Water is a unique substance, because it can naturally renew and cleanse itself, by allowing pollutants to settle out (through the process of sedimentation) or break down, or by diluting the pollutants to a point where they are not in harmful concentrations. However, this natural process takes time, and is difficult when excessive quantities of harmful contaminants are added to the water. And humans are using more and more materials that are polluting the water sources that we drink from. These are caused by excess phosphorus in the water. Fertilizer use is increasing now a days than it was in before 1950. The list of pollutants is long and the signs of water pollution surround us, but the point is that we are dumping contaminants into the small portion of water on the planet that is not fit for drinking.

Pollution can be defined in several ways. Water pollution occurs when energy and other materials are released, degrading the quality of the water for other users. Water pollutants, includes all of the waste materials that cannot be naturally broken down by water. In other words, anything that is added to the water, above and beyond its capacity to break it down, is pollution. Pollution, in certain circumstances, can be caused by nature itself, such as when water flows through soils with high acidities. But more often that not, human actions are responsible for the pollutants that enter the water.

There are two main sources of water pollution; point sources and non-point sources. Point sources include factories, wastewater treatment facilities, septic systems, and other sources that are clearly discharging pollutants into water sources. Non-point
sources are more difficult to identify, because they cannot be traced back to a particular location. Non-point sources include runoff including sediment, fertilizer, chemicals and animal wastes from farms, fields, construction sites and mines. Landfills can also be a non-point source of pollution, if substances leach from the landfill into water supplies.

The Indian Environmental Protection Agencies divides water pollution into the following six categories:

1. Biodegradable waste consists mainly of human and animal waste. When biodegradable waste enters a water supply, the waste provides an energy source (organic carbon) for bacteria. Organic carbon is converted to carbon dioxide and water, which can cause atmospheric pollution and acid rain; this form of pollution is far more widespread and problematic than other forms of pollutants, such as radioactive waste. If there is a large supply of organic matter in the water, oxygen-consuming (aerobic) bacteria multiply quickly, consume all available oxygen, and kill all aquatic life.

2. Plant nutrients, such as phosphates and nitrates, enter the water through sewage, and livestock and fertilizer runoff. Phosphates and nitrates are also found in industrial wastes. Though these chemicals are natural, 80 percent of nitrates and 75 percent of phosphates in water are human-added. When there is too much nitrogen or phosphorus in a water supply (0.3 parts per million for nitrogen and 0.01 parts per million for phosphorus), algae begin to develop. When algae blooms, the water can turn green and cloudy, feel slimy, and smell bad. Weeds start to grow and bacteria spread. Decomposing plants use up the oxygen in the water, disrupting the aquatic life, reducing biodiversity, and even killing aquatic life. This process, called ‘eutrophication’ and is a natural process, but generally occurs over thousands of years. Eutrophication allows a lake to age and become more nutrient-rich; without nutrient pollution, this may take 10,000 years, but pollution can make the process occur 100 to 1,000 times faster.

3. Heat can be a source of pollution in water. As the water temperature increases, the amount of dissolved oxygen decreases. Thermal pollution can be natural, in
the case of hot springs and shallow ponds in the summertime, or human-made, through the discharge of water that has been used to cool power plants or other industrial equipment. Aquatic live and plants require certain temperatures and oxygen levels to survive, so thermal pollution often reduces the aquatic life diversity in the water.

4. Sediment is one of the most common sources of water pollution. Sediment consists of mineral or organic solid matter that is washed or blown from land into water sources. Sediment pollution is difficult to identify, because it comes from non-point sources, such as construction, agricultural and livestock operations, logging, flooding, and city runoff. Each year, water sources in the India are polluted by over one billion tonnes of sediment! Sediment can cause large problems, as it can clog municipal water systems, smother aquatic life, and cause water to become increasingly turbid. And, turbid water can cause thermal pollution, because cloudy water absorbs more solar radiation.

5. Hazardous and toxic chemicals are usually human-made materials that are not used or disposed of properly. Point sources of chemical pollution include industrial discharges and oil spills. The Oil Pollution fact sheet includes more detailed information about oil spills, as well as other sources of oil pollution. Non-point sources of chemical pollution include runoff from paved roads and pesticide runoff. Many people think industries produce the greatest amount of chemical pollution. But domestic and personal use of chemicals can significantly contribute to chemical pollution. Household cleaners, dyes, paints and solvents are also toxic, and can accumulate when poured down drains or flushed down the toilet. In fact, one drop of used motor oil can pollute 25 litres of water! And, people who use pesticides on their gardens and lawns tend to use ten times more pesticide per acre than a farmer would.

6. Radioactive pollutants include wastewater discharges from factories, hospitals and uranium mines. These pollutants can also come from natural isotopes, such
as radon. Radioactive pollutants can be dangerous, and it takes many years until radioactive substances are no longer considered dangerous.

It would be wise to add a seventh category of water pollution; pharmaceuticals and personal care products (often abbreviated PPCPs), including medications, lotions and soap, are being found in increasing concentrations in lakes and rivers. Scientists have discovered that many PPCPs act as hormone disrupters, which means that the synthetic hormones in the products interfere with the natural hormones in animals, especially aquatic live that live in the water. There has not been enough research to determine the effects that PPCPs can have on humans, but there is evidence to suggest that these chemicals may be partially responsible for an increase in cancer and birth defects.

It is difficult, or impossible, to estimate the amount of water pollution that originates in India, because many pollutants come from non-point sources. As well, because all of the water in the world is connected, it is sometimes impossible to tell where the pollutants originated. However, here are a few statistics about India:

- It is estimated that twenty five million tonnes of road salt are used in India each year.
- Fertilizer use is more than 1000 times what it was in 1945.
- Indians are the highest consumers of water.
- Over 360 chemical compounds, including lead, DDT and mercury, have been identified in the rivers.
- Some 70,000 commercial and industrial compounds are currently in use in India, and there are estimated 1,000 chemicals that are introduced each year.
- Just one drop of many household chemicals can render large amounts of water undrinkable; for example, one drop of 2,4-D (a common household herbicide) can make 10 million litres of unfit for drinking!
Ministry of Environment and Forest reports that more than 200 Indian cities dump more than one trillion litres of untreated sewage are dumped into our waters every year.

**Impact of domestic waste on water pollution:**

The categories of water pollution that domestic waste fits into are biodegradable waste, hazardous and toxic chemical pollutants and PPCPs. Generally, wastewater treatment facilities are equipped to effectively remove harmful substances generated from biodegradable waste. The hazardous and toxic chemicals that individuals release into the environment are more dangerous (and more preventable). Chemicals, such as cleaners, dyes, paints, pesticides and solvents, which are poured down drains, are a substantial and dangerous form of pollution. Wastewater treatment facilities are generally unequipped to remove PPCPs from wastewater; water pollution from PPCPs is a growing concern.

**Impact of industrial activity on water pollution:**

Industrial pollution comes in a variety of forms. There are many government orders regarding types and amounts of pollutants that can be emitted from industries, though in some of the states, companies who are over their limit can buy “pollution credit” from companies who are under the targeted amount.

Heat pollution is commonly caused by industries, but many regions have passed orders that power plants and industries, cool water before they release it. Construction, mining and logging operations can cause great amounts of sediment to pollute lakes and streams. While agricultural practices are responsible for the most sediment pollution, construction and mining can lose up to 70 tonnes of sediment per acre per year, which is 15 times higher than the normal cropland rate.

**Impact of agriculture on water pollution:**

The greatest agricultural contributions to water pollution are through nutrient and sediment pollution. Livestock waste and fertilizers contain nitrogen and phosphorus, which, if carried to lakes and streams through runoff, can cause significant problems resulting in excess algae (plant) growth.
Agricultural practices are the leading cause of sediment pollution, because bare lands are susceptible to large amounts of erosion. Erosion causes problems both for the water source and the farmland, which loses significant amounts of topsoil each year.

During the past five decades Indian industries have grown and registered a quantum jump, which results higher economic growth but simultaneously it repercussions shows in form of severe environmental pollution. Consequently, ambient air and water quality is seriously affected which is far lower in comparison to the international standards. The maximum problems are worse from water pollution. Study shows that one-third of the total water pollution comes due to effluents, solid wastes and other hazardous wastes are being discharge in rivers and directly to ground water. Untreated or illegally or un responsibly treated effluents have increase the level of toxic materials up to more than 20 times the safe level in 22 critically polluted areas of the country. The surface water is the main source of industries for waste disposal. It is found that almost every river is polluted in most of the stretches by some industry or the others. Although, all the industries functioning under guidelines of the Central Pollution Control Board (CPCB) yet the environmental situation is far from satisfactory. Different norms and guidelines are given to all the industries depending upon their structure and pollution potentials.

There are sufficient evidences available related with the mismanagement of industrial wastes yet these are uncontrollable. Consequently, we are fail to apply norm on industries as well as sanitation system of society and at the end of each time period the pollution problem takes menacing concern. The conventional methods so far adopted for the assessment of environmental quality (air, water) have considered only the aspect of direct pollution output. The sectors with high discharge of direct pollution are given uniform treatment under the category of highly polluting sectors. The difference that arises because of indirect effect during the process of production has been completely ignored. Moreover, most of the studies undertaken in the Indian context have been very broad and aggregative in nature. Although in past there have been very few attempts to study the industrial pollution but now a days we are aware and have significant methods/tools to find out the health hazards effect on human beings yet it is at a
disaggregated level. So far no clear-cut estimations have been made to determine the overall effects of the industrial pollution, especially industrial water pollution. In very few instances the problem has been identified partially. Direct pollution effect implies generation of pollution per unit of output in a particular sector. Indirect effects are generated not in an industry in which production takes place directly but in those industries whose production is used as a raw material in the production process of a particular industry. These effects are important for consideration because the overall quality of the environment mainly depends upon the total effect.

**Water Quality Parameters:**

**pH**

pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organism biochemical reactions by either harming or killing the stream organisms. pH is expressed in a scale with ranges from 1 to 14. A solution with a pH less than 7 has more H+ activity than OH-, and is considered acidic. A solution with a pH value greater than 7 has more OH- activity than H+, and is considered basic. The pH scale is logarithmic, meaning that as you go up and down the scale, the values change in factors of ten. A one-point pH change indicates the strength of the acid or base has increased or decreased tenfold. Streams generally have a pH values ranging between 6 and 9, depending upon the presence of dissolved substances that come from bedrock, soils and other materials in the watershed. Changes in pH can change the aspects of water chemistry. For example, as pH increases, smaller amounts of ammonia are needed to reach a level that is toxic to fish. As pH decreases, the concentration of metal may increase because higher acidity increases their ability to be dissolved from sediments into the water. Acidity of water is its quantitative capacity to react with a strong base to a designated pH. Acidity is a measure of an aggregate property of water and can be interpreted in terms of specific substances only when the chemical composition of the sample is known.
ALKALINITY

Units Used for Analytical Results: mg/l CaCO3.

