CHAPTER 1

INTRODUCTION

Summary

This chapter begins with a brief description of water as the precious natural resource, global water environment scenario, factors affecting the quality of groundwater and other aspects. An exclusive literature survey on water quality is discussed. The pollution of groundwater and other fresh water system and the problems arising from various wastes are highlighted. Particular attention was drawn to the harmful affects of solid wastes on drinking water quality and the eventual ill effects on animals and plants. The chapter concludes with a comprehensive review of the water quality situation in India with special reference to Assam, pertaining to the topic, particularly the quality of drinking water and its impacts on environment is also emphasized.

1.1 Water- the Precious Natural Resource

Water is a marvelous substance flowing, swirling, seeping, constantly moving from sea to land and back again. It shapes the earth’s surface and moderates our climate. Water is essential for life. It is the medium in which all living processes occur. Water dissolves nutrients and distributes them to cells, regulates body temperature, supports structures, and removes waste products. In short, clean fresh water is one of our most precious natural resources. The quality of water is of vital concern for man since it is directly linked to human health. In modern times, the horrors of drought in Ethiopia and results of severe flooding in Bangladesh are vivid illustrations of the important place of water in the environment.

The presence of a safe and reliable source of water is an essential prerequisite for the establishment of a stable community. The quality of water varies widely with respect to its various uses. The water quality suitable for one purpose may not be satisfactory for another. Water samples having high turbidity, colour, objectionable taste and odor are normally rejected for drinking purpose. However,
mere senses do not guarantee a water sample to be safe for drinking. It should be free from pathogenic microorganisms and chemical substances that are hazardous to human health. Explosive population growth has exerted tremendous pressure on the water bodies. The geochemical characteristics of an area also determine the presence and concentrations of various chemical substances in the water bodies of that particular area. Owing to direct relationship of drinking water with public health and very limited supply of potable fresh water, the problems regarding drinking water quality is specially considered.

The lack of knowledge and equipment to monitor and control the quality of water in the environment is best illustrated by the fact that the science of bacteriology was not fully appreciated until the mid nineteenth century. For several decades after this, many water supplies to be drawn from rivers downstream of effluent discharges, which received little or no treatment; annual rounds of typhoid and cholera were a regular feature on life and death. Control of water quality by careful selection of sources and treatment process has virtually eradicated water born epidemics in the developed countries, but this still remains a problem in the third world. Thus, the water related diseases are rare in developed countries because of the availability of efficient provisions for adequate water supply and wastewater disposal systems. Contamination of drinking water by domestic and industrial wastes as well as human and animal excreta is a common feature in the third world.

Chemical contamination of drinking water, either naturally or by anthropogenic sources, is a matter of serious concern as the toxic chemicals do not show acute health effects unless they enter into the body in appreciable amounts, but they behaves as cumulative poisons showing the adverse health effects after a long period of exposure. The increased in the use of thousands of new synthetic compounds in the fields of industry and agriculture has added many potentially toxic chemical substances in the aquatic environment. They are asbestos, barium, beryllium, cadmium, cyanides, fluorides, nitrates, nitrites, lead, nickel, mercury, selenium, silver etc. as inorganic constituents and pesticides, phenols, polynuclear aromatic hydrocarbons, halogenated hydrocarbons etc. amongst the organic constituents. These materials are mutagenic, teratogenic as well as carcinogenic. The
water quality parameters such as colour, taste, odour, temperature, pH, D.O, B.O.D, C.O.D, dissolved solids, turbidity influences the water chemistry. Chemical constituents such as Zn, Cu, Fe, Mn, H₂S etc. although non-toxic, interfere with the aesthetic quality of water. Of the potentially harmful substances some appear to have a threshold effect in that, provided the concentration lies below some critical level, no harm is caused. Other contaminants appear not to have such level, so that any intake is potentially harmful, which is particularly true for carcinogens.

The potable water contaminated with municipal sewages is the prime cause of dangerous diseases in living beings. Faecal pollution leads to introduction of variety of intestinal pathogens viz. bacteria, virus, and parasites causes infections of intestinal track like typhoid, paratyphoid, cholera, polio, amoebic dysentery and hepatitis. Water contaminated with municipal sewage cause enteric disease endemic in the community. The agents of enteric diseases viz. bacillary and amoebic dysentery, tape worm infections, shistomiasis, ascariasis, and a number of virus diseases including poliomyelitis are often detected in the municipal wastewater. A variety of skin infections and in the mucous membranes of the eye, ear, nose and throat is caused by microorganisms present in water naturally.

Water is a prime need for human survival and industrial development. It is required for direct consumption or indirectly for washing, cooling, cleaning, transportation, or even for waste disposal. The important sectors of human activity that require water are irrigation, industries, thermal power plant, live stock management, hydroelectric power generation, navigation, wild life preservation and recreational activities. According to 1970 estimates, about 3500 cubic Kms of water are drawn for human use every year (Asthana, 1999). Agriculture is the biggest consumer of fresh water. Almost 76% of the total water used by mankind have to be diverted to grow food. Power generation requires 6.2% and industries consume 5.7% of total fresh water. Domestic requirement and livestock management taken together consume only 4.3% of the total water drawn. Rest of the fresh water consumed by navigation, fisheries, hydroelectric power generation, recreational activities etc., much of which flows down to the sea. The amount of water drawn for human use is never used up completely. A large fraction is return to the surface deposits or stream
flows often in a polluted state, which can be used as such, or after treatment to remove impurities. Out of the total quantity of water (3500 cubic Kms) drawn, the amount of water irrecoverably consumed was estimated to be about 2200 cubic Kms (L'Vovitch, 1979). The water consumption has a downward trend in recent years because of water economy, re-use, recycling and increased capacity to store the surface flow - a set of practices man has been forced to adopt. Without careful planning and economy in the management of water resources, many countries in the world would face acute water shortage in future.

Ground water, the major source of rural water supply was depleting fast in many areas of northeast of India due to expanding irrigated agriculture base as a result, the ministry of water resource had emphasis in 2007 on irrigation development projects especially in northeast. Rapid lowering of ground water table in many areas had given rise to ingress of sea water into aquifers which has rendered the water from wells, hand pumps unfit for human consumption.

