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Water Quality and Standards

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4.1 Important Properties of Water

Water is vitally important substance with properties that are unique, interesting and wide-ranging in potential impact. An understanding of its nature and behaviour requires knowledge of certain fundamental facts about its chemical and physical characteristics. Several of those characteristics play major roles in determining water quality and causing changes in it, either through natural phenomena or impacts brought about by humans and their activities.

The colourless, odourless liquid looks a very normal thing, yet, this is not true. As a chemical, it is unique. It is a compound of great stability, a remarkable solvent and a powerful source of chemical energy.

4.1.1 Physical State

Water is the only common material that exists naturally in all three states on earth and the earth is apparently the only planet in the solar system that sustain water in this way. No other substance except water occurs in three states - solid as ice, liquid as water and gaseous as vapour- at the same time. This rare phenomenon is possible due to the unusual structure of the water molecule.

At low temperature, it is present as ice, a solid in which the molecules form relatively rigid circular structures. In this state, the molecules have little motion and possess only low energy as compared with the other two states.

As a fluid, it moves readily to fit the shape of any container in which it is placed or flows from one location to another in response to the application of only slight force. With the addition of heat, the water molecules achieve higher energy levels. They are much more widely separated into a gaseous state (water vapour) and disperse readily among the molecules of other gases occupying the same volume mixing with them.

The three physical states of water are not mutually exclusive, they can coexist and often do. Moreover the portions in each state are not fixed or independent of each other, but the molecules can exchange between them continuously. In the gaseous state, water is monomeric (existing as a single molecule) while in the solid state (Ice) water molecules strongly interact with each other forming an ordered structural lattice.

At 4 mm pressure and 0.0075 °C temperature (called triple point) all the three phases of water i.e. water, vapour and ice exist together.

4.1.2 Density and Specific Gravity

The density of water depends on its temperature and chemical content. Density also is influenced by pressure, but close spacing of the liquid molecules requires very high pressure to cause even slight changes in density. Thus, in most of the applications, those effects usually are ignored and it is assumed that water is **"incompressible"**.

It may be heated, cooled, frozen, evaporated, used to dissolve other materials, be subjected to all manner of physical and chemical change and yet finally returns to its normal form of liquid water. Most other materials under such conditions lose their initial identity and only with considerable difficulty that they return to their original state. Due to this property it is probably the **most stable material known**. It is available today in as much quantity as it was many millions of years ago.

The density of water increases with a reduction in temperature down to 4°C(39°F). but further cooling causes a slight decrease, producing its **maximum density at 4°C temp.** The maximum density of water at 4 °C is due to the breaking of the hydrogen bonds part of the energy supplied is utilized in separating the water molecules free of the hydrogen bonding. The density of "fresh" water including most waste waters is usually cited in practical water literature as 1000 kg/m^3 (8.34 Ib/gal) sea water usually has a density of 1025 kg/m^3.

The specific gravity of a substance is merely the ratio of its density to that of pure water at 4° C. The specific gravity of water is numerically equal to its density, when expressed in grams per cubic centimeter, because the density of water at 4°C is 1.00000 9/cm^2.

4.1.3 Specific heat

The " **specific heat**" of a substance defines the relationship between the amount of heat transferred to or from it and the change in temperature produced by that exchange. Water requires 1.0 calorie for each gram to raise the temperature by one degree celcius. Accordingly its specific heat is 1.0 cal./g/°C.

Water has the highest specific heat in nature, except for very few substances, including ammonia. This means that the transfer of a given amount of heat to or from water produces far less temperature change than it would in most other substances. That large heat capacity accounts for the stabilizing effects of large water bodies on atmospheric temperature and climate near them.

4.1.4 Vapour Pressure

Partial pressure of total pressure of gas phase within the vessel that is exerted by water vapour is called **vapour pressure** for pure water it varies with temperature in the range of O^{o}C to 100^{o}C. At the freezing point, water still extents a slight vapour pressure, in fact, even ice at substantially lower temperature does so an d can release water molecules as vapour. At upper end of the temperature scale, the vapour pressure reaches 101 KPa which is equal to atmospheric pressure at sea level. That produces spontaneous formation of vapour bubbles in the liquid(Boiling), if pressure in the system is equal to 1 atm. At higher altitudes, water boils at lower temperatures because its vapour pressure reaches the reduced atmospheric pressure at a lower temperature. The practical significance of vapour pressure in natural water air systems includes the fact that it is vital in determining rates of evaporation from lakes and streams.

4.1.5 Evaporation and condensation.

When the vapour pressure of water exceeds its partial pressure in the atmosphere in contact with it, there is a net transfer from liquid to gas. That process is called **evaporation.**

The opposite process-condensation- refers to a net transfer of molecules from gas to liquid, which occurs when partial pressure of water vapour in the gas exceeds vapour pressure of the water in contact with it.

