Chapter 1
INTRODUCTION

1.1 Background

Water is the most basic requirement for social and economic development of human societies. This is basic requirement of healthy life, and a fundamental right of the human being to live quality life. The rapid increase in world population and the increasing demand of food to feed this population has made this planet natural resources deplete. As a result of this long term effect of man upon his environment are being questioned. Environment means an organisms surrounding. As water is a part of environmental system so the preservation of quality of environment and ecological balance is a prime consideration. Much of the current concern with regards to environmental quality is focused on water because of its importance in maintaining the human health and health of the ecosystem. Fresh water is finite resource, essential for agriculture, industry and even human existence, without fresh water of adequate quantity and quality, sustainable development will not be possible.

The water quality and human health are closely related. The rapid development in agriculture, land mining, urban and civic globalization, and industrialization activities, is causing the river water contamination with hazardous waste; and wastewater is becoming a common phenomenon. The domestic waste from each building along with the effluent of small scale industries is disposed into the open drains and gutters which ultimately enter into the rivers. The quality of water is mainly deteriorated by human activities. Waste comprises liquid waste discharged by domestic residences, commercial properties, industry or agriculture and can encompass a wide range of potential contaminants and concentrations (APHA 1998).

The increasing demands and rising standards for drinking water, together with the diffuse pressure on groundwater resources due to urban development and agricultural
practices, makes the management of many drinking-water supply systems a complex interplay between economic, social and technical factors (Epting et al., 2008; Peters, 2009)\(^2\). The rapid growth of urban areas has affected ground and surface water quality due to over exploitation of resources and improper waste disposal practices. So it is absolutely necessary to ascertain the portability of water before it is used for human consumption. The water used for drinking purpose should be free from toxic elements, living and non-living organisms and excess amount of minerals that may be hazardous to health. Water pollution has many causes and characteristics (Manivanan, R., 2008)\(^3\). Natural phenomena such as volcanoes, storms, earthquakes etc. also cause major changes in water quality.

1.2 Water Pollution

1.2.1 Introduction

Water they say is life, and indeed they were right. With about 70% of the earth’s cover being water, it undeniably becomes one of our greatest resources. Water Pollution is largely a problem due to rapid urbanization and industrialization. The large scale urban growth due to increase in population or migration of people from rural areas to urban areas has increased domestic effluents while industrial development manifested either due to setting up of new industries or expansion of the existing industrial establishments resulting of generation copious volume of industrial effluents. Human activity and cattle grazing also add to the river pollution. Pollution of river bodies has become a major and global problem that is becoming critical in developing nations of the world because of inadequacy or quality water for drinking and domestic purposes. This makes pollution of river bodies a global issue that has no respect for national or international boundaries (Gupta, RC, 2012)\(^4\). Water pollution not only affects water quality but also threatens human health, economic development, and social prosperity (Milovanovic, 2007)\(^5\). River basins are highly vulnerable to pollution due to absorption and transportation of domestic, industrial, and agricultural waste water; therefore, it is significant to control water pollution and monitor water quality (Simeonov, 2003)\(^6\).

1.2.2 Definition
World Health Organization described water pollution as - “The change in the physical, chemical and the biological properties of water or such discharge of liquid, gaseous or solid substances into water as well, which likely to creates nuisance or render such water harmful to public health safety or welfare or domestic commercial industrial agricultural or other legitimates uses of water including changes in temperature due to discharge of hot-water”.

In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewater from different sources. Sewage is created by residences, institutions, hospitals and commercial and industrial establishments (APHA 1998). Raw influent includes household waste liquid from toilets, baths, showers, kitchens, sinks, and so forth that is disposed of via sewers. In many areas, sewage also includes liquid waste from industry and commerce. As rainfall runs over the surface of roofs and the ground, it may pick up various contaminants including soil particles and other sediment, heavy metals, organic compounds animal waste and oil and grease (FWPCA 1998). Consequently, the problem was taken up when effluents of these industries go into the water system and change the physicochemical quality of water and make it unfit for drinking and other uses (Kumar Ashok, 2010).
1. 2. 3 Sources

- **Factory waste**

  Industries produce huge amount of waste which contains toxic chemicals and pollutants which can cause air pollution and damage to us and our environment. They contain pollutants such as lead, mercury, sulphur, asbestos, nitrates and many other harmful chemicals. Many industries do not have proper waste management system and drain the waste in the fresh water which goes into rivers, canals and later in to sea. The toxic chemicals have the capability to change the colour of water, increase the amount of minerals, also known as Eutrophication, change the temperature of water and pose serious hazard to water organisms.