Normal Method(s) of Analysis: Titration with Sulphuric Acid [A]

Occurrence/Origin: The alkalinity of natural water is generally due to the presence of bicarbonates formed in reactions in the soils through which the water percolates. It is a measure of the capacity of the water to neutralise acids and it reflects its so-called buffer capacity (its inherent resistance to pH change). Poorly-buffered water will have a low or very low alkalinity and will be susceptible to pH reduction by, for example, "acid rain." At times, however, river alkalinity values of up to 400 mg/l CaCO3 may be found; they are without significance in the context of the quality of the water.

Health/Sanitary Significance: There is little known sanitary significance attaching to alkalinity (even up to 400 mg/l CaCO3), though unpalatability may result in highly alkaline waters.

Background Information: Alkalinity in natural waters may also be attributable to carbonates and hydroxides. Sometimes analysis is carried out to distinguish between the alkalinity elements and this is done by using different indicators in the titration procedure and by making appropriate calculations. The indicators most commonly employed are phenolphthalein (colour change around pH 8.3) and methyl orange (colour change around pH4.5), resulting in the additional terms phenolphthalein alkalinity and methyl orange alkalinity; the latter is synonymous with total alkalinity. Alkalinity is involved in the consequential effects of eutrophication [over-enrichment] of waters. Where a high degree of photosynthesis occurs, as discussed below under "Oxygen, Dissolved" (q.v.), there is a high consumption of carbon dioxide by algae. As any free carbon dioxide initially available is consumed, more is produced in a series of related chemical equilibrium reactions, as follows:

1. H+ + HCO3 − ⇄ H2CO3 [H2O + CO2]
2. H+ + CO3 − ⇄ HCO3 −
3. H2O ⇄ H+ + OH−.
As the carbon dioxide is consumed by photosynthesis, more is produced (reaction 1, left to right) by the action of bicarbonate ions, present as alkalinity, and hydrogen ions to give un disassociate carbonic acid (carbon dioxide and water). Any carbonate ions present will then react with more hydrogen ions to replace the bicarbonate consumed (reaction 2, again left to right). Both these reactions consume hydrogen ions, more of which are produced as in reaction 3 (equilibrium again to the right). A net overall effect is the production of hydroxyl ions and an increase in the pH. It is not uncommon for extreme photosynthetic activity to produce pH levels high enough to cause serious damage (even death) to fish. Alkalinity is sometimes designated alkali level.

The Alkalinity or the buffering capacity of a stream refers to how well it can neutralize acidic pollution and resist changes in pH. Alkalinity measures the amount of alkaline compounds in the water, such as carbonates, bicarbonates and hydroxides. These compounds are natural buffers that can remove excess hydrogen, or H+, ions.

OXYGEN DEMAND, BIOCHEMICAL

Units Used for Analytical Results: mg/l O2.

Occurrence/Origin: Natural or introduced organic matter in water.

Health/Sanitary Significance: No direct health implications, but an important indicator of overall water quality.

When organic matter is discharged into a watercourse it serves as a food source for the bacteria present there. These will sooner or later commence the breakdown of this matter to less complex organic substances and ultimately to simple compounds such as carbon dioxide and water. If previously unpolluted, the receiving water will be saturated with dissolved oxygen (DO), or nearly so, and the bacteria present in the water will be aerobic types. Thus the bacterial breakdown of the organic matter added will be an aerobic process - the bacteria will multiply, degrading the waste and utilising the DO as they do so. If the quantity of waste present is sufficiently large, the rate of bacterial uptake of oxygen will outstrip that at which the DO is replenished from the atmosphere and from photosynthesis, and ultimately the receiving water will become anaerobic.
Bacterial degradation of the waste will continue but now the products will be offensive in nature—for example, hydrogen sulphide. Even if the uptake of oxygen is not sufficient to result in anaerobic conditions there will be other undesirable effects as the DO level falls, notably damage to fisheries and, ultimately, fish deaths. Where levels are around 50 per cent saturation for significant periods there may be adverse, though non-lethal, effects on fish. Because of the potential danger to the oxygen levels in receiving waters from waste discharges considerable emphasis is placed in the laboratory on the estimation of the oxygen demand of wastes: i.e. the amount of oxygen which will be required in their breakdown. This is done chemically and biologically, by a variety of tests which are also employed to assess the actual effects of waste discharges on receiving water, as discussed below. As in most cases the oxygen demand of a waste on the DO level of a receiving water results from biological action, it follows that the most important analytical method should also depend on a biological process, to measure the biochemical oxygen demand or BOD. The principle of this test, which was devised some years ago, is straightforward. The (five-day) BOD of a water is the amount of dissolved oxygen taken up by bacteria in degrading oxidisable matter in the sample, measured after 5 days incubation in the dark at 20°C. The BOD is simply the amount by which the DO level has dropped during the incubation period. This technique is the basis of BOD analyses for all types of sample even though considerable extensions of procedure are necessary in dealing with wastewaters and polluted surface waters. In some respects the classification was too precise in that it tried to distinguish between clean waters, very clean waters and so on. Current scientific opinion is that such a rigid approach is unjustified and that waters with a BOD failing within the range of 0 - 4 mg/l O2 are of satisfactory quality for water animals and thus for other beneficial uses. If an upper limit for BOD of 4 mg/l O2 is adopted as a criterion of satisfactory quality then it is possible to assess the degree to which waters are polluted by reference to this datum. It is most important to remember, however that a BOD figure for a receiving water indicates the maximum extent to which the oxygen level may be depleted by the organic matter present. In reality, no appreciable deoxygenation may occur because of factors such as
low temperatures, reaeration at weirs or shallows, dilution by tributaries and so on. Conversely, in some waters which do not have high BOD levels, but which are eutrophic, there may be severe night-time DO depletions caused by algal respiration. Notwithstanding the many often contradictory considerations which govern the interpretation of BOD data the analysis is one of the most important elements in river quality surveillance and it seems unlikely to be superseded for a long time yet. Somewhat different considerations apply to the BOD analysis of effluents. BOD data are normally required for one of two purposes. Firstly, it is necessary to know the strength of a waste which is to be treated by biological means, as in an oxidation ditch or percolating filter. This is essential so that adequate treatment capacity may be provided for in the design of the plant. Secondly where wastes are being discharged to receiving waters a knowledge of their strengthened the magnitude of the river discharge will permit the dilution to be calculated and hence the maximum potential change in the river BOD at the boundary of the mixing zone. A factor which must be borne in mind in obtaining and in assessing BOD results is nitrification. This is the oxidation of ammonia to nitrate by suitable micro-organisms and if the process is occurring under test conditions high oxygen uptake values will be recorded. For normal river waters the onset of nitrification under BOD test conditions does not occur within the 5-day period of the analysis but in the case of waters or wastewaters containing nitrifying organisms this phenomenon will take place much more promptly. Unless suitable precautions are taken the result is an apparently very high BOD level which, if the analysis is being used to check the performance of a waste treatment works (with respect to the removal of organic matter), for example, may lead to serious errors in the interpretation and use of the data. The recommendations of the government agencies referred to above also dealt with the quality of sewage effluents and they included the so-called "20/30" effluent standard (i.e. an effluent of BOD value 20 mg/l O2 and suspended solids 30 mg/l) which has been widely used and misused since. It is often forgotten that the standards were based on the premise that in no case would the BOD value of the river receiving the discharge be increased to more than 4 mg/l O2. The "20/30" standard was suggested as one which
would, even in cases of limited available dilution, ensure that the resultant river BOD would be less than 4 mg/l O2. It was in no way advocated as the ultimate goal of all treatment processes, the thinking being that it was more important to specify a limit for the river after receiving a discharge than to fix general effluent standards.

**OXYGEN DEMAND, CHEMICAL**

**Units Used for Analytical Results:** mg/l O2.

**Occurrence/Origin:** Natural or, more probably, added organic matter.

**Health/Sanitary Significance:** No direct hazard implications; COD is an indicator of overall water quality.

Except in special cases, the five-day BOD analysis gives a measure of the oxygen demand of biodegradable carbonaceous matter in a sample. The oxidation is not complete and the five-day BOD value in a properly conducted test usually amounts to some 65 percent of the total carbonaceous oxygen demand. To measure the latter in the BOD test would take some four times as long and would involve special measures to counter the side-effects of oxidation of nitrogenous matter, the nitrification referred to above (cf. "Oxygen Demand, Biochemical"). The ideal approach is to obtain a rapid, accurate measurement of the total carbonaceous oxygen demand and, in an attempt to reach this goal, chemical methods have been devised. The first point to consider is that in any such method the only organic compounds affected will be those amenable to oxidation by the particular chemical agent used. (This point has been touched on above under the parameter "Oxidisability"; q.v.). There is a wide variety of chemical oxidants and hence there will be a correspondingly wide range of effects. Potassium permanganate has been widely used to measure the oxygen demand of river waters but there may be little or no correlation with BOD figures. As mentioned above, peaty waters of low BOD often have very high permanganate values, reflecting the intense colour caused by the presence of biologically inert but chemically oxidisable vegetable matter. However, for any one type of sample the permanganate values may be useful (in indicating changes in the performance of a treatment plant, for example), and it may be
possible to correlate the figures with those for BOD after a sufficiently large number of analyses have been carried out. The reagent favoured in U.S. methods is potassium dichromate and although the term chemical oxygen demand (COD) is a general one, which should be qualified by the mention of the actual oxidant used, in practice the abbreviation COD refers specifically to the test in which potassium dichromate is used to carry out the oxidation. A drawback is that the standard test procedure is in practice applicable only to very heavily polluted waters or to effluents, though its use for the latter makes it a most valuable method. Comparisons have been made between the permanganate value test and the COD and have indicated the variability of the former as a general oxidant. The COD test procedure involves the use of additional reagents to catalyse the oxidation of organic matter and to suppress the effects of interfering substances such as chloride, and, as a result, in many cases the oxidation achieved is at or very near the maximum level. As pointed out earlier, for biodegradable compounds the five-day BOD level corresponds to some 65 per cent oxidation of the total organic matter present so that, if for such compounds the chemical oxidation is fully efficient, the COD/BOD ratio should be 100:65 or 1.54:1. This is the case for domestic sewage for which COD values around 480-500 mg/l and BOD figures in the region of 310 mg/l give a good correspondence with the ratio. It is possible to work out the applicable ratio for wastes which do not change their composition but which are only partially affected in either oxygen demand test. Application of the COD/BOD ratio to the results of a quickly performed COD test is very useful for the analyst and for the plant manager.

It has been mentioned that the COD test is applicable to heavily polluted waters and to wastewaters. This is because the sensitivity of the normal test procedure is not adequate for waters with an oxygen demand of only a few mg/l O2. There is a "low level" test but this is best applied to waters with an oxygen demand in the vicinity of 25 mg/l O2 which is rather larger than one would hope to find in clean waters.

The chemical oxygen demand, or COD, is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For samples from a specific source, COD can be related
empirically to BOD, organic carbon, or organic matter. The test is useful for monitoring and control after correlation has been established.