Because molecules of liquid that are vaporizing must absorb energy from their surroundings evaporation is referred to as a **"cooling"** process. Conversely, that same amount of heat is given off by molecules during condensation, causing it to be termed a **"heating"** process.

Evaporation from land and water areas provides a continuous supply of vapour to the atmosphere, and subsequent condensation of that vapour as rain and snow supplies most of our fresh water needs. On the other hand, evaporation also can be an important debit, through that process, substantial amount of our fresh water resources are lost to the atmosphere from lakes, streams and vegetation. In water treatment, the combination of controlled evaporation and subsequent condensation in distillation systems permits production of fresh water from oceans and other saline sources.

4.1.6 Freezing and Melting.

When water freezes, the molecules - readjust in configuration to form a rigid structure in which they are in the liquid phase. This causes a decrease in density which accounts for the fact that ice floats and has great practical significance.

The freezing of water is unusual compared to other liquids. Hydrogen bonding in water produces a crystal arrangement that causes ice to expand beyond its original liquid volume so that its density is less than that of the liquid and ice floats. If these were not the case, lakes would freeze from the bottom and life as we know it could not exist.

Water also releases more heat upon freezing than do other compounds. Furthermore, for each incremental change in temperature, water absorbs or releases more heat, i.e. has great heat capacity than many substances, so it is an effective heat transfer medium.

When the molecular arrangement of water changes during freezing, there is a strong tendency to exclude impurities from the crystalline structure of the ice. That provides the basis for processes that produce fresh water from sea water through freezing.

4.1.7 Viscocity

Viscocity is another property of water affecting its treatment and use. It is a measure of internal friction -the friction of one layer of molecules moving across another. As water temperature rises, this internal friction decreases. Because of temperature effect, dissolved salts and gases can diffuse more rapidly through warmer water.

4.2 Chemical Characteristics

4.2.1 Molecular Structure

It is known that a water molecule is composed of one oxygen and two hydrogen atoms through a linkage that is called a **"covalent bond"** This bond is exceedingly strong bond due to which the water molecule is very tight in structure and highly stable, accounting for some of waters unique characteristics.

Hydrogen bond and Polar nature.

A water molecule is a symmetrical because of the arrangement of the hydrogen and oxygen atoms. Two hydrogen atoms are located 105 apart, adjacent to the oxygen atom, positively charged on the hydrogen side and negatively charged on the oxygen side. For this reason water is said to be **Dipole.** Due to this, water molecule exerts dipole magnet with north and south poles. This causes the molecules to agglomerate, the hydrogen of one molecule attracting the oxygen of neighbouring molecule. The linking of molecule resulting from this attractive force is called **"Hydrogen bonding"**. In liquid phase, hydrogen bonding does not produce a regular structural pattern but exerts a strong influence on **solvent capacity, surface**

tension, latent heat and other properties. The effects of having covalent bonds within water molecules and hydrogen bonding between them accounts for the unusual characteristics of this compound. The high strength of its bonding system requires expenditure of more than the usual amount of energy for a molecule of its weight, before it can escape from the liquid into the gas phase. This causes water to have an unusually **high latent heat of vaporization.** The bonds also account for waters high latent heat of fusion and high heat capacity.

Its bonding strength also is responsible for the unusual cohesive nature of water, producing very high **surface tension.** This high surface tension supports insects on its surface.

Hydrogen bonds are formed with glass and other compounds that water "wets", producing forces that are responsible for its **capillary action.** This capillary action makes it possible for water to move though soils, roots, plants and the human body.

4.2.2 Ionization

Some water molecules dissociate into electrostatically charged ions as under :

$$H_2O \text{ --------> } H^+ + OH^-$$

Water ionizes so very slightly producing only 10^{-7} moles of hydrogen and 10^{-7} moles of hydrogen ions per litre, that is an insulator - it cannot conduct electrical current. In pure water, the hydrogen ion concentration is 10^{-7} moles/litre. The reciprocal of 10^{-7} is 10^7, and the logarithm of that number is 7. Therefore the pH of 7 indicates that the hydrogen ion concentration is the same as that of pure water. A lower pH indicates that water is more **acid,** while a higher pH means reduced **acidity.**

As salt or other ionizing materials dissolve in water, electrical conductivity develops. The conductivity of naturally occurring waters provide a measure of their dissolved mineral content.

4.2.3 Universal Solvent

Water is as close as any compound to being the **"Universal Solvent"**, virtually all chemicals are soluble in it to some extent. Water molecules in contact with a crystal orient themselves to neutralize in contact with a crystal orient themselves to neutralize the attractive forces between the ions in the crystal structure. The liberated ions are then hydrated by these water molecules, preventing them from recombining and recrystalizing. This **solvency** and **hydration** effect is shown by waters relatively high dielectric constant.

