

2. Organic and inorganic components of surface water and ground water

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2.1 Introduction

Water quality is the physical, chemical, biological, and aesthetic characteristics of water which determines its fitness for a variety of uses and for protecting the health and integrity of aquatic ecosystems. Another general perception of water quality is that of a simple property that tells whether water is polluted or not. Water quality depends on the local geology and ecosystem, as well as human uses such as sewage dispersion, industrial pollution, and use of water bodies as a heat sink, and overuse (which may lower the level of the water). In order for water to be acceptable for drinking there should be a good balance in terms of the physical, chemical and bacteriological qualities of water. Moreover, water should be free from minerals and organic substances which could cause adverse physiological impacts. In addition, disease causing microorganisms should be removed for a water to be taken as healthful drink for human consumption. Also drinking water should be aesthetically acceptable; it should be free from apparent turbidity, color, and odor and from any objectionable taste.

As pointed earlier, pollution at the source of water or the inadequate treatment methods used are the major reasons behind poor quality of drinking water. In most cases, water for drinking purposes in Ethiopia is sourced from either groundwater or surface water sources. Water Resource can be classified as: Surface Water which raw water (i.e. withdrawn directly from rivers, lakes, or reservoirs) is rarely cleans enough for human consumption. So, it should be treated to purify it. Surface water source generally requires more extensive treatment than groundwater source.

The water flowing over the earth's surface in the form river, lake, streams etc. is known as Surface water. 97% saltwater (oceans and seas), 2.4% glaciers and polar ice caps 0.6% other land surface water such as rivers, lakes, and ponds

Ground Water is all water that saturates the tiny spaces between alluvial material (sands, gravel, silt, clay) or the crevices or fractures in rocks. This includes the aeration zone, aquifers, saturation zones, capillary water, and water-bearing rocks.

The quality of groundwater depends on the composition of the recharge water, the interactions between the water and the soil, soil-gas and rocks with which it comes into contact in the unsaturated zone, and the residence time and reactions that take place within the aquifer. Therefore, considerable variation can be found, even in the same general area, especially where rocks of different compositions and solubility occur. The principal processes influencing water quality in aquifers are physical (dispersion/dilution, filtration and gas movement), geochemical (complexation, acid-base reactions, oxidation-reduction, precipitation-solution, and adsorption-desorption) and biochemical (microbial respiration and decay, cell synthesis). Groundwater quality is influenced by the effects of human activities which cause pollution at the land surface because most groundwater originates by recharge of rainwater infiltrating from the surface. The rainwater itself may also have an increased acidity due to human activity. The unsaturated zone can help reduce the concentrations of some pollutants entering groundwater (especially micro-organisms), but it can also act as a store for significant quantities of pollutants such as nitrates, which may eventually be released. Some contaminants enter groundwater directly from abandoned wells, mines, quarries and buried sewerage pipes which by-pass the unsaturated zone (and, therefore, the possibility of some natural decontamination processes). Artificial pollution of groundwater may arise from either point or diffuse sources. Some of the more common sources include domestic sewage and latrines, municipal solid waste, agricultural wastes and manure, and industrial wastes (including tipping, direct injection, spillage and leakage). The contamination of groundwater can be a complex process. Contaminants, such as agricultural chemicals, spread over large sections of the aquifer recharge area may take decades to appear in the groundwater and perhaps longer to disappear after their use has ceased. Major accidental spills and other point sources of pollutants may initially cause rapid local contamination, which then spreads through the aquifer. Pollutants that are fully soluble in water and of about the same density (such as chloride-contaminated water from sewage) will spread through the aquifer at a rate related to the groundwater flow velocity. Pollutants those are less dense than water will tend to accumulate at the water table and flow along the surface. Dense

compounds such as chlorinated solvents will move vertically downwards and accumulate at the bottom of an aquifer.