The effects of withdrawal of more water than the total annual input may be drastic. Five states of United States, viz. Colorado, Kansas, Nebraska, New Mexico and Oklahoma, depend heavily on the underground fresh water aquifer called Ogallala for the supply of fresh water. Its depletion due to huge over drafts in these states causes the total agricultural area to decline by more than 15% (Slogett and Dickason, 1986). Heavy pumping has resulted in lowering the water tables by 25 meters in Tamil Nadu in India (Sandra Postel, 1985). In Beijing-Tienjin area of China in Phoenix and Tucson, Arizona, a combination of agricultural and urban needs has been lowering the ground water table by several meters a year (Brown, 1987). In absence of rains, it is the water table below, which sustains natural plant growth and keeps earth's surface moist and humid. With receding water tables, agriculture has suffered and the process of gradual desertification has started. Hence, effective management of water resources and control of pollution are becoming increasingly important for sustainable development and human welfare.
Thus, human race appears to have reached the point at which it has realized many of its mistakes in the misuse of water and is laying down standards, recommendation and guidelines to control water quality at various stages of water cycle in an attempt to reverse a trend, which in many countries had almost reached disaster level.

It is, therefore, of utmost importance to determine the quality of drinking water with respect to all of its constituents. Proper remedial measures should be taken and if required, to ensure the quality criteria formulated by various regulating bodies. The need of monitoring drinking water quality has been universally recognized.

1.2 A Review of Published Literature

1.2.1 General Introduction

Water, the abundantly available natural resource, is an essential constituent of all animal and vegetable matter and forms about 75% of the matter of earth’s crust. In order to ensure the right quality and quantity of water to be used for industrial and municipal purposes, it is important to monitor water quality thoroughly taking all the aspects into consideration, particularly the chemical and biological composition. Water is a scarce and fading resource (Wetzel, 1992; Naiman, 1996) and its management can have an impact on the flow and the biological quality of rivers and streams (Walmsley, 1995; Tricot, 1993). In Mediterranean areas, water has been one of the limiting factors of economic activity for many years (Gleick, 1993; Hamdy et al, 1995) even in large rivers (Conway et al, 1996). The concern over water quality is of relatively recent origin and public focus. On the problems associated with water quality has been very strong since about 1950.

During the last several decades’ tremendous growth of literature and database on water quality and water pollution studies have occurred. Therefore, an exhaustive literature survey is a mere impossible work. In this review emphasis has been given only on the modern trends in water research as applicable to or having
some relevance to the present study. Thus, old literature has not been extensively cited. Moreover, as since this study does not either to test the existing methods of analysis or to evolve new methods, literature reports describing methodology only have been mostly excluded.

Water obtained from different sources is associated with a large number of impurities of various kinds from grounds or soil with which it comes into contact. Water also gets contaminated with sewage and industrial wastes or effluents when these are allowed to flow into running water or through percolation through the ground.

The distribution of water often is described in terms of interacting compartments in which water resides. The length of time water typically stays in a compartment is its residence style. A water molecule stays in the ocean for about 3000 years. Nearly all worlds’ water is in the oceans. Oceans play a crucial role in moderating the earth’s temperature, and over 90% of the worlds living biomass is contained in the oceans. Only about 0.02% of the worlds’ water is in a form accessible to man and other organisms that depend on fresh water (Cunningham and Cunningham, 2007). The hydrologic cycle constantly redistributes water. The total amount of water on our planet is immense-more than 1404 million km$^3$ (370 billion billion gal). This water evaporates from moist surfaces, falls as rain or snow, passes through living organisms, and returns to the ocean. Every year about 500,000 km$^3$, or a layer of 1.4 m thick, evaporates from the oceans. More than 90% of the moisture falls back on the ocean. The 47000 km$^3$ carried onshore joins some 72000 km$^3$ that evaporates from lakes, rivers, soil and plants. Plants play a major role in the hydrologic cycle, absorbing ground water and pumping it into the atmosphere by transpiration.

The total surface area of the earth is 50,000 million hectares; 20% of this area are land and the remaining 80% is covered by water (Kannan, 1991). Thus, water is the most abundant as well as vital resource on the earth. The world’s total water resources are estimated at 1.37X10$^8$ ham. Of this, 97.2% saltwater mainly in seas and oceans and not suitable for drinking, irrigation and industrial use. Only
2.8% is available as fresh water at any time on the planet of earth. Out of this 2.8%, about 2.2% is available as surface water and 0.6% as ground water. Again, of the 2.2% of surface water, 2.15% is locked in the ice caps and glaciers and only order of 0.01% \((1.36 \times 10^4 \text{ M ha})\) is available in lakes and reservoirs and 0.0001% in streams; the remaining being in other forms-0.001% as vapour in the atmosphere, 0.002% as soil moisture in the top 0.6 m. Out of 0.6% ground water, only about 0.3% \((41.1 \times 10^4 \text{ M ha})\) can be economically extracted with present drilling technologies, the remaining being unavailable as it is located below a depth of 800m (Raghunath, 1987).

The earth received nearly 50,000 km\(^3\) of precipitation in every year. Out of which only 110, 000 km\(^3\) falls on land and 65% of it lost by evaporation and transpiration. A part of the remaining 35% fills in rivers, lakes, ponds, wetlands and reservoirs and the rest enters the grounds and is stored in the aquifers (World Resources, 1992-93).

The approximate annual water resources in India are estimated at 4000 km\(^3\). The basic source of water for India is rainfall over most part of the country and snowfall in the northern region. Of this 4000 km\(^3\), 1700km\(^3\) is lost to atmosphere, 2150km\(^3\) goes into the ground, the balance 150km\(^3\) becomes the direct surface runoff to the streams. Out of 2150 km\(^3\) of water percolating into ground, only 500km\(^3\) percolates deeply and becomes ground water while remaining 1650km\(^3\) is retained as soil moisture and goes back to atmosphere through evaporation and transpiration (Asthana,1999). Moreover, contribution to ground water during flood is around 50km\(^3\). Global findings reveal that, ground water is the source of one third of drinking water and less than two third is obtained from surface waters (Masters,1994).