This characteristic often creates problems because it is practically impossible to produce and store pure water. The atoms of dissolved substances exist **"ions"** which are electrically charged atoms or groups. They are joined by electrostatic forces - ionic bonds-readily dissolved in water. On the other hand, the water molecules retain their basic structure because of co-vallent bond strength and hydrogen bonding for that reason, most substances dissolved in water do not change the basic chemical character of water itself.

4.2.4 Osmotic Pressure.

Another important phenomenon occurring in water solutions related to dissolved matter (solutes) is osmotic pressure. If two aqueous solutions are separated by a membrane, water will pass from the more dilute into the more concentrated one. This important process controls the performance of all living cells. It also explain the **food preservation** by salting. **Reverse Osmosis** principle is used for desalination of water.

The role of water as a **biological fluid** is widely recognised and well narrated in the chapter on water and health.

4.3 Concept of Water Quality.

Water quality means different things to different persons because of the various perspectives from which they approach it. Generally, it refers to characteristics or attributes of water, good or bad, that relate to its acceptability for certain purposes or uses.

Often it is tempting to view quality in the context of a simple hierarchy based on purity, in which water with the lowest concentration of constituents is viewed as best. This may seem logical but, unfortunately, meaningful evaluation of water quality is not that simple. Many other factors must be taken into consideration.

The term **"Water Quality"** is a widely used expression which has an extremely broad sprectum of meanings. The quality of water is closely linked with the nature of use to which the water is put. Since the desirable characteristics of a water vary with its intended use, quality required for one purpose may not be suitable for other purpose.

The point may be established through a simple example. If one uses a scale based on purity, distilled water must rate very near the top, and sea water would be classified as relatively poor because it contains high concentration of salts. It is well known that many types of fish and other aquatic life thrive in the ocean, specifically because they require salts,trace elements and nutrients in concentration approximately those actually there. According, ocean water is a desirable medium for growing those organisms and should be considered as high in quality for that purpose inspite of the impurities. On the other hand, the same organisms would not survive long in distilled water because the necessary chemicals would be absent, making that an unacceptable environment for them. Thus, we must rate distilled water as poor in quality for that purpose.

Now consider a different example - water added to high-pressure boilers evaporates and produces steam, leaving behind most salts that enter with the water. Excessive salt accumulations may cause boiler corrosion and scale formation problems. Water used for this purpose should be as low in salt content as possible, making distilled water excellent and sea-water poor in quality for boiler make up.

These two examples illustrate that water quality cannot be evaluated meaningfully without considering the use for which the water is being considered. Quality requirements for a stream that will be used as a public water supply are different from those that would make it desirable for fishing and both may differ from the quality suitable for irrigation, swimming or aesthetic aspects.

From a technological point of view, water quality means those characteristics which are usually defined in terms of appropriate physical, chemical and biological parameters, preferably ones that can be measured quantitatively and reproducibly to avoid ambiguity in reporting or discussing them. In this context, water quality is relatively simple and strait forward, at least conceptually, because accurate quantitative data compiled in accordance with sound scientific principles form an excellent basis for discussion and agreement.

Evaluation of the quality of a stream or lake must consider (1) consideration of various constituents in the water and (2) uses that the resource will be called on to satisfy. Quality can be judged accurately only by comparing concentrations of various constituents in water with those that would be optimum for the intended use.

In short water quality is not absolute. It has practical meaning only when related to some specific use of the water. The water quality is dynamic, and its changing parameters require one to be in constant touch with many segments of scientific world. The water scientists are making advances in the assessment and quantization of water quality parameters. However, other segments of science are generating new products and new water contaminants at an ever-increasing rate. Man himself is multiplying and his range is increasing. The products of population growth and industrial development are reflected in a deteriorating water quality in previously unaffected areas.

4.4 Historical need for water quality

Historically, civilizations began and centered within regions of abundant water supplies. Water quality was not very well documented, and people knew relatively little about disease as it related to water quality. Early historical treatment was performed only for the improvement of the appearance or taste of the water. No definite standards of quality other than general clarity or palatability were recorded by ancient civilizations.

The first drinking water standards were issued at least 4000 years ago. In **"The Quest for Pure Water"**, Baker quotes a Sanskrit Source;

"It is directed to heat foul water by boiling and exposing to sunlight and by dipping seven times into a piece of hot copper, then to filter and cool in an earthen vessel".

Hippocrates, the father of medicine (460 to 354 B.C) stated that **"Water contributes much to health"**. His interest in water centered on the selection of the most health-giving source of supply rather than purifying the waters that were bad. Apparently, ancient people deduced by observation that certain waters promoted good health, while others produced infection. And, although they knew nothing about the cause of diseases, they appeared, at least in some instances, to have been astute enough to recognise the health giving properties of pure and wholesome water. Unfortunately, such information had to be acquired as a result of illness and death of many people.