2.2 Water Quality Characteristics

For the purpose of classification, the impurities present in water may be divided into the following three categories. In general, on the basis of the of the water quality guidelines and standards water quality parameters could be categorized as physical, chemical, and biological characteristics. The degree of safety of water quality for drinking purpose could be directly related to these three major parameters classes. Therefore, a single water body could be assessed for its suitability for different uses on the basis of these water quality parameters. Water quality parameter standards could also well be used to assess the quality of water for drinking purpose.

2.2.1 Physical Characteristics

Drinking water is supposed to be free from objectionable taste, odor, color and suspended materials which are also known as aesthetic parameters. These parameters include those which are detectable by the senses such as turbidity, color, taste, and odor. Poor monitoring of these parameters might result in the water supply to be rejected or unconventional possible poor quality sources to be adopted. These physical parameters are generally important to achieve good aesthetic value of water and as the same time they are simple and inexpensive for monitoring. The physical parameter of water includes also parameters like that of hardness, pH, salinity, and TDS. In some instances, the physical quality of water could also be influenced by the chemical water quality. The measurable characteristics that determine these largely subjective qualities are true color which is the color that remains after any suspended particles have been removed, turbidity which could be interpreted as the cloudiness caused by fine suspended matter in the water, hardness which indicates the reduced ability to get a lather using soap, total dissolved solids (TDS), pH, temperature, taste, odor and dissolved oxygen). While using or drinking water, people could experience the taste, odor, feel and appearance of water. This could be used as a measure of quality from users' perspective. For instance, the physical characteristics of water could be used to indicate the presence of corrosion and encrustation in pipes or fittings.

Physical characteristics include:

- ✓ Turbidity
- ✓ Color

- ✓ Taste and odor
- ✓ Temperature
- ✓ Foam.
- ✓ Total dissolved solid
- ✓ Electrical Conductivity

1. Turbidity

The measure of suspended and colloidal matter in water is known as turbidity. The suspended or colloidal matters could be finely divided organic and inorganic matters, clay, silts, soluble organic compounds, plankton, and other microscopic organisms causing the water to change its color from its original and acceptable purity level. On the other hand, turbidity can be also expressed as the optical property that causes light to be scattered and absorbed. In this regard, it is difficult to establish a relation between the turbid property of water and the weight concentration of suspended or colloidal matter due to the fact that the light scattering properties of these matters are dependent on the size, shape and refractive index of the particles.

Turbidity is caused due to presence of suspended and colloidal solids. The suspended solids may be dead algae or other organisms. It is generally silt, clay rock fragments and metal oxides from soil.

The amount and character of turbidity will depend upon:

- ✓ The type of soil over which the water has run and
- ✓ The velocity of the water

When the water becomes quite, the heavier and larger suspended particles settle quickly, while the lighter and more finely divided ones settle very slowly. Very finely divided clay may require months of complete quiescence for settlement. Ground waters are normally clear because, slow movement through the soil has filtered out the turbidity. Lake waters are clearer than stream waters, and streams in dry weather are clearer than streams in flood because of the smaller velocity and because dry-weather flow is mainly ground water seepage. Low inorganic turbidity (silt and clay) may result in a relatively high organic turbidity (color). The explanation of this is that low inorganic turbidity permits sunlight to penetrate freely into the water and

stimulates a heavier growth of algae, and further, that organics tend to be absorbed upon soil fractions suspended in water.

Turbidity is a measure of resistance of water to the passage of light through it. Turbidity is expressed as NTU (Nephelometric Turbidity Units) or PPM (parts per million) or Milligrams per liter (mg/l).

Turbidity is measured by:

1) Turbidity rod or Tape 2) Jacksons Turbidimeter 3) Bal's Turbidimeter
The sample to be tested is poured into a test tube and placed in the meter and a unit of turbidity is read directly on the scale by a needle or by digital display. Drinking water should not have turbidity more than 5 NTU. This test is useful in determining the detention time in settling for raw water and to dosage of coagulants required to remove turbidity. Sedimentation with or without chemical coagulation and filtration are used to remove it.