The available fresh water resources are not homogenously distributed on the earth. It is generally accepted that within the range of 1000-2000 m\(^3\) of fresh water per person a year, there is stress on food production economic development and environmental protection. India, along with Portugal, Ghana, Spain, Pakistan, South Africa, Sudan, United Kingdom and Germany is a water stressed country. The water rich
category includes Guyana, Liberia, Venezuela, Brazil, Ecuador, Burma, Cameroon, Guatemala and Nepal. The water scarce countries are Belgium, Yemen, Algeria, Netherlands, Kenya, Israel, Singapore, Jordan, Saudi Arabia, Malta, Egypt and Bahrain. Direct consumption of water by the people is actually a relatively small percentage of the total water demand. The use of water in agriculture is by far the most important global use and this use is particularly important in the developing countries. Agriculture consumes about 65% of all renewable water, industry around 20% and public water supply only about 7% (Tebbutt, 1998). In 1987, 3240 km$^3$ of fresh water was withdrawn throughout the world with a world average per capita use of 660 m$^3$. Of this 69% was use in agriculture, 23% in industry and 8% in domestic uses (World Resources, 1992-93). The sector wise water use pattern in India is: agriculture-95%, domestic-3% and industry-1% (Kannan, 1991).

Ground water is an important source of water supply throughout the world. The ground water within 1 km of the surface is more than 100 times the volume of all the fresh water lakes, rivers and reservoirs combined. About 2 billion people—nearly one-third of the world’s population—depends on ground water for drinking and other purposes. Every year 700 km$^3$ are withdrawn by humans, mostly from shallow, easily polluted aquifers (Cunningham and Cunningham, 2007). For many rural and small communities, ground water is the only source of drinking water (Canter, 1987). Its use in irrigation, industries and domestic usage continues to increase where perennial surface water sources are absent. The geology of a particular area has a greater influence on quality of water and its movement. Many a times, ground water carries higher mineral contents than surface water, when there is slow circulation and longer period of contact. Changes in ground water quality with the passage of time have a hydrologic significance. The quality also varies due to change in chemical composition of formations. Geochemical studies of Ogallala aquifer, south high plains of Texas and New Mexico were conducted by Native and Smith (1987) and concluded that the geochemistry of the aquifer is controlled by the surface topography of the underlying formations, the thickness and permeability of the alluvial deposits. The ground water chemistry is controlled by the composition of its recharge components as well as by geologic and hydrologic variations within the

The nature and extent of water pollution depends upon the following factors:

- Physical, chemical and biological characteristics of different types of wastewaters originating from an area.
- Waste water disposal systems including static and dynamic techniques for treatment of domestic and urban sewage; and also treatment and pre-treatment of industrial waste water
- Hydrologic characteristics of diluting bodies, extent of dilution and self-purification.
- Hygienic conditions and health situation of the communities.
- Socio-economic characteristics of the communities i.e. urban, industrial, agricultural etc. creating the waste.

Screening of the literature reveals that many workers have studied the ground water quality (Kreitler and Jones, 1975; Murrel, 1975; Brooks and Cite, 1979; Grossly and Spading, 1979; Hontrone and Blough, 1989; Panda, 1996; Singh, 1997; Simpson and Hayes, 1998; Kaushik et al., 1997; Zaw and Chiswell, 1999; Reddy and Lin, 2000; Choudhari et al., 2001; Gyananath et al., 2001; Sarkar et al., 2005; Nalina et al., 2006; Garg et al., 2006; Tamlurkar et al., 2006; Singh et al., 2006; Naeem et al., 2007) and impact of industrial effluents (Kannan, 1991; Rai et al., 2006), refuse dumps (Saprykina, 1977; Jaroslav, 1985; Dayal,1991) and their leachates (Nicholson, 1983; Khan, 1994; Olaniya et al., 1998; Singh,1998; Kumar Swamy, 2000; Rai et al., 2006; Jadhav et al., 2006; Gitanjali et al., 2006) on under ground water or near by surface water.
1.2.1.a Problem of Ground Water Pollution Associated with Drinking Water Quality

Ground water is treated with pollution from the sources of domestic wastes, industrial wastes, agricultural wastes, run-off from urban areas; soluble effluents rich in nutrients (nitrogen and phosphorous), suspended and dissolved solids, organics and pathogens (Gupta, 1996). The extent of pollution is likely to be more in sandy soils with high water table conditions and in humid regions. Pollution of ground water has been observed in M.P., Gujarat, Maharshtra, Punjab, U.P. and Delhi (Kaushik et al., 1963; Thapliyal et al., 1972; Tamlurkar et al., 2006; Naeem et al., 2007;). Olaniya and Saxena (1977) observed pollution effects in well waters upto a distance of 450 meters in sandy soils of Jaipur, Rajasthan due to soluble salts and leachates from refuse dumps. Other potential sources of ground water contamination are wastewater treatment lagoons, mine spills, transport accidents, urban and rural garbage, refuse dumps, barnyard, manures and leaching and downward movement of pollutants. Wastewater from bathrooms, sinks, wash basins, etc. also contains a high concentration of aerobic heterotrophic microorganisms and coliform bacteria and introduce much turbidity to surface water (Rose, 1991).

The World Health Organization (WHO) has given a set of guideline values for drinking water quality. The guideline value for each water quality parameters sets out the levels of concentration of the constituent ensuring aesthetically pleasant water without any significant risk of human health (WHO, 1984; Helmer et al., 1991). These guideline values, along with tolerance limits prescribed by the Indian Standards Institute (Trivedy, 1990) and EPA standards of USA (Train, 1979) are given in Appendix-1. Complex physico-chemical processes involving the pollutants and other constituents of water continuously alter the quality of water.

Ground water is not absolutely free from the menace of pollution because human activities are constantly adding industrial, domestic and agricultural wastes to ground water reservoirs at an alarming rate. The main cause of ground water
pollution is the disposal of sewage water and effluent from various industries into fresh water aquifers (Patel, 1991). During percolation of water, through natural filtration occurs in the layers of soils through which the water slowly moves, yet soluble pollutants, viz. trace elements are not affected by filtration action of the soil, through some other processes like adsorption may take place (Mittal, 1998). The contaminated ground water aquifer remain contaminated for hundred of years because of very slow movement of water in these aquifers, typically 30.0m/year (Jerry, 1986). Generally, the ground water contamination is irreversible, i.e. once it is contaminated; it is difficult to restore the original water quality of the aquifer. Excessive mineralization of ground water degrades water quality producing an objectionable taste, odour and excessive hardness. Soil water interactions through mechanisms of adsorption and ion exchange often determine the characteristics of surface run-off and eventually the receiving water bodies (Bolt, 1976). Similar interactions are also possible between chlorine and other constituents of water, particularly the organic compounds. Formation of halogeno-organic compounds during chlorinating of natural water and their harmful effects have been widely reported (Fayad and Tawabini, 1991; Rao, 1996; Veeraih and Prasad, 1996; Boorman et al., 1999)

Assessing human health risks from enteric pathogens in water has been done on an empirical basis in the past. Application of formalized risk assessment methodology for toxic chemicals in the environment has led to the development of goals and standards to ensure adequate protection from these risks. Recently it has been applied to estimate the risks of infection and illness from enteric pathogens in water (Hass et al., 1993). Wastewater treatment systems involving intermittent filtration through porous media, including engineered media filters and natural soil infiltration systems, have attracted much attention because of their high purification performance with respect to organic nutrients and bacteria. Infiltration system may pose a bacterial pollution risk to ground water and neighbouring drinking water supply sources unless properly designed and operated (Steviv et al., 1999).