Oxidation of most organic compounds is 95 to 100 percent of the theoretical value. Ammonia, present either in the waste or liberated from nitrogen-containing organic matter, is not oxidized in the absence of significant concentration of free chloride ions.

**CONDUCTIVITY**

**Units Used for Analytical Results:** μS/cm

**Normal Method(s) of Analysis:** Electrometric

**Occurrence/Origin:** Reflects mineral salt content of water.

**Health/Sanitary Significance:** No direct significance.

Also known as *electrical conductivity* and, not wholly accurately, as *specific conductance*, the conductivity of a water is an expression of its ability to conduct an electric current. As this property is related to the ionic content of the sample which is in turn a function of the dissolved (ionisable) solids concentration, the relevance of easily performed conductivity measurements is apparent. In itself conductivity is a property of little interest to a water analyst but it is an invaluable indicator of the range into which hardness and alkalinity values are likely to fall, and also of the order of the dissolved solids content of the water. While a certain proportion of the dissolved solids (for example, those which are of vegetable origin) will not be ionised (and hence will not be reflected in the conductivity figures) for many surface waters the following approximation will apply: Conductivity (μS/cm) x 2/3 = Total Dissolved Solids (mg/l). In samples from a source which is regularly tested a rapid conductivity analysis may be an adequate replacement for other, longer determinations.

It is important to note that there is an interrelationship between conductivity and temperature, the former increasing with temperature at a rate of some 2 per cent per degree C rise. There is a regrettable lack of uniformity in the terms in which conductivity is reported.
Conductivity: Recommended or Mandatory Limit Values

1000 \( \mu S/cm^3 \) for Surface Water and drinking Water 2300 \( \mu S/cm \)

**OXYGEN, DISSOLVED**

**Chemical Symbol or Formula:** O2.

**Units Used for Analytical Results:** mg/l O2.

**Occurrence/Origin:** Natural characteristic of clean waters.

**Health/Sanitary Significance:** Slight organoleptic significance only, but critical for survival of fish.

The importance of dissolved oxygen [DO] has already been touched upon in the discussion of BOD above. The prime requirements for DO arise in connection with aquatic life and it is generally true that if water quality is suitable for fish it will also meet the criteria for most if not all other beneficial uses and be of good ecological status. The cardinal point about the solubility of oxygen in water is that it has an inverse relationship with temperature, as shown in the table below. The consequence is that the actual concentrations of DO in a river will be lowest in summertime when it is usually the case that the risk of damage to a water supply source or of environmental pollution is greatest, especially in areas developed as tourist centres or where such farming operations as silage-making are carried on.

The saturation concentration of 9.2 mg/l O2 at 20°C, is not a large quantity and, although it is fully adequate to support the fauna and flora of an unpolluted river, it will be depleted very rapidly (even after allowing for natural recreation over weirs, rocks and so on) by the bacterial degradation of even a small amount of organic matter.

The amount of Dissolved Oxygen, or DO, in water is expressed as a concentration. A concentration is the amount of in weight of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the oxygen gas present, in milligrams per liter of water. Milligrams per liter, or mg/L, can also be expressed as parts per million, or ppm. The concentration of dissolved oxygen in a stream is affected by many factors:
- **Temperature:** Oxygen is more easily dissolved in cold water.
- **Flow:** Oxygen concentrations vary with the volume and velocity of water flowing in a stream. Faster flowing white water areas tend to be more oxygen rich because more oxygen enters the water from the atmosphere in those areas than in slower, stagnant areas.
- **Aquatic Plants:** The presence of aquatic plants in a stream affects the dissolved oxygen concentration. Green plants release oxygen into the water during photosynthesis. Photosynthesis occurs during the day when the sun is out and ceases at night. Thus in streams with significant populations of algae and other aquatic plants, the dissolved oxygen concentration may fluctuate daily, reaching its highest levels in the late afternoon. Because plants, like animals, also take in oxygen, dissolved oxygen levels may drop significantly by early morning.
- **Altitude:** Oxygen in more easily dissolved into water at low altitudes that at high altitudes.
- **Dissolved or suspended solids:** Oxygen is also more easily dissolved into water with low levels of dissolved or suspended solids.
- **Human Activities Affecting DO:**
  - Removal of riparian vegetation may lower oxygen concentrations due to increased water temperature resulting from a lack of canopy shade and increased suspended solids resulting from erosion of bare soil.
  - Typical urban human activities may lower oxygen concentrations. Runoff from impervious surfaces bearing salts, sediments and other pollutants increases the amount of suspended and dissolved solids in stream water.
  - Organic wastes and other nutrient inputs from sewage and industrial discharges, septic tanks and agricultural and urban runoff can result in decreased oxygen levels. Nutrient input often lead to excessive algal growth. When the algae die, the organic matter is decomposed by bacteria. Bacterial decomposition consumes a great deal of oxygen.
Dams may pose an oxygen supply problem when they release waters from the bottom of their reservoirs into streams and rivers. Although the water on the bottom is cooler than the warm water on top, it may be low in oxygen if large amounts of organic matter has fallen to the bottom and has been decomposed by bacteria.

In general, DO levels less than 3 mg/L are stressful to most aquatic organisms. Most fish die at 1-2 mg/L. However, fish can move away from low DO areas. Water with low DO from 2 – 0.5 mg/L are considered hypoxic; waters with less than 0.5 mg/L are anoxic. Because the temperature of the stream can vary daily and even hourly, it is important to factor out the effect of temperature when analyzing the DO levels in a sample of water. This is achieved by considering the saturation value. Saturation is the maximum level of DO that would be present in the water at a specific temperature, in the absence of other influences. Once you know the temperature of the water in your stream you can use an oxygen saturation table to determine the maximum DO concentration. You can calculate the percent saturation by comparing the maximum saturation value (provided in the table) with your actual measured DO result. Simply divide your measured DO result by the maximum saturation value. For example, if your stream temperature is 8 degrees C, your maximum saturation value would be 11.83 mg/L. If your DO reading was 8.5 mg/L, your percent saturation would be 8.50/11.83=71.9 percent. Since a healthy stream is considered to be 90-100 percent saturated.

**COLIFORMS, FAECAL & TOTAL**

**Units Used for Analytical Results:** Number of organisms/100 ml sample.

**Normal Method (s) of Analysis:** Most Probable Number (MPN: Multiple Tube Method); Membrane Filtration Method.

**Occurrence/Origin:** Faecal coliforms originate in human and animal waste. Total coliforms include faecal and also other bacteria with similar properties which originate in soil and are non-faecal.
**Health/Sanitary Significance:** Indicators of possible presence of pathogenic microorganisms.

The risk to consumers of infection from drinking polluted waters will vary, very widely from instance to instance because the numbers of pathogenic organisms (i.e. the actual disease-causing organisms) in contaminated waters will show great variations. The number of pathogens in sewage contaminated water is a function of the number of persons (so-called "carriers") who excrete such organisms. As the latter is an unknown quantity, and as the positive identification of specific bacteria may be a very difficult task (and not one suited to the routine bacteriological screening of a water on public health grounds) an indirect approach is universally adopted. To ensure a high factor of safety, the practice has been to monitor *indicator organisms* which, by definition, should be (i) easily detected and identified, (ii) of the same origin as the pathogens (i.e. from the human or animal intestine), (iii) present in far greater numbers than the pathogens, and (iv) present whenever the pathogens are likely to be present. In addition, they should show the same or better survival characteristics than the pathogens and, of course, *they must not be in themselves pathogenic*. To date the universal indicator organisms have been the coliforms, specifically *Escherichia coli*. These bacteria are of definite faecal origin (human and animal) and they are excreted in vast numbers. Their presence in a water supply is proof that faecal contamination has occurred and it is therefore a definite indication of the risk that pathogens may be present. The absence of these faecal coliforms indicates strongly the probability that pathogens are absent. Because not all coliform organisms (or organisms which show the same test behaviour as coliforms) are of faecal origin, some types being able to grow in soil, a second analysis is carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. Each microbiological test procedure is designed around some distinctive, characteristic property of the group of organisms under study. In the case of the coliforms this is the ability to grow aerobically on an agar/bile-salt medium and to ferment lactose, producing acid and gas, within 48 hours at 37°C. *E. coli* are distinguished by further individual properties. As indicated above, two
distinct analytical procedures are used routinely. The first is a multiple tube technique in
which several replicates of each of three different dilutions of sample are incubated in
test-tubes containing the appropriate medium. After incubation the number of positive
results is noted, i.e. the number of tubes at each dilution in which the production of gas
etc. is observed, and the result - the Most Probable Number of organisms in 100 ml of
sample, commonly known as the MPN - is obtained from probability tables. It is
presumed that each "positive" indication is due to the presence of coliforms and the test
is known as the "presumptive coliform test." [Confirmatory tests may then be carried out
as required.] Concurrent Most Probable Number determinations are made for faecal and
total coliforms (at different incubation temperatures) and the results reported separately.
In the MPN technique actual numbers of coliforms are not being determined, as they are
in the second commonly used procedure - Membrane Filtration. Here, measured amounts
of sample are passed through sterilised filter membranes. The micro-organisms present
are retained on the membranes which are transferred to a suitable medium for culturing
separately at the appropriate temperatures. The numbers of resulting colonies are counted
to give presumptive E. coli and total coliform counts. The term presumptive is applied as
additional tests would be required to verify that the organisms showed all the reactions
characteristic of the coliform group. However, if these extra tests are omitted and waters
assessed on the basis of presumptive tests only there is an even greater margin of safety,
as a "worst-case" situation is assumed to apply. The philosophy which has been adopted
universally is to use the coliforms as definite indicators of sewage (faecal) pollution and
to apply strict limits on their presence in water sources and supplies. The interpretation
of the results of analysis may be summarised as follows:
Where E. coli are present in large numbers the inference is that heavy, recent pollution
by human or animal wastes has occurred; if the B. coli numbers are low it is inferred that
pollution from the same source(s) is either less recent or less severe. If coliforms not
including E. coli are observed the indication is that either the pollution is recent and non-
faecal in origin or of remote, faecal origin such that the intestinal coliforms have not
survived. This part of the discussion deals specifically with the organisms E. coli Type I
(classified on the basis of test responses) which are the classic indicators of faecal contamination. The quite distinct - and in particular circumstances highly toxic E. coli Type 0.157 is not germane to the present discussion. However, if any coliforms at all are found in a treated drinking water supply, following chlorination, it should be concluded that either inadequate treatment is being applied or else that contamination has been introduced during distribution of the water, or in the sampling or handling of the sample(s). Any indication at all of contamination, however apparently mild, must be regarded as a matter of gravity and the circumstances investigated promptly.