By the eighteenth century, filtration of particles from water was established as an effective means of clarifying water. The general practice of making water clean was well recognised by that time, but the degree of clarity was not measurable. The first municipal water filtration plant started operations in 1832 in Paisley, Scotland. Aside from the frequent references of concern for the aesthetic properties of water, historical records indicate that standards for water quality were notably absent upto and including much of the nineteenth century.

With the realization that various epidemics (e.g. Cholera and Typhoid) had been caused and /or spread by water contamination, people saw that the quality of drinking could not be accurately judged by sensory perception. Reliance on taste and smell was not an accurate means of judging the acceptability of water, more stringent quality criteria would be a necessary historical development. As a result, in 1852 a law was passed in London stating that all waters should be filtered. This was representative of the new heights that had been reached in the ability to observe and correlate facts. In 1855. epidemiologist Dr. John Snow was able to prove empirically that cholera was a water borne disease. In the late 1880s, Pasteur demonstrated the particulate germ theory of disease which was based upon the new science of bacteriology. Only after a century of generalised public observations of deaths due to waterborne diseases was this cause-and-effect relationship firmly established.

4.5 Common Philosophy of Water Quality.

A common man expects clean and palatable water for drinking and other domestic uses. In the ancient time it was said that **"water which looks well and cooks well"** is a good and acceptable water. All other water uses must be subordinated to man's need for healthful fluid for his consumption. The water intended for drinking and other domestic purposes should possess the following characteristics.

- It should not contain any visible suspended impurities. (Turbidity).
- It should be aesthetically acceptable having unobjectionable colour, odour and taste.
- It should not contain any minerals or chemicals which may cause adverse physiological effects.
- It should not contain any micro-organisms (Pathogens) which are capable to produce diseases.
- It should not form scale while boiling and should not consume more soap in washing (Not hard).
- It should not be aggressive (Having high CO_2) to cause corrosion.
- It should not create stains on laundry and plumbing fixtures (Fe and Mn should be low
- It should have reasonable temperature.

In assessing the quality of drinking water, the consumer relies completely upon his senses. Water constituents may affect the appearance, smell, or the taste of the water and the consumer will evaluate the quality and the acceptability essentially on these criteria. Water that is highly turbid, highly coloured, or has an objectionable taste will be regarded as dangerous and will be rejected for drinking purposes. However, we can no longer rely entirely upon our senses in the matter of quality judgment. The absence of any adverse sensor effects does not guarantee the safety of water for drinking.

4.6 Assessment of Quality

The quality of water is assessed by various parameters which are classified as physical, chemical and biological. This classification helps in assessing the quality of water for its beneficial uses or treatment required for its upgradation. The treatment is decided based on the constituents present and the quality required.

Physical	Colour, odour. temperature, taste. conductivity, pH and turbidity.
Chemical	Inorganic salts organic compounds metals.
Biological	Faecal indicators. Different norms.
Radiological	Naturally occurring Sr^{90} and Ra^{226}.

Control of water quality for any purpose, be it protection of supply for some beneficial uses or the conditioning of process water, involves treatment altering or upgrading quality to a level appropriate to the intended use. Water treatment is accomplished by engineered system and the goal of sound engineering includes a concern for minimum cost consistent with health, safety and product requirements. Therefore if quality is to be changed, some way must be found to decide when the change has been carried for enough in the interests of both economy and suitability of the finished water to its intended use. This involved two concepts - **"Standards" or Requirement and Criteria.**

4.7 Water Quality Criteria.

The best efforts of knowledgeable persons and groups to define quality characteristics of water that are necessary or desirable for various specific uses are summarised periodically in the form of "Water Quality Criteria". A comparison of data for the water in question with the appropriate published criteria provides a basis for judging probability that the resource would be satisfactory for beneficial uses that are under consideration, and, if not, what changes in quality would be necessary to make it suitable for those purposes.

It must be emphasized that the "quality criteria" should not be viewed as valid and absolute limits, but only as guidelines that can be used for preliminary judgments. "Criteria" represent the best efforts of knowledgeable groups to define specific quality characteristics that are necessary to support various water uses, based on state-of-the-art information. They provide bases for judging whether water quality in a resource is suitable for its proposed uses and, if not, what specific changes might be necessary to make it so. The criteria are not absolute values, but judgment calls that include safety margins and are subject to change as new knowledge and conditions develop. Criteria could be assigned numbers but they do not form the rigid standards.

4.8 Guidelines

Guidelines are less rigid than standards and are usually not legally enforceable. However, they serve the purpose of control factors, if they are fair and reasonable. Guideline values for drinking water quality represent the level (concentration or number)of a constituent that ensures an aesthetic pleasing water and does not result in any significant risk to the health of the consumer. The quality of water defined by the guideline values is such that it is suitable for human consumption and for all usual domestic purposes, including personal hygiene, These values are intended for use by countries as a basis for the development of standards, in the context of prevailing environmental, social, economical dietary and cultural conditions, which if properly implemented will ensure the safety of drinking water supply. These values provide basis for decision making in the following activities.

- Laws. Regulations, and Standards.
- Approval of new sources (Feasibility and treatability).
- Sanitary survey.

- Monitoring programme.
- Watershed protection.
- Operation of water works.
- Developing code of practice.
- Inspection and quality control.

4.9 Water Quality Standards

By definition the term "**Standard**" applies to any definite rule, principle or measure established by authority. The fact that a standard has been established by an authority makes it quite rigid, official or quasi-legal. However, an authoratitive origin does not necessarily mean that the standard is fair, equitable, or based on sound scientific knowledge, for it may have been established somewhat arbitrarily on the basis of inadequate technical data tempered by a cautions factor of safety. Nevertheless some sort of parameters are necessary.

A far better way to describe an administrative decision by a regulatory body is "**requirement**". It represent a requisite condition to fulfill a given mission. It does not necessarily have the connotation of scientific justification nor does it give an impression of immutability.

It is obvious that standards which are manmade are subject to change as knowledge of their validity or otherwise becomes available. Water quality standards are different from criteria and should not be confused with it. It should be noted that water quality criteria and water quality standards are not interchangeable terms. They are established by different groups for different purposes and may or may not be closely related to each other in practice. Sometimes standards are set at concentrations that are identical to applicable criteria but that may be inappropriate under other circumstances.

The criteria whereby standards have been derived are based on aesthetics or consumer acceptance such as Turbidity, colour, odour, taste, palatability (TDS and chloride), pathogenicity, (MPN of indicative organisms) chemically related illnesses (fluoride, nitrates), toxicity(Arsenic, Mercury), Carcinogenicity (Chromium), Biomagnification through food chain, etc.

4.10 Bases for Establishing Standards.

For establishing the standards, following bases are used.

- Established or current practice.
- Attainability, either easily or reasonably attainable -
    - Technologically and

- Economically.

- Educated guess, making use of best information available.
- Experimentation (Animal exposure).
- Human exposure
  - Taking advantage of occurring catastrophe.
  - Experimentation with humans directly.
- Mathematical model or treatment.(Probability, Mode percentile).

The existing water quality standards have been derived mostly from two factors -

- Educated guess
- Attainability.

Water Standards affects the selection of raw water sources, choice of treatment processes and design criteria, range of alternatives for modifying existing treatment plants to meet current or future standards and treatment costs. Persons working in the field of drinking water should know what standards are currently applicable and what changes can be expected in the future so treatment plants can be designed and operated in compliance with the regulations, to ensure acceptable quality of water.

4.11 Bacteriological Requirements.

No bacteriological examination of water, however exact, can take the place of a complete knowledge of the conditions at the source of supply and throughout the distribution system. The examination of a single sample can indicate no more than the conditions prevailing at the moment of sampling and a satisfactory results can not guarantee that the observed conditions will persist in the future. The quality of a water supply can be assessed only by a series of samples over a definite period of time.

The major danger associated with drinking water is the possibility of its recent contamination by sewage or human excrement and even the danger of animal pollution must not be overlooked.

When pathogenic micro-organisms are present in faeces or sewage, they are almost always greatly outnumbered by the excremental organisms and these intestinal organisms are easier to detect in water. The absence of these organisms in water indicates that the disease-producing micro-organisms are also absent.

The organisms most commonly used as indicators of pollution are **Escherichia Coli** and the coliform group as a whole. It is now considered desirable to use the term **"Faecal Coliform"** in place of E-Coliform. The term **"Faecal Colifom"** includes a slightly wider spread of organisms than the term E-Coli, but these are all of definite faecal origin and are indicative of recent faecel pollution. All members of the colifom group may be of faecal origin, they are foreign to water and must be regarded as indicative of pollution.

The search for faecal streptococci, of which the most characteristic type is streptococcus faecalis and for anaerobic spore-forming organisms, of which **clostridium welchii** is particularly typical, may be of value in confirming the faecal nature of pollution in doubtful cases. The presence of 'clostridium welchhii' in a natural water suggest that faecal contamination has occurred and in the absence of organisms of the coliform group, suggests that the contamination occurred a long time ago.

The biological examination of water or as it is sometimes called, the microscopical examination is of value in -

- determining the causes of objectionable taste and odour in water and controlling remedial treatments.
- aiding in the interpretation of various chemical analysis and
- explaining the causes of clogging in distribution pipes and filters.

The biological qualities of a water are of greater importance when the supply has not undergone the conventional flocculation and filtration. Chlorination at all dosage normally employed in water works is ineffective against certain parasites including amoebic cysts. They can be excluded only by effective filtration or higher chlorine doses than can be tolerated without subsequent dechlorination.

The drinking water shall be free from microscopic organisms such as algae, zoo plankton, flagellates, parasites and toxin producing organisms.

The Bureau of Indian Standards(BIS) has formulated following standards for bacteriological quality of water (IS:10500/1991)

- Coliform per 100 ml sample should be absent in 95% of samples throughout any year.
- No sample should contain more than 10 coliform.
- Coliform organisms should be absent in two consecutive samples.
- No sample should contain E.coli

4.12 Virological Requirements.

To be acceptable, drinking water should be free from any viruses infectious for man. This objective may be achieved

- by the use of a water supply from a source which is free from waste water and is protected from faecal contamination; or
- by adequate treatment of a water source that is subject to faecal pollution.

Viruses can be removed toa great extent during water treatment, if the latter is carried out efficiently. In a water, in which fre chlorine is present, active viruses will be generally absent, if coliformorganisms are basent. For this rason and because coagulation, sedimentaiton and filtration, in themselves, may contribute to the removal of viruses from water, the importance of such treatments must be stressed.

Adequacy of treatment cannot be assessed in an absolute sense because neither the available monitoring techniques nor the epidemiologica evaluation is sufficiently sensitive to ensure the absence of viruses. However, it is considered at prsent that contaminate source water may be regarded as adequately when treated the following conditins are met.

- turbidity of 1 NTU orless is achieved.
- disinfection of the water with at least 0.5 mg/l of free residual chlorine after a contact period of at least 30 minutes at a pH below 8.0.

Where virological facilities cn be provided, it i desirable to examine the raw water source and the finished drinking water for the presence of viruses. This will provide baseline data to evaluate the health risk face by the population. A reference method should be used for theconcentrationand detecitn of viruses inlarge columes of drinking water (e.g. 100-1000 litres).

4.13 Physico-chemical Quality

There are certain substances which, if present in supplies of drinking water at concentration above certain levels, may give rise to actual danger to health. heavy metals in water exceeding certain level are responsible for causing toxic effects. Similarly pesticides are also considered toxic, hence there should be absent in drinking water.

Other physico-chemical parameters interfere with the beneficial use of water at excessive levels and hence their upper values need to be prescribed.

4.14 Surface Water Quality

The precipitation reaching the earth's surface may either run off over the land into streams and lakes or infiltrate into the ground. Water available on the surface of the earth is called **surface water**. It may be flowing like rivers and streams or stagnant like pond, lake or ocean. The surface water flow has great variation in relation to intensity of rainfall. Surface water is not polluted through sewage or industrial wastes, is supposed to be low in dissolved ingredients. Turbidity will be high rainy season having moderate to low range in remaining months. Being open to sky and easily accessible by man and animals, surface waters are subjected to biological contamination also.

Surface water quality is dependent on the following aspects.

- Soil characteristics
- Vegetation

- Precipitation intensity and Duration
- Temperature and
- Land use patterns

Due to natural processes and pollution, the raw water may have the following composition.

- Suspended matter - clay, sand, flocs, organics, microbes, algae
- Colloidal matter - clay, proteins, silica, organics, bacteria, viruses
- Dissolved matter - ions, gases, humic substances, organics
- Aquatic organisms - cyclopes, Dalphia, fish etc.

Actually surface water and ground water sources are not always separate. The surface water at one point on the earth may become ground water at another point, then may emerge again as surface water at a third point.

4.15 Ground Water Quality

The term ground water is used to denote the water which has saturated the pores or interstices of subsoil. Ground water is derived from precipitation on earth's surface that gradually percolates to the subsoil through porous strata or openings through formations. Ground water occurs in many types of geological formations. Sub-surface water is the general term applied to all water present in the subsoil. In very broad sense all the water which occurs below the surface of the earth may be called **Ground water.**

Ground water is available from shallow and deep wells. It is normally clean due to straining effect of soil and do not have any turbidity or suspended solids. Biological parameters are also found absent they do not reach deep into underground strata. On the other hand movement of water through soil strata increases the concentration of dissolved constituents. Because of large storage and long retention times, ground waters exhibitless variability in quality than surface waters. They tend to be much move uniform in temperature, chemical characteristics and biological content. Filtration through soil usually removes essentially all of the suspended matter, including organisms, but the mineral content of ground water is usually higher than surface water. The composition ad concentration of substances dissolved in unpolluted ground water depend on the chemical composition of precipitation, on the biological and chemical reactions occurring on the land surface and in the soil zone and on the mineral composition of the aquifers and confining beds through which the water moves.

4.16 Water Quality Standards in India.

The earliest attempt in India to prescribe drinking water standards was made by Environmental Hygiene Committee in 1959. Indian Council of Medical Research was the first to establish Standards of drinking water quality in 1960. Subsequently standards were included in "Manual on Water Supply" which was published in 1962 by Ministry of Health. This was revised in 1975 by the Ministry of Works and Housing. The Indian Standards Institution (Now renamed as "Bureau of Indian Standards") issued its own standards in February 1983 under IS:10500-1983. These standards are revised in 1991 by BIS.

A statement of drinking water quality standards formulated and recommended by various agencies like BIS and Government of India (CPHEEO) guidelines prescribed by WHO and Standards of European Community are given in **Table - 4.1.** Indian Standards are mostly falling in line with WHO's guidelines, except for a few cases where Indian Standards are relaxed to some extend considering the local conditions and requirements.

Water Supply authorities in Gujarat are currently following the standards recommended by Bureau of Indian Standards. (i.e. 10500 / 1991) for deciding the potability of water.

4.17 Water quality in Gujarat

The water quality of Gujarat is discussed elaborately in Chapter No. 13 on **Result and Discussion** and hence is not repeated here.

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Table - 4.1
Drinking Water Quality Standards formulated by various agencies

Sr No	Characteristic/ Constituent	World Health Organisation Geneva(1984)	Bureau of Indian Standards New Delhi IS 10500 (1991)		RNDWM, DRD, GOI, New Delhi 1989		Standards recommended by CPHEEO Min. of Urban Development GOI (1991)		EPA (USA)	The European Community (1980)
		Recommended guideline value $	Desirable limit	Permissible limit in the absence of Alternate source	*Acceptable	**Cause for rejection	*Acceptable	**Cause for rejection	Recommanced Limit(1989)	
A.	PHYSICO-CHEMICAL									
1	Colour(TCU) Platinum cobalt scale	15	5(Hazen Units)	25*[a] (Hazen Units)	5	25	5	25	15	20
2	Taste and Odour	Inoffensive to most consumers	Unobjectionable	Unobjectionable	Unobjectionable	Unobjec-tionable	Unobjectionable	Unobjectionable	3 TON (Odor)	Unobjectionable (Odour)
3	Turbidity (NTU)	5 JTU	5	10	2 5 JTU	10 JTU	2 5 JTU	10 JTU	1-5	4
4	Dissolved Solids(mg/l)	1000	500	2000	500	1500	500	1500	500	1500
5.	pH range	6 5 to 8 5	6 5 to 8 5	No relaxation	7 0 to 8 5	<6 5 to>9 2	7 0 to 8 5	<6 5 to > 9.2	6 5 to 8 5	6 5 to 8.5
6	Total Hardness (as $CaCO_3$) (mg/l)	500	300	600	200	600	200	600	--	--
7	Calcium (as Ca)(mg/l)	--	75	200	75	200	75	200	--	100
8	Magnessium (as Mg) (mg/l)	--	--	--	30	150	30	150*[c]	--	50
9	Copper (as Cu) (mg/l)	1 0	0 05	1 5	Not mentioned	Not mentioned	0 05	1.5	1 0	0 1
10	Iron (as Fe) (mg/l)	0 3	0 3	1 0	0 1	1 0	0 1	1 0	0 3	0 20
11	Manganese (an Mn) (mg/l)	0 1	0 1	0 3	0 05	0 5	0 05	0 5	0 05	0 05
12	Chloride (as Cl) (mg/l)	250	250	1000	200	1000	200	1000	250	200
13	Sulphate (as SO_4) (mg/l)	400	200	400*[f]	200	400	200	400	250	Not mentioned
14	Nitrate (as NO_3) (mg/l)	10(as N)	45	100	45	100	45	45	10 0(as N)	50
15	Fluoride (as F) (mg/l)	1 5	1 0	1 5	1 0	1 5	1 0	1 5	0 7 to 2 4	0 7 to 1.5
16	Phenolic compounds (as Phenol) (mg/l)	--	0 001	0 002	Not Mentioned	Not Mentioned	0 001	0.002	--	--
17	Zinc (as Zn) (mg/l)	5 0	5 0	15 0	*	*	5 0	15 0	5 0	1 5
18	Anionic detergents (as MBAS) (mg/l)	--	0 2	1 0	*	*	0 2	1 0	--	--
19	Mineral Oil (mg/l)	--	0 01	0 03	*	*	0 01	0 3	--	--
20	Residual free chlorine (mg/l) (min)	--	0 2*[h]	--	*	*	Not Mentioned	Not Mentioned	--	--
21	Pesticides (Max.) (mg/l)	--	Absent	0 001	*	*	*	*	--	--
22	Alkalinity (Max) (mg/l)	--	200	600	*	*	*	*	--	--
23	Aluminium (as Al) (Max) (mg/l)	0 2	0 03	0 2	*	*	*	*	0 05	0 2
24	Boron (Max) (mg/l)	--	1 0	5 0	*	*	*	*	--	--
25	Sodium (as Na) (mg/l)	200								175
26	Phosphorous (as P_2O_5) (mg/l)									5

Table 4·1 contd......

B RADIOACTIVE SUBSTANCES

1	Gross Alpha activity	0.1 Bq/l	–	0 1Bq/l (Max)	Not mentioned	Not mentioned	3 0 pCi/l	3 0 pCi/l	15 pCi/l	–
2	Gross Beta activity	1 Bq/l	–	1 pCi/l (Max)	*	*	30 pCi/l	30 pCi/l	50 pCi/l	–

C TOXIC SUBSTANCES

1	Arsenic (as As) (mg/l)	0 05	0 05	No relaxation	*	*	0 05	0 05	0.05	0 05
2	Cadmium (as Cd) (mg/l)	0 005	0 01	*	*	*	0 01	0 01	0 01	0 005
3	Cyanide (as CN) (mg/l)	0 1	0 05	*	*	*	0 05	0 05	–	50 µg/l
4	Lead (as Pb) (mg/l)	0 05	0 05	*	*	*	0 10	0 10	0 05	0 05
5	Selenium (as Se) (mg/l)	0 01	0 01	*	*	*	0 01	0 01	0 01	0 01
6	Mercury (total as Hg) (mg/l)	0 001	0 001	*	*	*	0 001	0 001	0 002	0 001
7	Chromium (as Hexavalent Cr) (mg/l)	0 05	0 05	*	*	*	0 05	0 05	0 05	0 05
8	Polynuclear aromatic hydrocarbons (PAH) (mg/l)	–	–	–	*	*	0 2	0 2	–	–

Note :

$ These guidelines are intended to supersede both the European (1970) and international (1971) standards for drinking water quality.

* The figures indicated under the column "Acceptable" are the limits upto which water is generally acceptable to the consumers.

** Figures in excess of those, mentioned under "Acceptable" render the water not acceptable, but still may be tolerated in the absence of alternative and better source but upto the limits indicated under column "cause for rejection" above which the supply will have to be rejected.

*a Extended to 25 only if toxic substances are not suspected, in absence of laternate sources.

*b Dissolved solids relaxable upto 3000 mg/l in cases where alternate osurces are not available within reach.

*c If there is less sulphate, magnessium upto 100 mg/l Mg may be allowed at the rate of 1 mg/l Mg for every 4 mg/l decrease in sulphates.

*e If there are 250 mg/l of sulphates, magnesium content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2 5 units of sulphates.

*f May be extended upto 400, provided Magnesium(as Mg) does not exceed 30 mg/l.

*g More information is required to prescribe a value but in no circumstances should the level exceed 100 mg NO_3/l.

*h To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be Min. 0.5 mg/l

Table 4·2 Important properties of water

Sr. No.	PROPERTY	VALUE
1.	Density of water (32^o F)	1.00 gram/cm^3
2.	Density of Ice (32^o F)	0.92 gram/cm^3
3.	Weight of water (32^o F)	62.416 lb/ft^3
4.	Density of water at 1 atmosphere (25^o C)	0.997044 gm/cm^3
5.	Specific gravity (4^o C)	1.0
6.	Boiling Point	100^o C (212^o F)
7.	Freezing Point	0^o C (32^o F)
8.	Melting Point	0^o C (32^o F)
9.	Critical Temperature	347^o C (657^o F)
10.	Critical Pressure	217 atm
11.	Specific Heat	1.0
12.	Heat of Fusion	80 cal/gram
13.	Heat of vaporization	540 cal/gr. 1073 Btu/lb (at 32^o F)
14.	Specific electric conductivity (25^o C)	1 X 10^{-7} / ohm. cm
15.	Dielectric constant (25^o C)	78
16.	Vapor Pressure (25^o C) (32^o F)	23.756 mm Hg. 6.11 millibars 0.09 lb/in^2
17.	Surface tension (32^o F)	0.00518 lb/ft 71.97 dyne/cm
18.	Absolute viscocity (32^o F)	0.374 X 10^{-4} lb.sec/ft.^{2}
19.	Dynamic viscocity (25^o C)	0.8949 Centipoises 0.8949 X 10^{-2} $\frac{\text{dyne. sec}}{cm^2}$
20.	Kinematic viscocity (32^o F)	1.93 X 10^{-5} ft^2/sec.
21.	- DO -- (25^o C)	0.8976 Centistokes 0.8976 X 10^{-2} cm^2/sec.
22.	Elastic Modulus (32^o F)	287,000 lb/in^2
23.	Thermal conductivity (32^o F) under 1^o C/cm under 1^o F/in	 ....0.00139 cal/sec/cm^2 ....0.00111 Btu/sec/ft^2