Municipal wastewater is a major source of contamination of water bodies in urban areas. It carries domestic and sanitary wastewater, industrial wastewater and
storm water run-off from roofs, streets, etc. The wastewater is rich in nitrogen and phosphorous for excessive microbial growth. Municipal wastewater infiltrated with sewage water often cause bacterial pollution of the water sources. Wastewater from bathrooms, sinks, basins etc. also contain high concentration of aerobic heterotrophic microorganisms and coliforms bacteria. Enter-viruses are more resistant than coliforms to inactivation by natural factors in the water environments and to most water and wastewater treatment processes. Adenoviruses and reoviruses, although clinically considered to be respiratory, have been found in wastewater. Of these, the virus of infectious hepatitis has cause over fifth water borne epidemics (Rose et al., 1991; Arun et al., 1996; Shuval, 1977).

Factors effecting ground water pollution are:

- Depth of water table-the extent of pollution is more in sandy soils and humid regions having high water table condition.
- Rainfall pattern-rainfall also picks up substantial contaminants from dust and air and joins the aquifer below.
- Soil properties-such as texture, structure and filtration rate.
- Distance from the sources of contamination.

Ground water is about 210 billion m$^3$ including recharge through infiltration, seepage and evapotranspiration. One third of this is extracted for irrigation, industrial and domestic use. Nearly 98% of the fresh water on the earth lies below its surface. The remaining 2% are present in lakes, rivers, streams and reservoirs. Of the fresh water below the surface, about 90% satisfies the description of 'ground water' i.e. water which occurs in saturated materials, below the water table (Kannan, 1991; Cunningham and Cunningham, 2007).  

1.2.1.b Sources of Contamination in Ground Water

Ground water is treated with pollution from the following sources (Trivedy et al., 1987; Ahel, 1991):

- The substances, which are deposited or stored in the ground above the water table.
• Soluble effluents, domestic, industrials and agricultural wastes, which are water-soluble products that are placed on, land surface and streams.
• The disposal, storage and extraction of materials below the water table.

The purifying processes like dilution, bio-chemical degradation etc are absent in ground water but these are important in surface water.

1.2.1.c Harmful Effects of Ground Water Pollution

Ground water is the major source of water for all living creatures. Ground water pollution is the major cause for the spread of epidemics and chronic diseases in man. It causes diseases like cholera, typhoid, dysentery, diarrhoea, jaundice, hepatitis etc. About 600 million episodes of diarrhea and nearly 46 lacs children death are reported every year because of contaminated water and lack of sanitation (WHO, 1993). An estimated 80% of all diseases and over one third of death in developing countries are caused by the consumption of contaminated water and an average of as much as one tenth of each person’s productive time is sacrificed to water related diseases (Raka et al., 1999).

Ground water of high rainfall areas contains iron in toxic amounts. In deep tube wells iron exists as ferrous state, which on taking out rapidly changes to light yellow orange colour due to oxidation, and precipitated as ferric hydroxide. Such water is extremely harmful for drinking purposes as prescribed limits of iron is 0.3 mg/L (WHO, 1993). Woolen industries contribute large amounts of toxic metals like Hg, Cr, Fe, Ni, Cu and Cyanides to ground water causing skin and stomach diseases in man (Sharma and Kaur, 1996-97).

The use of polluted ground water for irrigating the agricultural fields damages crops and decreases grain production. Polluted water acutely affects soil fertility by killing bacteria and soil microorganisms. It also increases alkalinity in the soils. Ground water pollution effects plant metabolism severely and disturbs the whole ecosystem. Irrigation with poor quality water containing higher concentration of cations and anions may adversely affect the properties of soil by increasing salt content and exchangeable sodium of salt solution (Lal and Singh, 1974).
The quality of underground water of semi-arid tract and their impact on soil showed the deterioration of soil. Uses of such water for irrigation affect adversely the crop production.

In developed countries, the sewage from urban areas is collected in sewers and is treated through several stages for removing the pollutants before being discharged into rivers, lakes or coastal waters. In developing and underdeveloped countries, more than 95% of urban sewage are discharged into surface water without treatment. In these countries neither sewer nor sewage treatment facilities are available and therefore, pathogenic contamination of public water supplies has remained the main threat to human health (Page, 1987).

Disastrous cases of ground water pollution have been reported from several parts of the world. In USA, 3500 people died in New York due to cholera by the use of polluted well water in the year 1932. In 1960, the United States Geological Survey observed high content of sulphate, phosphate, nitrates and chlorides in the water of dug wells of Crosby town in North Sakota. The industrial toxicological research centre, Lucknow (1986) has reported manganese (Mn) contamination of well water in India. In 1977, in Janakpuri, New Delhi, severe outbreaks of hepatitis are reported, where drinking water is found contaminated with sewage ((Sharma and Kaur, 1996-97).

1.2.1.d Pollution of Fresh Water

Water pollution is defined as the presence of materials in water, which interfere unreasonably with one or more beneficial uses of it. According to WHO, water pollution occurs due to foreign constituents, either from natural or anthropogenic sources, contaminated with water supplies, may be harmful to life because of their toxicity, reduction of normal oxygen level of water, aesthetically unsuitable and spread epidemic diseases. All natural water system contain a variety of contaminants arising from erosion, leaching and weathering processes. The pollution of fresh water occurs due to foreign constituents may be categorized as follows (Turk et al., 1984):
• Water is a universal solvent. A large number of minerals, which remains as positive and negative ions, get dissolved in water. The important positive metal ions that are toxic are copper, cadmium, mercury, arsenic, chromium, nickel and lead gets dissolved in aquatic system originating from industrial, mining and agricultural wastes.

