
UNIT 2 WATER QUALITY ANALYSIS

Structure

- 2.1 Introduction
 - Objectives
- 2.2 Physical Characteristics of Water
- 2.3 Chemical Characteristics of Water
- 2.4 Microbiology of Water
 - 2.4.1 Bacteria
 - 2.4.2 Viruses
 - 2.4.3 Plankton
 - 2.4.4 Algae
 - 2.4.5 Fungi
 - 2.4.6 Protozoa
 - 2.4.7 Microbiological Water Quality Determination
- 2.5 Water Borne Diseases
- 2.6 Drinking Water Standards
- 2.7 Handling and Collection of Water Samples
 - 2.7.1 Collection of Samples – Guidelines
 - 2.7.2 Methods of Sampling
 - 2.7.3 Frequency of Sampling
- 2.8 Summary
- 2.9 Answers to SAQs

2.1 INTRODUCTION

The most of the earth water sources get their supplies from precipitation, which at the time of formation contains pure water. During its fall through atmosphere of the earth in various forms such as rain and snow etc., it dissolves various gases, traces of minerals and other substances. After its contact with the surface of earth, it picks-up or dissolves various physical, chemical and micro-organic impurities. As water seeps into ground water reservoir, most of the suspended impurities are filtered out, but on the other hand it dissolves minerals and salts present in various layers of earth through which it travels before meeting the water table.

The impurities which water dissolves or carries might make water more useful and potable or make it unfit and harmful for drinking purpose depending on the contents it carries. Therefore, before planning for degree and type of treatment for raw water, an engineer should have the knowledge of nature and magnitude of impurities present in raw water and their permissible limits for wholesome water.

In this unit, we shall discuss the various types of substances present in water, water borne diseases, collection of water sample and drinking water quality as per Indian standards.

Objectives

After studying this unit, you should be able to

- discuss the physical characteristics of water,

- describe various chemical substances present in water,
- list and describe various microorganisms present in water and their affect on human body,
- be aware of drinking water standards prescribed by Bureau of Indian Standards, and
- know the various methods of sampling of water for water quality testing.

2.2 PHYSICAL CHARACTERISTICS OF WATER

Physical characteristics mainly include **colour, taste and odour, turbidity, temperature and conductivity**.

Colour

Pure water is colourless. Colour in untreated water is mainly caused by following :

- (a) Humic and peaty material.
- (b) Naturally occurring metallic salts, mainly of iron and manganese.
- (c) Algae.
- (d) Discharge of untreated or partially treated water from industries.

Water often appears coloured (apparent colour) due to material in suspension, while true colour is contributed by dissolved solids which remain after removal of suspensions by pretreatment and filtration methods.

The colour of water is usually expressed in Hazen units which are the same as the platinum-cobalt scale. The standard unit of colour is that which is produced by one milligram of platinum cobalt dissolved in one litre of distilled water. Different standard colour intensities representing 1 ppm, 2 ppm, 3 ppm etc. can be prepared by dissolving 1 mg, 2 mg, 3mg respectively of platinum cobalt in 1 litre of water. The colour of a sample is inspected by comparing the colour of the water sample with other glass tubes (called Neosler tubes) containing standard solution of different colour intensities.

Small colour intensities are measured by tintometer. The instrument is lighted from inside and contains an eye piece with two holes. A slide of standard coloured water is seen through one hole and the slide of water to be tested is seen from the other hole. The coloured slide is replaced by another till a match is obtained. The standard colour intensity corresponding to the matching represents the intensity of colour of the water sample being tested.

Although the maximum permissible colour limit for public water supply is 20 on cobalt scale it should preferable be less than 10.

Odour and Taste

The dissolved organic materials, inorganic salts and dissolved gases impart taste and odour to water. Although taste and odour occur together, there are certain non-volatile substances such as sodium chloride, which give rise to tastes without causing odour. For drinking purpose, water must not contain

any undesirable or objectionable taste and odour. However, taste imparted by dissolved oxygen and dissolved carbon dioxide are generally desirable.

Taste and odour is a subjective test which may be expressed upon description rather than quantitative results, but many times the extent of taste and odour of a sample is measured quantitatively by threshold odour number or simple threshold odour. The threshold odour number represents the dilution ratio at which the odour is hardly detectable. Water sample to be tested is gradually diluted in the ratio of 1:4 with distilled water. The mixture at which the detection of odour by human observation is lost is determined. The number of times, the sample is diluted, represents the threshold odour number.