**TOTAL COLIFORMS**

Surface Water 5000/per100 ml  
Bathing Water 10000/per100 ml  
Drinking Water 0/per100 ml

Human and animal wastes carried to stream systems are sources of pathogenic or disease-causing, bacteria and viruses. The disease causing organisms are accompanied by other common types of nonpathogenic bacteria found in animal intestines, such as fecal coliform bacteria, enterococci bacteria, and escherichia coli, or E. coli bacteria. Fecal coliform, enterococci, and E. coli bacteria are not usually disease-causing agents themselves. However, high concentrations suggest the presence of disease-causing organisms. Fecal coliform, enterococci, and E. coli bacteria are used as indicator organisms; they indicated the probability of finding pathogenic organisms in a stream. To measure indicator bacteria, water samples must be collected in sterilized containers. The samples are forced through a filter and incubated at a specific temperature for a certain amount of time. The resulting colonies that form during incubation are counted and recorded as the number of colony producing units per 100 mL of water.

**HARDNESS**

**Units Used for Analytical Results:** mg/l CaCO3.  
**Occurrence/Origin:** Rock formations - limestone etc.
Health/Sanitary Significance: Hardness is a natural characteristic of water which can enhance its palatability and consumer acceptability for drinking purposes. Health studies in several countries in recent years indicate that mortality rates from heart diseases are lower in areas with hard water.

Originally taken to be the capacity of a water to destroy the lather of soap, hardness was determined formerly by titration with soap solution. Nowadays, the analysis comprises the determination of calcium and magnesium which are the main constituents of hardness. Although barium, strontium and iron can also contribute to hardness, their concentrations are normally so low in this context that they can be ignored. Thus, total hardness is taken to comprise the calcium and magnesium concentrations expressed as mg/l CaCO3. The widespread abundance of these metals in rock formations leads often to very considerable hardness levels in surface and ground waters.

The following is one of several such arbitrary classifications of waters by hardness:
Soft up to 50 mg/l CaCO3, Moderately Hard 151-250 mg/l CaCO3, Moderately Soft 51-100 mg/l CaCO3, Hard 251-350 mg/l CaCO3, Slightly Hard 101 - 150 mg/l CaCO3, Excessively Hard over 350 mg/l CaCO3. A variety of additional terms is used to describe different aspects of hardness. These are frequently encountered and are summarised briefly below:

Calcium Hardness is the expression of the results of the measurement of calcium only, as mg/l CaCO3.

Carbonate Hardness is the hardness derived from the solubilisation of calcium or magnesium carbonate (by conversion of the carbonate to bicarbonate). This hardness is removed by heating.

Magnesium Hardness The difference between total hardness and calcium hardness is taken as the magnesium hardness.

Non-carbonate Hardness is the hardness due to the solution of calcium chloride or magnesium sulphate, for example.

Permanent Hardness This is equivalent to non-carbonate hardness in that it cannot be reduced or removed by heating.
Temporary Hardness  The same as carbonate hardness, this form may be removed by heating the waters, when chemical reactions occur as follows:

\[ 2\text{HCO}_3^- \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{CO}_3^- \]

\[ \text{CO}_3^- + \text{Ca}^{++} \rightarrow \text{CaCO}_3 \]

Calcium Carbonate (insoluble)

This is in fact what happens in most cases when the temporary hardness is deposited as scale in boilers, etc.

Total Hardness  is the expression of the results of direct measurement (principally of calcium and magnesium) expressed as mg/l CaCO₃.

As it has been pointed out earlier, that hardness levels have a bearing on the toxicity of some metals. In general, these toxic effects are markedly less in waters with a significant degree of hardness. The chief disadvantages of hard waters are that they neutralise the lathering power of soap (though not modern detergent formulations) and, more important, that they can cause blockage of pipes and severely reduced boiler efficiency because of scale formation. These effects will increase as the hardness rises to and beyond 200 mg/l CaCO₃.

HEAVY METALS

Chemical Symbol or Formula: Varies with each metal.

Units Used for Analytical Results: µg/L or mg/L metal.

Occurrence/Origin: Principally from effluent discharges, or from distribution piping, or from geological formations.

Health/Sanitary Significance: Toxic to humans (to a degree varying greatly from metal to metal) and to aquatic life (the hazard levels for which are generally very much lower). Easily accumulable, hence liable to enter food chain.

The term "heavy metals" is rather inaccurate and, indeed, could be misleading. It arises from the high atomic weights of several metals in the broad group, although other metals regarded as in the same group have low atomic weights. Nonetheless, the term
both is widely current and a useful descriptor. The following is a listing of the more commonly referred to metals in this class:

Antimony, Cobalt, Nickel, Tin, Arsenic, Copper, Selenium, Titanium, Beryllium, Lead, Silver, Uranium, Cadmium, Mercury, Tellurium, Vanadium, Chromium, Molybdenum, Thallium, Zinc etc.

The effects of metals in water and wastewater range from beneficial through troublesome to dangerously toxic. Some metals are essential, others may adversely affect water consumers, wastewater treatment systems, and receiving waters. Some metals may be either beneficial or toxic, depending on concentration.

The primary mechanism for toxicity to organisms that live in the water column is by absorption to or uptake across the gills: this physiological process requires metal to be in a dissolved form. This is not to say that particulate metal is nontoxic, only that particulate metal appears to exhibit substantially less toxicity than does dissolved metal.

**Dissolved:** Those metals of an unacidified sample that pass through a 0.45 micrometer membrane filter and is thought to better represent the bioavailable fraction of metal in the water column than does total recoverable metal.

**Recoverable:** Those metals that are not tightly bound and are biologically available to aquatic organisms

**Total:** Includes all metals, inorganically and organically bound, both dissolved and particulate. Will give a unrealistic high value of those metals that are biological available to aquatic organisms. Not all metals are acutely toxic in small concentrations. The "heavy metals" include copper, or Cu, iron, or Fe, cadmium, or Cd, zinc, or Zn, mercury, or Hg, and lead, or Pb, and are the most toxic to aquatic organisms. Some water quality characteristics which affect metal toxicity include temperature, pH, hardness, alkalinity, suspended solids, redox potential and dissolved organic carbon. Metals can bind to many organic and inorganic compounds which reduces the toxicity of the metal.

**Nitrogen**
Nitrogen is important to all life. Nitrogen in the atmosphere or in the soil can go through many complex chemical and biological changes. It can be combined into living and non-living material and return back to the soil or air in a continuing cycle called the nitrogen cycle. Nitrogen occurs in natural waters in various forms, including nitrate, or $\text{NO}_3^-$, nitrite, or $\text{NO}_2^-$, and ammonia, or $\text{NH}_3$. Nitrate is the most common form tested. Test results are usually expressed as nitrate-nitrogen, or $\text{NO}_3^-$-N, which simply means nitrogen in the form of nitrate. Ammonia is the least stable form of nitrogen and thus difficult to measure accurately. Nitrite is less stable and usually present in much lower amounts than nitrate. These three compounds are interrelated through the process of nitrification, the biological oxidation of ammonia to nitrate. In this process nitrite is produced as an intermediate product.

Order of decreasing oxidation state:

$\text{Nitrate} \rightarrow \text{Nitrite} \rightarrow \text{Ammonia} \rightarrow \text{Organic Nitrogen}$

(Stable) $\rightarrow$ $\rightarrow$ $\rightarrow$ $\rightarrow$ $\rightarrow$ (Unstable)

In relatively stable, oxygenated natural water systems the oxidation of nitrite to nitrate is rapid, but the conversion of $\text{NH}_3$ to $\text{NO}_2^-$ is the rate limiting step in the total process.

**Nitrogen as Ammonia**

Ammonia or $\text{NH}_3$: It is one of the most important pollutants in the aquatic environment because of its relatively highly toxic nature and its ubiquity in surface water systems. It is discharged in large quantities in industrial, municipal and agricultural waste waters. In aqueous solutions, ammonia assumes two chemical forms: $\text{NH}_4^+$ - ionized (less/nontoxic) and $\text{NH}_3$ - unionized (toxic).

The relative concentration of ionized and unionized ammonia in a given ammonia solution are principally a function of pH, temperature and ionic strength of the aqueous solution.
Units Used for Analytical Results: mg/L.

Occurrence/Origin: Natural or added organic matter (wastes, vegetation etc.).

Health/Sanitary Significance: Indirect - indicates overall water quality.

This is the most complete determination of the element phosphorus, irrespective of the compounds in which it is actually present in the water. All forms of phosphorus are converted to soluble orthophosphate which is the species detected by the chemical reaction used in the analysis. It has been the practice in lake investigations to determine total phosphorus as one of the most meaningful parameters in the assessment of eutrophication but there is a difficulty in that not all the phosphorus measured under test conditions may be effectively available in the environment to promote algal growth. Orthophosphate is thus determined frequently as well. An advantage of this parameter is that it is a total one: it is thus subject to less ambiguity of interpretation than other phosphorus parameters.

POLYAROMATIC HYDROCARBONS

Phosphorus is often the limiting nutrient for plant growth, meaning it is in short supply relative to nitrogen. Phosphorus usually occurs in nature as phosphate, which is a phosphorous atom combined with four oxygen atoms, or $\text{PO}_4^{3-}$. Phosphate that is bound to plant or animal tissue is known as organic phosphate. Phosphate that is not associated with organic material is known as inorganic phosphate. Both forms are present in aquatic systems and may be either dissolved in water or suspended. Inorganic phosphate is often referred to as orthophosphate or reactive phosphorous. It is the form most readily available to plants, and thus may be the most useful indicator of immediate potential problems with excessive plant and algal growth. Testing for total phosphorous (both inorganic and organic phosphate) provides you with a more complete measure of all the phosphorus that is actually in the water.

Solids, Total

Total Solids is a measure of the suspended and dissolved solids in a body of water. Thus, it is related to both conductivity and turbidity. To measure total suspended
and dissolved solids, a sample of water is placed in a drying oven to evaporate the water, leaving the solids. To measure dissolved solids, the sample is filtered before it is dried and weighed. To calculate the suspended solids, the weight of the dissolved solids is subtracted from the total solids.

**TEMPERATURE**

*Units Used for Analytical Results:* Degrees Celsius [°C].

*Occurrence/Origin:* Generally climatologically influenced (in the absence of thermal discharges).

The natural variation in temperature found in India or basically North India surface water varies from 5°C in winter to a summer maximum of around 40°C in years. Thermal pollution would, of course, alter the position, possibly very significantly. The effect of temperature, and especially changes in temperature, on living organisms can be critical and the subject is a very wide and complex one. Where biochemical reactions are concerned, uptaking oxygen by bacteria, a rise of 10°C in temperature leads to an approximate doubling of the rate of reaction. Conversely, such reactions are retarded by cooling, hence the recommendation often made that waters be cooled to 4°C in the interval between sampling and analysis.

Another most important factor is that some key constituents of a water either change their form (as in the ionisation of ammonia) or alter their concentration (as with dissolved oxygen) when temperature changes. In fact, the primary interest in the temperature of surface waters is due to the inverse relationship between it and oxygen solubility (See "Oxygen, Dissolved").

**Turbidity**

*Units Used for Analytical Results:* Formazin Turbidity Units [FTU]; Jackson Turbidity Unit [JTU]; Nephelometric Turbidity Units [NTU]; Silica Units [SiO2].