• Many oxygen containing organic compounds such as alcohols, sugars and acids also go into water solution. The aquatic organism helps in bioaccumulation of these compounds. The organic and inorganic compounds, which are normally considered insoluble, can remain dissolved in trace amounts that may be significant to impose undesirable properties to water.

• A large number of pathogenic micro-organism remain indefinitely in water, which are contaminants and whose ceaseless motion prevents setting

• The particles, particularly whose settings rates are extremely low, may remain in water as suspended solids.

• Insoluble materials like metals react with water to form soluble products.

• Some dissolved substances react with other insoluble substances bringing them into solution. Many minerals are converted to soluble forms by acids in water.

• Living organisms metabolized nutrients matter in water producing waste products that remain in water as contaminants.

• Water may carry a large number of floating matters e.g. oil spill, which are water contaminants.

• Excess nutrients from sewage and soil erosion enter fresh water bodies cause algal blooms and deplete the oxygen content of water.
1.2.1.e Water Pollutants

Materials or factors, which cause adverse effect on the natural quality of any component of the environment, are called pollutants. In Environmental Protection Act (1986) of India, environmental pollution means "any solid, liquid or gaseous substances present in such concentration as may be or tend to be injurious to environment; and the environmental pollution means the presence in the environment of any environmental pollutant." A pollutant may be defined as a chemical (a nutrient, radioactive substance, an organic compound) or a geochemical substance (soil particles); a physical parameter like heat or micro organism which is put to an ecosystem or environment with actual or potential, adverse or harmful, unpleasant and inconvenient effects (Trivedy et al., 1987). They behave in different ways when added to water. Based on their natural disposal, pollutants are of two types:

- Bio-degradable
- Non-biodegradable

Biodegradable pollutants are easily decomposable wastes by natural processes and also by some artificial methods, which include microbial action and radiation. Action of microbes such as bacteria, fungi, protozoa and municipal sewage treatment plant enhances nature's great capacity to decompose and recycle. The degradation rate of a biodegradable pollutant is a function of particular pollutant, the quality of receiving water, temperature and other environmental factors.

Non-biodegradable pollutants are either non-degraded or degraded very slowly by natural biological processes. Pollutants of this class are aluminum cans, mercurial salts, long chain phenolic chemicals, DDT, arsenic salts, glass, tin container, plastics etc. These pollutants accumulate on the earth as well as biologically magnified. They affect the rate of photosynthesis. Their concentration in the aquatic environment may be reduced by dilution. These pollutants often unaffected by normal water and wastewater treatment processes. Therefore, their presence in a particular water body may impose limitation on its uses (Tebbutt, 1998).
The adverse effects of water pollutants are:

- Reduction of self-purification of water bodies, loss of aesthetic and recreational value of water.
- Pathogenic microbes spread diseases through potential carrier, that is, water.
- Deterioration of taste produced by industrial effluents.
- Undesirable effects on aquatic life (e.g. eutrophication disrupting the whole aquatic environment).
- Loss of aquatic production such as fish and prawn.
- Corrosion of structures.
- Deterioration of agricultural fields due to irrigation by polluted water.
- Accumulation of toxic substances in aquatic ecosystem and ultimately in human body.
- Adverse effects on industrial use of water especially in food, paper and textile industries.
- Adverse effects on availability of safe, clear water.

Major water pollutants can be classified into following types:

1. Oxygen demanding wastes,
2. Inorganic chemicals and mineral substances,
3. Synthetic organic compounds,
4. Suspended solids,
5. Disease causing agents,
6. Plant nutrients,
7. Radioactive wastes, and
8. Thermal discharges.

Table 1.1 Sources and Impacts of Major Water Pollutants

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<td>1. Oxygen demanding wastes.</td>
<td>Domestic sewage; industrial discharges and biodegradable organics-these wastes are decomposed by bacteria depleting oxygen from water.</td>
<td>Harmful to aquatic organisms; fish life may become impossible at very low dissolved oxygen levels.</td>
<td>Although it is less important to drinking water (Camp, 1964), low dissolved oxygen contents may affect the taste of water. Also, increased water treatment cost.</td>
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<td>2. Inorganic chemicals and mineral substances (a) Toxic chemicals</td>
<td>Urban and agricultural run off, municipal and industrial discharges, leachate from landfills.</td>
<td>Reduced growth and survivability of fish, eggs and young; fish decreases.</td>
<td>Increased cost of water treatment, increased rate of some forms of cancer, reduced availability and health of fish and other aquatic species.</td>
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<td>(b) Heavy Metals</td>
<td>Industrial discharges; atmospheric depositions, road run-off, discharges from sewage treatment plants; creation of reservoirs; acidic mine drainage.</td>
<td>Decline in fish population due to failed reproduction; lethal effects on invertebrates leading to reduced food for fish.</td>
<td>Increased cost of water treatment; itai-itai and mina mata diseases; kidney dysfunction; Carcinogenesis; reduced availability and health of fish and other aquatic species.</td>
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<td>(c) Acids</td>
<td>Atmospheric decomposition, mine effluents; industrial discharges.</td>
<td>Elimination of sensitive aquatic organisms; release of trace metals from soils, rocks and metal surfaces such as water pipes.</td>
<td>Reduced availability of fish and other species.</td>
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<td>1</td>
<td>Chlorides</td>
<td>Roads treated with salts for ice removed; brine production in oil extraction; mining.</td>
<td>Toxic to fresh water-life at high levels.</td>
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<td>3</td>
<td>Synthetic organic compounds.</td>
<td>Agricultural run-off, urban areas combined sewers; logged areas; chemical manufacturing and other industrial processes.</td>
<td>Reduced dissolved oxygen; fish kills; reduced abundance and diversity of aquatic life.</td>
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<td>4</td>
<td>Suspended solids.</td>
<td>Agricultural fields; livestock feed lots; logged hillsides; degraded stream banks; road construction.</td>
<td>Reduced sunlight for photosynthesis by bottom vegetation; reduced food for predators; clogging of gills and filter; reduced survival of eggs and young.</td>
</tr>
<tr>
<td>5</td>
<td>Disease causing agents.</td>
<td>Raw and partially treated sewage; animal wastes; dams that reduce water flow.</td>
<td>Reduced survival and reproduction in fish and other aquatic life.</td>
</tr>
<tr>
<td></td>
<td><strong>1</strong></td>
<td><strong>2</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>6. Plant nutrients.</td>
<td>Fertilized agricultural fields, livestock feed lots; landscaped urban areas; raw and treated sewage discharges; industrial discharges.</td>
<td>Stimulated growth of algae and aquatic weeds resulting depletion of oxygen contents, reduction in diversity and growth of large plants; release of toxins from sediments; reduced diversity in vertebrates and invertebrates; fish kills.</td>
<td>Increased water treatment cost; risk of reduced oxygen carrying capacity in infant blood; possible formation of carcinogenic nitrosamines; reduced availability of fish and other species; impairment of recreational uses.</td>
</tr>
<tr>
<td>7. Radio-active wastes</td>
<td>Mining and processing of ores to produce usable radio-active substances; nuclear weapons; nuclear power plant; uses of radio-isotopes in medical, industrial and research applications.</td>
<td>Enzyme inhibition in invertebrates; reduced cell division; effect on permeability of cell membrane allowing abnormal interchange of materials; effects on metabolic activities.</td>
<td>Serious skin cancer, carcinoma, melanoma, breast cancer, leukemia, DNA damage, cataracts; the radio-active sickness which includes the symptoms of nausea, vomiting, anorexia, epilation, lethargy and general weakness; reduced availability of aquatic species.</td>
</tr>
<tr>
<td>8. Thermal Discharges.</td>
<td>Urban landscape; un-shaded streams; coal fired or nuclear fuel-fired stream power plants; discharges from dams.</td>
<td>Elimination of cold-water species of fish and others; reduced oxygen due to increased plant growth; increased vulnerability of some fishes to toxic wastes, parasites and diseases.</td>
<td>Reduced availability of fish and associated species.</td>
</tr>
</tbody>
</table>
1.2.2 Magnitude of Wastes Problem