2. Color

Color is caused by materials in solution or colloidal conditions and should be distinguished from turbidity, which may cause an apparent (not true) color. True color is caused by dyes derived from decomposing vegetation. Colored water is not only undesirable because of consumer objections to its appearance but also it may discolor clothing and adversely affect industrial processes.

Before testing the color of water, total suspended solids should be removed by centrifugal force in a special apparatus. The color produced by one milligram of platinum in a liter of water has been fixed as the unit of color. The permissible color for domestic water is 20ppm on platinum cobalt scale.

3. Temperature

Temperature increase may affect the portability of water, and temperature above 15°C is objectionable to drinking water. The temperature of surface waters governs to a large extent the biological species present and their activity. Temperature has an effect on most chemical

reactions that occur in natural water systems. It also has pronounced effect on the solubility of gases in water.

Temperature directly impacts many of the physical and biological characteristics of water. During the physical analysis of temperature, it is a common practice to express it in degree Celsius. The analysis of temperature should be done on site immediately after collecting the water sample. Cool water is commonly more pleasant than warm water. Furthermore, variation in temperature impacts the degree of tolerance to various inorganic constituents as well as chemical pollutants which commonly affect the taste of drinking water. Water temperature should be kept lower than 15°C for drinking purpose.

Generally, the growth of microorganisms could be facilitated due to high water temperature resulting in unpleasant taste, odor, color and create pipe corrosion problems. Therefore, it is a good practice to keep the temperature of water within the limits of the guidelines. Keeping the temperature within the standard range protects the development of mesophilic pathogenic bacteria.

4. Foam

Foam from various industrial waste contributions and detergents is primarily objectionable from the aesthetic standpoint.

5. Tastes and Odor

The terms taste and odor are themselves definitive of this parameter. Because the sensations of taste and smell are closely related and often confused, a wide variety of tastes and odors may be attributed to water by consumers. Substances that produce an odor in water will almost invariably impart a taste as well. The converse is not true, as there are many mineral substances that produce taste but no odor.

Many substances with which water comes into contact in nature or during human use may impart perceptible taste and odor. These include minerals, metals, and salts from the soil, and products from biological reactions, and constituents of wastewater. Inorganic substances are more likely to produce tastes unaccompanied by odor. Alkaline material imparts a bitter taste to water, while metallic salts may give salty or bitter taste.

Organic material, on the other hand, is likely to produce both taste and odor. a multitude of organic chemicals may cause taste & odor problems in water with petroleum-based products being prime offenders. Biological decomposition of organics may also result in taste-and odor producing liquids and gases in water. Principal among these are the reduced products of sulfur that impart a rotten egg taste and odor. Also certain species of algae secrete an oily substance that may result in both taste and odor.

Consumers find taste and odor aesthetically displeasing for obvious reasons. Because water is thought of as tasteless and odorless, the consumer associates taste and odor with contamination and may prefer to use a tasteless, odorless water that might actually pose more of a health threat.

6. Total Dissolved Solids (TDS)

A wide variety of inorganic and organic mineral deposits like that of calcium, magnesium, potassium, sodium, or salts such as chlorides, bicarbonates, sulfates can be dissolved in water as water is a strong solvent.

Undesirable tastes and color changes in the appearance of drinking water could occur due to the above listed minerals or salt contents. Moreover, in drinking water the presence of total dissolved solid (TDS) could arise from industrial wastewater and sewage.

7. Electrical Conductivity

The ability of a substance to conduct electric current is referred to as electrical conductivity. is the conductivity of a body of unit length and unit cross-section at a specified temperature is called specific electrical conductance and it is mostly expressed in ms/cm (micro Siemens per centimeter). At 25 °C, only a few hundreds of micro Siemens per centimeter conductance is available in pure water. When the temperature of a solution increases the specific electrical conductivity also increases. Thus, temperature has direct relationship with electrical conductivity.

Availability of charged ionic particles in water solution results in an increase in conductivity of the solution. Therefore, measurement results of electric conductivity are indications of the presence of ionic concentration hence, as the ionic concentrations increases conductance of the

solution is also increases. The conductivity of a solution depends upon the quantity of dissolved salts present and for dilute solutions, it is approximately proportional to the TDS content. Conductivity measurements are therefore used to determine concentrations of dissolved salt or the concentration of ionized matter in general.