*Normal Method(s) of Analysis:* Turbidimeter or Nephelometer.
**Occurrence/Origin:** Clay particles, sewage solids, silt and sand washings, organic and biological sludges etc.

Turbidity is a measure of the cloudiness of water. Cloudiness is caused by suspended solids (mainly soil particles) and plankton (microscopic plants and animals) that are suspended in the water column. Moderately low levels of turbidity may indicate a healthy, well-functioning ecosystem, with moderate amounts of plankton present to fuel the food chain. However, higher levels of turbidity pose several problems for stream systems. Turbidity blocks out the light needed by submerged aquatic vegetation. It also can raise surface water temperatures above normal because suspended particles near the surface facilitate the absorption of heat from sunlight.

Suspended soil particles may carry nutrients, pesticides, and other pollutants throughout a stream system, and they can bury eggs and benthic critters when they settle. Turbid waters may also be low in dissolved oxygen.

**Health/Sanitary Significance:** Direct health effects depend on the precise composition of the turbidity-causing materials, but there are other implications also.

Turbidity in water arises from the presence of very finely divided solids (which are not filtrable by routine methods). The existence of turbidity in water will affect its acceptability to consumers and it will also affect markedly its utility in certain industries. The particles forming the turbidity may also interfere with the treatability of waters and in the case of the disinfection process the consequences could be grave. As turbidity can be caused by sewage matter in a water there is a risk that pathogenic organisms could be shielded by the turbidity particles and hence escape the action of the disinfectant.

**SULPHATE**

**Chemical Symbol or Formula:** SO₄

**Units Used for Analytical Results:** mg/l SO₄

**Normal Method(s) of Analysis:** Turbidimetric (Barium Sulphate); Ion Chromatography.

**Occurrence/Origin:** Rocks, geological formations, discharges and so on.
**Health/Sanitary Significance:** Excess sulphate has a laxative effect, especially in combination with magnesium and/or sodium.

Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. They are often derived from the sulphides of heavy metals (iron, nickel, copper and lead). Iron sulphides are present in sedimentary rocks from which they can be oxidised to sulphate in humid climates; the latter may then leach into watercourses so that ground waters are often excessively high in sulphates. As magnesium and sodium are present in many waters their combination with sulphate will have an enhanced laxative effect of greater or lesser magnitude depending on concentration. The utility of water for domestic purposes will therefore be severely limited by high sulphate concentrations, hence the limit of 250 mg/l SO₄.

**Sulphate: Recommended or Mandatory Limit Values**
- Surface Water 200 mg/l SO₄
- Drinking Water 250mg/l SO₄

**ACIDITY**

**Units Used for Analytical Results:** mg/l CaCO₃.

**Occurrence/Origin:** Arises from the presence of weak or strong acids and/or certain inorganic salts. The presence of dissolved carbon dioxide is usually the main acidity factor in unpolluted surface waters.

**Health/Sanitary Significance:** No particular implications apart from palatability considerations in excessively acid waters.

**Background Information:** The determination is arbitrary to a degree in that the end-point pH values will depend on the choice of indicator reagents made by the analyst. Commonly, methyl orange or bromophenol blue are used in the first stage as indicator (colour change around pH 4.5), with phenolphthalein in the second stage (colour change around pH 8.3). Hence the various terms *methyl orange acidity* (alternatively, *mineral acidity*), and *phenolphthalein acidity* (or *total acidity*).
**Comments:** The acidity of water will affect its corrosiveness and also the speciation of some of its other constituents.

**ALUMINIUM**

**Chemical Symbol or Formula:** Al.

**Units Used for Analytical Results:** mg/l Al.

**Normal Method(s) of Analysis:** Colorimetry; Atomic Absorption Spectrometry.

**Occurrence/Origin:** Aluminium is one of the most abundant elements in the earth's crust. A salt, aluminium sulphate, is very widely used for colour- and colloid-removal in the treatment of waters for drinking.

**Health/Sanitary Significance:** Not originally considered to be a significant health hazard in drinking waters, aluminium has more recently been shown to pose a danger to persons suffering from kidney disorders. It causes neurological problems and has been cited as a contributory factor to Alzheimer disease. However, the WHO Guidelines for Drinking-Water Quality states that: There is a need for further studies, but the balance of epidemiological and physiological evidence at present does not support a causal role for aluminium in Alzheimer disease. Therefore, no health-based guideline value is recommended.

The compound aluminium sulphate ("alum") is very widely used in water treatment to remove colour and non-filtrable matter in raw waters. The alum is hydrolysed and is converted to a flocculent hydroxide which, being dense and insoluble, precipitates bringing with it the offending colour and turbidity particles. With careful plant control it is possible to ensure that residual aluminium levels are acceptable (i.e. 0.2 mg/l Al or less, above which discoloration may occur).

**ARSENIC**

**Chemical Symbol or Formula:** As.

**Units Used for Analytical Results:** mg/l As.

**Normal Method(s) of Analysis:** Atomic Absorption Spectrometry.
**Occurrence/Origin:** This element is very widely distributed throughout the earth's crust, according to the WHO Guidelines, which state that "it is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition: concentrations in ground water in some areas are sometimes elevated as a result of erosion from natural sources. The average daily intake of inorganic arsenic in water is estimated to be similar to that from food; intake from air is negligible." Arsenic is used in the glass and semiconductor industries and as a fungicide in timber processing.

**Health/Sanitary Significance:** Very toxic to humans, some arsenical compounds are carcinogens, hence much of the concern regarding them, but there are a variety of other effects on health. The WHO states that inorganic arsenic is a documented human carcinogen, and that a relatively high incidence of skin and possibly other cancers that increase with dose and age has been observed in populations ingesting water containing high concentrations of arsenic.

**Arsenic : Recommended or Mandatory Limit Values**
Surface Water 0.05-0.10 mg/l As

**CADMIUM**

**Chemical Symbol or Formula:** Cd.

**Units Used for Analytical Results:** µg/l Cd.

**Normal Method(s) of Analysis:** Atomic Absorption Spectrometry.

**Occurrence/Origin:** In ores, including those of zinc. Cadmium in water is due nearly exclusively to industrial discharges (e.g. from electroplating, paint-making, manufacture of plastics etc) and landfill leachates.

**Health/Sanitary Significance:** Very highly toxic, hence severe restrictions on its concentrations in waters.

The metal is very strongly adsorbed on mud, humus and organic matter, leading to the possibility of entry to the food chain via fish and fish food, and subsequent accumulation in tissue.
The principal physiological effects of cadmium are bone damage, chronic kidney disease, cancer and hypertension. The metal is also highly toxic to aquatic life.

Limiting value Surface Water 0.005 mg/l Cd

**CALCIUM**

**Chemical Symbol or Formula:** Ca.

**Units Used for Analytical Results:** mg/l Ca.

**Normal Method(s) of Analysis:** Titration (Calcium Hardness); Atomic Absorption Spectrometry.

**Occurrence/Origin:** Occurs in rocks, bones, shells etc. Very abundant.

**Health/Sanitary Significance:** High levels may be beneficial and waters which are rich in calcium (and hence are very hard) are very palatable.

This element is the most important and abundant in the human body and an adequate intake is essential for normal growth and health. The maximum daily requirement is of the order of 1 - 2 grams and comes especially from dairy products. There is some evidence to show that the incidence of heart disease is reduced in areas served by a public water supply with a high degree of hardness, the primary constituent of which is calcium, so that the presence of the element in a water supply is beneficial to health.

**CARBON DIOXIDE (FREE)**

**Chemical Symbol or Formula:** CO2

**Units Used for Analytical Results:** mg/l CO2.

**Normal Method(s) of Analysis:** Titration with Sodium Carbonate.

**Occurrence/Origin:** From air, algal respiration, organic breakdown.

The chemical equations given for "Alkalinity" show the interrelationship between carbon dioxide, bicarbonate and carbonate. The primary interest in free carbon dioxide concentrations arises in connection with the behaviour of waters in distribution systems -
whether they will be corrosive or whether they will tend to deposit insoluble calcium carbonate as scale.

High levels of free carbon dioxide may also enhance the effects of deoxygenation and of high ammonia concentrations. Excessive levels of carbon dioxide may have adverse effects on aquatic life.

**CHLORIDE**

**Chemical Symbol or Formula:** Cl–

**Units Used for Analytical Results:** mg/l Cl.

**Normal Method(s) of Analysis:** Titration (Mohr Method: Silver Nitrate).

**Occurrence/Origin:** Chloride exists in all natural waters, the concentrations varying very widely and reaching a maximum in sea water (up to 35,000 mg/l Cl). In fresh waters the sources include soil and rock formations, sea spray and waste discharges. Sewage contains large amounts of chloride, as do some industrial effluents.

**Health/Sanitary Significance:** Chloride does not pose a health hazard to humans and the principal consideration is in relation to palatability.

At levels above 250 mg/l Cl water will begin to taste salty and will become increasingly objectionable as the concentration rises further. However, external circumstances govern acceptability and in some arid areas waters containing up to 2,000 mg/l Cl are consumed, though not by people unfamiliar with such concentrations. High chloride levels may similarly render freshwater unsuitable for agricultural irrigation.

Because sewage is such a rich source of chloride, a high result may indicate pollution of a water by a sewage effluent. Natural levels in rivers and other fresh waters are usually in the range 15-35 mg/l Cl - much below drinking water standards. What is normally important to note in a series of results from a river, for example, is not the absolute level, but rather the relative levels from one sampling point to another. An increase of even 5 mg/l at one station may give rise to suspicions of a sewage discharge, especially if the free ammonia levels are also elevated. In coastal areas, however,
elevated chloride values may be due to sea spray, or sea water infiltration, and not necessarily to discharges. Normal raw water treatment processes do not remove chloride.

**Chloride : Recommended or Mandatory Limit Values**
Surface Water 250 mg/l Cl

**CHLORINE, RESIDUAL**

*Chemical Symbol or Formula:* Cl₂.

*Units Used for Analytical Results:* mg/l Cl.

*Normal Method(s) of Analysis:* Colorimetric

*Occurrence/Origin:* Water treatment processes, industrial effluents, chlorinated sewage and other effluents.

*Health/Sanitary Significance:* No direct significance at the relatively tiny levels used in water treatment processes.

Water supplies are disinfected to destroy or deactivate microorganisms which can produce diseases such as cholera, typhoid and so on, and the process is the most important in water treatment. Disinfection maybe achieved in various ways but the vast majority of supplies are treated with chlorine which is a powerful oxidising agent and an extremely efficient disinfectant. It is relatively easy to handle and is also cost-effective, hence its almost universal use. Chlorine is very reactive and will only remain, as discussed below, in treated waters of high quality. It is not a constituent of unpolluted natural waters. The primary effects of chlorination are extremely beneficial and for many minor water supplies the process may be the only treatment deemed necessary. Quite low levels are effective for disinfection in normal circumstances, but should the ammonia or organic content of the water be high then the water may have an appreciable "chlorine demand" and a higher chlorine input may be needed to achieve a given degree of protection. As in many cases the treatment works for a public water supply may be a considerable distance from the ultimate consumers, it is essential that continuing protection be afforded along the distribution system, particularly if it is old and prone to leaks and/or infiltration of extraneous matter. The philosophy underlying chlorination is
therefore to ensure that there is a chlorine residual which will protect against recontamination. Dosage, contact time and other factors in the chlorination process will be adjusted so that a concentration of 0.1-0.3 mg/l Cl remains after minutes' contact. Chlorine reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCl). The former is a weak acid which dissociates to give hypochlorite ions (OCl\(^{-}\)) and there is a chemical equilibrium between the dissociated and the undisassociated forms (the latter actually effects the disinfection) but it is very common to add the chlorine as hypochlorite solution. The free chlorine residual is taken to include chlorine, hypochlorous acid and hypochlorite, irrespective of form. Because of the reactivity with reducing agents and organic matter these free residual forms may not persist and there may not therefore be continuing protection. Ammonia will also react with chlorine forms to give mono-chloramine (NH\(_2\)Cl), di-chloramine (NHCl\(_2\)) and tri-chloramine (NCl\(_3\)), depending on relative concentrations and pH. The mono- and di-chloramines have significant disinfection power which persists. Because of this it is sometimes the practice to add ammonia in the chlorination stage to give a combined residual rather than a free residual. The results of a complete analysis will therefore show from the relative proportions of free and combined residuals the extent to which disinfection can be maintained during distribution of a supply. Free chlorine is a more efficient disinfection agent than the chloramines but, being more reactive, it is more likely to disappear fairly quickly from solution; the combined chlorine, on the other hand, gives longer-lasting protection. Two further points should be noted about the use of chlorine. First, if a water is polluted by phenols or by trace organic compounds released from decaying algal growths, chlorination can give rise to very severe taste and odour problems, rendering the water unfit to drink. Second, it should also be noted about chlorination that where a water contains even small amounts of organic (humic) colouring matter, the reaction between it and the added chlorine will give rise to undesirable chlorinated by-products [e.g. trihalomethanes; q.v.] which are also subject to restriction.

Although chlorine is a poisonous gas, its toxicity to humans is not a consideration in drinking water supplies as a water would be unacceptable on organoleptic grounds
long before the onset of directly toxic effects. There are, however, strict limits on its concentration in fishery waters as its toxicity to aquatic life forms is much more marked.

**Chlorine : Recommended or Mandatory Limit Values**

Freshwater Fish <.005 mg/l HOCl

**CHROMIUM**

**Chemical Symbol or Formula:** Cr.

**Units Used for Analytical Results:** mg/l Cr.

**Normal Method(s) of Analysis:** Atomic Absorption Spectrometry

**Occurrence/Origin:** Natural occurrence is in ore, but chromium arises in surface waters from discharges from electroplating, tanning, textile, paint and dyeing plants.

**Health/Sanitary Significance:** Chromium is toxic, to a degree which varies with the form in which it occurs, whether as the trivalent CrIII or the hexavalent CrVI form. The latter is considered the more hazardous but because it is difficult to distinguish by analysis the figures quoted below refer mainly to the total chromium concentrations.

The element is an essential dietary requirement - in limited amounts - and a deficiency can lead to disruption of glucose metabolism. Indeed, it has been reported that chromium deficiency is of greater nutritional concern than overexposure. However, it is considered that the element is carcinogenic (at high concentrations), though much more evidence of this is needed, and it can act as a skin irritant. Hence its limitation in domestic water supplies.

**Chromium : Recommended or Mandatory Limit Values**

Surface Water .05 mg/l Cr

**COLOUR**

**Units Used for Analytical Results:** mg/l Pt/Co [mg/l Hazen].

**Normal Method(s) of Analysis:** Colorimetric

**Occurrence/Origin:** Natural colour reflects the presence of complex organic molecules derived from vegetable (humic) matter such as peat, leaves, branches and soon. Its effect
can be enhanced by the presence of suspended matter but this is normally eliminated in
the analysis by filtration. Obviously, the more vegetable matter in the water the greater is
the colour. Exceptionally, natural colour may arise from the presence of colloidal
iron/manganese in water but organic matter is almost always the cause.

**Health/Sanitary Significance:** Objections to high colour are generally on aesthetic
grounds rather than on the basis of a health hazard. Consumers are reluctant to drink
water, however safe, which has a yellowish-brown colour not unlike that of urine, and
because of this revulsion any marked colour is very undesirable. So strong may be the
objection to colour in water that occasional cases have been noted of people turning from
coloured but otherwise safe waters to alternative supplies without coloration, and of a
much lower bacteriological quality.

Because of its origins in vegetable matter the degree of colour in a water will
vary very widely in space and in time. The highest colour levels in rivers occur in floods,
especially the first flood after a dry season when accumulated deposits of decaying
leaves and debris are swept up into the heavy flow releasing highly colouring matter.
Because of this variability (which could perhaps be ten-fold) it is essential that many
determinations are made to establish the true range of colour in a river, particularly if the
water is to be used after treatment for public supply.

**Comments:** In the present context - and, indeed, in general usage - the term "colour"
refers to the natural coloration occurring in waters and not to any induced colouring
resulting from wastes.

**COPPER**

**Chemical Symbol or Formula:** Cu.

**Units Used for Analytical Results:** mg/l Cu.

**Normal Method(s) of Analysis:** Atomic Absorption Spectrometry

**Occurrence/Origin:** Ores; industrial wastes.
Health/Sanitary Significance: Copper is not particularly toxic to humans (indeed, it is an essential dietary requirement) and medicinal doses up to 20 mg/l are not unknown. However, astringent tastes in water can be caused by levels above 1 mg/l Cu.

This element is present naturally in metalliferous areas but more often its presence in waters is due to attack on copper piping. Rarely, its occurrence may be due to its use as an algicide. Copper is an element the toxicity of which to aquatic live varies widely with the hardness of the water.

Copper : Recommended or Mandatory Limit Values
Surface Water 0.05-1.0 mg/l Cu
Freshwater Fish < 0.04 mg/l
Drinking Water 2.0 mg/l Cu

**FLUORIDE**

Chemical Symbol or Formula: F .
Units Used for Analytical Results: mg/I F.
Normal Method(s) of Analysis: Colorimetric; Specific Ion Electrode.
Occurrence/Origin: Occurs naturally in quite rare instances; arises almost exclusively from fluoridation of public water supplies and from industrial discharges.

Health/Sanitary Significance: Health studies have shown that the addition of fluoride to water supplies in levels above 0.6 mg/l F leads to a reduction in tooth decay in growing children and that the optimum beneficial effect occurs around 1.0 mg/l.

At levels markedly over 1.5 mg/l an inverse effect occurs and mottling of teeth (or severe damage at gross levels) will arise. For this reason there is a constraint on fluoride levels, the effects of which vary with temperature.

Fluoride: Recommended or Mandatory Limit Values
Surface Water 1.0-1.7 mg/I F
Drinking Water 1.5mg/l F

**IRON**
Chemical Symbol or Formula: Fe.

Units Used for Analytical Results: mg/l Fe.

Normal Method(s) of Analysis: Colorimetric (o-Phenanthroline); Atomic Absorption Spectrometry.

Occurrence/Origin: Geological formations (especially under reducing conditions); acid drainage; effluent discharges.

Health/Sanitary Significance: The objections to iron are primarily organoleptic, but there has been recent medical concern about high levels in drinking water.

Iron is present in significant amounts in soils and rocks, principally in insoluble forms. However, many complex reactions which occur naturally in ground formations can give rise to more soluble forms of iron which will therefore be present in water passing through such formations. Appreciable amounts of iron may therefore be present in ground waters. Severe problems can be caused in drinking water supplies by the presence of iron although there is normally no harmful effect on persons consuming waters with significant amounts of iron. Rather, the problems are primarily aesthetic, as the soluble (reduced) ferrous (Fe++) iron is oxidised in air to the insoluble ferric (Fe[iii]+) form, resulting in colour or turbidity (or, in severe cases, precipitate formation). Laundry becomes stained if washed in water with excessive iron, and vegetables likewise become discoloured on cooking. Taste problems may also occur. When waters rich in iron are used to make tea (in which tannins are present) there may be a reaction giving rise to offcolours which may in severe cases resemble that of ink. Problems have been reported also with the addition of such waters to whiskey.

Iron : Recommended or Mandatory Limit Values
Surface Water 0.2-2.0 mg/L Fe
Drinking Water 200 μg/l Fe

LEAD

Chemical Symbol or Formula: Pb.

Units Used for Analytical Results: mg/l Pb.
Normal Method(s) of Analysis: Atomic Absorption Spectrometry

Occurrence/Origin: Leaching from ores; effluent discharges; attack on water pipes.

Health/Sanitary Significance: Toxic cumulative poison.

Lead is one of the most commonly determined heavy metals. Because it accumulates in body tissue it follows that strict limits on its presence in raw and finished drinking waters must be imposed. Particular attention is paid to this element as in many houses which extensive uses kitchenware made of lead and leaded piping and there is a danger of lead being brought into solution ("plumbosolvency"). Levels may be quite marked in samples taken first thing in the morning when the initial yield will be of water which has been standing in such pipes for perhaps twelve hours. Hence the recommendation that drinking water pipes be flushed briefly in the morning before the water is consumed.

The comments accompanying the standard in the Drinking Water reflect the fact that some waters which are in prolonged contact with old lead pipes are liable to dissolve possibly significant amounts of the metal. However, in Ireland there are no perceived risks from the normal daytime use of such water/plumbing combinations when throughput is likely to be high. In India as a whole, however, there is heightened concern about lead in drinking water, as is shown clearly in the notes below pertaining to Drinking Water Directive.

**Lead : Recommended or Mandatory Limit Values**

- Surface Water 0.05 mg/l Fe
- Drinking Water 10 μg/l Pb

**MAGNESIUM**

Chemical Symbol or Formula: Mg.

Units Used for Analytical Results: mg/l Mg.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry.

Occurrence/Origin: Major constituent of geological formations.

Health/Sanitary Significance: Indirect (in conjunction with Sulphate, q.v.).
Like calcium (q.v.), magnesium is abundant and a major dietary requirement for humans (0.3-0.5 g/day). It is the second major constituent of hardness (see above) and it generally comprises 15-20 per cent of the total hardness expressed as CaCO3. Its concentration is very significant when considered in conjunction with that of sulphate (q.v.). Magnesium sulphate is used medicinally as "Epsom Salts," a laxative.

MERCURY

Chemical Symbol or Formula: Hg.

Units Used for Analytical Results: μg/l Hg.

Normal Method(s) of Analysis: Flameless Atomic Absorption Spectrometry [C]; or ICP [inductively-coupled plasma] Spectroscopy [D].

Occurrence/Origin: Normally from industrial waste discharges.

Health/Sanitary Significance: Very toxic, especially in organo-mercury compounds (e.g. methyl-mercury).

This is a very toxic element, the hazards of which are magnified by the accumulation of organo-mercury compounds in fish. It is generally industrial in origin (dental amalgams, anti-fouling paints, plastics manufacture, Hgter-y-making, paper-making and so on) though some comes from the natural environment.

There have been some major pollution incidents (notably in Japan) where both death and severe damage to health has been caused to many people consuming fish and shellfish contaminated by heavy industrial discharges of mercury.

Mercury : Recommended or Mandatory Limit Values

Surface Water 0.001 mg/l Hg

Drinking Water 1.0 μg/l Hg

NICKEL

Chemical Symbol or Formula: Ni.

Units Used for Analytical Results: mg/l Ni.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry
**Occurrence/Origin:** Principal sources are minerals and industrial wastes.

**Health/Sanitary Significance:** Very limited.

This is another metallic element which is of moderate concern because of possible carcinogenicity as far as humans are concerned; it also has variable harmful effects on aquatic life. It is toxic to plant life, too, and is a hazard to fish (generally in the mg/l concentration range).

**Nickel : Recommended or Mandatory Limit Values**

Drinking Water 20.0 µg/l Ni

**NITRATE**

**Chemical Symbol or Formula:** NO₃

**Units Used for Analytical Results:** mg/l N or mg/l NO₃⁻.

**Normal Methods of Analysis:** Manual/Automated Colorimetry; Specific Ion Electrode.

**Occurrence/Origin:** Oxidation of ammonia: agricultural fertiliser run-off.

**Health/Sanitary Significance:** Hazard to infants above 11 mg/l N [50 mg/l NO₃].

Relatively little of the nitrate found in natural waters is of mineral origin, most coming from organic and inorganic sources, the former including waste discharges and the latter comprising chiefly artificial fertilisers. However, bacterial oxidation and fixing of nitrogen by plants can both produce nitrate. Interest is centred on nitrate concentrations for various reasons. Most importantly, high nitrate levels in waters to be used for drinking will render them hazardous to infants. The nitrate itself is not a direct toxicant but is a health hazard because of its conversion to nitrite which reacts with blood haemoglobin to cause methaemoglobinaemia. Of increasing importance is the degree to which fertiliser run-off can contribute to eutrophication problems in lakes. Sewage is rich in nitrogenous matter which through bacterial action may ultimately appear in the aquatic environment as nitrate. Hence, the presence of nitrate in ground waters, for example, is cause for suspicion of past sewage pollution or of excess levels of fertilisers or manure slurries spread on land. (High nitrite levels would indicate more recent pollution as nitrite is an intermediate stage in the ammonia-to-nitrate oxidation).
In rivers high levels of nitrate are more likely to indicate significant run-off from agricultural land than anything else and the parameter is not of primary importance per se. However, it should be noted that there is a general tendency for nitrate concentrations in rivers to increase as a result of enhanced nutrient run-off; this may ultimately lessen their utility as potential sources of public water supply. Nitrite concentrations in rivers are rarely more than 1 - 2 per cent of the nitrate level so that it may therefore be acceptable to carry out the analytically convenient determination of nitrate + nitrite at the same time. This determination is correctly referred to as total oxidised nitrogen.

**Nitrate : Recommended or Mandatory Limit Values**

Surface/Drinking Water 50 mg/l NO₃

**NITRITE**

**Chemical Symbol or Formula:** NO₂

**Units Used for Analytical Results:** mg/l NO₂

**Normal Methods of Analysis:** Manual or Automated Colorimetry

**Occurrence/Origin:** Generally from untreated or partially treated wastes.

**Health/Sanitary Significance:** Methaemoglobinemia-causing agent [cf. Nitrate].

Nitrite exists normally in very low concentrations and even in waste treatment plant effluents levels are relatively low, principally because the nitrogen will tend to exist in the more reduced (ammonia; NH₃) or more oxidised (nitrate; NO₃) forms. Because nitrite is an intermediate in the oxidation of ammonia to nitrate, because such oxidation can proceed in soil, and because sewage is a rich source of ammonia nitrogen, waters which show any appreciable amounts of nitrite are regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.03 mg/l NO(C)₂. Values greater than this may indicate sewage pollution.

The significance of nitrite (at the low levels often found in surface waters) is mainly as an indicator of possible sewage pollution rather than as a hazard itself although, as mentioned above under "Nitrate" (q.v.), it is nitrite rather than nitrate which is the direct toxicant. There is, accordingly, a stricter limit for nitrite in drinking waters.
In addition, nitrites can give rise to the presence of nitrosamines by reaction with organic compounds and there may be carcinogenic effects.

**Nitrite : Recommended or Mandatory Limit Values**

Freshwater <0.01-0.03 mg/l NO$_2$

Drinking Water 0.50 mg/l NO$_2$

**PESTICIDES (INDIVIDUAL & TOTAL)**

**Units Used for Analytical Results:** $\mu$g/l specific compound(s).

**Normal Method(s) of Analysis:** Chromatographic techniques

**Occurrence/Origin:** Synthetic compounds - agricultural discharges, spillages or runoff, industrial waste discharges.

**Health/Sanitary Significance:** Compounds of great acute or chronic toxicity.

This broad designation is used in govt Directives to encompass a large group of compounds with either related uses or similar chemical composition. The substances covered comprise insecticides (organo-chlorine and organo-phosphorus), herbicides, fungicides, PCBs (polychlorinated biphenyls) and PCTs (polychlorinated terphenyls). Compounds such as pesticides are among those which cause mortality or severe reproductive or genetic problems in fauna and which also qualify for inclusion under the broad heading of substances which possess carcinogenic, mutagenic or teratogenic properties. As such, they are highly undesirable in waters of virtually any type.

**Pesticides : Recommended or Mandatory Limit Values**

Surface Water 0.0005-0.005 mg/l

Drinking Water 0.10 $\mu$g/l

**SULPHIDE**

**Chemical Symbol or Formula:** S

**Units Used for Analytical Results:** mg/l S.

**Normal Method(s) of Analysis:** Lead Acetate Paper (Qualitative); Specific Ion Electrode.
Occurrence/Origin: From anaerobic decomposition of organic matter in water or in waste, and from bacterial reduction of sulphate.

Health/Sanitary Significance: Toxic effects on man and aquatic life.

The principal interest in sulphide arises because of its toxicity, and also the odour problems associated with the presence of undissociated hydrogen sulphide (H2S) which is produced by anaerobic reduction of sulphate. There is an equilibrium relationship between the dissociated and undissociated H2S forms which is dependent on pH. If the latter is above 8 there will be no odour problems but as the pH drops to under 7 any H2S present will give rise to offensive odours. This is because the chemical equilibria:

\[ H_2S \rightleftharpoons H^+ + HS^- \rightleftharpoons H^+ + S \]

will shift to the left, favouring the presence of un dis-associated hydrogen sulphide, which is a highly toxic substance. It is the H2S species which particularly affects aquatic life and which has caused fatalities to persons working in sewers.

A problem associated with sulphide is the so-called "crown corrosion" of concrete sewers. If these are not well ventilated the H2S present can be converted by aerobic bacteria resident on the sewer walls above the level of the wastewater to sulphuric acid which will then attack the sewer.

TIN

Chemical Symbol or Formula: Sn.

Units Used for Analytical Results: mg/l Sn.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry.

Occurrence/Origin: Ores, effluents from tin-plating and alloy manufacture.

Health/Sanitary Significance: Little concern regarding tin itself and its inorganic compounds.

Tin has only rarely been found in water - and then only in trace concentrations. The level of exposure from foods, natural as well as canned, is rather higher than would be expected to result from consumption of a water supply. No specific standards have been laid down for (inorganic) tin.
ZINC

Chemical Symbol or Formula: Zn.

Units Used for Analytical Results: mg/l Zn.

Normal Method(s) of Analysis: Atomic Absorption Spectrometry.

Occurrence/Origin: Natural geological occurrence and from wastes.

Health/Sanitary Significance: Inhalation of zinc-containing fumes can cause a variety of physiological effects, but principal significance of excessive amounts in water is that emetic effects occur.

Zinc is essential to man but if ingested in gross amounts it has an emetic effect. However, the concern in water supply arises in regard to taste not toxicity, and quite high levels are permissible. In fishery water, in contrast, the toxic action is much more important and very much lower limits have been imposed.

The toxicity of zinc to aquatic life is (as with copper) dependent on the hardness of the water: it decreases with rising hardness.

INDIAN STANDARD SPECIFICATIONS FOR DRINKING WATER IS: 10500

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Requirement desirable Limit</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Colour</td>
<td>5</td>
<td>May be extended up to 50 if toxic substances are suspected</td>
</tr>
<tr>
<td>2.</td>
<td>Turbidity</td>
<td>10</td>
<td>May be relaxed up to 25 in the absence alternate</td>
</tr>
<tr>
<td>3.</td>
<td>pH</td>
<td>6.5 to 8.5</td>
<td>May be relaxed up to 9.2 in the Absence</td>
</tr>
<tr>
<td>4.</td>
<td>Total Hardness</td>
<td>300</td>
<td>May be extended up to 600</td>
</tr>
<tr>
<td>5.</td>
<td>Calcium as Ca</td>
<td>75</td>
<td>May be extended up to 200</td>
</tr>
<tr>
<td>6.</td>
<td>Magnesium as Mg</td>
<td>30</td>
<td>May be extended up to 100</td>
</tr>
<tr>
<td>7.</td>
<td>Copper as Cu</td>
<td>0.05</td>
<td>May be relaxed up to 1.5</td>
</tr>
<tr>
<td>8.</td>
<td>Iron</td>
<td>0.3</td>
<td>May be extended up to 1</td>
</tr>
<tr>
<td>9.</td>
<td>Manganese</td>
<td>0.1</td>
<td>May be extended up to 0.5</td>
</tr>
<tr>
<td>10.</td>
<td>Chlorides</td>
<td>250</td>
<td>May be extended up to 1000</td>
</tr>
<tr>
<td>11.</td>
<td>Sulphates</td>
<td>150</td>
<td>May be extended up to 400</td>
</tr>
<tr>
<td>12.</td>
<td>Nitrates</td>
<td>45</td>
<td>No relaxation</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>---</td>
<td>--------</td>
<td>-----</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td>13.</td>
<td>Fluoride</td>
<td>0.6 to 1.2</td>
<td>If the limit is below 0.6 water should rejected, Max. Limit is extended to 1.5</td>
</tr>
<tr>
<td>14.</td>
<td>Phenols</td>
<td>0.001</td>
<td>May be relaxed up to 0.002</td>
</tr>
<tr>
<td>15.</td>
<td>Mercury</td>
<td>0.001</td>
<td>No relaxation</td>
</tr>
<tr>
<td>16.</td>
<td>Cadmium</td>
<td>0.01</td>
<td>No relaxation</td>
</tr>
<tr>
<td>17.</td>
<td>Selenium</td>
<td>0.01</td>
<td>No relaxation</td>
</tr>
<tr>
<td>18.</td>
<td>Arsenic</td>
<td>0.05</td>
<td>No relaxation</td>
</tr>
<tr>
<td>19.</td>
<td>Cyanide</td>
<td>0.05</td>
<td>No relaxation</td>
</tr>
<tr>
<td>20.</td>
<td>Lead</td>
<td>0.1</td>
<td>No relaxation</td>
</tr>
<tr>
<td>21.</td>
<td>Zinc</td>
<td>5.0</td>
<td>May be extended up to 10.0</td>
</tr>
<tr>
<td>22.</td>
<td>Anionic detergents (MBAS)</td>
<td>0.2</td>
<td>May be relaxed up to 1</td>
</tr>
<tr>
<td>23.</td>
<td>Chromium as Cr**6</td>
<td>0.05</td>
<td>No relaxation</td>
</tr>
<tr>
<td>24.</td>
<td>Poly nuclear aromatic Hydrocarbons</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>25.</td>
<td>Mineral Oil</td>
<td>0.01</td>
<td>May be relaxed up to 0.03</td>
</tr>
<tr>
<td>26.</td>
<td>Residual free Chlorine</td>
<td>0.2</td>
<td>Applicable only when water is Chlorinated</td>
</tr>
<tr>
<td>27.</td>
<td>Pesticides</td>
<td>Absent</td>
<td>--</td>
</tr>
<tr>
<td>28.</td>
<td>Radio active</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
## DRINKING WATER SPECIFICATION: IS: 10500, 1992 (Reaffirmed 1993)

### TOLERANCE LIMITS

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameter</th>
<th>IS: 10500 Requirement (Desirable limit)</th>
<th>Undesirable effect outside the desirable limit</th>
<th>IS: 10500 Permissible limit in the absence of alternate source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Essential Characteristics</td>
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<td></td>
<td></td>
<td></td>
<td>Following Results are expressed in mg/l :</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Desirable Characteristics</td>
<td></td>
</tr>
</tbody>
</table>

1. **pH**
   - 6.5 – 8.5
   - Beyond this range the water will effect the mucous membrane and/or water supply system
   - No relaxation

2. **Colour (Hazen Units), Maximum**
   - 5
   - Above 5, consumer acceptance decreases
   - 25

3. **Odour**
   - Unobjectionable
   - --
   - --

4. **Taste**
   - Agreeable
   - --
   - --

5. **Turbidity, NTU, Max**
   - 5
   - Above 5, consumer acceptance decreases
   - 10

### Following Results are expressed in mg/l:

6. **Total hardness as CaCO₃, Max**
   - 300
   - Encrustation in water supply structure and adverse effects on domestic use
   - 600

7. **Iron as Fe, Max**
   - 0.30
   - Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria.
   - 1.0

8. **Chlorides as Cl, Max**
   - 250
   - Beyond this limit taste, corrosion and palatability are effected
   - 1000

9. **Residual, Free Chlorine, Min**
   - 0.20
   - --
   - --

### Desirable Characteristics

10. **Dissolved solids, Max**
    - 500
    - Beyond this palatability decreases and may cause gastro intentionial irritation
    - 2000

11. **Calcium as Ca, Max**
    - 75
    - Encrustation in water supply structure and adverse effects on domestic use
    - 200

12. **Magnesium as Mg, Max**
    - 30
    - --
    - 100

13. **Copper as Cu, Max**
    - 0.05
    - Astringent taste, discoloration and corrosion of pipes, fitting and utensils will be caused beyond this
    - 1.5

14. **Manganese as Mn, Max**
    - 0.1
    - Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures
    - 0.3
<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>15.</td>
<td>Sulphate as SO$_4$ Max</td>
<td>200</td>
<td>Beyond this causes gastro intestinal irritation when magnesiun or sodium are present</td>
</tr>
<tr>
<td>16.</td>
<td>Nitrates as NO$_3$</td>
<td>45</td>
<td>Beyond this methanemoglobinemia takes place</td>
</tr>
<tr>
<td>17.</td>
<td>Fluoride, Max</td>
<td>1.0</td>
<td>Fluoride may be kept as low as possible. High fluoride may cause fluorosis</td>
</tr>
<tr>
<td>18.</td>
<td>Phenolic compounds as C$_6$H$_5$OH, Max</td>
<td>0.001</td>
<td>Beyond this, it may cause objectionable taste and odour</td>
</tr>
<tr>
<td>19.</td>
<td>Mercury as Hg, Max</td>
<td>0.001</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>20.</td>
<td>Cadmium as Cd, Max</td>
<td>0.01</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>21.</td>
<td>Selenium as Se, Max</td>
<td>0.01</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>22.</td>
<td>Arsenic as As, Max</td>
<td>0.05</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>23.</td>
<td>Cyanide as CN, Max</td>
<td>0.05</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>24.</td>
<td>Lead as Pb, Max</td>
<td>0.05</td>
<td>Beyond this, the water becomes toxic</td>
</tr>
<tr>
<td>25.</td>
<td>Zinc as Zn, Max</td>
<td>5</td>
<td>Beyond this limit it can cause astringent taste and an opalescence in water</td>
</tr>
<tr>
<td>26.</td>
<td>Anionic detergents as MBAS, Max</td>
<td>0.2</td>
<td>Beyond this limit it can cause a light froth in water</td>
</tr>
<tr>
<td>27.</td>
<td>Chromium as Cr$_{VI}$, Max</td>
<td>0.05</td>
<td>May be carcinogenic above this limit</td>
</tr>
<tr>
<td>28.</td>
<td>Ploynuclear aromatic hydrocarbons as PAH, Max</td>
<td>--</td>
<td>May be carcinogenic</td>
</tr>
<tr>
<td>29.</td>
<td>Mineral Oil, Max</td>
<td>0.01</td>
<td>Beyond this limit undesirable taste and odour after chlorination take place</td>
</tr>
<tr>
<td>30.</td>
<td>Pesticides, Max</td>
<td>Absent</td>
<td>Toxic</td>
</tr>
<tr>
<td>31.</td>
<td>Radioactive materials a) $\alpha$ emitters Bq/l, Max</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>32.</td>
<td>Alkalinity, Max</td>
<td>200</td>
<td>Beyond this limit taste becomes unpleasant</td>
</tr>
<tr>
<td>33.</td>
<td>Aluminum as Al, Max</td>
<td>0.03</td>
<td>Cumulative effect is reported to cause dementia</td>
</tr>
<tr>
<td>34.</td>
<td>Boron, Max</td>
<td>1</td>
<td>--</td>
</tr>
</tbody>
</table>
## General Standards For Discharge Of Environmental Pollutants Effluents

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Parameter</th>
<th>Inland Surface water</th>
<th>Public Sewers</th>
<th>Land of irrigation</th>
<th>Marine/Costal areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Colour and odour</td>
<td>Of Annexure-1</td>
<td>--</td>
<td>See 6 of Annexure -1</td>
<td>See 6 of Annexure -1</td>
</tr>
<tr>
<td>2.</td>
<td>Suspended solids mg/l, max.</td>
<td>100</td>
<td>600</td>
<td>200</td>
<td>a. For process waste water 100 b. For cooling water effluent 10 per cent above total suspended matter of influent</td>
</tr>
<tr>
<td>3.</td>
<td>Particle size of suspended solids</td>
<td>Shall pass 850 micron IS Sieve</td>
<td>--</td>
<td></td>
<td>a. Floatable solids, solids max. 3 mm b. Settleable solids. Max 856 microns</td>
</tr>
<tr>
<td>4.</td>
<td>pH value</td>
<td>5.5 to 9.0</td>
<td>5.5 to 9.0</td>
<td>5.5 to 9.0</td>
<td>5.5 to 9.0</td>
</tr>
<tr>
<td>5.</td>
<td>Temperature</td>
<td>Shall not exceed 5°C above the receiving water temperature</td>
<td>--</td>
<td>--</td>
<td>Shall not exceed 5°C above the receiving water temperature</td>
</tr>
<tr>
<td>6.</td>
<td>Oil and grease, mg/l max.</td>
<td>10</td>
<td>20</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>7.</td>
<td>Total residual chlorine, mg/l max</td>
<td>1.0</td>
<td>--</td>
<td>--</td>
<td>1.0</td>
</tr>
<tr>
<td>8.</td>
<td>Ammonical nitrogen (as N), mg/l, max.</td>
<td>50</td>
<td>50</td>
<td>--</td>
<td>50</td>
</tr>
<tr>
<td>9.</td>
<td>Total nitrogen (as N), mg/l, max.</td>
<td>100</td>
<td>--</td>
<td>--</td>
<td>100</td>
</tr>
<tr>
<td>10.</td>
<td>Free ammonia (as NH₃), mg/l, max.</td>
<td>5.0</td>
<td>--</td>
<td>--</td>
<td>5.0</td>
</tr>
<tr>
<td>11.</td>
<td>Biochemical oxygen demand (3 days at 27°C), mg/l, max</td>
<td>30</td>
<td>350</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Chemical oxygen demand, mg/l, max</td>
<td>250</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>Arsenic (as As), mg/l, max</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Mercury (as Hg), mg/l, max</td>
<td>0.01</td>
<td>0.01</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Lead (as Pb), mg/l, max</td>
<td>0.1</td>
<td>0.1</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Cadmium (as Cd), mg/l, max</td>
<td>2.0</td>
<td>1.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>Hexavalent chromium (as Cr+6), mg/l, max</td>
<td>0.1</td>
<td>2.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Total chromium (as Cr), mg/l, max</td>
<td>2.0</td>
<td>2.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>Copper (as Cu), mg/l, max</td>
<td>3.0</td>
<td>3.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>Zinc (as Zn), mg/l, max</td>
<td>5.0</td>
<td>15</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Selenium (as Se), mg/l, max</td>
<td>0.05</td>
<td>0.05</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>Nickel (as Ni), mg/l, max</td>
<td>3.0</td>
<td>3.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>Cyanide (as CN), mg/l, max</td>
<td>0.2</td>
<td>2.0</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>Fluoride (as F), mg/l, max</td>
<td>2.0</td>
<td>15</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>Dissolved phosphates (as P), mg/l, max</td>
<td>5.0</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>Sulphide (as S), mg/l, max</td>
<td>2.0</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>Phenolic compounds (as C$_6$H$_5$OH), mg/l, max</td>
<td>1.0</td>
<td>5.0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>Manganese (as Mn)</td>
<td>2 mg/l</td>
<td>2 mg/l</td>
<td>2 mg/l</td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Iron (as Fe)</td>
<td>3 mg/l</td>
<td>3 mg/l</td>
<td>2 mg/l</td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>Vanadium (as V)</td>
<td>0.2 mg/l</td>
<td>0.2 mg/l</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>Nitrate Nitrogen</td>
<td>10 mg/l</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

* These standards shall be applicable for industries, operations or processes other than those industries. Operations or process for which standards have been specified in Schedule of the Environment Protection Rules 1989.*