Huge amounts of wastes are produced by human activities through anthropogenic processes such as agricultural, domestic, urban, industrial, mining sources, radioactive, use of pesticides and fertilizers etc. Various wastes generated by human activities viz. agricultural wastes (plant remaining, processing wastes, animal wastes, fertilizers, pesticides, insecticides, herbicides etc.); domestic wastes (garbage, rubbish, kitchen wastes etc.); industrial wastes (wastes of mining, manufacturing and construction works, paper industries, chemical industries etc.) and municipal wastes (street sweeping, wastes from schools, colleges and other institutions etc.) are constantly poured in water deteriorating it to such an extent that it becomes unfit for living communities. Agricultural wastes cause lots of pollution problems. India having the world’s largest bovine population, houses 50% of world’s buffaloes and 15% of all goats and cattle in the world. These produced nearly 400 million tones of manure every year adding up to the bulk of solid wastes (Kannan, 1991).

The rapid growth in population has led to greater density of people in the living areas. As a result, people have moved to urban areas abandoning rural settings in search of employment, comfort and facilities. Thus urban areas have become over-loaded with population that they can barely hold or support. In urban conglomerations approximately one fifth of India’s total population lives and generates about 15 million tones of solid wastes every year. In the major cities of India, the quantity of solid wastes generated per person per day varies from 300-600 grams. Characteristically, wastes generated in Indian major cities contain a high compostable and low combustable matters. Urban areas are characterized by a preponderance of impermeable surfaces such as roads and highways compared to easily permeable soils and vegetation in rural and virgin areas. Therefore, the urban run-off grows in volume, velocity and temperature and collects all sorts of pollutants from litter and pet droppings to toxic substances from atmospheric deposition (Mitchell and Stapp, 1990).
Byproducts and wastes are integral parts of, if not all, at least many of the industrial manufacturing processes. The industrial discharge seldom meets quality standards—before disposal to natural aquatic systems. Therefore, waterborne diseases have been very common. The problem is also compounded by acute shortage of potable water, which leads people to take resort to unconventional, unsafe water sources. As for example, in 1988, 79% of urban dwellers and 73% of rural peoples of India had access to safe drinking water while only 38% of the former and 4% of the later had access to sanitation services (World Resources, 1992-93).

1.2.3 Drinking Water Quality

Undesirable components in water will affect the appearance, smell or the taste of water and a person can evaluate the acceptability of water samples with his senses. But this is no longer true. Waters vary widely in their characteristics and therefore it is not desirable to give specifications for what might be termed as “normal” samples. A way of appreciating the significance of water quality parameters is to consider the various standards and guidelines, which are used to specify water quality for various uses. In the case of potable water, it is accepted practice to use guidelines or standards, which are based on an assessment of the importance of a particular parameter or a group of parameters. The water quality parameter can be grouped as (Tebbutt, 1998).

1. Organoleptic Parameters

These parameters are readily observable but have little health significance. Typical examples of this group are colour, suspended matter, taste and odour. Guidelines for these parameters are generally set on the basis of aesthetic consideration.

2. Natural Physico-Chemical Parameters

The normal quality parameters such as pH, conductivity, dissolved oxygen, alkalinity, hardness, dissolved solids etc. are included in this category. Some of
these have limited health significance, but generally the guidelines are intended to ensure chemically balanced water.

3. **Undesirable Substances in Excessive Amounts**

A wide variety of substances belong to this group. Some of which may be directly harmful at high concentration, some may produce undesirable tastes and odours, and others may not be directly harmful in themselves but indicators of pollution. Chloride, fluoride, nitrate, iron, manganese, phenol and total organic carbon are constituents of this group. Guideline levels of these substances are based either on consumer acceptability or their significance in relation to other factors.

4. **Toxic Substances**

A considerable number of inorganic and organics such as arsenic, lead, mercury, cyanides, organo-phosphorous compounds, pesticides and tri-halomethanes are included in this group. The severity of the toxic effects of a particular substance on consumers of water containing it depends on the dose received, the period of consumption and other dietary and environmental factors. Since the main concern in drinking water is with the long-term effects of exposure to low levels of potentially toxic materials, it is not easy to set limits on a scientific basis.

5. **Microbiological Parameters**

These are the most important parameters in determining safety of drinking water, standards of which are based on the need to ensure the absence of bacteria, indicative of pollution by human wastes.

No samples can be considered as safe if it is not subjected to rigorous test. Thus the acceptability of a water sample cannot be evaluated by mere senses such as the appearance, taste or the odour of the sample. The World Health Organization and other quality regulating bodies have prescribed the guideline values of the parameters for drinking water. The guidelines or standards have been set out ensuring aesthetically pleasant water without any significant risk to human health.
(WHO, 1993; Helmer et al., 1991). The WHO guideline values along with tolerance limits prescribed by the Indian standard Institute (Trivedy, 1990) and EPA standards of USA (Train, 1979) are given in appendix-I.