2.2.2 Chemical Characteristics

It is difficult to find naturally existing pure water as most of the water sources have chemicals naturally that have leached from the surrounding environment. Most of the time, there is a little or no adverse impacts imposed from the naturally occurring chemicals. Even, some of them could be beneficial for human health. On the contrary, water could be contaminated resulting in deterioration of its quality due to human made chemicals. These chemicals could be sourced from one of the following or the combination of industrial effluents, municipal solid waste as well as sewage flows, agricultural effluents, or runoff from urban and towns.

1. Total Solids

Total solids include the solids in suspension colloidal and in dissolved form. The quantity of suspended solids is determined by filtering the sample of water through fine filter, drying and weighing. The quantity of dissolved and colloidal solids is determined by evaporating the filtered water obtained from the suspended solid test and weighing the residue. The total solids in a water sample can be directly determined by evaporating the filtered water obtained from the suspended solid test and weighing the residue. The total solids in a water sample can be directly determined by evaporating the water and weighing the residue of the residue of total solids is fused in a muffle furnace the organic solids will decompose where as only inorganic solids will remain. By weighing we can determine the inorganic solids and deducting it from the total solids, we can calculate organic solids.

2. Alkalinity

It is defined as the quantity of ions in water that will react to neutralize hydrogen ions. Alkalinity is thus the measure of the ability of water to neutralize acids. By far the most constituents of alkalinity in natural waters are carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxide (OH^-). These compounds result from the dissolution of mineral substances in the soil atmosphere. Effects:

- i) Non pleasant taste
- ii) Reaction between alkaline constituent and cation (positive ion) produces precipitation in pipe.

3. pH

pH is a measure of the concentration of free hydrogen ion in water. It expresses the molar concentration of the hydrogen ion as its negative logarithm. Water and other chemicals in solution therein, will ionize to a greater or lesser degree. Pure water is only weakly ionized. Increasing acidity leads to higher values of (H) , thus to lower values of pH. Low pH is associated with high acidity, high pH with caustic alkalinity.

pH is important in the control of a number of water treatment and waste treatment processes and in control of corrosion. It may be readily measured potentially by use of a pH meter.

The pH of pure water refers to the degree of acidity and alkalinity of solutions with respect to hydrogen and hydroxide ions. PH refers to the measure of the potential hydrogen ion H^+ existing in water. Therefore, pH is expressed by numbers ranging in between 0 and 14. In general, neutral water is the one having a pH value of 7. Water is considered as an acidic when the pH value lower than 7 occur and a pH value greater than 7 is taken as basic. Generally, the pH value of drinking water ranges between 6 and 8.5.

4. Dissolved Oxygen (DO)

Dissolved oxygen is present in variable quantities in water. Its content in surface waters is dependent upon the amount and character of the unstable organic matter in the water. Clean surface waters are normally saturated with DO.

The amount of oxygen that water can hold is small and affected by the temperature. The higher the temperature, the smaller will be the DO. Gases are less soluble in warmer water.

Temperature ($^{\circ}C$)	0	10	20	30
DO(mg/l)	14.6	11.3	9.1	7.6

Oxygen saturated waters have pleasant taste and waters lacking in DO have an insipid tastes. Drinking water is thus aerated if necessary to ensure maximum DO. The presence of oxygen in

the water in dissolved form keeps it fresh and sparkling. But more quantity of oxygen causes corrosion to the pipes material.

5. Oxygen Demand

Organic compounds are generally unstable be oxidized biologically or chemically to stable, relatively inner end produce such as CO_2 , H_2O & NO_3 . Indicators used for estimation of the oxygen demanding substance in water are Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Oxygen Demand (TOD) and Total Organic Carbon (TOC). An indication of the organic content of water can be by measuring the amount of oxygen required for stabilization.