Turbidity

The turbidity is an indication of the clarity of water and is defined as the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a sample of water. Although turbidity is caused due to suspended solids the turbidity cannot be fully correlated with the quantitative measurement. It depends on shape, size and refractive indices of the suspended particles as well. The turbidity is measured by a turbidity rod or by a turbidity-meter with optical observations and is expressed as the amount of suspended matter in mg/l or ppm. The standard unit is that which is produced by 1 milligram of finely divided silica in 1 litre of distilled water. Turbidity units are expressed as NTU or JTU depending on instruments used for its measurement.

Temperature

Temperature of water is dependent on atmospheric and ground condition. Generally, it is found to be 2°C to 3°C higher or lower than ambient temperature. However, for potable water, a temperature of 10°C is highly desirable whereas temperatures above 25°C are considered to be objectionable.

Conductivity

Conductivity is the measurement of the ability of a solution to carry electrical currents. It is an excellent indicator of total dissolved salts in a water sample. The total amount of dissolved salts present in a water sample is estimated by measuring specific conductivity of water, which is determined by a portable dionic water tester and is expressed in micro-mhos per cm at 25°C. With the conductivity measurement we can have an idea about the total dissolved salts in water sample.

2.3 CHEMICAL CHARACTERISTICS OF WATER

Chemical characteristics are a result of the solvent properties of water and they are often important in specifying water quality. Some chemical characteristics are due to natural properties but other may be more influenced by external pollution.

PH Value

The pH value is a measurement of acidity or alkalinity of water. It is one of the most important factors in water chemistry because many processes involved in water treatment is pH dependent. Pure water is slightly ionized into positive hydrogen (H^+) ions and negatively charged hydroxyl (OH^-) moles/l. This neutral point is temperature dependent and occurs at pH 7.0 at

25°C. When the concentration of hydrogen ions exceeds that of the hydroxyl ions, the solution has acidic characteristics and pH value in that case is less than 7 whereas when hydroxyl ions increase, the water is said to be having basic characteristics and pH value is greater than 7.

Acidity

The acidity of water is a measure of its capacity to neutralize bases. Acidity of water is caused by the presence of uncombined carbon dioxide, mineral acids, salts of strong acids and weak bases. It is expressed as mg/l in terms of calcium carbonate.

Acidity in an unpolluted water is usually due to dissolved carbon dioxide, which produces weak carbonic acid. Humic, fulvic and other organic acid produced by decomposition of vegetation also give rise to acidity in water but the pH value is usually more than 3.7. Due to presence of mineral acids, water polluted by industrial effluents have pH less than 3.7. Acidic water having pH less than 4.5 is considered to be undesirable as water becomes unpalatable and it affects aquatic life besides causing corrosion in water carrying pipes, etc.

Alkalinity

Alkalinity is due to bicarbonate, carbonate and hydroxide ions in the water. They are usually in association with calcium, magnesium, sodium and potassium. Sometimes alkalinity is quoted in terms of CaCO₃. Bicarbonate alkalinity is in equilibrium with carbon dioxide in the pH range of 4.6 to 8.3. Above pH 8.3 free carbon dioxide ceases to exist and combines to give carbonate and bicarbonate alkalinity. No limits have been given for alkalinity level in water but high concentration of sodium bicarbonate gives rise to taste problems.

Hardness

Hardness in water is defined as that characteristic which prevents formation of sufficient lather or foam when such water is mixed with soaps. Hardness due to presence of bicarbonates and carbonates of calcium and magnesium are known as temporary hardness because such hardness is removed by simple boiling or by adding lime to water. Due to presence of sulphates, chlorides and nitrates of calcium or magnesium present in water the hardness does not go by boiling and it requires some special treatment for removing hardness or making it soft. Such hardness is known as permanent hardness. Hardness is commonly defined as the calcium carbonate equivalent of calcium and magnesium ions present in water and is expressed in mg/l. The hardness in mg/l can be determined by determination of amounts of calcium and magnesium ions present in water by filtration.

Total hardness (mg/l) of CaCO₃

$$\begin{aligned} &= \left\{ \text{Ca}^{++} \text{ in mg/l} \times \frac{\text{Combining Weight of CaCO}_3}{\text{Combining Weight of Ca}^{++}} \right\} \\ &+ \left\{ \text{Mg}^{++} \text{ in mg/l} \times \frac{\text{Combining Weight of CaCO}_3}{\text{Combining Weight of Mg}^{++}} \right\} \dots (2.1) \end{aligned}$$

The combining weight of Ca^{++} , Mg^{++} and CaCO_3 are 20, 12, and 50, respectively.

$$\therefore \text{Total Hardness} = \text{Ca}^{++} \text{ mg/l} \times \frac{50}{20} + \text{Mg}^{++} \text{ mg/l} \times \frac{50}{12}$$

Sometimes, the hardness is expressed in degree of hardness. Each British degree of hardness is equal to 14.25 mg/l. Comparison of hardness level expressed in mg/l as CaCO_3 is given in Table 2.1.