1.2.4 Problems Related to Drinking Water Quality

The toll of water related disease is frightening in its extent, particularly in the developing countries. Millions of people die every year as the consequence of unsafe water. The degree of ground water pollution is much less than in surface water as the soil acts as an adsorbent retaining a large part of colloidal and soluble ions with a maximum of its cation exchange capacity. The magnitude of the problem can be realized from the following statistics:

- Over five million people die each year from water related diseases.
- In developing countries 80% of all illness is water related.
- At any time half of the population in developing countries will be suffering from one or more of the main water related diseases.
- A quarter of the children born in developing countries will have died before the age of five, the great majority from water related diseases (Tebbutt, 1998). Thus the problems associated with drinking water quality are matters of serious concern.

Municipal wastewater is a source of contamination of water bodies in urban areas. A large number of organisms coming from human wastes, kitchen wastes and soils become incorporated in the wastewater stream through regular washing, rainfall, land run-off and leachates. In flow of domestic wastewater also introduces considerable amounts of phosphates and borates from the use of detergents and washing powders. The organic compounds viz. carbohydrates, fats and proteins present in domestic wastewater are reduced an aerobically in the bed sediments producing methane, carbon dioxide, ammonia and hydrogen sulphide (Farrimond, 1980).

Municipal wastewater, infiltrated with sewage water often cause bacterial pollution of the water sources. Wastewater from bathrooms, sinks, washbasins, etc.
also contains high concentration of aerobic heterotrophic microorganisms and coliform bacteria. Water can serve as an efficient transmitter of human pathogenic microorganisms, which are of sewage origin. Domestic sewage carries from 1 to 100 enteric viruses per ml, of more than 60 types all of which are considered to be pathogenic to man.

In entrapped water sources viz. ponds, lakes etc, lack of turbulence help the particulate matters to settle down, which enhance the penetration of sunlight. This leads to increased photosynthetic activity and algal growth, water productivity increases substantially. Again, productivity of water is a function of high inorganic and organic contents of water. Thermal stratification prevents entry of air into the lower layers. This results in drastic reduction of dissolved oxygen content, which tremendously affects fish and other aquatic life. The resultant anaerobic conditions in lower layer increase solubilization of iron and manganese from soil enhancing growth of organisms, which are responsible for undesirable tastes, and odors of water (Gower, 1980).

Many anthropogenic factors tend to increase the fertility of water resources leading to eutrophication. Eutrophications of entrapped water sources due to excessive concentrations of nutrients are not uncommon (Hammer, 1986). Normally, algae utilize carbon dioxide, orthophosphates and trace nutrients for growth and reproduction and enter into the aquatic food chain. Productivity of aquatic food chain is a function of availability of nitrogen and phosphorous, which are very often scarce in natural waters.

In eutrophic conditions, the nutrients become abundant resulting in bloom of blue-green algae which can not enter easily into the aquatic food chain and causes unpleasant taste and smell in water resulting higher treatment cost for their removal (Poonghzhali et al., 2001). Decaying algae settle to the bottom resulting dissolved oxygen content and resulting profile growth or rooted weeds. The types of nutrients responsible for such condition have been identified. Nitrogen and phosphorous play major roles in this regard and algal blooms can occur at very low levels of
concentrations of these nutrients, such as 0.3 mg/L of nitrate-nitrogen and 0.01 mg/L of phosphorous (Gower, 1980; Tebutt, 1998).

Dry leaves from trees may significantly affect quality of entrapped water. These results in a deoxygenating effect while water-soluble leaf components such as terpenes, phenols etc are well known toxic compounds (Liken et al., 1978).

In aquatic ecosystem metals can exist in soluble state as free metal ions and as organic and inorganic complexes, colloidal dispersion and suspended particulates (either directly or as adsorbed species) states. They may be accumulated in the bottom sediments in colloidal and particulate forms. The metals may be re-released from the sediments depending upon the physiochemical conditions such as pH and oxidation potential and also various biotic factors (Harding and Whitton, 1996). Bacteria and other microorganisms also compete very effectively with the sediments in accumulating metals and may ultimately transport metals to the food chain of higher animals including man (Patrick and Lontit, 1979; Evans, 1989).

Lead present in surface water is one of the most important metals of environmental concern. Lead finds it pathway to surface water from road run-off and atmospheric washout processes. This metal originates in organic tetra alkyl compounds used as antiknock additives for gasoline. Besides lead, the presence of other heavy metals in road run-off assimilated water bodies has been reported. The concentration ranges of various metals in road run-off and urban run-off are enlisted in table 1.2 (Pope, 1980).

The spectrum of pesticide activity often extends far beyond the pests and therefore termed as biocides. The chemical compounds used as pesticides persist in the environment for fairly long time. Their biological magnification through food web often leads to their spread throughout the biosphere. Pesticides include insecticides, herbicides, fungicides, algicides, rodenticides, weedicides and other such chemicals. Pesticides are extremely helpful to man in saving the food grains and safety from diseases.
Table 1.2 Concentration Ranges of Metals in Road and Urban Run-off

<table>
<thead>
<tr>
<th>Metal</th>
<th>Road run-off (mg/L)</th>
<th>Urban run-off (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>0.024 – 10.4</td>
<td>1 – 113</td>
</tr>
<tr>
<td>Mercury</td>
<td>-</td>
<td>0.029</td>
</tr>
<tr>
<td>Nickel</td>
<td>-</td>
<td>0.02 – 1.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.02 – 4.9</td>
<td>1 – 15</td>
</tr>
<tr>
<td>Iron</td>
<td>0 – 3.05</td>
<td>5 – 440</td>
</tr>
<tr>
<td>Copper</td>
<td>0.06 – 0.48</td>
<td>0.007 – 2.5</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.013 – 0.056</td>
<td>0.002 – 0.01</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.023 – 0.08</td>
<td>0.018 – 1.0</td>
</tr>
</tbody>
</table>

But widespread and indiscriminate uses of such chemicals have grossly poisoned every component of the biosphere. There has been an increasing appreciation of the injury to human health and aquatic and wildlife populations from exposure to concentrations of these persistent toxic substances over the past four decades. Most of them are mutagenic, teratogenic and carcinogenic in nature. No level of exposure to a chemical carcinogen should be considered toxicologically insignificant for man (Shuval, 1977; Trivedy et al., 1987; De, 1996; Rao and Rao, 2000). Weedicides and herbicides are generally metabolic inhibitors, which stop photosynthesis and other metabolic activities of some plants and also affect fish production in seawater where such water is ultimately discharged. This effect is called boomerang or backlash effect on marine fauna.