BOD is the quality of oxygen required for the biochemical oxidation of the decomposable matter at specified temperature within specified time. (20°C and 5 day)
It depends on temperature and time t.

6. Nitrogen

The forms most important to water quality engineering include;

- a) **Organic – nitrogen:** in the form of protein, amino acids and urea.
- b) **Ammonia – nitrogen:** nitrogen as ammonium salts. E.g. (NH_4) . CO_3
- c) **Nitrate- nitrogen:** an intimate oxidation stage. Not normally present in large quantity.
- d) **Nitrate- nitrogen:** final oxidation product of nitrogen.
- e) **Gaseous nitrogen (N_2)**

The presence of nitrogen compounds in surface waters usually indicate pollution excessive amount of ammonia and organic nitrogen may result from recent sewage discharges or runoff contamination by relatively fresh pollution. Therefore, water containing high org-N & ammonia –N levels are considered to be potentially dangerous. While waters in which most of nitrogen is in nitrate form are considered to somewhat stabilized to constitute prior pollution.

7. Hardness

Hardness is caused by the sum of the alkali earth elements present in water although the major constituents are usually calcium and magnesium. These materials in water react with soap, causing precipitation which as scum or curd on the water surface. Until enough soap has been

dissolved to react with all these material s, no lather can be formed. Water that behaves like this is said to be '*hard*'. The hardness compounds are temporary and permanent:

1. Temporary hardness (carbonate hardness)

- Calcium bicarbonate ($\text{Ca}(\text{HCO}_3)_2$)
- Magnesium bicarbonate ($\text{Mg}(\text{HCO}_3)_2$)

2. Permanent hardness' (non- carbonate hardness)

- Calcium sulfate (CaSO_4)
- Magnesium chloride (MgSO_4)
- Calcium chloride (CaCl_2)
- Magnesium chloride (MgCl_2)

The most usual compounds causing alkalinity, calcium and magnesium bicarbonate, happen also to cause the temporally hardness. Hence, when the alkalinity and hardness are equal, all the hardness is temporary. If the total hardness is greater than the alkalinity, then the excess hardness represents permanent hardness. On the other hand, if the total hardness is less than the alkalinity, the difference indicates the presence of sodium bicarbonate, which adds to the alkalinity but doesn't increase the hardness.

A generally accepted classification of hardness is as follows:

Soft	<509 mg/l as CaCO_2
Moderately hard	50 – 150 mg/l as CaCO_3
Hard	150- 300mg/l as CaCO_3
Very hard	>300 mg/l as CaCO_3

Generally a hardness of 100 to 150 mg/liter is desirable. Excess of hardness leads to the following effects:

1. Large soap consumption in washing and bathing
2. Fabrics when washed become rough and strained with precipitates.
3. Hard water is not fit for industrial use like textiles, paper making, dye and ice cream manufactures.

4. The precipitates clog the pores on the skin and make the skin rough
5. Precipitates can choke pipe lines and valves
6. It forms scales in the boilers tubes and reduces their efficiency
7. Very hard water is not palatable

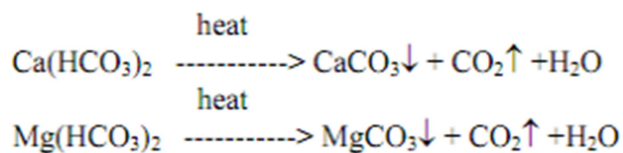
when softening is practiced when hardness exceeds 300mg/lit. Water hardness more than 600mg/lit have to be rejected for drinking purpose.

Methods of removal of hardness:

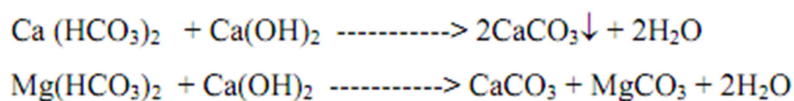
1. Boiling
2. Lime addition
3. Lime soda process
4. Caustic soda process
5. Zeolite process

Methods 1 and 2 are suitable for removal of temporary hardness and 3 to 5 for both temporary and permanent hardness.