Table 2.1 : Comparison of Hardness

Range (mg/l)	Hardness Level
0-50	Soft
50-100	Moderately Soft
100-150	Slightly Hard
150-200	Moderately Hard
Over 200	Hard
Over 300	Very Hard

If the hardness is less than 150 mg/l, it is not economical to soften the water. The problems caused by excessive hardness give rise to formation of scale in boilers and hot water system. Temporary hardness to some extent is preferable, because water softer than 30-50 mg/l tends to be corrosive and is likely to take lead from pipes into the water supply.

Chloride Content

Chlorides, which are compound of chlorine, with other elements or radicals are present in mostly all natural water. The range of concentration is very wide. The concentration due to chloride is mostly with Sodium, i.e. NaCl (the common salt) and to some extent with Calcium and Magnesium. They are the most stable components in water. Chlorides in water are derived from natural mineral deposits, from agricultural or irrigation discharge, from sewage and industrial effluents. Most of the rivers and lakes have chloride concentration less than 50 mg/l. Chlorides are not detrimental to health but the salt intake (i.e. the common salt or NaCl) for people suffering from heart or kidney ailment has to be restricted. However, salt intake from drinking water is very small compared to that from food stuffs. For a water supply scheme, it is better to restrict the chloride content to a limit to 200 mg/l.

Fluoride

Fluoride occurs sometimes naturally in water. If not, it should be added in controlled quantity during treatment process. Fluoridation of water supplies to a level of 1 mg/l is safe and effective in reducing dental caries. The greatest advantage against teeth decay is when water is drunk in childhood during the period of tooth formation. However, optimum concentration of fluoride has to be controlled because excessive amount leads to fluorosis, which causes mottling of the teeth and sometimes bone damage both in children and adults. Ground water passing through chalk or limestone under clay formations, may have high concentration of fluoride. Since specialized treatment is to be applied to control higher concentration of fluoride, the treatment becomes quite costly and it is better to go for some other source containing lesser fluoride content.

Pesticides

Pesticides cover a wide range of compounds. They include inorganic compounds such as copper sulphate, chlorinated hydrocarbons such as DDT and Aldrin, etc. Pesticides come into natural water from direct application for aquatic plants, insect control and percolation, run-off from agricultural fields and discharges from industries. The organic compounds especially chlorinated hydrocarbons are toxic even when present in traces and make the chemical and bio-chemical degradation reduced. Discharge of pesticides in the water course has to be controlled because accidental discharge of pesticides in bulk becomes more serious causing death of fish and other aquamarine life, which may necessitate the water intakes to be temporarily shut down. Removal of pesticides are done by oxidative treatment using ozone, chlorine dioxide or potassium permanganate. Absorption by activated carbon is most effective.

Sulphates

Presence of sulphates in water may be from different sources. Dissolution of gypsum and other mineral deposits containing sulphates from oxidation of sulphides, sulphites and from industrial effluents is the main cause. Sulphates in water contribute permanent hardness. High level of sulphates concentration imparts taste and if combined with magnesium and sodium has a laxative effect. Bacterial reduction of sulphates under anaerobic conditions produces hydrogen sulphide, which is an objectionable gas smelling like rotten eggs, which could be reduced with the help of aeration.

Phenols

Phenol compounds in surface water are mainly found due to pollution from industries. Effluents from petrochemicals, is one of the main sources of phenols. Natural phenols are found in water from decaying algae. Phenols are also found in ground water in the area with oil bearing strata. Presence of phenols makes water objectionable in taste and odour. Phenols are removed by superchlorinating process, in which excess chlorine chemically decomposes the phenol. Oxidation with ozone or by absorption on activated carbon help in removal of phenols.

Nitrogen Content

The presence of nitrogen in water may be found to occur in one or more of the following forms – free ammonia, nitrates, nitrites and organic nitrogen. Presence of nitrogen in water indicates presence of organic matter. The free ammonia indicates recent decomposition of organic matter; nitrites indicate presence of partly decomposed organic matter. Organic nitrogen represents the stage before decomposition of organic matter has started. Presence of free ammonia in water indicates the presence of undecomposed organic matter. For potable water, its value has to be restricted upto 0.15 mg/l. The presence of organic nitrogen indicates pollution and limiting value in potable water is 0.3 mg/l. Presence of nitrites is highly dangerous and, therefore, its permissible limit in potable water is nil. Nitrates represent fully oxidized organic matter and, as such, is not harmful. However, excess of nitrate may present health problems in infants and concentration has to be limited upto 45 mg/l. Excessive presence of nitrogen in any kind indicates pollution and the form in which it is present indicates period or history of the water pollution.

Dissolved Gases

Water contains various gases such as nitrogen, methane, hydrogen sulphide, carbon dioxide and oxygen which are normally get dissolved in water due to its contact with the atmosphere and ground surfaces. Hydrogen sulphide gives bad taste and odour even in small quantity. Carbon dioxide indicates biological activities; causes corrosion, increases the solubility of many minerals in water and thus gives taste to water.

Oxygen in the dissolved state is generally obtained from atmosphere and pure natural surface water is usually saturated with it. The oxygen is also being consumed by organic substances present in water for their oxidation, hence if dissolved oxygen content in natural water is less than saturation it indicates the presence of organic matter. The amount of dissolved oxygen in water can be found by exposing water sample for 4 hours at a temperature of 27°C with 10% acid solution of potassium permanganate. The quantity of oxygen absorbed is calculated. Its permissible limit for potable water is about 5 to 10 ppm. The extent of organic matter present in water sample can also be easily estimated by supplying oxygen to this sample and finding the oxygen consumed by the organic matter present in water. This oxygen demand is known as Biochemical Oxygen Demand (BOD).

Elements Present in Water

Various elements such as iron, magnesium, aluminum, copper, sodium, manganese and arsenic and lead (free or in combination) are present in water. Different tests are conducted to detect their presence and necessary treatments are done to restrict their presence within permissible limits.

2.4 MICROBIOLOGY OF WATER

Many types of micro-organism such as bacteria, virus, algae, plankton and fungi etc. are present in water. Some are helpful and some cause diseases if present in drinking water.

2.4.1 Bacteria

Bacteria are minute single cell organism having no defined nucleus and chlorophyll. Their presence can be detected by circumstantial evidences or chemical reactions. They belong to group of organisms known as “fission fungi” and reproduce by direct splitting of a parent cell into two daughter cells and not by any complicated reproductive process.

These are classified according to :

- their shape (cylindrical, spherical and curved, etc.),
- oxygen requirement (aerobic, non-aerobic and facultative), and
- harmful/beneficial (pathogenic/non-pathogenic).

Bacteria which require oxygen for their survival are known as aerobic bacteria, whereas those which can survive in the absence of free oxygen, are known as anaerobic bacteria. And those bacteria which can survive with or without free oxygen are known as facultative bacteria.

In the cycle of life and death of all plants, animals and men, these non-pathogenic bacteria cause degradation of all organic matter and synthesis of mineralized food material by means of which all plant life on the earth is surviving. Certain bacteria are deadly to man and animals and enter their tissues causing serious

water borne diseases such as cholera, typhoid, infectious hepatitis etc. These harmful bacteria are known as pathogenic bacteria or pathogens. The bacteria which are harmless are also known as non-pathogenic bacteria. Most of the bacteria of coliform group come under this category.

2.4.2 Viruses

Viruses are micro-organism closely related to bacteria. These living and self-propagating bodies are not visible even with the strongest compound microscope. They are known to be made up of particular matter and are filtered out by very fine collodion filters. They cannot be filtered by unglazed porcelain by which bacteria is removed from liquids. Some of the bacteria have been found to exist in virus forms at some stages in their life history. Viruses differ from bacteria in the fact that they are much smaller and they multiply only within suitable host cells (in which they produce changes), giving rise to a range of diseases.

2.4.3 Plankton

These are microscopic plants and animal life that float in water and serve as a food for small sea creatures and fish. Generally, they are not injurious to health but they affect the taste of water by secreting oily liquid, which give bad taste and odour to water. Large quantities of plankton impart green, brown or yellow hue colour to water. Due to their colouring tendencies, they may affect some industries like laundries, dye works, photographic paper etc.

2.4.4 Algae

They are a type of plant that grows in water and flourishes in the presence of sunlight. They contain green substance chlorophyll, which permits them to utilize sunlight for their growth and conversion of carbon dioxide, water and other substances into organic carbon compounds. Hence, they flourish fast in sunlight. They are divided into three categories or groups – diatomaccae, chlorophyllceac and cyanophyceae. Each of the groups consists of many varieties.

2.4.5 Fungi

These are plants, which grow without sunlight and live on other plants or animals dead or live. Sizes of fungi vary to a great extent. Some are fairly large while others are microscopic. Sometimes they grow in water mains and are removed with chlorine treatment.

2.4.6 Protozoa

Protozoa are tiny microscopic animals, in fact the simplest and most primitive of all animals. Their bodies are not made up of cells, hence they are said to be acellular. Protozoans produce protective and resistant cysts to tide over unfavourable conditions. The commonest method of reproduction is asexual, by fission. Most of the members of this phylum live in water and damp soil, where they help to decompose organic matter by feeding on bits of the remains of dead plants and animals. Digestion is intra-cellular. In nature's complex food-web, they serve as food for small aquatic animals. Some protozoan are parasitic causing diseases in man and in live stock and other animals in which man has an interest. Amoebae and paramecium are examples of free living protozoan. Plasmodium (causing malaria), Entombed (causing amoebic dysentery) and Trypanosoma (causing sleeping sickness) are examples of parasitic protozoans.

2.4.7 Microbiological Water Quality Determination

The methods to estimate the microbiological quality of water are :

- (a) Membrane Filter (MF) technique
- (b) Standard Plate Count Test (SPT)
- (c) Most Probable Number (MPN)

Membrane Filter (MF) Technique

This method determines and measures presence of coliform bacteria. In this method, 10 ml sample water is filtered through a sterile membrane of special type having porosity of 80%. On this membrane, the bacteria is retained if present. After filtration the membrane is put in contact with nutrients (M-Endo's medium) at 35°C for 24 hours that permits growth of only coliform colonies. The coliform organisms are developed into visible colonies, which are counted.

Standard Plate Count Test (SPT)

The bacteria are made to grow as colonies by inoculating a known volume of water sample in a solidifiable nutrient medium (Nutrient Agar). The water sample is kept in a petridish and nutrient medium poured on the petridish. The petridish is kept for incubation at 35°C for 24 hours. The colonies of bacteria, if present, develop as spots and are counted down. The bacteria density is expressed as number of colonies for 100 ml of sample. If more colonies develop, counting becomes difficult. In that case, the sample is diluted with sterile water and SPT done and the dilution factor is accounted while expressing the result.

Most Probable Number (MPN)

Most Probable Number is a number, which represents the bacterial density, which is most likely to be present in the water. Different dilution of sample of water is mixed with lactose broth and incubated in test tubes for 48 hours at 37°C. The presence of acid or carbon dioxide gas in the test tubes indicates the presence of coliform bacteria. Referring to the standard statistical tables, MPN of E Coli per 100 ml of water is determined. In order to ensure that the water is safe for drinking and free from pathogenic bacteria and other organisms, it is seen that on an average not more than one coliform colony is present per 100 ml of water. The test is generally performed on 5 samples and an average of the coliform colonies taken, which should not exceed 1 per 100 ml, and results are compared with standard table. It is ensured that while taking samples of bacteriological test, sample should be collected from different points of distribution system and tested immediately after they are collected and in no case testing should be done beyond 24 hours of collection.

2.5 WATER BORNE DISEASES

Water borne diseases are those diseases primarily spread through contaminated water. These are infectious in nature and may spread through direct contact or through flies, etc. These can be classified as shown in Table 2.2.

Table 2.2 : Classification of Water-borne Diseases

Type of Disease	Name of Disease	Organism Responsible
Bacterial Diseases	Typhoid/Paratyphoid fever	<i>Salmonella typhi</i> bacteria
	Cholera	<i>Vibrio-cholerae</i> bacteria
	Bacillary dysentery	<i>Shiga bacillu/Flexner bacillu/sonne bacillus</i>
Viral Diseases	Hepatitis/jaundice	<i>Hepatitis virus</i>
	Poliomyelitis	<i>Polio virus</i>
Protozal Diseases	Amoebic dysentery	<i>Entamoeba histolytic</i> protozoa

Water is the main media for spread of such diseases. Thus these are called as water borne diseases. All these water-borne diseases affect primarily the intestinal tract and are spread always by excretal matter. Sometimes urine also contains enormous number of pathogenic organisms especially in case of typhoid fever.

In order to prevent spread of water-borne disease, following measures may be taken to check the spread of such diseases :

- (a) The water supply must be thoroughly checked and disinfected before supply.
- (b) The water pipe lines should be frequently tested, checked and inspected so as to detect any leakage and possible source of contamination from surroundings. The leaking joints must be sealed as early as possible.
- (c) In laying or designing the water distribution system, attempts should be made to keep sewer lines and water lines as far as possible.
- (d) The general habit of cleanliness must be encouraged amongst the people. People should not be allowed to urinate or defecate as and where desired. Public urinals and latrines should be provided at places of public gatherings.
- (e) In case of doubts about the supply, people should be forewarned and advised to use boiled water. An extra dose of chlorine must be added to the supply to serve as disinfectant.
- (f) As soon as some cases of such disease are reported, people must on a large scale be inculcated and immunized against that disease.

SAQ 1



- (a) Explain the significance of following with reference to water quality criteria.
 - (i) Turbidity
 - (ii) pH
 - (iii) Chloride
- (b) List various bacteriological tests conducted for estimating micro-biological quality of water.

- (c) What do you understand by the term “water-borne disease”? Name one water-borne disease under each of bacterial, viral and protozoa origin that can be controlled by proper treatment of water.

2.6 DRINKING WATER STANDARDS

To provide aesthetically attractive, hygienically safe and potable water to the consumer, quality of water should be of highest possible standards consistent with geographical and sociological constraints. Every country has, therefore, set their own standards for the quality of water supplies depending on their local conditions. In our country, standard for drinking water is presently based upon recommendations of Bureau of Indian Standards: 10500 (1991). These standards are presented in Table 2.3.

**Table 2.3 : Indian Standard Drinking Water Specification
(BIS-10500 : 1991)**

Parameters	Desirable-Tolerable	If No alternative Source Available, Limit Extended
Essential Characteristics		
Turbidity (NTU Unit)	Less than 5	10
Colour (Hazen Scale)	Less than 5	25
Odour	Unobjectionable	–
Taste	Agreeable	–
pH	6.5-8.5	No relaxation
Total hardness (as CaCO ₃) mg/l, <i>Max</i>	300	600
Iron (as Fe) mg/l, <i>Max</i>	0.3	1.0
Chlorides (as Cl) mg/l, <i>Max</i>	250	1000
Residual, free chlorine, mg/l, <i>Min</i>	0.2	–
Fluoride (as F) mg/l, <i>Max</i>	1.0	1.5
Desirable Characteristics		
Dissolved solids mg/l, <i>Max</i>	500	2000
Calcium (as Ca) mg/l, <i>Max</i>	75	200
Magnesium (as Mg), mg/l, <i>Max</i>	30	100
Copper (as Cu) mg/l, <i>Max</i>	0.05	1.5
Manganese (as Mn) mg/l, <i>Max</i>	0.1	0.3
Sulphate (as SO ₄) mg/l, <i>Max</i>	200	400
Nitrate (as NO ₃) mg/l, <i>Max</i>	45	100
Phenolic compounds (as C ₆ H ₅ OH) mg/l, <i>Max</i>	0.001	0.002
Mercury (as Hg) mg/l, <i>Max</i>	0.001	No relaxation
Cadmium (as Cd), mg/l, <i>Max</i>	0.01	No relaxation
Selenium (as Se), Mg/l, <i>Max</i>	0.01	No relaxation
Arsenic (as As), mg/l, <i>Max</i>	0.05	No relaxation
Lead (as Pb), mg/l, <i>Max</i>	0.05	No relaxation
Zinc (as Zn), mg/l, <i>Max</i>	5	15
Anionic detergent (as MBAS) mg/l, <i>Max</i>	0.2	1.0

Chromium (as Cr ⁶⁺) mg/l, <i>Max</i>	0.05	No relaxation
Polynuclear aromatic hydrocarbons (as PAH) g/l, <i>Max</i>	–	–
Mineral oil mg/l, <i>Max</i>	0.01	0.03
Pesticides mg/l, <i>Max</i>	Absent	0.001
Radioactive materials:		
(a) Alpha emitters Bq/l, <i>Max</i>	–	–
(b) Beta emitters pci/l, <i>Max</i>	–	–
Alkalinity mg/l, <i>Max</i>	200	600
Aluminium (as Al), mg/l, <i>Max</i>	0.03	0.2
Boron, mg/l, <i>Max</i>	1	5