All water sources have some capacity to cope with significant inputs of organic load. But excessive amount will cause undesirable effects on quality of water. Organic discharges lead to dense bacterial colonies, resulting inevitably in deoxygenating and anaerobic conditions where only tolerant species can survive. Besides enhancing BOD and COD of surface water, these organisms enter human food chain directly or through bioaccumulation in fish. More than one thousand organic compounds have been identified in water, many of which are toxic, a few are known as carcinogens (Shuval, 1977).
1.2.5 Water Pollution Studies in India

Water pollution studies are emerging as a great public concern today. It poses a serious problem in cities and industrial areas. The scenario of ground water pollution in developing countries, like India are likely to be more grimmer with more population pressure and inadequate waste disposal facilities. People are becoming more conscious about the nature of ground water and its uses with concern for its future utility when affected not only by waste disposal activities but also by the current uses of extravagance and over exploitation especially in urban areas. However, the quality of ground water available in an area is as most important as the quality of resources (Rengaraj et al., 1998). It has been reported that in the developing countries, pollution of ground water may causes 80% of human diseases (Ramachandran, 1994). WHO (2004) has estimated that nearly 5 million human deaths occur every year from polluted drinking water. In India, 30%-40% deaths are attributed to contaminated drinking water (Roy, 1994). B.K.Handa (1986) studied the hydro geochemical zones in a few places in India and indicated that the chemical composition of ground water was affected by the use of fertilizers. Rai et al. (2006) studied the affect of fertilizer industry on surface and ground water quality in Raghogarh (M.P.)

Experienced gained during the last decades has shown that liquid emissions (leachates) pose the most important hazards for the environments (Belevi and Baccini, 1992). In most of the Indian cities, refuse is dumped in the low-lying areas. The dumping is done haphazardly as a result of which the adjoining land gets enriched in salts and trace metals (Olaniya et al., 1998) and these infiltrate into ground water through leachates during rains. Investigations on water quality from various sources viz. ground water (ring wells, tube wells etc.), Surface water (rivers, ponds, streams etc.) and PHE supply water with regard to physico-chemical, biological and trace and toxic substances have drawn much attention in recent times.

According to a survey conducted by the Health Department of UP, drinking water in about 11 important cities is highly contaminated and totally unfit for human consumption. A staggering of 70% of the available water in India is polluted, as
reported by scientists at NEERI, Nagpur (Sharma and Kaur, 1996-97). 50% to 75% of human population in Lucknow, Kanpur, Agra, Varanasi, Allahabad, Ballia, Jaunpur, Basti, Mumbai, Gorakhpur, Kolkata, Chennai, Delhi, Durgapur is acutely suffering from a number of stomach ailments. These water borne diseases include cholera, typhoid, enteric fever, gastroenteritis, amoebiasis and guinea worm diseases.

The study of ground water quality in Nanded (Maharashtra) revealed significant changes of water quality during different seasons of the year (Gyananath et al., 2001). The ground water in Tambaram (Tamilnadu) has been shown to have temperature: 30-31°C, pH: 7.4-9.2, Conductance: 1.02-3.81 µscm⁻¹, TDS: 627-2438 ppm, TSS: 90-150 ppm, TS: 717-2550 ppm, Total Hardness: 385-1068 ppm, Chloride: 111-790 ppm, alkalinity: 358-440 ppm, Acidity: 19-72 ppm, DO: 6.60-7.28 ppm, BOD: 3.0-8.2 ppm, COD: 23-36 ppm. The ground water quality of these areas has been shown to be unsuitable for drinking and domestic purposes (Sophia, 2001). Similarly, the qualities of ground water in many parts of the country were found to be degraded (Rao and Rao, 1991; Kumar et al., 1995; Singh and Parwana, 1999; Srinivas et al., 2000; Tyagi et al., 2000; Aurangabadkar et al., 2001). However, availability of ground water suitable for drinking and other uses, is also not uncommon (Patel, 1991; Jain, 1996; Dhembare et al., 1998; Jain, 1998; Rengaraj et al., 1998).

Fluoride related health hazard is a major environmental problem in many regions of the world. Many studies has been reported to have high fluoride content in tube well, ring well etc. which is due to weathering of fluoride bearing rocks and fluoride containing wastes from industries. In India, the fluorosis endemic states are Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Rajasthan, Assam, Tamil Nadu, Uttar Pradesh, Punjab, Haryana, Maharashtra, Kerela, Jammu and Kashmir and New Delhi (Kumar et al., 2000). The other fluorosis endemic countries are Argentina, USA, Morocco, Algeria, Libya, Kenya, Tanzania, South Africa, China, Australia, New Zealand, Japan and Thailand (MRD, 1993; Paul, 1999). The drinking water sources, particularly those located in brick kiln areas of Uttar Pradesh were identified to be fluoride contaminated (Malhotra et al., 1998). High fluoride contents
of drinking water were also reported in a considerable number of studies (Gupta et al., 1994; Tripathy and Singh, 1996; Reddy, 1998; Dahiya et al., 2000; Srivastava et al., 2000; Singh et al., 2006). Das et al., (1998) investigated sources of high fluoride in ground water around Anugul, Orissa and concluded that the shallow ground water showed occurrence of high fluoride in pockets, scattered all over the area without any definite pattern. The geochemistry of well water samples pointed towards a geological source of high fluoride content in the area.

The fluorosis problem is serious in India and other developing countries because major portion of population living in rural area has to depend on available ground water sources for their water requirement. In India, more than 76% of the population lives in rural areas. The problem of endemic fluorosis occurs in varying intensity in different parts of the country. An extensive survey of the community water supplies has shown that around 25 million people in rural areas consume water with fluoride content more than the maximum permissible concentration of 1.5 mg/L (Jain et al., 2000). Around 20 million people in India are severely affected by fluorosis and around 40 million are exposed to risk (Chinoy, 1991). The deep wells and the mineral springs situated in endemic areas contain high concentration of fluoride (MRD, 1993; