pOH} = -\log(10^{-9}) = 9$$

Now, $\text{pH} + \text{pOH} = 14$

$$\therefore \quad \text{pH} = (14 - 9) = 5.$$

Problem 5-13.

If the hydrogen concentration is 3×10^{-2} mole/l, calculate the hydroxide concentration.

Solution:

As per equation (3),

$$[\text{H}^+] \times [\text{OH}^-] = 10^{-14} \text{ mole/l}$$

$$\therefore \quad [3 \times 10^{-2}] \times [\text{OH}^-] = 10^{-14} \text{ mole/l}$$

$$\therefore \quad [\text{OH}^-] = \frac{1}{3} \times 10^{-12} \text{ mole/l}$$

(5) ***Alkalinity:*** The term *alkalinity* with reference to the water and waste water is defined as the capacity of substances contained in the water to take up hydroxium $\left(\text{H}_3^+\text{O}\right)$ to reach a defined pH value (4.3 to 14). The alkalinity is due to the presence of bicarbonate $\left(\text{HCO}_3^-\right)$, carbonate $\left(\text{CO}_3^{--}\right)$ or hydroxide (OH^-).

The determination of alkalinity is very useful in waters and wastes because it provides buffering to resist the changes in pH value. The alkalinity is usually divided into the following *two* parts:

(1) Total alkalinity i.e. above pH 4.5

(2) Caustic alkalinity i.e. above pH 8.2.

The alkalinity is measured by the volumetric analysis. The various types of indicators are available for this purpose. The commonly adopted *two* indicators are as follows:

(1) Phenolphthalein : pink above pH 8.2 and colourless below pH 8.2

(2) Methyl orange : red below pH 4.5 and yellow-orange above pH 4.5.

The bromcresol green-methyl red indicator may be preferable to methyl orange as the colour change from greenish-blue above pH 4.5 to light pink below pH 4.5 is more definite.

The amount of alkalinity is expressed in terms of $CaCO_3$. If the strength of titrant solution is N/50, 1 ml of titrant solution will be equal to 1 mg $CaCO_3$ because the equivalent weight of $CaCO_3$ is 50.

$$\text{Thus, Alkalinity in mg/l as } CaCO_3 = \frac{\text{Total reading}}{\text{Vol. of sample in ml}} \times 1000.$$

If the strength of titrant solution is N/40, the equation will be as follows:

$$\text{Alkalinity in mg/l as } CaCO_3 = \frac{\text{Total reading} \times (0.025 \times 50 \times 1000)}{\text{Vol. of sample in ml}}$$

$$= \frac{\text{Total reading}}{\text{Vol. of sample in ml}} \times 1250.$$

The neutralization of OH^- is complete at pH 8.2. The neutralization of CO_3^{--} is only half complete at pH 8.2 and not fully completed until a pH value of 4.5 is reached. Thus alkalinity on pH scale is represented as follows:

(1) The range of total alkalinity is 4.5 to 14.

(2) The range of bicarbonate i.e. HCO_3^- alkalinity is from 4.5 to 8.2.

(3) The range of carbonate i.e. CO_3^{--} alkalinity is from 8.2 to 10.

(4) The range 0 to 4.5 indicates no alkalinity.

Table 5-2 can be used for finding out the alkalinity of a sample with the process of titration. The letter P indicates phenolphthalein reading and the letter T indicates total alkalinity.

TABLE 5-2
DETERMINATION OF ALKALINITY

Result of titration	Hydoxide alkalinity as $CaCO_3$ (OH^-)	Carbonate alkalinity as $CaCO_3$ (CO_3^{--})	Bicarbonate alkalinity as $CaCO_3$ (HCO_3^-)
$P = 0$	0	0	T
$P < 0.5\ T$	0	2P	T − 2P
$P = 0.5\ T$	0	2P	0
$P > 0.5\ T$	2P − T	2(T − P)	0
$P = T$	T	0	0

Following rules should be kept in mind while finding out the alkalinity of a sample:

(1) For simplicity, it is assumed that HCO_3^- and OH^- alkalies cannot come together in the same sample.

(2) The alkalinities of other than carbonate, bicarbonate and hydroxide origin are absent.

(3) OH^- alone gives initial pH of about 10.

(4) CO_3^{--} will be present at $pH \geq 8.2$

(5) OH^- and CO_3^{--} together give initial pH of about 10.

(6) CO_3^{--} and HCO_3^- can exist together.

(7) HCO_3^- alone gives initial $pH < 8.2$.

The determination of alkalinity of water is helpful for the following *reasons*:

(i) It assists in finding out the quantity of lime and soda-ash required for the removal of hardness.

(ii) It helps to neutralise the acids produced during flocculation.

(iii) It leads to the reactions which may occur between alkalinity and certain cations in the water. The resultant precipitate can foul pipes and other appurtenances of the water distribution systems.

(iv) The excess alkalinity is harmful for irrigation which leads to the soil damage and reduce crop yields.

(v) The highly alkaline water is usually unpalatable.

(vi) The large amount of alkalinity imparts a bitter taste to the water.

(vii) The natural waters are sometimes rendered alkaline to control corrosion due to acids.

(viii) The waste waters containing excess caustic alkalinity are not to be discharged into natural streams or sewers.

(ix) The water having alkalinity less than 250 mg/1 is desirable for domestic consumption and for R.C.C. construction.

Problem 5-14.

From the following data of volumetric analysis, calculate the hydroxide, carbonate and bicarbonate alkalinities:

Sample 100 ml	Total ml of titrant to reach end point	
	Phenolphthalein	Mythyl orange
A	10	15.5
B	14.4	38.6
C	8.2	8.4
D	0	12.7

Solution:

Sample A:

$$P = \frac{10 \times 1000}{100} = 100$$

$$T = \frac{15.5 \times 1000}{100} = 155$$

$$\therefore \quad 0.5\ T = 77.5$$

As $P > 0.5\ T$, from table 5-2,

OH^- alkalinity $= 2P - T = (200 - 155) = 45$

CO_3^{--} alkalinity $= 2(T - P) = 2(155 - 100) = 110$

HCO_3^- alkalinity $= 0$.

Sample B:

$$P = \frac{14.4 \times 1000}{100} = 144$$

$$T = \frac{38.6 \times 1000}{100} = 386$$

$$\therefore \quad 0.5\ T = 193$$

As $P < 0.5\ T$, from table 5-2,

OH^- alkalinity $= 0$

CO_3^{--} alkalinity $= 2P = 288$

HCO_3^- alkalinity $= T - 2P = (386 - 288) = 98$.

Sample C:

$$P = \frac{8.2 \times 1000}{100} = 82$$

$$T = \frac{8.4 \times 1000}{100} = 84$$

$$\therefore \quad 0.5\ T = 42$$

As P > 0.5 T, from table 5-2,

$$OH^{-} \text{ alkalinity} = 2P - T = (164 - 84) = 80$$

$$CO_3^{--} \text{ alkalinity} = 2(T - P) = 2(84 - 82) = 4$$

$$HCO_3^{-} \text{ alkalinity} = 0.$$

Sample D:

$$P = 0$$

$$T = \frac{12.7 \times 1000}{100} = 127$$

As P = 0, from table 5-2,

$$OH^{-} \text{ alkalinity} = 0$$

$$CO_3^{--} \text{ alkalinity} = 0$$

$$HCO_3^{-} \text{ alkalinity} = T = 127.$$

Problem 5-15.

Find out the total and individual (species-wise) alkalinity from the following laboratory record:

Strength of titrant : N/40
Volume of sample : 50 ml
Phenolphthalein end point : 5.6 ml
Methyl orange end point : 13.5 ml.

Also estimate the pH value of sample.

Solution:

As strength of titrant is N/40,

$$P = \frac{5.6 \times 1250}{50} = 140$$

$$T = \frac{5.6 \times 1250}{50} = 337.5$$

$\therefore$ $0.5\ T = 168.75$

As $P < 0.5\ T$, from table 5-2,

OH^{-} alkalinity $= 0$

CO_3^{--} alkalinity $= 2P = 280$

HCO_3^{-} alkalinity $= T - 2P = (337.5 - 280) = 57.5.$

As CO_3^{--} and HCO_3^{-} exist together, the pH value of sample will be between 8.2 to 10.

Problem 5-16.

A water sample with pH 9 had a caustic alkalinity of 70 mg/l, total alkalinity of 230 mg/l and total hardness of 300 mg/l, all as $CaCO_3$. Calculate the amounts of the various forms of alkalinity present and the amount of non-carbonate hardness.

Solution:

The pH of sample is 9 and hence the neutralization of CO_3^{--} is only half completed.

$\therefore$ Carbonate i.e. CO_3^{--} alkalinity $= 2 \times$ Caustic alkalinity

$= (2 \times 70)$

$= 140$ mg/l.

Now, Total alkalinity $= CO_3^{--}$ alkalinity $+ HCO_3^{-}$ alkalinity

$\therefore$ $230 = 140 + HCO_3^{-}$ alkalinity

$\therefore$ HCO_3^{-} alkalinity $= (230 - 140) = 90$ mg/l.

Also, Total hardness $=$ Alkalinity $+$ Non-carbonate hardness

$\therefore$ N.C.H. $= (300 - 230)$

$= 70$ mg/l.

