1.0 GENERAL INTRODUCTION

Water is among the most essential requisites that nature provides to sustain life for plants, animals and humans. It is the most abundant and essential compound in nature. It fills depressions in the earth’s crust to form lakes, seas and oceans. The total quantity of freshwater on earth could satisfy all needs of the human population were it evenly distributed and accessible. Environmental conditions such as salinity, oxygen, temperature and nutrients influence the composition, distribution and growth of its biota. Water is never pure in a chemical sense. It contains impurities of various kinds dissolved as well as suspended. These include dissolved gases (H\textsubscript{2}S, CO\textsubscript{2}, NH\textsubscript{3}, N\textsubscript{2}), dissolved minerals (Ca, Mg, Na salts), suspended matter (Clay, Silt & Sand) and microbes. These are natural impurities derived from the atmosphere, catchment areas and the soil. The marine water quality studies were focussed by several scientists\textsuperscript{1-4}.

The total volume of water on earth is \( \approx 1.4 \text{ billion km}^3 \). The volume of fresh water resources is \( \approx 35 \text{ million km}^3 \) or about 2.5\% of the total volume. Of these freshwater resources \( \approx 24 \text{ million km}^3 \) or 68.9\% is in the form of ice and permanent snow cover in mountainous regions, the Antarctic and Arctic regions. Some 8 million km\(^3\) or 30.8\% is stored underground in the form of ground water.
Freshwater lakes and rivers contain an estimated 105000 km³ or ≈ 0.3% of the world’s freshwater.

1.01 Sources of natural water

The natural water can be obtained from four main sources:

(i) Rain water
(ii) Spring & well water
(iii) River water
(iv) Sea water

In India the main source of water is rain. However, the time-distribution of precipitation is quite uneven. As a result there are floods in many parts of the country during the June-September period; the same regions might experience acute water scarcity during the January-May period. The annual yield from rainfall is estimated to be about 400 million hectares (MHM) and out of this, 70 MHM of water evaporates immediately, 115 MHM runs off into surface water bodies and the remaining percolates into the soil. Based on rainfall records & run off coefficients, the total annual flow through rivers in India is estimated to be around 168 MHM.

1.02 Distribution of rain water

The mass balance of annual rainfall shows that about 70% is lost by direct evaporation and transpiration by plants, while the remaining 30% goes into the stream flow. The approximate breakup of this stream flow, as consumed by man, is 8% for irrigation, 2% for domestic use, 4% for industries and 12% electrical utilities. Irrigation for agricultural purposes and electric power plants are the major consumers of water.
The aggregate surface water resources were reported as about 100 MHM by “Irrigation Commission, Government of India” Report (1972). The total flow of all the rivers of India is about 7% of the flow of all rivers in the world and about two and half times the runoff of the Mississippi river basin.

1.1 INTRODUCTION

1.1.1 Pollution

Pollution is the introduction of contaminants into the natural environment that causes adverse change. Pollution can take the form of chemical substances or energy such as noise, heat or light. Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants. Pollution is often classified as point source or non-point source. Pollution started from the prehistoric times when man created his first fires. According to a 1983 article in the Journal Science, soot found on ceilings of prehistoric caves provides ample evidence of the high levels of pollution that was associated with inadequate ventilation of open fires. The forging of metals appears to be a key turning point in the creation of significant air pollution levels outside home. Core samples of glaciers in Greenland indicate increases in pollution associated with Greek, Roman & Chinese metal production but at that time the pollution was comparatively less and could be handled by nature. There are various types of pollutions in the environment i.e. air pollution, water pollution, noise pollution, thermal pollution, light pollution etc.

Any part of the environment may be affected and almost anything may be a pollutant. The only criterion is that the addition of a pollutant result in undesirable
changes. The impact of an undesirable change may be largely aesthetic hazy air obscuring a distant view or the unsightliness of road side litter, for instance. The impact may be on ecosystems as a whole-die-off of fish or forests for example. Or the impact may be on human health-toxic wastes contaminating water supplies. The impact may also range from very local. The contamination of an individual well, for instance to global. We tend to think of pollution as the introduction of human-made materials into the environment, but undesirable changes may be caused by the introduction of too much of otherwise natural compounds; fertilizer nutrient introduced into waterways and carbon-di-oxide introduced into the atmosphere are examples.

The very nature of our existence necessitates the production of wastes. Our job in remediating present and future pollution problems is parallel to the concept of sustainable development itself. For sustainability, eco-systems dispose of wastes and replenish nutrients by recycling all elements, thereby avoiding both pollution and the depletion of resources. Any shift in the naturally dynamic equilibrium existing among the environmental segments. Hydrosphere/Atmosphere/Lithosphere (Sediment) gives rise to state of pollution. The atmosphere is a mixture of gases extending outwards from the surface of the earth, which has evolved from elements of earth which converted to gaseous form during the process of formation and metamorphosis. The lithosphere is the mantle of rocks constituting the earth’s crust. The hydrosphere consists of oceans, seas, lakes, rivers and streams and the shallow ground water bodies that interflow with the surface water.
The nature now is not pure as it was & the main cause which has disrupted its purity is the mankind. Man in order to fulfill his requirements has gifted the environment with various pollutants which has resulted in an unhealthy & unsafe atmosphere. The beautiful earth, called the blue planet, its atmosphere, land and water, each and every part is polluted. Pollution has resulted in various disease affecting man himself, the animals on land and the aquatic animals.

Water pollutants originate from a host of human activities and reach surface water or ground water through an equally diverse host of pathways. Water pollution is caused by the presence of undesirable and hazardous materials and pathogens beyond certain limits. Much of the pollution is due to anthropogenic activities like discharge of sewage, effluents and wastes from domestic and industrial establishments, particulate matter and metals and their compounds due to mining and metallurgy and fertilizer & pesticides runoffs from agricultural activities.

Water accepts and holds foreign matter in various ways:-

Water is usually good solvent. It is especially good at dissolving mineral salts, which typically consist of negative and positive ions. The positive ions are those of metals, including many that are poisonous, such as the ions of the copper, cadmium, mercury & lead. Water is also a good solvent for many organic compounds that contain oxygen, such as alcohols, sugars and organic acids. Furthermore many materials that are normally considerable insoluble in water are in fact very slightly soluble, many endanger a sustainable development of these resources. The observed status of a system at any point in time results from the collective interaction of all these processes, both natural and anthropogenic.
Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion and weathering of crystal materials, physical conditions such as slope and bedrock geology) degrade surface waters and impair their use.

The earth is an oxygen water planet. Oxygen and water are essential for all life. Water is used everywhere for drinking, washing, bathing, irrigating, cooling and manufacturing almost anything. It is the universal solvent. Water is thus spoiled everywhere. The only large scale agency for restoring water to a state fit for further use is Nature. The sun’s heat evaporates the water of the oceans and returns it to earth as rain. The rivers “inhale” oxygen with every swirl of the water and green aquatic plants yield more oxygen to the waters through photosynthesis. As long as this natural process of recuperation can match the process of despoilation, the rivers sustain life. But modern industrial society is rapidly overtaking this natural cleaning capacity.

The water bodies- rivers, lakes and estuaries are continuously subjected to a dynamic state of change with respect to their geological age and geochemical characteristics. The dynamic balance in the aquatic eco-system is upset by human activities, resulting in pollution, which is manifested dramatically as fish kill, bad taste of drinking water, offensive odours and unchecked growth of weeds.

Rivers have always been the most important fresh water resources, along the banks of which our ancient civilization have flourished and until most of the developmental activities are dependent upon them. River water finds multiple uses
in every sector of development like agriculture, industry, transportation, aquaculture, public water supply etc. However, since old times rivers have also been used for cleaning and disposal purposes. Huge loads of wastes from industries, domestic, sewage and agricultural practices find their way into large scale deterioration of the water quality. The growing problem of degradation of our river ecosystem has necessitated the monitoring of water quality of various rivers all over the country to evaluate their production capacity, utility potential and to plan restorative measures.

Rivers and the surrounding land drained by them (catchments) are very important wildlife habitats. The water itself provides the environment for fish, plants and animals while the banks and nearby land support creatures such as ottes, king fishers and dragon flies and a variety of water-loving plants. 97% of the water on the earth is salt water. However, only 3% is fresh water, slightly over 2/3rd of this is frozen in glaciers and polar ice caps. The remaining unfrozen fresh water is found mainly as groundwater, with only a small fraction present above ground or in air.

Surface water is water in a river, lake or fresh water wet land. Surface water is replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapo-transpiration and sub-surface seepage.

Thus, hydrocarbons are said to be insoluble in water (“oil and water do not mix”) yet benzene for example dissolves in water to the extent of almost 0.1%. That may not sound like much, but it would have a terrible taste and besides, benzene is toxic to humans.
1. Insoluble particles, if they are small enough, may settle so slowly that for all practical purposes they remain in water indefinitely.

2. Some insoluble materials, especially certain metals, react with water to produce soluble products.

3. Nutrient matter is metabolized by living organisms in water, and the resulting waste products may be pollutants.

4. Living organisms themselves, if they are pathogens, may be considered pollutants. Their own energy of motion keeps them from settling out of solution.

5. A soluble substance may react with an insoluble contaminant and bring it into solution. For example acids in water react with many minerals and thus dissolve them.

6. Finally, a contaminant may pollute water simply by floating on it. Water is denser than almost all hydrocarbons; therefore, petroleum floats on water. A floating oil spill is certainly a water pollutant.

Foreign substances in water can be classified according to their size of the particles.

1.1.2 Suspended particles

These particles have diameters of more than about 1 micrometer and are the largest. They are large enough to settle out of water reasonably, quickly and to be retained by many common filters. They are also large enough to absorb light, thus making water containing.
(a) **Colloidal particles:** These particles are so small that their settling rate is insignificant and they pass through the holes of most filter media; therefore they cannot be removed from water by settling or by ordinary filtration. Water that contains colloidal particles appears cloudy when observed at right angles to a beam of light (The same phenomenon occurs in air; colloidal dust particles can be seen best when observed at right angles to a sharply focussed light beam in an otherwise dark room). The colours of natural waters, such as the blues, greens, and reds of lakes or seas are caused largely by colloidal particles.

(b) **Dissolved matter:** It does not settle out, is not retained on filters and does not make water cloudy even when viewed at right angles to a beam of light. The particles of such matter are no longer than about one-thousandth micrometer in diameter. If they are electrically neutral, they are called molecules. If they bear an electrical charge, they are called ions. Cane sugar (sucrose), grain alcohol (ethanol) and “permanent antifreeze (ethylene glycol) are substances that dissolve in water as electrically neutral molecules. Table salt (NaCl) on the other hand, dissolves as positive sodium and negative chloride ions.

Natural waters contain substances in all three categories. Natural water range from tastily potable to poisonous.

### 1.1.3 Types of water pollutants

There are large numbers of water pollutants which may be broadly classified as:-
1. Organic pollutants
2. Inorganic pollutants
3. Sediments
4. Radioactive materials
5. Thermal pollutants

1.1.3.1 Organic pollutants

Organic pollution occurs when an excess of organic matter such as manure or sewage, human and animal wastes, pathogens, leaves, grass clippings, trash, synthetic organic compounds and oil. These organic pollutants cause serious problems if enters the body of water untreated. With the exception of plastics and some human made chemicals, these wastes are biodegradable.

Dissolved oxygen (D.O.) is an essential requirement of aquatic life, i.e. plant and animal population in any water body. The optimum D.O. in natural water is 4-6 ppm. Decrease in this D.O. value is an index of pollution mainly due to organic matter, e.g. sewage (domestic and animal), industrial wastes from food processing plants, paper mills and tanneries; wastes from slaughter houses and ment-packing plants; run-off from agricultural lands etc. All these materials undergo degradation by bacterial activity in the presence of D.O., the net result being the deoxygenation process and quick depletion of D.O.

\[ C + O_2 \rightarrow CO_2 \]

Bacteria keep the water depleted in D.O. as long as there is dead organic matter to support their growth. A lack of oxygen can kill aquatic organisms. As the aquatic
organisms die, they are broken down by decomposers which lead to further depletion of the oxygen levels.

Pesticides

Pesticides is the general name for insecticides, acaricides, rodenticides, molluscides, herbicides, fungicides and similarly active compounds. Surface waters are the main receptors for pesticides contamination from the agricultural use. Though there can be benefits using pesticides, inappropriate use can counter productively increase pest resistance and kill natural enemies of pests. Over 98% of spread insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments and food.

Pesticides can contaminate unintended land and water when they are sprayed aerially or allowed to run-off fields. There are four major routes through which pesticides reach the water: It may drift outside of the intended area when it is sprayed, it may percolate, or leach, through the soil, it may be carried to the water as run-off or it may be spilled, for example accidentally through neglect. They may also be carried to water by eroding soil. Factors that affect a pesticides ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop and the method used to apply the chemical.

Fish and other aquatic biota may be harmed by pesticide-contaminated water. Pesticide surface runoff into rivers and streams can be highly lethal to aquatic life sometimes killing all the fish in a particular stream. Application of herbicides to bodies of water can cause fish kills, when the dead plants rot and use
up the water’s oxygen, suffocating the fish. Some herbicides, such as copper
sulphite, that are applied to water to kill plants are toxic to fish and other water
animals at concentrations similar to those used to kill the plants. Repeated exposure
to sublethal doses of some pesticides can cause physiological and behavioral
changes in fish that reduce populations, such as abandonment of nests and broods,
decreased immunity to disease, and increased failure to avoid predators.
Application of herbicides to bodies of water can kill off plants on which fish
depend for their habitat. Pesticides can accumulate in bodies of water to levels that
kill of zooplankton, the main source of food for young fish. The faster a given
pesticide breaks down in the environment, the less threat it poses to aquatic life.
Insecticides are more toxic to aquatic life than herbicides and fungicides.

1.1.3.2 Inorganic pollutants

This group consists of inorganic salts, mineral acids, finely divided metals
on metal compounds, trace elements, complexes of metals with organics in natural
water and organometallic compounds. The metal-organic interactions involve
organic species of both pollutant (such as EDTA) and natural (eg. fulvic acids)
origin. Such interactions depend on and play a role in redox equilibria, colloid
formation, acid base reactions and micro-organisms-mediated reactions in water.
These have an impact on the toxicity of metals in aquatic ecosystems and on the
growth of algae in water. Polyphosphate in detergents, the major source of
phosphate in water, serve as algal nutrients and are of much concern as water
pollutants. However, in an efficient sewage-treatment plant, it is possible to remove
phosphates from sewage containing organic wastes as well as detergents. Various
researchers have studied about the inorganic pollutants\textsuperscript{5-21}. The most common inorganic pollutants are as follows:-

\textbf{1.1.3.2.1 Alkalinity}

Alkalinity is a measure of the ability of water to neutralize acids. It is a commonly measured water characteristic that has little meaning or importance to the typical homeowner. Calcium (Ca) is a major component of alkalinity, as it is with hardness. High alkalinity of water, that means it is probably hard too. There is no drinking water standard for alkalinity.

\textbf{1.1.3.2.2 Arsenic (As)}

Arsenic occurs in ground water from both natural sources and human activities. It is odourless and tasteless in drinking water. Arsenic has a primary drinking water standard because it can cause skin lesions, circulatory problems and nervous system disorders. Prolonged exposure also can cause various forms of cancer. The present Arsenic drinking water standard (0.05 mg/l) is being studied and will likely be lowered to 0.005 mg/l in the near future.

\textbf{1.1.3.2.3 Barium (Ba)}

Like arsenic (As) barium occurs naturally in small concentrations in many groundwater supplies. Barium has a primary drinking water standard of 2.0 mg/l because it causes nervous and circulatory system problems, especially high blood pressure. Standard water softeners are effective in removing barium.

\textbf{1.1.3.2.4 Chloride (Cl\textsuperscript{–})}

Chloride occurs naturally in most ground water but may become elevated due to leaching from salt storage areas around highways or from brines produced
during gas well drilling. Other possible sources of chloride are sewage effluent, animal manure and industrial waste. Chloride has a secondary drinking water standard of 250 mg/l because it may cause a salty taste in the water.

1.1.3.2.5 Copper (Cu)

Copper usually originates from corrosion of copper plumbing in the home. Copper has a secondary drinking water standard of 1.0 mg/l because it causes a bitter, metallic taste in water and a blue-green stain in sinks and bathtubs. Copper levels above 1.3 mg/l are a health concern because they may cause severe stomach cramps and intestinal illness.

1.1.3.2.6 Iron (Fe)

Iron is a common natural problem in ground water that may be worsened by mining activities. Iron does not occur in drinking water in concentrations of health concern to humans. The secondary drinking water standard for iron is 0.3 mg/l because it causes a metallic taste and orange-brown stains that make water unsuitable for drinking and clothes washing.

1.1.3.2.7 Lead (Pb)

If lead is detected in drinking water, it probably originated from corrosion of the plumbing system. If water supply is corrosive, then any lead present in the plumbing system may be dissolved into the drinking water. Lead concentrations are usually highest in the first water out of the tap (known as “first draw” water) since this water has been in contact with the plumbing for longer time. Lead concentrations typically decrease as water is flushed through the plumbing system. Lead poses a serious health threat to the safety of drinking water. Long term
exposure to lead concentrations in excess of the drinking water standard has been linked to many health effects in adults including cancer, stroke and high blood pressure. At even greater risk are the fetus and infants up to four years of age, whose rapidly growing bodies absorb lead more quickly and efficiently. Lead can cause premature birth, reduced birth weight, seizures, behavioral disorders, brain damage and lower IQ in children.

1.1.3.2.8 \( \text{H}_2\text{S} \)

It is naturally gas that is common in groundwater very small concentrations of hydrogen sulphide in water are offensive to most individuals. Although hydrogen sulphide is a highly toxic gas, only under the most unusual conditions would it reach level toxic to humans as a result of its occurrence in drinking water. More often, it is simply an aesthetic odour problem that can be removed using several treatment processes.

1.1.3.2.9 Nitrate (\( \text{NO}_3^- \))

Nitrate in drinking water usually originates from fertilizers or from animal or human wastes. Nitrate concentrations in water tend to be highest in areas of intensive agriculture or where there is a high density of septic systems. Nitrate has a secondary drinking water standard that was established to protect the most sensitive individuals in the population. These segments of pollution are prone to methemoglobinemia (blue baby disease) when consuming water with high nitrates. The primary drinking water standard or MCL is 10 mg/l as nitrate-nitrogen (\( \text{NO}_3^- \)-N) but it is 45 mg/l as nitrate (\( \text{NO}_3 \)).
1.1.3.2.10 Sulphate (SO$_4^{2-}$)

Sulphates occur naturally as a result of leaching from sulphur deposits in the earth. It has a secondary drinking water standard of 250 mg/l because it may impart a bitter taste to the water at this level.

1.1.3.3 Sediments

The natural process of soil erosion gives rise to sediments in water. It represents the most extensive pollutants of surface waters. As a matter of rough estimate, suspended solid loadings reaching natural waters are about 700 times as large as the solid loading from sewage discharge. Soil erosion gets enhanced 5-10 times as a result of agricultural development and about 1000 times due to construction activities. Strip-mining activities have a great influence on the erosion rate in an area.

Bottom sediments are important sources of inorganic and organic matter in streams, fresh water estuaries and oceans. The bottom sediments are subjected to anaerobic i.e. reducing conditions. The level of organic matter in sediments is usually higher than in soils. Bottom sediments have the ability to exchange cation with the surrounding aquatic medium.

Sediments and suspended particles are also important repositories for trace metals, e.g. Cr, Cu, Mo, Ni, Co and Mn.

1.1.3.4 Radioactive materials

The human activities are responsible for radioactive pollution, which are as follows:

(a) Mining and processing of ores to produce usable radioactive substances.
(b) Use of radioactive materials in nuclear power plants.

(c) Use of radioactive materials in nuclear weapons.

(d) Use of radioactive isotopes in medical, industrial research applications.

A typical uranium ore contains about 2-5 lbs of U₃O₃ per ton so that large amounts of ore are processed for extraction of uranium. As a result, large quantities of ‘uranium tailings’ are produced, which pose the problem of radioactive pollution.

Nuclear weapons testing in air, leakage from underground nuclear detonations, etc. give rise to radioactive fall out. The latter has far-reaching effects on the environment and mankind. Sr⁹⁰, a long lived component of radioactive fallout, is chemically similar to Ca and accompanies Ca in soil, plants, animals and finally into man in bones and teeth. The presence of Sr⁹⁰ in bones leads to disorders in blood-cell formation, and cause anemia or more serious disorders.

The radio nuclides found in water include Ra-226 and K-40 originating from leaching of minerals; Sr-90, I-131, Cs-137, Ba-140, Cs-141, Kr-85, Co-60, Mn-54, Fe-55 and Pu-239 originating from reactors and uranium testing. The levels of radio nuclides found in water are measured in units of Pico curies, 10⁻¹⁰ curie (3.7×10⁻² disintegration per second or 2.2 dis, pr min). The permissible level is 3 Pico curies/l of Rs-226 and 10 Pico curies/L or Sr-90.

1.1.3.5 Thermal pollutants

It is the degradation of water quality by any process that changes ambient water temperature. A common cause of thermal pollution is the use of water as a coolant by power plants and industrial manufactures. When water used as a coolant
is returned to the natural environment at a higher temperature, the change in temperature decreases oxygen supply and affects ecosystem composition. Urban run-off storm water discharged to surface waters from roads and parking lots can also be a source of elevated water temperatures.

When a power plant first opens or shuts down for repair or other causes, fish and other organisms adapted to particular temperature range can be killed by the abrupt change in water temperature known as “thermal shock”.

Elevated temperature typically decreases the level of dissolved oxygen in water. This can harm aquatic animals such as fish, amphibians and other aquatic organisms. Thermal pollution may also increase the metabolic rate of aquatic animals, as enzyme activity, resulting in these organisms consuming more food in shorter time than if their environment were not changed.

High temperature limits oxygen dispersion into deeper waters, contributing to anaerobic conditions. This can lead to increased bacteria levels when there is ample food supply. Many aquatic species will fail to reproduce at elevated temperatures. Primary producers are affected by warm water because higher water temperature increases plant growth rates, resulting in a shorter life span and species overpopulation. This can cause an algae bloom which reduces oxygen levels.

Temperature changes of even one to two degrees Celsius can cause significant changes in organism metabolism and other adverse cellular biology effects. Principal adverse changes can include rendering cell wall less permeable to necessary osmosis, coagulation of cell proteins and alteration of enzyme
metabolism. These cellular level effects can adversely affect mortality and reproduction.

A large increase in temperature can lead to the denaturing of life-supporting enzymes by breaking down hydrogen and sulphide bonds within the quaternary structure of the enzymes. Decreased enzyme activity in aquatic organisms can cause problems such as the inability to break down lipids which leads to malnutrition.

In limited cases, warm water has little deleterious effect and may even lead to improved function of the receiving aquatic ecosystem. This phenomenon is seen especially in seasonal waters and is known as thermal enrichment.

Releases of unnaturally cold water from reservoirs can dramatically change the fish and macroinvertebrate fauna of rivers, and reduce river productivity. In Australia where many rivers have warmer temperature regimes native fish species have been eliminated and macroinvertebrates fauna have been drastically altered. Due to sudden fall of water temperature the contraction on dam and bridge pylon may take place. The temperatures for freshwater fish can be as low as 50ºF, saltwater 75ºF and tropical 80ºF.

1.1.4 Adverse effects of polluted water

Water pollution has been seriously affecting the life of humans, plants as well as animals. The ecosystem of rivers, streams, lakes, seas and oceans is also getting deteriorated due to the contamination of water, through various sources. This condition also leads to the outbreak of numerous diseases, majority of them being lethal & contagious. Water pollution has worst impact on all plants and
organisms that live in the water bodies. In all cases, the impact is damaging to individual species and populations but also to the natural biological communities when pollutants are discharged directly or indirectly into water bodies without proper treatment to remove harmful constituents then water pollution occurs. Adverse effects of the polluted water had has been of high interest to environmentalists²²-⁴³.

Water pollution is like a slow poison which slowly and gradually affects the aquatic ecosystem, its plants, animals and human body adversely. Different types of chemicals and microbial pollutants affect humans and animals in different ways. Various consequences of water pollution on humans include:-

(a) The toxic effluents from industries seep into water bodies & disrupt the aquatic ecology. Various forms of marine life such as shellfish and fish are exposed adversely to these effluents. Heavy metals discharged from industries mix with water in streams and rivers and can cause serious health consequences to humans if ingested.

(b) The sewage effluents are the main cause of microbial infiltration in lakes and rivers. The microbial water pollution is the main cause of various water borne diseases like typhoid fever, diarrhea and cholera. The harmful bacteria enter our body through potable water and are one of the main causes of infant mortality.

(c) The discharge of organic nutrients into a body of water increase the aerobic algae count and eat up oxygen, causing serious suffocation to aquatic animals.
(d) Acid rain chemicals such as sulphate particles can cause adverse effects to marine health in rivers and lakes.

(e) The suspended particulate matter discharged into rivers lakes and streams block the penetration of sunlight. This disrupts the process of photosynthesis in aquatic plants and stunts their growth. The discharged suspended particulates reduce the quality of potable water and cause serious health consequences to humans & marine animals.

Pollution with sewage or manure runoff can cause microbial contamination of drinking. This results in gastrointestinal disease that can be fatal in high risk individuals. Most individuals suffer no adverse effects from high levels of nitrates, infants cannot convert them into a harmless substance; if they consume nitrates, they can die from blue baby syndrome.

Drinking water comes from surface water, such as lakes, rivers & from ground water. Pollution in these sources affects the quality & safety of water available at homes.

Carcinogenic pollutants found in polluted water might cause cancer. Diseases affecting the heart, poor circulation of blood and the nervous system and ailments like skin lesion are often linked to the harmful effects of water. Pollution affects the chemistry of water. The pollutants, including toxic chemicals, can alter the acidity, alkalinity, conductivity and temperature of water.

As per the records 14000 people perish or incur various communicable disease due to the consumption of contaminated drinking water. Alteration in the chromosomal make up of the future generation is fore seen as a result of water pollution.
Discharge from the power stations reduces the availability of oxygen in $\text{H}_2\text{O}$ body in which they are dumped.

### 1.1.5 River water

Rivers have always been the most important freshwater resources, along the banks of which ancient civilizations have flourished and still most of the developmental activities are dependent upon them. It is a large natural water course flowing towards an ocean, a lake, a sea or another river and usually fed along its cause by converging tributaries. In a few cases, a river simply flows into the ground or dries up completely before reaching another body of water. Small rivers may also be called by several other names, including stream, creek, brook, rivulet, run tributary and rill. Rivers had have been the most sincere, useful and close companion of creature and hence studied exhaustively.

Rivers are part of the hydrological cycle. Water within a river is generally collected from precipitation through a drainage basin from surface run-off and other sources such as groundwater recharge springs and the release of stored water in natural ice and snow packs (e.g. from glaciers). Potamology is the scientific study of rivers.

The water in a river is usually confined to a channel made up of a stream bed between banks. In larger rivers there is also a wider flood plain shaped by flood waters over-tapping in the channel. Flood plains may be very wide in relation to the size of the river channel. This distinction between river channel and flood plain can be blurred especially in urban areas where the flood plain of a river channel can become greatly developed by housing & industry.
The term upriver refers to the direction leading to the source of the river, which is against the direction of flow. Likewise, the term down river describes the direction towards the mouth of the river, in which the current flows.

Rivers in India may be classified as:-

2. Himalayan rivers
3. Peninsular rivers
4. Coastal rivers
5. Rivers of inland drainage basin

1. The Himalayan Rivers are perennial as they are generally snow-fed and have reasonable flow throughout the year. During the monsoon Himalayas receive very heavy rainfall and the rivers discharge the maximum quantity of water causing frequent floods.

2. The peninsular rivers are generally rain-fed and therefore, fluctuate in volume. A large number of the streams are non-perennial.

3. The coastal rivers especially on the west coast are short in length and have limited catchments areas. Most of them are flashy and non-perennial.

4. The river of inland drainage basin (of western Rajasthan) is of an ephemeral character. They drain towards the individual basins or salt lakes.

1.1.5.1 River water pollution

It is a form of water pollution that refers to the contamination of rivers. River pollution occurs when waste and different other pollutants are discharged into river without being properly treated. Moving water dilutes and decomposes
more rapidly than standing water, but many rivers and streams are significantly polluted all around the world.

The pollution density, assimilation and self purification capacity directly affect river hydrogeometric properties (flow, velocity, dispersion, depth, width, slope, cross sectional area etc.), because the degree of pollution is related to dilution of matter being discharged and therefore constitute the most important characteristic factor of pollution in a river. A wide spectrum of different pollutants originating from natural and anthropogenic emission sources occurs in the aquatic environment. The number of pollutants as well as the loads delivered into the aquatic environment due to human activities has increased. Each year over 1000 new compounds appear in the environment due to the ever intensifying industrial activities of humans, and that undoubtedly, leads to increased toxicological and ecotoxicological risks. Since diluted organic matter in a river is transformed with self-biological oxidation. Velocity of biological stabilization depends on temperature and travel time.

The role of sewage water\textsuperscript{61-69} in pollution is of great concern to ecologists & environmentalists in India and the world. When the rubbish or wastes are thrown into the river, the solid sinks to various levels in the water, they are attacked by two kinds of organisms: the aerobes, which cannot do without oxygen and hence populate oxygen rich upper layers, the anaerobes which shy away from oxygen and so live in the depths. Each consumes the rubbish descending to its level, converting the complex organic materials into inorganic and mineral matter that cannot putrefy and so despoil water. The aerobes begin multiplying as they sense the presence of
rubbish. As they consume the dissolved and suspended wastes, they use up the oxygen present in the water. Algae present in water then absorb the inorganic & mineral matter produced by the aerobes and convert it back into useful organic matter. In process they release oxygen into water through photosynthesis.

River is a mobile source of fungal, macro & microbial pollution studied by life scientists. Along with solid matter there are also disease germs. Rivers contain a variety of aquatic protozoa that destroy many of these germs. The oxygen required for the survival of the protozoa comes from the intake of the rivers or from algae. When quantum of waste goes up the amount of oxygen required to consume it, by the aerobes and the protozoa increases. But river can supply a limited amount of oxygen. As this oxygen begins to deplete the aerobes & protozoa begin to die off. As oxygen level falls in upper layer the anaerobes rise and act on waste by extracting hydrogen. The hydrogen combines with sulphur from the wastes to form H₂S a foul smelling gas. The water becomes turbid & sunlight cannot penetrate the surface. The algae in absence of sunlight begin to die and so do the fish and the river remains a “foul” river, smelly & sluggish, devoid of life & a menace to all other life. Pollutants are from point as well as non-point sources. Point sources are domestic, municipal and sewer discharge, power generation plants and industrial waste discharge. Some of them like, breweries, slaughter houses and sanitary operations, paper mills and wastewater treatment plants contribute major quantities of oxygen-demanding substances. These substances can deplete dissolved oxygen (D.O.) and create anaerobic conditions in water bodies. Suspended matter also contributes to oxygen depletion in water bodies by blocking penetration of sunlight
and interfacing with photosynthetic activity. This results in an increase in oxygen demand-biological oxygen demand (BOD) and chemical oxygen demand (COD). Nitrogen and phosphorous containing compounds (nutrients) can promote accelerated eutrophication of water bodies.

Heat is universal pollutant, as it drastically alters the ecology of water bodies, by lowering the amount of dissolved oxygen in water: thus accentuating the oxygen deficiency for aquatic organisms. Trace metals, hydrocarbons, hazardous chemicals, bacteria and a variety of pathogens are other pollutants that can cause a wide variety of problems in water courses.

Non-point sources are storm drainage, operations involving agriculture, timber and forest-product operations. Mobile vehicular discharge is also a source of contamination affecting through atmospheric pollution. All most all rivers of India such as Ganga, Gomti, Godavari, Cauvery, Brahmaputra, Yamuna are being polluted.

**1.1.5.2 Sources of river water pollution**

There are various sources of pollution caused into rivers. Specific studies have been conducted for rivers\textsuperscript{80-88} such as Ganga, Yamuna, Brahmaputra, Sai & Gomti etc.

**1.1.5.2.1 Industrial effluents**

The industrial sewage consists of polluted water from industrial and chemical processes. These discharges usually contain specific pollutants, which are related to the nature of products handled in an industry and the processes followed. Industries located along water ways contribute a number of chemical pollutants,
some of which are toxic in any concentration. Such pollutants may originate from metallurgical, paper and pulp, cloth and cellulose fibers, and food, beverage and tannery wastes, detergents, plastics and petrochemicals. Discharge from hospitals and utility sources and power generation plants also comes in this category. In highly industrialized zones, if the industrial sewage are not separately treated before discharge into water ways serious pollution conditions develop. Industries contribute to water pollution through atmospheric pollution also. Hot water from power generating installations, discharged into water streams, cause thermal pollution. Ganga river at Varanasi is continuously polluted due to untreated sewage disposal & dead body cremation. Several scientists have studied the physico-chemical characteristics of industrial effluents\textsuperscript{89-97}.

The disposal of industrial wastes is often conducted without critical appraisal of the losses incurred. Usually no consideration is taken with regard to the deleterious environmental impact upon the receiving water body. There are numerous effluents leading to heavy metal enrichment of the aquatic environment. High concentration of metallic effluents such as mercury, cadmium, zinc, iron, manganese and others generated from the untreated effluents accumulates in the food chain and hence affect the human health when the food is consumed. This contaminant then interferes with the enzyme activity and the formation of red blood cells that may cause harmful effect in humans. The release of metallic effluent from industrialization increases the fertility of the sediment in water column that consequently causes eutrophication, decrease of the oxygen level in the water leading to death of the aquatic living organisms. The high release of metallic
effluent also causes chronic health problems to the aquatic organism. This effluent have the tendency to interfere with the microbial diseases, skeletal abnormalities caused by impending calcium metabolism of fishes and also disrupts the enzymatic activities by inhibiting or accelerating the enzymatic reaction. The interactive effect between the metal and other contaminants that are found in the sewage effluent increases the toxicity of the water and hence gives harmful effect to marine organism. Insoluble pollutants resulting from industrial activity forms a surface layer that hinders the access of oxygen in the air. The large particles or suspended matter settles on the bed of the stream and cause further pollution. On the other hand the fine suspended particles clog the respiratory organ of fish causing it impossible to survive.

1.1.5.2.2 Domestic sewage

It refers to waste water that is discarded from households. It is also called sanitary sewage. Domestic and municipal sewage carries used water from houses, offices and other buildings in a city. Most of it (nearly 99.9%) is water. Though the contaminants add up to more than 0.1%, they contain a wide variety of dissolved and suspended impurities. The nature of these impurities and the large volume of sewage in which they are carried make disposal of domestic wastewater a significant technical problem. Sewage is the primary source of pathogenic organisms, oxygen-demanding waste matter and plant nutrients. Domestic sewage has been studied by various workers.98

Today, many people dump their garbage into streams, lakes, rivers and seas, thus making water bodies the final resting place of cans, bottles, plastics and other
household products. The various substances that are used for keeping houses clean add to water pollution as they contain harmful chemicals. In the past, people mostly used soaps made from animal and vegetable fat for all types of washing. But most of today’s cleaning products are synthetic detergents and come from the petrochemical industry. Most detergents and washing powders contain phosphates which are used to soften the water among the things. These and other chemicals contained in washing powders affect the health of all forms of life in the water.

1.1.5.2.3 Agricultural sources

The use of land for agriculture and the practices followed in cultivation greatly affect the quality of ground water. Agricultural wastes, generally, consist of organic products. Fertilizers and other chemicals are spread over agricultural lands. These materials and crop, animal and chemical wastes enter water bodies, mainly in run-off from watershed lands and cause pollution. The inflow of manures from livestock feed lots to organic pollutants.

Intensive cultivation of crops causes chemicals from fertilizer (e.g. nitrate) and pesticides to seep into the groundwater, a process commonly known as leaching. The high nitrate content in groundwater is mainly from irrigation run-off from agricultural fields where chemical fertilizers have been used indiscriminately. Agricultural pollutants have been studied widely by scientists99.

1.1.5.2.4 Atmospheric deposition

There is accumulated evidence to establish a close relationship between atmospheric pollution and declining water quality on the globe. Airborne pollutants can be deposited on land or water. This type of deposition can take place,
sometimes, at great distances from its original source. The deposition itself can take several forms; ‘wet deposition’ occurs when air pollutants fall with rain, snow or fog. ‘Dry deposition’ takes place as dry particles or gases. These pollutants can fall directly on water or having fallen on land can be washed into a body of water as run-off.

1.1.5.2.5 Storm sewage

Storm sewage or storm water is the run-off from precipitation that is collected in a system of pipes or open channels. Such sewage carries organic materials, suspended and dissolved solids and other substances picked up as the water travels over the ground. Sewage discharge from domestic, municipal, food processing and other industrial concerns contain a variety of pollutants detrimental to water quality.

1.1.5.2.6 Mining wastes

Mining, milling, dressing and processing of ores give rise to dust, ore and metal discards and large quantities of effluents, which are discharged into streams, ponds and lakes. They not only increase sediments but also release toxic metals into the water sources.

Common trace metals found in sediments and mine effluents are Cd, Cu, Fe, Hg, Mn, Ni, Pb and Zn. Of these, heavy metals Cd, Hg, Pb and metalloids, such as As are among the most harmful of the elemental pollutants. Most of them have a great affinity for sulphur and attack-SH groups and disulphide bonds in proteins and other biological macromolecules. Cadmium, being chemically similar to zinc, replaces the latter in enzymes and thus affects enzyme action of Zn containing
proteins. Mercury is of great concern as a heavy-metal pollutant. Lead occurs in water in Pb(II) state. It is highly poisonous and causes anemia, central nervous system disorders, kidney and liver dysfunction.

1.1.5.3 Uses of river water

Water is a vital natural resource which is essential for a multiplicity of purposes. Its many uses include drinking and other domestic uses, industrial cooling, power generation, agriculture (irrigation) transportation and waste disposal. In the chemical process, industry water is used as a reaction medium a solvent, a scrubbing medium and a heat transfer agent. As a source of life for man, plants and other forms of life it can not be replaced. Several investigators have studied\textsuperscript{100-109} the uses of river water for various purposes.

1.1.5.3 Domestic water supply

Domestic water requirements vary from season to season and from rural to urban areas. In summer, the need for water is greater than that in rural areas. Moreover, it depends on factors like the standard of living and habits of people in the community.

1.1.5.3.2 Irrigation

Water requirements for irrigation are by far the highest among various uses of fresh water. The amount of water required for irrigation purposes varies with the climate of the region and the type of crops that are to be raised. Surface waters used for irrigation may be diverted through canals which afford gravity aided flows to the irrigation area.
1.1.5.3.3 Power generation

Cooling is the principal water use in thermal power generation and more than 99% of water used is required for condensor cooling. The water carrying waste heat is directly discharged into the natural aquatic system as sometimes it is passed through a cooling tower and then recirculated back into the condensor. In both cases, losses due to evaporation are roughly of the same order of magnitude. It has been estimated that in a 500 MW power plant about 40 million liters of water would evaporate per day with increasing capacity for thermal power generation, the demand for water will increase significantly. On the basis of assumption that a moderate one-third of total intake water is recirculated, the total annual withdrawal requirement in the year 2000 estimated to vary from 3.6 MHM for a low economic growth and high population scenario to 9.3 MHM for a high economic growth and low population scenario.

1.1.5.3.4 Industrial water use

Industry is much dependent on adequate water supplies. The enormous demand that industry has water is indicated by the water requirement of some key industrial processes. Major water users are steel, pulp & paper, textiles, chemicals & petroleum refining; they account for 80% of industrial water demand. Accurate projected requirements are not easily available for various industries in India but a rough estimate indicates that the annual intake of water by all industries will be between 1.7 and 3.9 MHM in the year 2000.

With a growing population the demand for fresh water is steadily increasing in India, but as with all other resources, there is a limit to fresh water supply. In
addition, the availability of high-quality water is dwindling because of misuse, waste and pollution.

**Table-1.0: Water requirements for selected industries per unit of product**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Unit product</th>
<th>Water requirement (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bread</td>
<td>ton</td>
<td>2100-4200</td>
</tr>
<tr>
<td>Beer</td>
<td>kilo litre</td>
<td>15000</td>
</tr>
<tr>
<td>Milk products</td>
<td>ton</td>
<td>20000</td>
</tr>
<tr>
<td>Wood pulp</td>
<td>ton of pulp &amp; paper</td>
<td>236000</td>
</tr>
<tr>
<td>Cotton bleaching</td>
<td>ton</td>
<td>300000</td>
</tr>
<tr>
<td>Chemicals-acetic acid</td>
<td>ton</td>
<td>417000-1000000</td>
</tr>
<tr>
<td>H₂SO₄</td>
<td>ton of 100% H₂SO₄</td>
<td>10400</td>
</tr>
<tr>
<td>Gasoline</td>
<td>kilo litre</td>
<td>7000-10000</td>
</tr>
<tr>
<td>Steel</td>
<td>ton</td>
<td>260000</td>
</tr>
</tbody>
</table>

**1.1.6 Water quality**

Water quality deals with the physical, chemical and biological characteristics in relation to all other hydrological properties. Any characteristic of water that affects the survival, reproduction, growth and production of aquaculture species, influences management decisions, causes environmental impacts or reduces product quality and safety can be considered a water quality variable. Other factors being the same, aquaculture species will be healthier, production will be more, environmental impacts will be less and quality better in culture systems with ‘good’ water quality than in those with ‘poor’ water quality.
Water quality provides current information about the concentration of various solutes at a given place and time. Unequal distribution of water on the surface of the earth and fast declining availability of useable fresh water are the major concerns in terms of water quantity and quality. Water quality standards vary significantly due to different environmental conditions, ecosystems and intended human uses. Sediments are indicators of quality of overlying water and its study is a useful tool in the assessment of environmental pollution. Shraddha Sharma et al. have worked on the evaluation of water quality of Narmada River with reference to Physico-chemical parameters at Hoshayabad (U.P.).

The water quality ultimately determines the survival and growth of cultured animal and plants. The quantity and quality of phytoplankton is a good indicator of water quality. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs. Human activities are a major factor determining the quality of the surface and ground water through atmospheric pollution, effluent discharges, use of agricultural chemicals, eroded soils and land use. The use of water for different purposes is decided by assessment of its water quality parameters and calculation of its quality index.

1.1.7 Water quality index (WQI)

National Sanitation Foundation (NSF) water quality index is an excellent management and general administrative tool in communicating water quality information. This index has been widely field tested and applied to data from a number of different geographical areas all over the world in order to calculate. WQI
(water quality index) of various water bodies, is based on some very important parameters that can provide a simple indicator of water quality? Though a single number can not full give the complexity of the water quality and can be over generalized it does provide a standardized method for comparing the water quality of various water bodies. The WQI translates a wide variety of environmental indicators into a simple system. Easy-to-understand information helps general public to comply with environmental regulations.

The (WQI) water quality index is evaluated taking into account various parameters (DO, faecal coliform, pH, BODs, temperature change, total phosphorous, nitrate, turbidity and total dissolved solids) that influence the water quality. More weightage is given to important factors (e.g. coliform is weighed more heavily, DO is more important than pH etc.).

The water quality index formula takes the following form:-

\[
\text{Index score} = 100 - \left[ \sqrt{\frac{F_1^2 + F_2^2}{F_3^2}} \right] \times 1.732
\]

Where,

\( F_1 \) represents the number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.

\[
F_1 = \left[ \frac{\text{Number of failed variables}}{\text{Total number of variables}} \right] \times 100
\]

\( F_2 \) represents the number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest.
F_2 = \left( \frac{\text{No. of failed tests}}{\text{Total number of tests}} \right) \times 100

F_3 represents the amounts by which measurements depart from objectives. This is an asymptotic capping function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 & 100.

\[ F_3 = \frac{nse}{0.01 \cdot nse + 0.01} \]

The nse variables represents the amount by which water quality is out of compliance. This is calculated by summing the departures of individual tests from their objectives and dividing by the total number of tests:

\[ nse = \frac{\sum_{i=1}^{n} \text{departure}_i}{\text{of tests}} \]

For the cases in which the test value must not exceed the objective:

\[ \text{departure}_i = \left( \frac{\text{Failed test}_i}{\text{Objective}_i} \right) - 1 \]

For the cases in which the test value must not fall below the objective:

\[ \text{departure}_i = \left( \frac{\text{Objective}_i}{\text{Failed Test}_i} \right) - 1 \]

For the cases in which the objective is zero

\[ \text{departure}_i = \text{failed test}_i \]

Departures are equivalent to the number of times by which a concentration is greater than (or less than) the objective.

\[ \text{WQI} = \frac{I_1 \cdot W_1 + \cdots + I_n \cdot W_n}{W_1 + \cdots + W_n} \]
Where \( I_i \) = unit indices;
\( W_i \) = weight of the \( i^{th} \) parameter;
\( n \) = number of parameters

Or, it can also be written as

\[
\text{NSF} \quad \text{WQI} = \sum_{i=1}^{n} W_i I_i
\]

Where

\( I_i \) is the sub-index for \( i^{th} \) water quality parameters

\( W_i \) is the weight (in terms of importance) associated with \( i^{th} \) water quality parameter.

**Table-1.1: Drinking water quality standards as recommended by USPH WHO & ISI.**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>USPH Standard</th>
<th>WHO Standard</th>
<th>ISI Standard (IS : 2296-1963)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>Colourless</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Odour</td>
<td>Odourless</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Taste</td>
<td>Tasteless</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pH</td>
<td>6.0-8.5</td>
<td>6.5-9.2</td>
<td>6.0-9.0</td>
</tr>
<tr>
<td>D.O.</td>
<td>4.0-6.0</td>
<td>-</td>
<td>3.0</td>
</tr>
<tr>
<td>T.D.S.</td>
<td>500</td>
<td>500</td>
<td>-</td>
</tr>
<tr>
<td>Cl</td>
<td>250</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>SO(_4)</td>
<td>250</td>
<td>200</td>
<td>1000</td>
</tr>
<tr>
<td>NO(_3)</td>
<td>&lt; 10</td>
<td>45</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>1.5</td>
<td>0.5</td>
<td>3.0</td>
</tr>
<tr>
<td>PO(_4)</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ca</td>
<td>100</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>Mg</td>
<td>30</td>
<td>150</td>
<td>-</td>
</tr>
<tr>
<td>C.O.D.</td>
<td>40</td>
<td>10</td>
<td>-</td>
</tr>
</tbody>
</table>
Classification Criteria standards based on NSF-WQI

<table>
<thead>
<tr>
<th>NSF-WQI</th>
<th>Description</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>91-100</td>
<td>Excellent</td>
<td>A</td>
</tr>
<tr>
<td>71-90</td>
<td>Good</td>
<td>B</td>
</tr>
<tr>
<td>51-70</td>
<td>Medium</td>
<td>C</td>
</tr>
<tr>
<td>26-50</td>
<td>Bad</td>
<td>D</td>
</tr>
<tr>
<td>0-25</td>
<td>Very bad</td>
<td>E</td>
</tr>
</tbody>
</table>

1.1.8 Water quality parameters (physico-chemical characteristics)

Water quality parameters provide important information about the health of a water body. These parameters are used to find out if the quality of water is good enough for drinking water recreation, irrigation and aquatic life. The scientists have devised various water quality parameters and their seasonal variation for measuring the pollution & purity of water which are as follows:

1.1.8.1 Alkalinity

It refers to how well a water body can neutralize acids. Alkalinity measures the amount of alkaline compounds in water, such as carbonates (CO$_3^{2-}$), bicarbonates (HCO$_3^-$) and hydroxides (OH$^-$). These compounds are natural buffers that can remove excess hydrogen ions that have been added from sources such as acid rain or acid mine drainage. Alkalinity mitigates or relieves metals toxicity by using available HCO$_3^-$ & CO$_3^{2-}$ to take metals out of solution, thus making it unavailable to fish. Alkalinity is affected by the geology of the watershed; watersheds containing limestone will have a higher alkalinity than watersheds where granite is predominant.
Alkalinity is not a pollutant. It is a total measure of the substances in water that have “acid-neutralizing” ability. Alkalinity indicates a solution’s power to react with acid & “buffer”. Alkalinity is important for fish and aquatic life because it protects or buffers against pH changes and makes water less vulnerable to acid rain.

1.1.8.2 Turbidity

Turbidity is a measure of how clear the water is. Total solids refer to the particles that are suspended or dissolved in the water. These suspended solids decrease the amount of light that passes through the water, thus decreasing its clarity. Turbidity and total suspended solids are generally indicators of the effects of storm water runoff, construction, agricultural practices, erosion, discharges or other activities such as boating, jet skiing or bottom feeding animals. In developed water sheds with high proportions of impervious surfaces such as roof tops, parking lots and roads, turbidity and total suspended solids often increase sharply during a rainfall.

Turbidity is a measure of the cloudiness of water, the cloudier the water the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt and organic matter, by plankton and other microscopic organisms that interfere with the passage of light through the water. Turbidity is closely related to TSS but also includes plankton and other organisms. Turbidity itself is not a major health concern, but high turbidity can interfere with disinfection and provide a medium for bacterial growth. It may also indicate the presence of microbes. High turbidity can be caused by soil erosion, urban run-off and high flow rates.
1.1.8.3 Colour

The appearance of colour in drinking water is caused by the absorption of certain wavelengths of normal white light by dissolved or colloidal dispersed substances, by fluorescence in the visible wavelength region from substances that absorb white or ultra violet light, by the presence of coloured suspended solids, and by the preferential scattering of short wavelengths of light by the smallest suspended particles. Colour measured in water that contains suspended matter is defined as “apparent colour”; “true colour” is measured in water samples from which particulate matter has been removed by centrifugation. In general, the true colour of a given water sample is substantially less than its apparent colour.

Colour may occur in water for any one or more of several seasons. It may be due to the presence of coloured organic substances originating in the decay or aqueous extraction of natural vegetation, such as in soil run-off, the presence of metals such as iron, manganese & copper which are abundant in nature, are weathered from rock or corroded from distribution systems by water, and are naturally coloured; or the presence of highly coloured industrial wastes, the most common of which are pulp and paper and textile wastes.

1.1.8.4 Odour & Taste

Odour and taste are associated with the presence of living microscopic organisms; or decaying organic matter inducing weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons. This taste is imparted to fish, rendering them unpalatable. While chlorination dilutes odour and taste caused
by some contaminants, it generates a foul odour itself when added to waters polluted with detergents, algae and some other wastes.

**1.1.8.5 Density**

Density is an indicator of the physical presence of chemicals in water. The density of water is related to salt content and water temperature. This is very useful parameters to measure because the salinity of a body of water is one of the main factors determining what organisms will be found there.

**1.1.8.6 Electrical conductivity**

Conductivity is a measure of how well water can pass an electric current. It is an indirect measure of the presence of the inorganic dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron & aluminium. The presence of these substances increase the conductivity of a body of water. Organic substances like oil, alcohol and sugar do not conduct electricity very well, and thus have a low conductivity in water. E.C of H$_2$O is a good indicator of pollution as most of the soluble pollutants exist as ions in H$_2$O.

Inorganic dissolved solids are essential ingredients for aquatic life. They regulate the flow of water in and out of organisms cells and are building blocks of the molecules necessary for life. A high concentration of dissolved solids, however, can cause water balance problems for aquatic organisms and decrease dissolved oxygen levels.

E.C. is a measure of the concentration of ion in solution. E.C. is temperature dependent. It is the reciprocal quantity and measures a material’s ability to conduct an electric current. It is commonly represented by the Greek letter $\sigma$ (sigma), but $\kappa$
(kppa) or γ (gamma) are also occasionally used, unit is siemens per metre. It is an excellent indicator of TDS which is a measure of salinity that affects the taste of potable water.

1.1.8.7 pH

pH measures hydrogen ion concentration in water and is presented on a scale from 0 to 14. A solution with a pH value of 7 is neutral; with a pH value less than 7 is acidic; with a pH value more than 7 is basic. Natural waters usually have a pH between 6 and 9. The pH of natural waters can be made acidic or basic by human activities such as acid mine drainage and emissions from coal-burning power plants and heavy automobile traffic.

The pH of water is critical to the survival of most aquatic plants and animals. Testing water samples for total alkalinity measures the capacity of the water to neutralize acids. This test is important in determining the estuary’s ability to neutralize acidic pollution from rainfall or waste water. Unanticipated decreases in pH could be indications of acid rain, run-off from acidic soils or contamination by agricultural chemicals.

1.1.8.8 Hardness

Hardness of water generally refers to the presence of chloride, sulphate, carbonate, bicarbonate etc. salt of calcium and magnesium. In household use, these cations (ions with a charge greater than +1) can prevent soap from sudsing and leave behind a white scum in bathtubs. In the aquatic environment, calcium and magnesium help keep fish from absorbing metals, such as lead, arsenic & cadmium, into their blood stream through their gills. Therefore, the harder the
water, the less easy it is for toxic metals to absorb onto gills. Water with 50ppm of hardness is considered to be soft. Hardness of 300ppm is however, permissible for domestic use, whereas it should be 2 to 80 ppm for boiler feeders, 10 to 250 ppm for various food processing industries and 0.05 ppm for laundry & textile industries. For agriculture, an upper limit of 150 ppm is usually recommended.

1.1.8.9 Total solids

Total solids are a measure of the suspended and dissolved solids in water. Suspended solids are those that can be retained on a water filter and are capable of settling out of the water column onto the stream bottom when stream velocities are low. They include silt, clay, plankton, organic wastes and inorganic precipitates such as those from acid mine drainage. Dissolved solids are those that pass through a water filter. They include some organic materials, as well as salts, inorganic nutrients and toxins.

The concentration of dissolved solids in stream water is important because it determines the flow of water in and out of the cells of aquatic organisms. Also, some dissolved inorganic elements such as nitrogen, phosphorus and sulphur are nutrients essential for life. Low concentrations of total solids can result in limited growth of aquatic organisms due to nutrient deficiencies. Elevated level of total solids however, can lead to eutrophication of the stream or increased turbidity. Both eutrophication and increased turbidity result in a decrease in stream water quality.

1.1.8.10 Total dissolved solids (TDS)

TDS is a measure of the combined content of all inorganic & organic substances contained in a liquid in; molecular, ionized or micro-granular (colloidal
sol) suspended from. Generally the operational definition is that the solids must be small enough to survive filtration through a sieve of the size of two micrometer. Total dissolved solids are normally discussed only for freshwater systems, as salinity comprises some of the ions constituting the definition of TDS.

The principal application of TDS is in the study of water quality of streams, rivers & lakes although TDS is not generally considered a primary pollutant. It is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. Primary sources for TDS in receiving waters are agricultural and residential runoff, leaching of soil contamination and point source water pollution discharge from industrial or sewage treatment plants. The most common chemical constituents are calcium, phosphates, nitrates, sodium, potassium and chloride which are found in nutrient run-off, general storm water run-off and run off from snowy climates where road de-icing salts are applied. The chemicals may be cations, anions, molecules or agglomerations on the order of one thousand or fewer molecules, so long as a soluble micro-granule is formed.

More exotic and harmful elements of TDS are pesticides arising from surface run-off certain naturally occurring TDS arise from the weathering and dissolution of rocks and soils.

1.1.8.11 Temperature

Water temperature is a controlling factor for aquatic life it controls the rate of metabolic activities, reproductive activities and therefore, life cycles. If stream temperatures increase, decrease or fluctuate too widely, metabolic activities may
speed up, slow down, mal function, or stop altogether. There are many factors that can influence the stream temperature. Water temperatures can fluctuate seasonally, daily and even hourly, especially in smaller sized streams. Water temperature is also influenced by the quantity and velocity of stream flow. The sun has much less effect in warming the waters of streams with greater and swifter flows than of streams with smaller, slower flows. Temperature affects the concentration of dissolved oxygen in a water body. Oxygen is more easily dissolved in cold water.

1.1.8.12 Dissolved oxygen (D.O.)

D.O. is the amount of oxygen dissolved in the water. D.O. is a very important indicator of a water body’s ability to support aquatic life. Fish “breathe” by absorbing dissolved oxygen through their gills. Oxygen enters the water by absorption, directly from the atmosphere or by aquatic plant and algae photosynthesis. Oxygen is removed from the water by respiration and decomposition of organic matter. The amount of D.O. in water depends on several factors, including temperature (the colder the water, the more oxygen can be dissolved); the volume and velocity of water flowing in the water body; and the amount of organisms using oxygen for respiration. The amount of oxygen dissolved in water is expressed as a concentration, in milligrams per litre (mg/l) of water. Human activities that affect D.O. levels include the removal of riparian vegetation, runoff from roads and sewage discharge. D.O. in natural & waste water depends on the physical, chemical & biological activities in the water body.

In cold water D.O. can reach concentrations upto 10ppm (parts per million); even less can be held in warm water. Bacteria keep the water depleted in D.O. as
long as there is dead organic matter to support their growth. Fish and shell fish are killed when the D.O. drops below 2 or 3ppm; some are less tolerant at even higher DO levels. Even a moderate amount of sewage, added to natural waters containing at most 10ppm D.O., can deplete the water of its oxygen and cause highly undesirable consequences well beyond those caused by the introduction of pathogens. The WHO (World Health Organization) suggested the standard of D.O. is > 5.00 mg/l. WHO specifies minimum value under the D.O. test as 6.5 mg/l and any value above 6.5 is considered as safe for drinking.

1.1.8.13 B.O.D. (Biological Oxygen Demand)

It is the amount of dissolved oxygen that is consumed by aerobic, heterogeneous populations of micro-organisms to oxidize or degrade the carbonaceous and nitrogenous components of bio-degradable organics in water. Excessive BOD loads are detrimental for the quality of river water as the resulting low DO concentration makes the river unsuitable for the life of flora & fauna. BOD is one of the key variables in water-quality models. Researchers and engineers use it to evaluate the biological and chemical conditions of rivers, to model the dissolved oxygen dynamics & to study the effects of releases in rivers from waste water treatment plants, factories, farms etc. A BOD test tells how much oxygen is being consumed.

BOD is a measure of the amount of organic material in the water, in terms of how much oxygen will be required to break it down biologically, chemically or both. The higher the BOD measure, the greater is the likelihood that dissolved oxygen will be depleted in the course of breaking it down. A high BOD causes so
much oxygen depletion that animal life is severely limited or precluded. A typical BOD value for raw sewage would be around 250ppm.

Some organic materials, such as chlorinated hydrocarbons, that are manufactured by industrial processes cannot be used as food by bacteria and therefore do not contribute to the BOD. As per WHO standard for BOD test, the maximum value under BOD should be 2mg/l for ensuring safety of water for drinking purposes. BOD values are expressed in milligrams of oxygen per litre of water. Pure water saturated with air at 25ºC contains 0.0084g, or 8.4mg, of oxygen per litre.

1.1.8.14 COD (Chemical Oxygen Demand)

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% 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 (19th Ed. Standard methods 1995).

COD is used as an indicator of Natural Organic Matter (NOM). The COD refers to the oxygen used up in converting organic wastes to inorganic materials. When the COD & BOD levels begin to overtake the DO levels then rivers begin to die. As per WHO standard for COD test the maximum value should be 50 mg/l.
1.1.8.15 Faecal Coliform Bacteria

These non-pathogenic bacteria are present in the faces and intestinal tracts of humans and other warm-blooded animals and can enter water bodies from human and animal waste. If a large number of faecal coliform bacteria (over 200 colonis/100 ml of water sample) are found in water, it is possible that pathogenic (disease or illness causing) organisms are also present in the water. Pathogens are typically present in such small amounts that it is impractical to monitor them directly. High concentrations of the bacteria in water may be caused by septic tank failure, poor pasture and animal keeping practices, pet waste and urban runoff.

1.1.8.16 Na⁺

The percentage of Na⁺ ions is often taken as important parameter deciding the suitability of water for irrigation. The source of sodium in water has been weathering of rocks. The concentration of sodium ions becomes remarkably high in saline & blackish water. This high concentration limits the biological diversity due to osmotic stress. Sodium salts have been highly soluble in water and causes softness.

If sodium content, in the form of chloride and sulphate, is very high, it makes the water salty in taste and unfit for human consumption. High sodium content in irrigation water brings about budding of soil. Because of this water intake of soil gets reduced and it becomes hard in which germination of seed becomes difficult.
1.1.8.17 Fe

Surface water generally contains less than 1ppm of Fe. Some ground waters and acid surface drainage may contain much higher levels of Fe. Water containing > 2ppm Fe cause staining of clothes (while washing) and porcelain, and imparts a bitter astringent taste. Fe may be in dissolved state, in a colloidal state that may be peptised by organic matter, in inorganic or organic complexes or in relatively coarse suspended particles. It may be either in the Fe$^{2+}$ or Fe$^{3+}$ state, suspended or filterable. The permissible limit for filterable Fe in drinking water is 0.3ppm.

1.1.8.18 Chromium

Cr salts are used in industrial processes and enter water bodies through discharge of waters. Chromate compounds are often added to cooling water for corrosion control. The normal level of Cr (VI) in drinking water is 3 to 40 ppb, the permissible level being 50 ppb.