- **Household Sewage**

  The sewage and waste water that is produced by each household is chemically treated and released in to sea with fresh water. The sewage water carries harmful bacteria and chemicals that can cause serious health problems. Pathogens are known as a common water pollutant; the sewers of cities house several pathogens.
and thereby diseases. Microorganisms in water are known to be causes of some very deadly diseases and become the breeding grounds for other creatures that act like carriers. These carriers inflict these diseases via various forms of contact onto an individual. A very common example of this process would be Malaria.

• Mining activities

Mining is the process of crushing the rock and extracting coal and other minerals from underground. These elements when extracted in the raw form contain harmful chemicals and can increase the amount of toxic elements when mixed up with water which may result in health problems. Mining activities emit several metal waste and sulphides from the rocks and is harmful for the water.

• Chemical fertilizers and Pesticides

Chemical fertilizers and pesticides are used by farmers to protect crops from insects and bacteria’s. They are useful for the plants growth. However, when these chemicals are mixed up with water produce harmful for plants and animals. Also, when it rains, the chemicals mixes up with rainwater and flow down into rivers and canals which pose serious damages for aquatic animals.

• Leakage from sewer lines

A small leakage from the sewer lines can contaminate the underground water and make it unfit for the people to drink. Also, when not repaired on time, the leaking water can come on to the surface and become a breeding ground for insects and mosquitoes.
• **Urban development**

As population has grown, so has the demand for housing, food and cloth. As more cities and towns are developed, they have resulted in increased use of fertilizers to produce more food, soil erosion due to deforestation, increase in construction activities, inadequate sewer collection and treatment, landfills as more garbage is produced, increase in chemicals from industries to produce more materials.

• **Animal waste**

The waste produce by animals is washed away into the rivers when it rains. It gets mixed up with other harmful chemicals and causes various water borne diseases like cholera, diarrhea, jaundice, dysentery and typhoid.

1. 2. 4 Types

In developing parts of the world, water pollution is a big problem. Industry is usually not the major cause of water pollution in developing countries. Often, the only water available for drinking in these countries is polluted with sewage and agricultural runoff, which can spread waterborne diseases. To prevent water pollution, people must understand where pollutants come from.

**Point-Source Pollution**

Thinking of water pollution, you probably can think of a single source, such as a factory, a wastewater treatment plant, or a leaking oil tanker. These are all examples of pollution discharged from a single source. Point-source pollution can often be identified and traced to a source. But even when the source of pollution is known, enforcing cleanup is sometimes difficult. Following are some additional examples of point-source pollution.

• Leaking septic-tank systems
• Leaking storage lagoons for polluted waste
• Leaking underground storage tanks that contain chemicals or fuels such as gasoline
• Polluted water from abandoned and active mines
• Water discharged by industries
• Public and industrial wastewater treatment plants

Nonpoint-Source Pollution

These come from many different sources that are often difficult to identify. For example, a river can be polluted by runoff from any of the land in its watershed. If a farm, a road, or any other land surface in a watershed is polluted, runoff from a rainstorm can carry the pollution into a nearby river, stream, or lake. Table 1.1 lists some additional causes of nonpoint pollution. Since, nonpoint pollutants can enter bodies of water in many different ways, they are extremely difficult to regulate and control. The accumulation of small amounts of water pollution from many sources is a major pollution problem.