Boiling

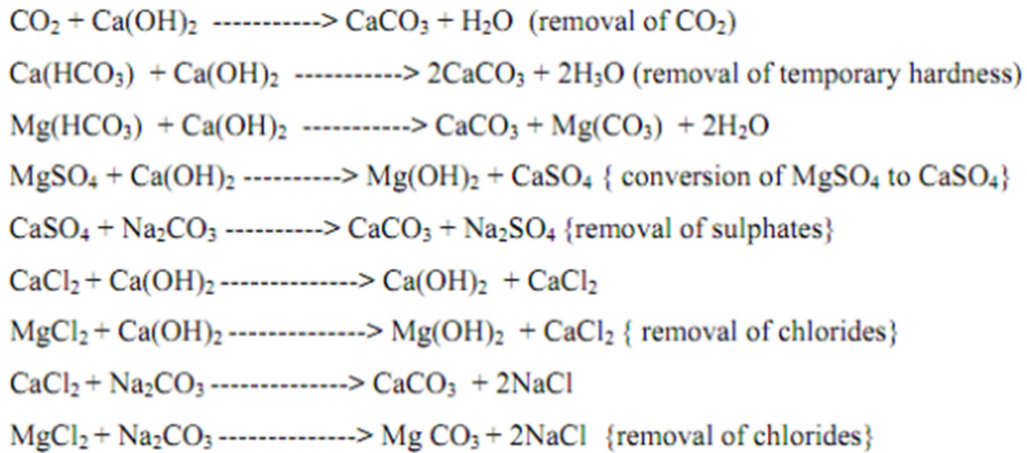


Addition of lime



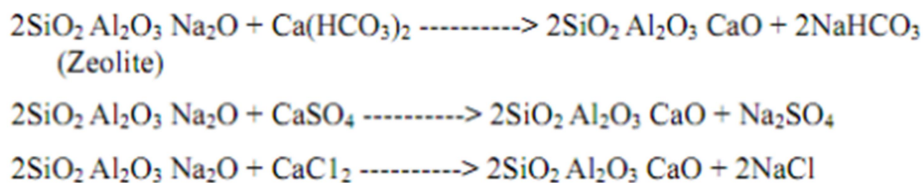
Lime soda process

In this method, the lime and is sodium carbonate or soda as have used to remove permanent hardness from water. The chemical reactions involved in this process are as follows.



Zeolite process

This is also known as the base-exchange or Ion exchange process. The hardness may be completely removed by this process. Zeolites are compounds (silicates of aluminum and sodium) which replace sodium ions with calcium and magnesium ions when hard water passes through a bed of zeolites. The zeolite can be regenerated by passing a concentrated solution of sodium chloride through the bed. The chemical reactions involved are:



8. Chloride

The natural waters near the mines and sea dissolve sodium chloride and also presence of chlorides may be due to mixing of saline water and sewage in the water. Excess of chlorides is dangerous and unfit for use. The chlorides can be reduced by diluting the water. Chloride may demonstrate an adverse physiological effect when present in concentration greater than 250mg/l and with people who are acclimated. However, a local population that is acclimated to the chloride content may not exhibit adverse effect from excessive chloride concentration. Because of high chloride content of urine, chlorides have sometimes been used as an indication of pollution.

9. Fluoride

It is generally associated with a few types of sedimentary or igneous rocks; fluoride is seldom found in surface waters and appears in ground water in only few geographical regions. Fluoride is toxic to humans and other animals in large quantities, while small concentrations can be beneficial.

Concentrations of approximately 1.0mg/l in drinking water help to prevent dental cavities in children. During formation of permanent teeth, fluoride combines chemically with tooth enamel, resulting in harder, stronger teeth that are more resistant to decay. Fluoride is often added to drinking water supplies if quantities for good dental formation are not naturally present.