✓ (6) *Acidity:* The term *acidity* with reference to the water and waste water is defined as the capacity of substances contained in the water to take up hydroxyl ions (OH^{-}) to reach a defined pH value (0 to 8.2).

The acidity are of the following *two* types:

(i) Carbon dioxide acidity

(ii) Mineral acidity.

(i) *Carbon dioxide acidity:* This acidity is due to the presence of CO_2 in ground water and surface water.

(ii) *Mineral acidity*: The mineral acidity is due to the presence of HCl, H_2SO_4, HNO_3 and strong organic acids. The mineral acidity is present in many industrial wastes and the important industries which discharge the acid effluents are electroplating industry, distillary industry, fertilizer industry, mining industry, etc.

The mineral acidity is determined by titrating or neutralizing sample with strong base NaOH to pH 4.3. The carbon dioxide acidity in the sample is calculated by neutralizing completely by continuing the titration till pH of 8.2 is reached. The amount of acidity is expressed in terms of $CaCO_3$. Then,

Total acidity (as $CaCO_3$) = Mineral acidity + CO_2 acidity.

The determination of acidity of water has got significance because of the following *reasons*:

(i) It affects the aquatic life.
(ii) It affects the biological treatment of sewage.
(iii) It corrodes pipes.
(iv) It decides the quantity of chemical dosages and line of treatment for industrial wastes.
(v) It interferes in the treatment of water as in case of water softening.
(vi) The water containing mineral acidity is unpalatable.
(vii) The water having acidity more than 50 mg/l cannot be used for R.C.C. construction.

(7) ***Metals and other chemical substances:*** The various tests are made to detect the presence of different metals and other chemical substances in a sample of water.

Table 5-3 gives the maximum concentration of metals and other chemical substances in potable water as recommended by U.S. Public Health Service standards.

(8) ***Nitrogen and its compounds:*** The nitrogen is present in water in the following *four* forms:

(i) Free ammonia
(ii) Albuminoid ammonia
(iii) Nitrites
(iv) Nitrates.

TABLE 5-3

CONCENTRATION OF METALS AND OTHER CHEMICAL SUBSTANCES IN POTABLE WATER

No.	Name of metal	Maximum permissible concentration in mg/litre
1	Alkyl Benzene Sulphonate. . . . (ABS)	0.50
2	Arsenic . . . . (As)	0.05
3	Barium . . . . (Ba)	1.00
4	Cadium . . . . (Cd)	0.01
5	Carbon Chloroform Extract. . . . (CCE)	0.20
6	Copper . . . . (Cu)	1.00
7	Cyanide . . . . (CN)	0.20
8	Fluoride. . . . . (F)	1.70
9	Hexavalent chromium	0.05
10	Iron . . . . (Fe)	0.30
11	Lead. . . . . (Pb)	0.05
12	Manganese . . . . (Mn)	0.05
13	Phenols	0.001
14	Selenium . . . . (Se)	0.01
15	Silver . . . . (Ag)	0.05
16	Sulphate . . . . (SO)	250
17	Zinc . . . . (Zn)	5.00

The amount of free ammonia in potable water should not exceed 0.15 p.p.m. and that of albuminoid ammonia should not exceed 0.3 p.p.m. The term *albuminoid ammonia* is used to represent the quantityof nitrogen present in water before the decomposition of organic matter has started.

The presence of nitrites indicates that the organic matter present in water is not fully oxidised or in other words, it indicates an intermediate oxidation stage. The amount of nitrites in potable water should be nil.

The presence of nitrates indicates that the organic matter present in water is fully oxidised and the water is no longer harmful. For potable water, the highest desirable level of nitrates is 45 mg per litre.

The free ammonia is measured by simply boiling the water. The ammonia gas is then liberated. The albuminoid ammonia is measured by adding strong alkaline solution of potassium permanganate ($KMnO_4$) to the water and then boiling it. The ammonia gas is then liberated. The nitrites and nitrates are converted chemically into ammonia and then measured by comparison with standard colours.

(9) ***Total solids:*** The term *solid* with reference to the environmental engineering is defined as the residue in water left after evaporation and drying in oven at 103°C to 105°C. The total solids consist of dissolved and suspended matter.

Dissolved solids: In natural waters, the dissolved solids mainly consist of inorganic salts like carbonates, bicarbonates, chlorides, sulphates, etc. together with small amounts of organic matter and dissolved gases. For measuring the total dissolved solids, the sample of water is placed in a clean porcelain dish and it is ignited in a muffle furnace. After partial cooling in the air, it is cooled in a desicator and is weighed.

Then, Total dissolved solids in mg/l $= \frac{(A - B)}{V} \times 1000$

where A = Final weight of the dish in mg
B = Initial weight of the dish in mg
V = Volume of sample in ml.

It may be noted that mere determination of the dissolved solids does not give a clear picture of the type of pollution. However many dissolved substances are undesirable in water and they impart displeasing colour, taste and odour.

The water with higher content of the dissolved solids has a laxative or sometimes reverse effect on the human body and it takes time for people to adjust with such water.

In a similar way, the high concentration of dissolved solids say 3000 p.p.m. may also produce distress in livestock and may lead to scaling in boilers, corrosion, etc.

The estimation of total dissolved solids is useful in determining the suitability of water for drinking purpose as well as for agriculture and industrial processes.

The permissible total dissolved solids for drinking water according to BIS is 500 mg/l with tolerable limit as 1500 mg/l.

Suspended solids: In surface water, the suspended solids consist of inorganic matter like silt or organic matter like algae. These materials are generally carried by erosive action of the flowing water over land. The ground water contains negligible quantity of suspended matter because of filtering action of soil strata through mechanical straining action.

The amount of suspended solids in surface waters increases with input of natural and man-made contamination. The term *coefficient of fineness* is sometimes used to indicate the rates of weight of the suspended solids to the turbidity of water.

For measuring suspended solids, the water is filtered through a fine filter and dry material retained on the filter is weighed. The drying is carried out for one hour in an oven at 105°C. The filtered water is evaporated in a muffle furnace at 600°C for 15 to 20 minutes. At 600°C, the organic solids are converted into CO_2 and H_2O and the inorganic salts are remained as ash.

Then, Total suspended solids in mg/l $= \dfrac{(W_2 - W_1)}{V} \times 1000$

Suspended volatile solids in mg/l $= \dfrac{(W_2 - W_3)}{V} \times 1000$

where W_1 = Initial weight in mg
W_2 = Weight of dry material retained on filter in mg
W_3 = Weight after evaporation in mg
V = Volume of sample in ml.

The suspended matter is objectionable in water for the following *reasons:*

(i) It is aesthetically displeasing.
(ii) It may include disease causing organisms.
(iii) It may release obnoxious odours.
(iv) It provides adsorption sites for chemical and biological agents.

The estimation of total suspended solids is extremely useful in the analysis of polluted waters and for evaluating the efficiency of treatment units.

III. Bacteriological tests:

The examination of water for the presence of bacteria is very important. The bacteria are very small organisms and it is not possible to detect them by microscopes. Hence they are detected by circumstantial evidences or chemical reactions.

The growth of bacteria takes place by cell division and there are various classifications of bacteria depending upon their shapes, oxygen requirements and effects on mankind. The last classification is important for the water supply engineer from the view point of public health. The bacteria may be harmless to mankind or harmful to mankind. The bacteria may be harmless to mankind or harmful to mankind. The former category is known as the *non-pathogenic bacteria* and the latter category is known as the *pathogenic bacteria*. It is not possible to isolate pathogenic bacteria with the help of laboratory instruments. Their chances of presence in a sample of water are increased in relation to the amount of non-pathogenic bacteria present in the sample of water.

The combined group of pathogenic and non-pathogenic bacteria is designated by bacillus coil (bacillus – bacterium and coli = intestine) or *B-coli group*. This group of bacteria is present in intestines of all living warm-blooded animals.

It should be noted that practically all natural waters contain some variety of bacteria and only in rare cases, such as the supply from deep boreholes, the water is found without the presence of any type of bacteria. Even rain before it touches the surface of earth collects dust and bacteria according to the nearness of dense populations, presence of industries, climatic conditions, etc. Subsequently numerous bacteria are added to the water by contact with the soil, vegetation, life and matter of the earth's surface.

The number and species of these bacteria differ to a great extent. Thus many of the bacteria found in water are derived from the air, soil and vegetation. Some of these are able to multiply and continue their existence while the remaining die out in due course of time.

Following facts in connection with bacteria in water are to be noted:

(1) A certain number of bacteria cannot be cultivated under laboratory conditions while it is possible to cultivate some varieties of bacteria under special conditions in laboratory.

(2) For surface waters, the seasonal changes have a marked and complex influence on the bacteria.

(3) Many varieties of bacteria produce colonies of various colours such as yellow-brown, red, green and violet.

(4) Only few varieties of bacteria can tolerate any degree of acidity or caustic alkalinity.

(5) Some bacteria continue to live and multiply, others find conditions unsuitable and succumb and there may be many new additions.

(6) The temperature of water has some bearing on bacterial multiplication. Each variety of bacteria has its own optimum temperature for multiplication.

(7) The amount and remoteness of sewage and manurial pollution are the most important sanitary considerations with regard to the bacterial contact of water.

(8) The bacterial purity of water varies according to the source of water i.e. whether from river, stream, lake, shallow well or deep well and these differ greatly among themselves.

(9) The density of a bacterial population in water depends largely on quantity and quality of food available. It may however be noted that the nutritional requirements of bacteria are very simple and as a matter of fact, the organically pure deep well waters can support comparatively large numbers of bacteria and for a certain period even permit rapid multiplication.

(10) The gaseous constituents of water also affect bacterial activity in water to a certain extent. For instance, the oxygen is favourable to some bacteria, but not to others.

(11) The inorganic constituents of the water can also create favourable or unfavourable conditions for the growth of bacteria.

(12) The nature of the organic matter as well as its quantity present in water will determine the degree of bacterial multiplication and also the types or varieties of bacteria that will develop.

(13) The presence of metals in water, especially of copper, silver and aluminium, has usually detrimental effect on bacteria.

(14) The process of sedimentation which takes place during the storage of water is considered to be a potent factor in the bacterial purification of water.

Apart from the main aim of finding out the sewage or manurial pollution, the bacteriology is also of great value for the following *purposes:*

(1) to ascertain the effect of rainfall or drought on sources of water supply;

(2) to ascertain the efficiency of chlorination of sewage works effluent;

(3) to find out the change in quality of water either at source or after passing through the distribution system of mains and reservoirs;

(4) to study the degree of pollution of river waters;

(5) to study the pollution of sea water near shores by tidal outfalls from sewage works;

(6) to work out the efficiency of purification system of water such as filtration, chlorination, etc.;

(7) to work out the pollution by bathers of swimming pool water and to ascertain the efficiency of purification process; etc.

It may be mentioned that the chemical analysis of water affords valuable information of past or remote pollution and as such, it cannot be relied upon to reveal all forms of recent pollution. On the other hand, the bacteriological analysis of water gives less information of the remote history of the water, but it discloses with ease and with great reliability, the immediate or recent causes of water pollution.

It is for this reason that the results of the chemical and bacteriological examinations should always be suitably correlated and an opinion should never be formed or expressed regarding the purity of water on the strength of the results of its chemical analysis only. It is quite likely that chemically pure water may reveal the presence of pathogenic bacteria during its bacteriological analysis and it is for this reason that the bacteriological examination of water has been given considerable significance and importance.

Following are the *two* standard bacteriological tests for the bacteriological examination of water:

(i) Total count or Agar plate count test
(ii) B-coli test.

(1) ***Total count or Agar plate count test:*** In this test, the bacteria are cultivated on specially prepared medium of agar for different dilutions of sample of water with sterilised water. The diluted sample is placed in an incubator for 24 hours at 37°C (i.e. blood heat) or for 48 hours at 20°C. These represent the so-called *hot counts and cold counts* respectively. The bacterial colonies which are formed, are then counted and the results are computed for 1 c.c. For potable water, the total count should not exceed 100 per c.c.

(2) ***B-coli test:*** This test is divided into the following *three* parts:

(a) Presumptive test
(b) Confirmed test
(c) Completed test.

The presumptive test is based on the ability of coliform group to ferment the lactose broth and producing gas. The confirmed test consists of growing cultures of coliform bacteria on media which suppress the growth of other organisms. The completed test is based on the ability of the culture grown in the confirmed test to again ferment the lactose broth.

(a) *Presumptive test*: Following procedure is adopted in this test:

(1) The definite amounts of diluted samples of water are taken in multiples of ten, such as 0.1 c.c., 1.0 c.c., 10 c.c., etc.
(2) The water is placed in standard fermentation tubes containing lactose broth.
(3) The tube is maintained at a temperature of 37°C for a period of 48 hours.
(4) If gas is seen in the tube after this period is over, it indicates presence of *B*-coli group and the result of test is treated as positive. If reverse is the case, it indicates absence of *B*-coli group and the result of test is treated as negative.
(5) A negative result of presumptive test indicates that water is fit for drinking.

(b) *Confirmed test:* This test is carried out in one of the following ways:

(1) A small portion of lactose broth showing positive presumptive test is carefully transferred to another fermentation tube containing brilliant green lactose bile. If gas is seen in the tube after 48 hours, the result is considered positive and the completed test becomes essential.

(2) A small portion of material showing positive presumptive test is marked on the plates containing Endo or eosin-methylene-blue agar. The plates are kept at 37°C for 24 hours. If colonies of bacteria are seen after this period, it indicates positive result and the completed test becomes essential. The colonies are prominent by metallic brightness and dark spots.

(c) *Completed test:* This test is made by introducing or inoculating bacterial colonies into lactose broth fermentation tubes and agar tubes. The incubation is carried out at 37°C for 24 to 48 hours. If gas is seen after this period, it indicates positive result and further detailed tests are carried out to detect the particular type of bacteria present in water. The absence of gas indicates negative result and the water is considered safe for drinking.

The recent development of field measurement of bacteria is that of membrane filter technique. The membrane contains microscopic pores which are capable of retaining bacteria. The water is filtered through the membrane and it is then incubated for a period of 20 hours along with nutrients. The colonies of bacteria, if any, can then be counted by means of microscope.

B-coli Index: This is an index or number which represents approximately the number of *B*-coli per c.c. of sample of water under consideration. The presumptive tests are carried out with different dilution ratios of the sample of water with sterilised water. A number of tests is carried out for each proportion and percentage of positive results is recorded. The difference between successive percentages is worked out and it is multiplied by the reciprocal of quantity of solution. The sum of such values indicates *B*-coli index. For potable water, the *B*-coli index should be preferably less than 3 and it should not exceed 10 in any event.

In order to arrange correctly a number of analytical results, the laws of probabilities are applied and from the available statistics of test data, the most probable number or M.P.N. is determined by applying the laws of statistics to the results of the test. This number removes the drawback of *B*-coli index and it indicates the bacterial density which is most likely to be present in water. It should however be remembered that the M.P.N. is not the absolute concentration of organisms that are present, but it only indicates a statistical estimate of that concentration.

For illustration of working out *B*-coli index, typical test results are recorded in table 5-4 and *B*-coli index of the case comes to 5.68.

TABLE 5-4

B-COLI INDEX CALCULATION

No.	Proportion	No. of tests	Positive results in percent	Difference	Reciprocal of column 2	Multiplication of columns 5 and 6
1	2	3	4	5	6	7
1	10 c.c.	100	1	0.30	0.10	0.03
2	1 c.c.	100	0.70	0.55	1	0.55
3	0.1 c.c.	100	0.15	0.11	10	1.10
4	0.01 c.c.	100	0.04	0.04	100	4.00
5	0.001 c.c.	100	Nil		1000	—
					Total	5.68

Maintenance of purity of waters:

Some of the measures which can be taken to maintain the purity of waters are as follows:

(1) The content of dissolved oxygen present in water should be high.

(2) The entry of undesirable elements such as acidic and alkaline discharges, hot discharges from thermal power stations, etc. into source of water supply should be prevented by suitable means.

(3) The presence of algae supplying oxygen to the water is desirable.

(4) The quantity of total dissolved solids, especially the chloride contents, should be very low.

(5) There should be absence of organic wastes exerting oxygen demand on water.

(6) There should be enough reaeration for the purpose of reoxygenation of water.

(7) The temperature of water should be maintained low.

(8) The turbulence of water should be encouraged to make available more oxygen from air.

Water-borne diseases:

The water is considered to be an important agent for carrying and spreading some of the dangerous diseases. The usual diseases carried by water are those of intestinal disorders such as cholera, dysentery, typhoid, etc.

The patients suffering from such diseases give out the organisms responsible for such diseases from their intestinal discharges. Such organisms then somehow obtain entrance to the sources of drinking water and the disease is thus further carried forward.

The water is also considered partly responsible for other diseases such as hepatitis, tuberculosis, gastro-enteritis, polimyelitis, etc.

The water-borne diseases are caused by pathogenic or harmful bacteria. The bacteria are found everywhere on surface of earth and they are in great excess even in natural unpolluted water bodies. However the water contaminated with sewage provides an excellent medium for the growth of bacteria.

Out of all bacteria, the pathogenic bacteria form only a very small quantity. Further, the pathogenic bacteria have only a short life in water and they offer less resistance to adverse influences. If the source of pathogenic bacteria is known and if water treatment plant is properly operated, it is possible to detect and to destroy the pathogenic bacteria and thus the danger of water-borne diseases may be avoided.

The most important water-borne bacteria responsible for water-borne diseases are *Salmonella typhi, Salmonella paratyphi, Shigella dysenterial* and *Vibrio cholerae*. The respective diseases spread by them are typhoid, paratyphoid, dysentery and cholera.

It is significant to note that the water-borne diseases are predominant even in developing countries and it is estimated that about five million babies die annually from water-borne diseases in such countries and that one in six of the world's population suffer every year from water-borne diseases.

The surveys conducted by World Health Organization indicate that about 86% of the rural populations in developing countries are without reasonable access to safe water. It is therefore very clear that the battle with water-borne diseases will be finally won only by continued attention to the pollution prevention and by maintaining quality of water upto the required standard. Thus the public health engineer in close co-operation with chemists and biologists will play a great role in preventing the spread of water-borne diseases.

Suitability of water for trade purposes:

The quality of water required for some of the common trades is as follows:

(1) *Artificial silk*: For the process of preparing artificial silk, the water to be used should be clear, bright and absolutely free from colour. It should also be soft and should contain only a small amount of saline constituents in solution.

(2) *Concrete products*: The water which is fit for drinking purposes is considered suitable for the preparation of cement concrete products. It should be clean and free from excess of sulphates and chlorides which are detrimental to the setting and solidity of the concrete.

(3) *Dairies*: The bacterial purity of water is essential and the quantity of saline constituents is of secondary importance. As a matter of fact, the water which may be excessively hard or may contain an amount of salt perceptible to the taste, can be used, if it is bacteriologically pure.

(4) *Dyeing*: For producing delicate tints in dyeing, extreme care should be taken to use the water of desired quality. It should be free from iron, colour and turbidity and should have the smaller quantity of the salts.

(5) *Laundries*: The water must be clear, soft and free from iron.

(6) *Manufacture of ice:* The water should be free from colour and suspended matter and should not contain metallic impurities such as iron and manganese. It should possess high degree of organic and bacterial purity as expected for drinking water.

(7) *Paper industry*: For manufacturing paper of good quality, the water must be free from colour and sedimentary matter and from every trace of iron and manganese. The saline constituents should be present in such quantity that no appreciable amount is deposited in the drying paper. However the water of any quality can be used for the manufacture of coarse brown paper.

(8) *Photographic films*: There should be sufficient supply of good water which must be colourless and absolutely free from suspended matter and metals such as iron, zinc and manganese.

(9) *Steam raising*: The water should be free from sedimentary matter and should contain little free carbonic acid. The salts which can easily be thrown out of solution by heat should be preferably absent. The water should have pH value less than 6.5. The calcium and magnesium chlorides are most undesirable because such water,

when boiled, separates out hydrochloric acid and it may perforate or damage the boiler plates at and above the water-level.

(10) *Tanning*: The water must be quite free from iron and lime salts should be present in the minimum possible amount.

Water for swimming pools:

The demand for bathing pools has increased during recent years and hence the question of water to be used for such purpose has attained considerable attention. The purity and safety of swimming pool water should be of the highest order.

The swimming or bathing pools can be divided into the following *three* categories:

(1) Natural bathing pools
(2) Partly natural and partly artificial bathing pools
(3) Artificial bathing pools.

(1) *Natural bathing pools:* These are usually found on rivers, ponds, etc. and in some cases, the water is of satisfactory purity due to an adequate flow of fresh water. The question of purity in such cases is usually ignored and in many cases, the water may be found to be polluted and unsafe for bathing purposes. Where such conditions prevail, it is the duty of the concerned authority to warn the public of the dangers by posting notices at important and clearly visible spots or points on the banks of the river.

(2) *Partly natural and partly artificial bathing pools:* These are constructed at seaside to take advantage of each tide. The attention should be paid to the location of the pool, the direction of sea currents and the quality of water. If there are chances of water pollution due to discharge of sewage in vicinity, the treatment plant should be installed. The partly artificial pools can be constructed on or near rivers and streams and they usually depend on the natural flow of the water for purification. However, if required, some system of filtration, usually coarse in character, may be installed as a safety measure.

(3) *Artificial bathing pools:* The desirability of the provision of ample facilities for swimming and bathing has led to the construction of artificial bathing pools by private clubs or public bodies at various pockets of a modern town or city.

Following factors are to be carefully considered when the project of an artificial bathing pool is taken in hand:

(i) circulation of water through the pool;
(ii) purity of the water throughout the bathing season;

(iii) selection of the site, preferably above or as far as possible below the outfall of sewage works;

(iv) system of treatment to maintain the desired degree of purity; etc.

The artificial bathing pool is usually filled with water from public water mains or from other suitable sources such as tube wells. The water is kept pure by any *one* of the following ways:

(a) The emptying, cleansing and refilling of the bath pool are carried out at certain intervals, say, after one, two or more days. This method is unsatisfactory and the water although good at the initial stage, becomes cloudy and polluted after a short period. The water thus becomes dangerous for use to the bathers because of its opacity. Sometimes the period of changing the water is decided by the number of bathers who used the pool and the clarity of water. It is evident that both these aspects are uncertain criteria for deciding bacterial impurity.

(b) The above method can be augmented by the periodical addition of a disinfectant such as chlorine compound to the bath water. This measure has some benefit and it reduces cost because the water is changed less frequently. It is however a haphazard measure which provides doubtful and unreliable protection.

(c) The continuous circulation of bath water through purification plant affords the most reliable method of maintaining purity of water. Hence, in this system, the bath is filled with pure water and during bathing hours, the water is continuously circulated by pumps, passing from the bath through the purification plant and then back to the bath pool. The quality of water will however depend on the capacity and efficiency of the purification plant and the number of bathers.

There are however all chances of contracting diseases in swimming pools which are not properly designed and ill-maintained. The infections can also be derived from polluted water entering the pool and also from matter subsequently added to the water from the skin, secretions and excretions of the bathers.

All such risks can be reduced to a minimum in the well-organised modern swimming pools where continuous circulation and purification of the water are efficiently operated.

The swimming in unsatisfactory pools is considered to be responsible for various diseases including infections of the following:

(1) ear (e.g., otitis media);
(2) eyes (e.g., conjunctivitis);
(3) gastro-intestinal tract (e.g., dysentery);
(4) respiratory system (e.g., pneumonia);
(5) skin (e.g., ringworm); and
(6) throat (e.g., tonsillitis).

QUESTIONS

1. What is meant by the term pure water?
2. What are the impurities present in water?
3. How the data oblained from turbidity are helpful?
4. Mention the scale of hardness.
5. Write short notes on:
   (1) Hardness
   (2) pH value and pH scale
   (3) M.P.N.
   (4) Sampling of water
   (5) Water-borne diseases
   (6) Nitrogen and its compounds
   (7) Maintenance of purity of waters
   (8) B-coli index
   (9) Agar plate count test.
6. Enumerate the tests which are carried out for the analysis of water.
7. Mention the standards for potable water.
8. Give sketches of the following:
   (1) Turbidity rod
   (2) Jackson turbidimeter
   (3) Baylis turbidimeter.
9. What is meant by pH value of water? How is it measured?
10. What are the reasons for the determination of alkalinity?
11. Define the term acidity and mention the reasons for its determination.
12. Define the term solid and discuss its various types.
13. What is the importance of bacteriological tests?
14. Discuss the *two* standard tests which are employed to examine water bacteriologically.

15. What is B-coli index? How is it determined?
16. What is turbidity? How is it measured?
17. Mention the maximum concentration of metals and other chemical substances in potable water.
18. What are the measures which can be taken to maintain the purity of waters?
19. What are the facts to be noted for solving problems on hardness?
20. What is alkalinity? How is it measured?
21. What are the usual types of water-borne diseases? Enumerate the bacteria responsible for them.
22. What are the reasons for the analysis of water?
23. Mention the precautions which are to be taken while collecting the sample of water to be analysed.
24. What are the peculiarities of bacteria?
25. What are the purposes of bacteriology?
26. Discuss about the quality of water required for some of the common trades.
27. Write a critical note on water for swimming pools.
28. What are the factors to be considered in the design of artificial bathing pools? How is the purity of water maintained in such pools?
29. Differentiate between the following:
    (1) Apparent colour and true colour
    (2) Carbon dioxide acidity and mineral acidity
    (3) Dissolved solids and suspended solids
    (4) Temporary hardness and permanent hardness
    (5) Free ammonia and albuminoid ammonia
    (6) Pathogenic bacteria and non-pathogenic bacteria
    (7) Confirmed and completed tests of B-coli test
    (8) Natural bathing pools and artificial bathing pools
    (9) Palatable water and potable water
    (10) Taste and odour
    (11) Acidic water and alkaline water
    (12) Anode and cathode
    (13) Total alkalinity and caustic alkalinity.

30. Give reasons for the following:

    (1) Some of the factories install their own water supply plant.
    (2) The test for temperature of water has no practical meaning.
    (3) The water contains various gases.
    (4) The excess hardness of water is undesirable.
    (5) It is desirable to maintain pH value of water very close to 7.
    (6) The water has lower contents of salt than sewage.
    (7) It has become a practice to refer only H-ion concentration in water.
    (8) The amount of nitrites in potable water should be nil.
    (9) The turbulence of water should be encouraged.
    (10) An opinion should never be formed or expressed regarding the purity of water on the strength of the results of its chemical analysis only.
    (11) The swimming in unsatisfactory pools is considered to be responsible for various diseases.
    (12) The water to be used for the preparation of cement concrete products should be free from excess of sulphates and chlorides.
    (13) The sampling is the most important part of any analysis.
    (14) It is not possible to find pure water in nature.
    (15) The bacteriological examination of water is of great value.
    (16) The water is considered to be an important agent for carrying and spreading some of the dangerous diseases.
    (17) The calcium and magnesium chlorides are most undesirable in water to be used for steam raising.
    (18) The M.P.N. is not the absolute concentration of organisms that are present.
    (19) The suspended matter is objectionable in water.
    (20) The determination of acidity of water has got significance.
    (21) The ground water contains negligible quantity of suspended matter.