Water pollutants also include both organic and inorganic factors. Organic factors include volatile organic compounds, fuels, waste from trees, plants etc. Inorganic factors include ammonia, chemical waste from factories, discarded cosmetics etc. The water that travels via fields is usually contaminated with all forms of waste inclusive of fertilizers that it swept along the way. This infected water makes its way to our water bodies and sometimes to the seas endangering the flora, fauna and humans that use it along its path.
<table>
<thead>
<tr>
<th>Type of pollutant</th>
<th>Agent</th>
<th>Major sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathogens</td>
<td>Disease-causing organisms, such as bacteria, viruses, protozoa, and parasitic worms</td>
<td>Mostly nonpoint sources; sewage or animal faeces, livestock feedlots, and poultry farms; sewage from overburdened wastewater treatment plants</td>
</tr>
<tr>
<td>Organic matter</td>
<td>Animal and plant matter remains, faeces, food waste, and debris from food-processing plants</td>
<td>Mostly nonpoint sources</td>
</tr>
<tr>
<td>Organic chemicals</td>
<td>Pesticides, fertilizers, plastics, detergents, gasoline and oil, and other materials made from petroleum</td>
<td>Mostly nonpoint sources; farms, lawns, golf courses, roads, wastewater, unlined landfills, and leaking underground storage tanks</td>
</tr>
<tr>
<td>Inorganic chemicals</td>
<td>Acids, bases, salts, and industrial chemicals</td>
<td>Point sources and nonpoint sources; industrial waste, road surfaces, wastewater, and polluted precipitation</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>Lead, mercury, cadmium, and arsenic</td>
<td>Point sources and nonpoint sources; industrial discharge, unlined landfills, some household chemicals, and mining processes; heavy metals also occur naturally in some groundwater</td>
</tr>
<tr>
<td>Physical agents</td>
<td>Heat and suspended solids</td>
<td>Point sources and nonpoint sources; heat from industrial processes and suspended solids from soil erosion</td>
</tr>
</tbody>
</table>

*Table 1.1: Causes of nonpoint pollution*
The current scenario has led to a consciousness about water preservation and efforts are being made on several levels to redeem our water resources. Industries and factory setups are restricted from contaminating the water bodies and are advised to treat their contaminated waste through filtration methods. People are investing in rainwater harvesting projects to collect rainwater and preserve it in wells below ground level.

1.2.5 Effects

Human infectious diseases are among the most serious effects of water pollution, especially in developing countries, where sanitation may be inadequate or non-existent. Out of all the physical environments of man, water influences human health very prominently and significantly. Furthermore the impact of water on human health are both direct and indirect. The direct impacts of water on health are derived from the quality of water consumed and the indirect impacts pertain to the quantity used for personal, domestic and household hygiene. The general observation of the international agencies is that the impact on health caused by the poor water supply is felt the most by the urban-poor as they typically lack access to services at levels which promote good health, often use water supplies of lower quality and commonly pay more per unit volume. The low-income communities are supposed to be at the greatest risk from water-related diseases. The impact on health caused by poor water supply is felt enormously by the urban economically weaker section of the society and hence warrants the need for surveillance programmes to focus mainly on the weaker group of the society. Water quality is a key factor in promoting good health as water may contain disease-causing microorganisms (pathogens) or chemicals that are toxic.

**Waterborne Infectious Diseases**

Developed countries are not immune to the problem of infectious waterborne diseases. Waterborne diseases occur when parasites or other disease-causing microorganisms are transmitted via contaminated water, particularly water contaminated by pathogens originating from excreta. These include typhoid, intestinal parasites, and most of the enteric and diarrheal diseases caused by bacteria,
parasites, and viruses. Among the most serious parasitic diseases are amoebiasis, giardiasis, ascariasis, and hookworm. Transmission of disease agents such as bacteria and cysts via contaminated but poorly treated municipal water is more common than it should be.

**Nutrient Pollution**

The discharges of nitrogen, phosphorus, and other nutrients come from agriculture, waste disposal, river line development, and fossil fuel use. Once nutrient pollution reaches the river line, it stimulates harmful overgrowths of algae, which can have direct toxic effects and ultimately result in low-oxygen conditions. Certain types of algae are toxic and overgrowths of these algae result in "harmful algal blooms," affecting marine mammals, and humans. The result can be illness and sometimes death.

**Chemical Contamination**

Over the years, many types of chemicals have gotten into our waterways - and they continue to do so today. Severe chemical spills and leaks into surfaces waters usually have an immediate effect on aquatic life (fish kills, etc.). There are a few broad categories of water pollution effects related to chemicals that are worth exploring further, which we do below.

**Pesticides**

Pesticides have been found in well water in India. Pesticide contamination of drinking water is a particular problem in rural agricultural areas where pesticide use is heavy and drinking water supplies come directly from groundwater or surface water. Pesticides can migrate via water into the food chain as well, ultimately being consumed by humans or animals in food.

In terms of general human health effects, pesticides can.

- Affect and damage the nervous system;
• Cause liver damage;
• Damage DNA and cause a variety of cancers;
• Cause reproductive and endocrine damage;
• Cause other acutely toxic or chronic effects.