Excessive intakes of fluoride can result in discoloration of teeth. Noticeable discoloration, called mottling, is relatively common when fluoride concentrations in drinking water exceed 2.0mg/l, but is rare when concentration is less than 1.5mg/l. Adult teeth are not affected by fluoride, although both the benefits and liabilities of fluoride during teeth formation years carry over into adulthood. Excessive concentrations of greater than 5mg/l in drinking water can also result in bone fluorosis and other skeletal abnormalities.

10. Organics

Many organic materials are soluble in water. Organics in natural water systems may come from natural sources or may result from human activity. Most natural organics consist of the decay products of organic solids, while synthetic organics are usually the result of wastewater discharges or agricultural practices. Dissolved organics in the form of starch, fats, proteins, alcohols, acid, aldehydes, cellulose, phenols and ester in water are usually divided into biodegradable and non-biodegradable materials.

Biodegradable materials consist of organics that can be utilized for food by naturally occurring microorganisms within a reasonable length of time. The amount of oxygen consumed during microbial utilization of organics is called biochemical oxygen demand (BOD). The BOD is measured by determining the oxygen consumed from a sample placed in an air-tight container and kept in a controlled environment for a preselected period of time say five days. Measurement of the biodegradable organic matters is usually done by the biochemical oxygen demand (BOD).

Measure of the non-biodegradable organic matters is usually done by the chemical oxygen demand (COD).

11. Metals and other chemical substances

Water contains various minerals or metal substances such as iron, manganese, copper, lead, barium, cadmium, selenium, fluoride, arsenic etc.

The concentration of iron and manganese should not allow more than 0.3ppm. Excess will cause discoloration of clothes during washing and incrustation in water mains due to deposition of ferric hydroxide and manganese oxide. Lead and barium are very toxic, low ppms of these are allowed. Arsenic, Selenium are poisonous, therefore they must be removed totally. Human beings are affected by presence of high quantity of copper in the water.

12. Toxic Organic Chemicals

These include Polynuclear Aromatic Hydrocarbons (PAH); Pesticides. E.g.: DDT and Phenol

2.2.3 Biological Characteristics

Drinking water quality should be such that it is free from all pathogenic microorganisms. Moreover, it should be free from bacteria resulting from excremental pollution of water. In this case, the primary indicators are coliform bacteria found in warm-blooded animals feces. Therefore, the microbiological drinking water quality should be controlled. Thus, monitoring and inspection should be done to check the presence of coliform bacteria through specified treatment techniques. Mostly, chlorine is used for disinfection as it is readily available and less expensive.

The microbial quality of water is associated with the existence of bacteria indicative of faecal sewage contamination such as total coliforms and faecal coliforms or *Escherichia coli*. Coliforms are found naturally in the soil and in the gut of humans as well as animals. Thus, if they are detected in water, it means that there occurs possible contamination of water. As bacteria like that of *E. coli* and certain species of *Enterobacter aerogenes* are present only in the gut of humans and animals their availability in water dictates possible faecal pollution of water. In summary, the main contaminants for drinking water quality from a health perspective are faecal pathogens, arsenic, and fluoride.

There might be several types of bacteria existing in drinking water. Therefore, in order to assess the microbiological water quality it is wise and efficient to establish indicator bacteria. The three most common bacteria indicators used are *Escherichia coli*, thermo tolerant bacteria, and total coliform. These bacteria are important in the assessment of the level of faecal contamination in drinking water. Therefore, total coliforms and fecal coliforms are the microbial organisms to be assessed in drinking water quality assessment.

A feature of most natural water is that they contain a wide variety of micro – organisms forming a balance ecological system. The types and numbers of the various groups of micro – organisms present are related to water quality and other environmental factors.

Microbiological indicators of water quality or pollution are therefore of particular concern because of their relationships to human and animal health. Water polluted by pathogenic micro- organisms may penetrate into private and or public water supplies either before or after treatment.

Water may serve as a medium in which literally thousands of biological species spend part of their life cycle. From the perspective of human use and consumption, the most important biological organisms in water are pathogens, those organisms capable of infecting or transmitting disease to humans. These waterborne pathogens include species of bacteria, viruses, protozoa, and helminthes (parasitic worm).

Since there are many different pathogens, it is not practical to monitor all of them. In reality, indicator organisms are identified and used in checking in biological water quality. The commonly used ones are total coliform, fecal coliform and *E.coli*. Clearly, although indicator organisms can usually provide a good indication of water biological quality, they cannot prove the water is safe and other methods must be used to confirm the absence of various pathogens if in doubt.

1. Coliforms

Coliform group testing indicates a proportion of contamination relative to an easily defined quantity of water. It involves estimating the number of fecal coliform bacteria present in a measured water sample. Not only are fecal coliforms always present in fecal wastes, water

recently contaminated with sewage will always contain coliforms, which will outnumber disease-producing organisms.

Fecal coliform bacteria do not themselves cause disease. These organisms are present in the intestinal tract of all mammals. Human bodily wastes contain literally millions of coliforms. While the correlation between coliforms and human pathogens in natural waters is not absolute, the number of fecal coliform bacteria present effectively indicates the water source's pollution levels.

2. Bacterium

Many are found in water. Some bacteria are indicator of pollution but are harmless; other few in number are pathogenic. Bacterial-borne diseases include: typhoid fever, cholera, and bacterial dysentery.

3. Viruses

These are group of infectious which are smaller than ordinary bacteria and that require susceptible host cells for multiplication and activity. Viral-born diseases include infectious hepatitis and poliomyelitis.

4. Algae

These are small, Chlorophyll bearing generally one-celled plants of varying shapes and sizes which live in water. When present in large numbers they may cause turbidity in water and an apparent color. They cause trouble in water works by undue clogging of filters, but their most troublesome characteristics in the taste and odor that they may cause

5. Protozoa

They are the lowest and simplest forms of animal life. Protozoa-born diseases include giardiasis and amebic dysentery.

2.3. Examination of Water Quality

Examination of water is made to help informing an opinion of the suitability of a water supply for public and other uses.

2.3.1. Sampling

Necessary to obtain a representation sample in a quantity sufficient for analysis complete preservation of sample is practically impossible; however, freezing or adding suitable preservatives may slow down changes in composition. Plastic, glass or metal sample containers are able introduce contamination to sample. Normally plastics are used for chemical analysis (except for oil & grease) and glass for bacteriological analysis.

2.3.2. Standard Tests

i. Titration (volumetric) method

Using burettes, pipets, and other volumetric glass ware, standard solutions are prepared using analytical and distilled water. The recommended determinations to be made by titration method are: Chloride (Cl^-), carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), DO, BOD, COD, calcium (Ca^{++}), magnesium (Mg^{++}), bromide (Br^-), hydroxide (OH^-), sulfide (S^{2-}), sulfite (SO_3^{2-}), acidity, alkalinity etc.

ii. Colorimetric method (using color as the basis)

Measuring amount of color produced by mixing with reagents at fixed wavelength (using spectrophotometer) or comparison with colored standards or discs (comparator). The recommended determinations made by colorimetric method are: color, turbidity, iron (Fe^{++}), manganese (Mn^{++}), chlorine (Cl_2), fluoride (F^-), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{---}), ammonia (NH_4^+), arsenic, phenols, etc.

iii. Gravimetric method (using weight as the basis)

By using weight of insoluble precipitates or evaporated residues in glassware or metal and accurate analytical balance. The recommended determinations made by gravimetric methods are: sulfate (SO_4), Oil and grease, TDS, TSS, TS, etc.

iv. Electrical method

By using probes to measure electrical potential in mill volts against standard cell voltage. The recommended determinations made by electrical methods are: pH, Fluoride (F⁻), DO, nitrate (NO₃), etc.

v. Flame spectra (emission & absorption) method

At fixed wave length characteristics to ions being determined measuring intensity of emission or absorption of light produced by ions excited in flame or heated sources. The recommended determinations made by flame spectra methods are: sodium (Na⁺), potassium (K⁺), lithium (Li⁺), etc.