Bacteriological Standards

- (a) **Water Entering the Distribution System :** The coliform count in any sample of 100 ml should be zero. Any sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation into both the purification process and the method of sampling.
- (b) Water in the distribution system should satisfy all the three criteria indicated below:
 - (i) The E. Coli count in 100 ml of any sample should be zero.
 - (ii) Coliform organisms present in any sample should be less than 100 per ml.
 - (iii) Coliform organisms should not be detectable in 100 ml of any two consecutive sample or 95% of the samples collected throughout the year. If coliform organisms are found, re-sampling should be done. The repeated presence of 1 to 10 coliform organisms in 100 ml or the appearance of higher numbers in any sample necessitates the investigation and removal of the source of pollution.
- (c) **Unpiped Water Supplied :** If water is supplied by wells, bore-holes and springs, it should satisfy the following criteria.
 - (i) Fecal coliforms should be zero per 100 ml of water.
 - (ii) If fecal coliform occurs frequently and sanitary protection cannot be improved, an alternate source must be found, if possible.
- (d) **Emergency Water Supplies :** Fecal and other coliform number per 100ml of water should be zero. In case of failure to meet above guideline, boiled water should be used.

Virological Quality of Drinking Water

The drinking water should be free from virus, which causes diseases to the consumers. It is desirable to examine the raw water sources and treated water for the presence of virus. But it is costly and requires elaborate facilities. In general, virological examination is done for plague forming unit (PFU) of virus. If PFU is zero, water can be considered as safe to drink. However, large volumes of drinking water is required to detect virus (e.g. 10 litres per PFU level). In practice, 0.05 mg/l of free residual chlorine for one hour is sufficient to inactivate virus.

SAQ 2



- (a) Write the tolerance limit for drinking water.
 - (i) Turbidity
 - (ii) Colour
 - (iii) TDS
 - (iv) Chloride
 - (v) Arsenic
- (b) Discuss the significance of virological standards of water for drinking purpose.

2.7 HANDLING AND COLLECTION OF WATER SAMPLES

The value of any laboratory analysis and test depends upon the method of sampling. Failure to observe proper precautions in securing a representative sample may result in an analysis which may unnecessarily reject a good water supply or more frequently it may certify a bad water as satisfactory.

In general, the shorter the time that elapses between collection of a sample and its analysis, the more reliable will be the results. For certain constituents and physical characteristics immediate analysis in the field is required in order to get realistic results, as the composition of the same may change before it arrives at the laboratory. The time elapsed between collection and analysis of the sample depends upon the character of the sample, the particular analysis and the conditions of storage. The time elapsed between collection and analysis should be recorded in the laboratory report.

The laboratory report should also mention if any preservative was added to the sample. If so, name of the preservative should be mentioned. Temperature can change very quickly, pH may change significantly in minutes, dissolved gases may be lost (e.g. oxygen, carbon dioxide, hydrogen sulphide, chlorine) or gained (e.g. oxygen, carbon dioxide). Therefore, determinations of temperature, pH and dissolved gases should always be carried out in the field. With change in pH, alkalinity and carbon dioxide balance, calcium carbonate may precipitate and this may cause a decrease in the values of calcium and total hardness. Iron and manganese form readily soluble compounds in their lower valence states and relatively insoluble compounds in their higher (oxidized) valence states. Hence, these may precipitate out, or may dissolve out of a sediment depending upon the redox potential of the sample.

Microbiological activity is responsible for changes in the nitrate-nitrite ammonia balance for decrease in phenols and in BOD or for the reduction of sulphate to sulphide. Sulphite, ferrous iron, iodide and cyanide may be lost through oxidation. Colour, odour and turbidity may increase, decrease or change quality. Sodium, silica and boron may be leached out of the glass container. Care should always be taken to obtain a sample that is truly representative of existing conditions and it should be handled in such a way that it does not deteriorate or become contaminated before reaching the laboratory. The record on the sample should include sufficient information to provide positive identification of the sample at a later date as well as the name of the sample collector, date, hour and exact location of collection. The water temperature, weather conditions, water level, stream flow also should preferably be indicated. Details of sampling points should be described by maps.

Before collecting samples from distribution system, the lines should be flushed for a sufficient period to ensure that the sample is representative of the supply, taking into account the diameter and length of the pipe to be flushed and the velocity of flow.

2.7.1 Collection of Samples – Guidelines

While collecting water samples for laboratory examination, following points should be kept in mind.

- (a) The sample should be handled in such a way that it does not deteriorate or is contaminated before it reaches laboratory.
- (b) Before filling the sample, bottle should be rinsed two or three times with water being collected.
- (c) Samples should be labeled giving the information regarding name of the collector, the date, hour and location.
- (d) Proper location, depth and frequency of sampling are important while collecting the sample from lakes and reservoirs because quality of water changes considerably due to seasonal stratification, rainfall, runoff and wind.
- (e) Samples for physical and chemical analysis should be collected in containers of pyrex glass or inert material like polythene.
- (f) Sterilised glass bottles provided with ground glass stopper having an overlapping rim should be used. The stopper and the neck of the bottle should be protected by brown paper.

2.7.2 Methods of Sampling

When samples are collected from a river or stream, the sampling point should be from top to bottom in the middle of the stream.

To collect sample from wells, the well has to be pumped for sufficient time to ensure that the sample represents the ground water source.

Methods of sampling depend on the type of equipment available, the nature of tests and purposes for which the results of the analysis are to be utilised.

Following two types of samples procedures are followed.

- (a) Grab or catch sampling.
- (b) Composite samples.

Grab or Catch Sampling

A single catch sample collected from the sampling spot at any instant to determine the character of the sample at that particular instant is known as a grab sample. The frequency of grab sampling depends upon the magnitude of fluctuation in the quality of the source. Grab samples are required in the following cases :

- (a) When frequent variation of certain constituents like pH and chlorine demand occur, grab samples are collected and tested instantaneously for correcting the operational procedures in the treatment plant.
- (b) When the unusual occurrence of certain impurities are noticed.
- (c) When the water-quality remains more or less the same over a period of time.
- (d) When the sample required immediate analysis after collection, such as tests for dissolved oxygen, carbon dioxide, residual chlorine, temperature, pH and sulphides.

Composite Sample

They are nothing but a mixture of grab samples collected at the same sampling points at different time. This process is known as time-composite sampling.

Integrated Samples

Mixture of grab samples collected from different points simultaneously is known as integrated samples. In a river or stream, the water composition varies across its width and depth, hence, the average composition of water is estimated by integrated sampling.

2.7.3 Frequency of Sampling

The frequency of collection of samples normally depends on the variability of the quality of tested water, the types of treatment processes used and other local factors. Samples for general systematic chemical examination should be collected at least once every three months in supplies serving more than 50,000 population and at least twice a year on supplies upto 50,000 population. However, more frequent sampling may be needed as per the local conditions.

For bacteriological sampling, the frequency of sampling and the locations of the sampling points should be such as to enable proper evaluation of bacteriological quality of entire water supply. The recommended number of samples to be collected from water distribution system is given in Table 2.4.

Table 2.4 : Minimum Sampling Frequency and Number from Distribution System

Population Served	Maximum Intervals between Successive Sampling	Minimum No. of Sample to be Taken from Entire Distribution System
Upto 20,000	One month	One sample per 5,000 of population per month
20,000-50,000	Two weeks	
50,001-100,000	Four days	
More than 100,000	One day	One sample per 10,000 of population per month

Source : *Manual on Water Supply and Treatment : III Edition (1999)*

SAQ 3



- Differentiate between grab and composite samples.
- Enumerate the guidelines to be followed while collecting water samples.
- Determination of temperature, pH and dissolved gases should always be carried out in field. Discuss.

2.8 SUMMARY

This unit presents an overview of physical characteristics of water, chemical substances that are normally present in water and various micro-organism that affect water quality and cause water-borne diseases. This unit gives an idea of precautionary measures to be taken to prevent water-borne diseases.

For providing wholesome water to consumers, prescribed standards of water quality are to be followed. An Indian standard of drinking water has been presented in this unit.

For physical, chemical and bacteriological analysis, sampling has to be done. If sampling is not done in proper way, the result of analysis will not be representative one. Handling and collection of water samples for different types of analysis also have been discussed in detail with relevant standards.

2.9 ANSWERS TO SAQs

SAQ 1

- (a) Refer Sections 2.2 and 2.3 for turbidity, pH and chloride respectively.
- (b) (i) Membrane Filter Test (MF)
(ii) Standard Plate Count Test (SPT)
(iii) Most Probable Number (MPN)
- (c) Refer Section 2.5.

SAQ 2

- (a) Refer Table 2.3.
- (b) Drinking water should be free from viruses that cause disease to the consumer. In general, virological examination is done for Plaque Forming Units (PFU) of viruses. For drinking water, PFU of viruses should be zero.

SAQ 3

- (a) A single sample collected at any instant to determine character of the sample at that particular instant is known as a grab sample whereas mixture of different grab samples collected at the same sampling point at different time is known as composite sampling.
- (b) Refer Section 2.7.1.
- (c) Refer Section 2.7.