Oil and Petroleum Chemicals

Exposure to oil or its constituent chemicals can alter the ecology of aquatic habitats and the physiology of marine organisms. Scientists know that oil (or chemical components of oil) can seep into marsh and sub-tidal sediments and lurk there for decades, negatively affecting marsh grasses, marine worms, and other aquatic life forms that live in, on, or near the sediment.

Mercury

In the water, the elemental mercury is converted to methylmercury by certain bacteria, after which it moves up the food chain of fish gobbling each other up. The effects of mercury on humans are already pretty well understood. Young children and fetuses are most at risk because their systems are still developing. Exposure to mercury in the womb can cause neurological problems, including slower reflexes, learning deficits, delayed or incomplete mental development, autism, and brain damage. Mercury in adults is also a problem, causing:

• Central nervous system effects like Parkinson's disease, multiple sclerosis, and Alzheimer's disease;
• Heart disease;
• Causing death or irreversibly damaging areas of the brain.

Other Chemicals

Tens of thousands of chemicals are used in industrial processes and are found in car-maintenance products, household cleaners, toiletries, and many other consumer products. Our current regimes for controlling whether these chemicals get into the
environment are not sufficient for keeping them out of the water, and the potential myriad effects are worrisome.

Once the contaminant enters the water source, it is a difficult and expensive to remove them. Unplanned and injudicious disposal of municipal waste are causing pollution of water bodies. The industries are also falling in the same line by not following regulation of establishing the effluent treatment plants, and the ecological status of water while these are not deemed to be pollution.

Identification and quantification of contaminants in the water and understanding the contaminant source is crucial to planning, mitigation and cleanup process of rivers. This also helps to mitigate the health hazards that these contaminants can cause to the civilization.

1.3 Ground Water

Groundwater is water located beneath the surface in soil and in geological formations. Sources of groundwater include seepage from the land surface, such as rainwater, snowmelt and water also that permeates down from the bottom of some lakes and rivers. Groundwater is a very important source of freshwater, making up 97 percent of the world’s accessible freshwater reserves. Pollutants usually enter groundwater when polluted surface water percolates down from the Earth’s surface. Any pollution of the surface water in an area can affect the groundwater. Pesticides, herbicides, chemical fertilizers, and petroleum products are common groundwater pollutants. Leaking underground storage tanks are another major source of groundwater pollution. As underground storage tanks age, they may develop leaks, which allow pollutants to seep into the groundwater. Other sources of groundwater pollution include septic tanks, unlined landfills, and industrial wastewater lagoons.

Groundwater is an increasingly important resource all over the world. The term groundwater is usually reserved for the subsurface water that occurs beneath the water table in soils and geologic formation that are fully saturated. It supports drinking water supply; livestock needs irrigation, industrial and many commercial activities. Groundwater is generally less susceptible to contamination and pollution
when compared to surface water bodies. Also the natural impurities in rainwater, which replenishes groundwater systems, get removed while infiltrating through soil strata. But, in India, where groundwater is used intensively for irrigation and industrial purposes, a variety of land and water based human activities are causing pollution of this precious resource. Importantly, groundwater can also be contaminated by naturally occurring sources. Soil and geologic formation containing high levels of heavy metals can leach those metals into groundwater. This can be aggravated by over-pumping wells, particularly for agriculture. Pollution caused by fertilizers and pesticides used in agriculture, often dispersed over large areas, is a great threat to fresh groundwater ecosystems (Mahananda, 2010).

Groundwater pollution is one of the most challenging environmental problems that the world faces. Even if groundwater pollution could be stopped tomorrow, some groundwater would remain polluted for generations to come. The process for some aquifers to recycle water and purge contaminants can take hundreds or thousands of years. Groundwater is also difficult to decontaminate because the water is dispersed throughout large areas of rock and sand. Pollution can cling to the materials that make up an aquifer, so even if all of the water in an aquifer were pumped out and replaced with clean water, the groundwater could still become polluted.

The mechanism of ground water pollution is quite different than that of surface water and is more complicated. Unlike the surface water pollution, the pollution of ground water is difficult to detect. The process of ground water pollution is comparatively much slow and the time lag between pollution discharge at land and when pollutants reach groundwater may be several years or decades. Surface and ground water gets polluted by addition of substances to the environment which are toxic to organisms (includes toxic heavy metals, radioactive wastes, which form acid rain in the atmosphere) or which facilitates the growth of organisms (addition of plant nutrients to water supplies from human, industrial and agricultural waste), and are considered undesirable in our water supplies.

The problem of ground water pollution in several parts of country has become so acute that unless urgent steps for detailed identification and abatement are taken, extensive ground water resources may be damaged. The quality of ground water
depends on a large number of individual hydrological, physical, chemical and biological factors. Physicochemical factors are very important in estimating the constituents of water and concentration of pollutant or contaminant. Water quality generally means the component of water which must be present for optimum growth of aquatic organisms. The determinant of good growth in water body includes dissolved oxygen, hardness, turbidity, alkalinity, nutrients, temperature, etc. Conversely, other parameters like biological oxygen demand, and chemical oxygen demand indicate pollution level of a given water body. Accurate assessment depends on the results generated by specific monitoring activities which define the physical, chemical and biological condition of the resource (Khanna, 2010).

1.4 Surface Water

When we think of Earth's water resources, we think of huge oceans, lakes, and rivers. Water resources like these are called surface waters. The most obvious type of water pollution affects surface waters. For example, a spill from an oil tanker creates an oil slick that can affect a vast area of the ocean. The natural processes, such as precipitation inputs, erosion, weathering of crustal materials, as well as the anthropogenic influences, viz, urban, industrial and agricultural activities, calling for increasing exploitation of water resources, together determine the quality of surface water in a region.

Causes of surface water pollution

Surface water pollution occurs when hazardous substances come into contact and either dissolve or physically mix with the water. Because of the close relationship between sediments and surface water, contaminated sediments are often considered part of surface water contamination. Sediments include the sand and soils on the bottom of an ocean, lake, or stream. Surface water can become contaminated in many ways. Surface water can be contaminated when hazardous substances are discharged directly from an outfall pipe or channel or when they receive contaminated storm water runoff. Direct discharges can come from industrial sources or from certain older sewer systems that overflow during wet weather. Storm water runoff becomes contaminated when rain
water comes into contact with contaminated soil and either dissolves the contamination or carries contaminated soil particles. Surface water can also be contaminated when contaminated groundwater reaches the surface through a spring, or when contaminants in the air are deposited on the surface water. Contaminated soil particles carried by storm water runoff or contaminants from the air can sink to the bottom of a surface water body, mix with the sediment, and remain.

**Effects of contaminated surface water**

Surface water contamination can change the entire water chemistry and may negatively affect all levels of an ecosystem. It can impact the health of lower food chain organisms and, consequently, the availability of the food supply up through the food chain. It can also impact the health of wetlands and impair their ability to support healthy ecosystems, control flooding, and filter pollutants from storm water runoff. Contaminated surface water can also affect the health of animals and humans when they drink or bathe in contaminated water or, for aquatic organisms, when they ingest contaminated sediments. One of the major concerns associated with contaminated surface water is the ability of aquatic organisms, like fish, to accumulate and concentrate contaminants in their bodies. When other animals or humans ingest these organisms, they receive a much higher dose of contamination than they would have if they had been directly exposed to the original source of the contamination.

1.5 Water Quality

The water used for drinking purpose should be free from toxic elements, living and non-living organisms and excess amount of minerals that may be hazardous to health.

**The quality** of surface water is a very sensitive issue. As the quality of groundwater resources being seriously threatened due to increasing sources of pollution, it may not be possible to sustain long term growth and development in the study area. It is, therefore, essential to protect public health from hazards by taking ameliorative
measures regularly and in time by conducting regular ground water quality monitoring (Subba Rao, 2000)\textsuperscript{11}.

The addition of various kinds of pollutants and nutrients through the agency sewage, industrial effluents, agricultural run-off etc. into the water bodies brings about a series of changes in the physicochemical and characteristics of water. The deterioration of water quality in fresh water resources day-by-day at a faster rate is now a global problem. Discharge of toxic chemicals, over pumping of aquifer and contamination of water bodies with substance that promote algae growth are some of the today’s major cause for water quality degradation. Direct contamination of surface water with metals in discharges from mining, smelting and industrial manufacturing, is a long-standing phenomenon. Today there is trace contamination not only of surface water but also of groundwater bodies, which are susceptible to leaching from waste dumps, mine tailings and industrial production sites. Organic manure, municipal waste and some fungicides often contain fairly high concentration of heavy metals. Soils receiving repeated applications of organic manures, fungicides and pesticides have exhibited high concentration of extractable heavy metals and that thereby increase their concentration in runoff (Moore, 1998)\textsuperscript{12}, while falling as rain, water picks up small amounts of gases, ions, dust and particulate matter from the atmosphere. These added substances may be arbitrarily classified as biological, chemical (both organic and inorganic), physical and radiological impurities. They include industrial and commercial solvents, metal and acid salts, sediments, pesticides, herbicides, plant nutrients, radioactive materials, decaying animal and vegetable matter and living microorganisms, such as algae, bacteria and viruses. These impurities may give water a bad taste, colour, odor or turbidity and cause hardness, corrosiveness, staining or frothing. \textit{Water quality reflects the composition of water as affected by natural cause and man’s cultural activities expressed in terms of measurable quantities and related to intended water use.}

Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits. Therefore, the suitability of water sources for human consumption has been described in terms of Water quality index (WQI), which is one of the most effective ways to describe the quality of
water. WQI utilizes the water quality data and helps in the modification of the policies, which are formulated by various environmental monitoring agencies. It has been realized that the use of individual water quality variable in order to describe the water quality for common public is not easily understandable. That's why, WQI has the capability to reduce the bulk of the information into a single value to express the data in a simplified and logical form. It takes information from a number of sources and combines them to develop an overall status of a water system. They increase the understanding ability of highlighted water quality issues by the policy makers as well as for the general public as users of the water resources. The present study reviews some of the important water quality indices used in water quality assessment and provides their mathematical structure, set of parameters and calculations along with their merits and demerits, which are being used worldwide. To understand and evaluate water quality, several parameters of the water such as temperature, dissolved mineral content, and number of bacteria etc. are measured and analyzed. Selected characteristics are then compared to numeric standards and guidelines to decide if the water is suitable for a particular use. Few parameters of water quality can be identified at the source itself. These parameters include temperature, pH, dissolved oxygen, and electrical conductance (an indirect indicator of dissolved minerals in the water). Analyses of individual chemicals generally are done at a laboratory.

The most common dissolved substances in water are minerals or salts such as calcium, sodium, bicarbonate, and chloride; plant nutrients such as nitrogen and phosphorus; and trace elements such as selenium, chromium, and arsenic. Most of the common constituents are not considered harmful to human health, although some constituents can affect the taste, smell, or clarity of water. Dissolved gases such as oxygen are common in natural waters.

1.6 Water Quality Parameters

The biological, physical and chemical characterization of water is defined as water quality parameters. The primary bases for such characterization are parameters which relate to portability, safety of human contact and for health of ecosystem.
These parameters are also used as a measure of the water condition relative to the requirements and or to any human need or purpose. Few of the commonly observed/reported water quality parameters can be:

**pH**

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. Streams generally have a pH values ranging between 6 and 9. Changes in pH can change the aspects of water chemistry and may disrupt aquatic organisms.

**Alkalinity**

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.

**BOD**

The Biological Oxygen Demand, or BOD, is the amount of oxygen consumed by bacteria in the decomposition of organic material. It also includes the oxygen required for the oxidation of various chemical in the water, such as sulphides, ferrous iron and ammonia. BOD is determined by measuring the dissolved oxygen level in a freshly collected sample and comparing it to the dissolved oxygen level in a sample that was collected at the same time but incubated under specific conditions for a certain number of days.

**COD**
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.

**Conductivity**

Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, phosphate, sodium, magnesium, calcium, iron and aluminium.

**Dissolved Oxygen**

The DO concentration in a stream is the mass of the oxygen gas present, in milligrams per litre of water.

**Hardness**

Hardness is frequently used as an assessment of the quality of water supplies. The hardness of a water is governed by the content of calcium and magnesium salts (temporary hardness), largely combined with bicarbonate and carbonate and with sulphates, chlorides, and other anions of mineral acids (permanent hardness).

**Metals**

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.

**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.
Total Solids

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.

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, malfunction, or stop altogether. Temperature affects the concentration of dissolved oxygen in a water body. Oxygen is more easily dissolved in cold water.

Turbidity

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. Dissolved oxygen decreases in turbid water.

1.7 Water Quality Index

Water quality can be considered as a measure of its suitability for a defined use based on selected physical, chemical, and biological characteristics. To determine water quality, several characteristics of the water such as temperature, dissolved mineral content, and number of bacteria etc. are measured and analyzed. Selected characteristics are then compared to numeric standards and guidelines to decide if the water is suitable for a particular use.

Water quality of natural water (surface and ground) depends upon its time of measurement and location. It varies from place to place, across the seasons, with climate, and with the types of soils and rocks through which water moves. Water from multiple sources flow down the hills or rocks and convert into streams. This
water while flowing may cause dissolution of minerals in rocks and soil, percolate through organic material such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. The flowing water may also carry plant residues and sand, silt, and clay to rivers and streams making the water appear "muddy" or turbid. Evaporation of water from rivers and streams causes higher concentration of dissolved minerals. Each of these natural processes changes the water quality and potentially the water use.

The Water Quality Index (WQI) can be used to identify geographic areas with water quality problems. The WQI also allows "drilling down" from the overall score to scores for individual parameters and scores for individual seasons. The index can even be used to evaluate trends. Indexes can provide a general understanding of water quality conditions but they don't give the whole picture.

Adequate oxygen levels in water are a necessity for fish and other aquatic life.

Understanding quality of water from raw data can be complex considering the geology, and physical location of sampling sites. It becomes difficult to know whether a particular result acceptable or not if familiarity with the area where the sample was taken is not known. To augment the data with insightful inferences, Water Quality Index (WQI) is established. Water quality index helps in integrating data into a meaningful scale that helps the public and water managers better understand results. Indexes are established in particular to compare the data at multiple stations. Providing WQI scores for complex data may also increase public awareness and understanding of water quality concerns.

The WQI can be used identify the overall score, scores for individual parameters and scores for individual seasons. The index can even be used to evaluate trends. Besides being general in nature, most indexes are based on a pre-identified set of water quality constituents. A particular station may receive a good WQI score, and yet have water quality impaired by parameters not included in the index. A satisfactory WQI at a particular station does not necessarily mean that water quality was satisfactory at all times. However, a good score should indicate that poor water quality was not chronic for any of the included parameters.
Initially, WQI was developed by Horton (1965) in United States by selecting 10 most commonly used water quality variables like dissolved oxygen (DO), pH, coliforms, specific conductance, alkalinity and chloride etc. and has been widely applied and accepted in European, African and Asian countries. The assigned weight reflected significance of a parameter for a particular use and has considerable impact on the index. Furthermore, a new WQI similar to Horton’s index has also been developed by the group of Brown in 1970, which was based on weights to individual parameter. Recently, many modifications have been considered for WQI concept through various scientists and experts.

A general WQI approach is based on the most common factors, which are described in the following three steps:

**Parameter Selection**

This is carried out by judgment of professional experts, agencies or government institutions that is determined in the legislative area. The selection of the variables from the 5 classes namely oxygen level, eutrophication, health aspects, physical characteristics and dissolved substances, which have the considerable impact on water quality, are recommended.

**Determination of Quality Function (curve) for Each Parameter Considered as the Sub-Index**

Sub-indices transform to non-dimensional scale values from the variables of its different units (ppm, saturation percentage, counts/volume etc.).

**Sub-Indices Aggregation with Mathematical Expression**

This is frequently utilized through arithmetic or geometric averages.
However, a huge number of water quality indices viz. Weight Arithmetic Water Quality Index (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) etc. have been formulated by several national and international organizations. These WQI have been applied for evaluation of water quality in a particular area. Moreover, these indices are often based on the varying number and types of water quality parameters as compared with respective standards of a particular region. Water quality indices are accredited to demonstrate annual cycles, spatial and temporal variations in water quality and trends in water quality even at low concentrations in an efficient and timely manner. On the basis of reviewed literature, available indices have many variations and limitations based on number of water quality variables used and not accepted worldwide. Hence, it needs worldwide acceptability with varying number of water quality variables. Various WQI determination methods have been described herein.

1.8 Problem on hand

The hilly Himalayan region is blessed with adequately high rainfall but an overwhelmingly high proportion of the same is restricted to the monsoon season. This results in paucity of water during non-monsoon months together with high rates of surface run-off that cause heavy land degradation and erosion. Great concern has been expressed about backwardness of the Uttarakhand region. It is true that the environment of the region has degraded, forests have disappeared, many small streams and springs have dried up, agricultural holdings are hardly able to sustain the local population, traditional occupations have sharply diminished and new jobs are almost non-existent leading to migration to the plains. At the same time, it is also true that the region has never had a shortage of resources. Uttarakhand is not as backward as some other hilly areas of the country such as Purvanchal and Bundelkhand. The shortage of water and other essential items of livelihood, like fuelwood and fodder, has been a consequence of extensive deforestation, land use change and forest fire. Himalyan springs on which people depend, have dried up due to interference in their natural recharge caused mainly by deforestation.
Uttarakhand is regarded as a leading sacred destination for pilgrims from India and around the world. However, the state has also maintained its unique culture, developmental needs and educational progress. The growing demand of the region and corresponding urbanization has introduced many industries viz. pharmaceutical, textiles, toy making, colouring etc. They dispose the waste directly or indirectly into the river water, which affects the BOD, COD, turbidity and also causes the physico-chemical changes. Rivers are getting contaminated due to waste disposing into them. The majority of the river pollution is organic waste, sewage, trash, food, and human and animal remains. Over the past few years, city populations along the river banks have grown at a tremendous rate, while waste-control infrastructure has remained relatively unchanged.

As hardly any systematic groundwater study has been attempted in the region, it would be necessary to initiate basic groundwater monitoring, including water level monitoring through installation of shallow piezometers coupled with test drilling at few selected sites and conducting tests of soil infiltration characteristics for assessment of utilisable groundwater resources. Based on the information obtained from these studies, exploratory wells could be drilled at selected hydrogeologically feasible locations. This exercise would provide an estimate of the groundwater availability and insight for further groundwater development.

There are many agencies those have carried out variety of research work in the state of Uttarakhand and almost every research has concluded that the Water Quality is declining day by day and the health status of those depending on natural water sources is at risk. Various parameters of water like turbidity, BOD, COD etc… including quantity of unwanted elements like Fluorine, Mercury, Nitrogen etc… are all above allowed limits with respect to domestic purposes standards.
1.9 Importance and Scope

This research work is targeted towards the eastern zone of Doon Valley which includes villages around Song river (area of interest) namely – Gullarghati, Balawala, Nathuwala, Dhaneri, Badrena, Kalluwala, Misserwala, Harrawala, Doiwala, Bhaniyawala, Nakronda etc. The current scope of the research is intended to evaluate the quality of water being used at study areas for drinking as well as domestic purposes. It is learned from literature review and previous researches being undertaken (in and nearby areas) that both; ground water as well as surface water is being heavily used in mixed proportions to fulfill daily needs of surrounding population spread across numerous scattered (small and big) developments (villages, towns etc.).

It is also known by the fact that major factors affecting the quality of water are both physical and chemical parameters (together called as physicochemical parameters). This study will try to learn the presence of all such parameters and their intensity (quantity per volume) in water samples thus establishing the facts about usability of this water for drinking and domestic purposes.

Towards the end of the research, we shall be able to identify the pollutants and also determine the factors leading to the water pollution. We aim to establish some parameters that lead to water pollution at source, such that this water is being treated properly before consumption. We also aim to provide some water purification methods that will meet local needs and are available locally.
1. 10 Research Objectives

The major focus areas of the research would be as mentioned below:

a) Identification and Analysis of both physical and chemical parameters in both ground and surface water.
b) To establish the Water Quality Index (WQI) of different water samples collected from sample site.
c) To do a comparative analysis of Water Quality Index (WQI) in context to drinking water standards.
d) To identify the major contaminants in ground and surface water and their probable sources.
e) To observe the temporal and spatial variation in ground and surface water quality.
f) To suggest remedial measures to avoid ground and surface water contamination.

1. 11 Research Hypothesis

A hypothesis may be defined as a proposition or a set of proposition set forth as an explanation for the occurrence of some specified group of phenomena. Hypotheses are the specific predictions made about the independent and dependent variables in the study. Usually the literature review has given background material that justifies the particular hypotheses that needs to be tested. As the area of interest for research work is eastern periphery of Dehradun Valley and based upon previous researches done in the said area there are various presumptions that can be considered with this research.

**Hypothesis 1** – The water in the area will have hardness and cations like Calcium and Magnesium (Ca$^{2+}$ and Mg$^{2+}$) and anions like Bi-carbonates (HCO$_3^-$), Carbonates (CO$_3^{2-}$), Chlorides (Cl$^-$), Nitrates (NO$_3^-$) etc would be the major constituents of water hardness.

**Hypothesis 2** – The other abundant element in natural (ground/surface) water may be Iron due to the high concentration of same in rocks and river beds.
Hypothesis 3 – Sodium is also expected to be excessive in quantity causing salinity of ground water.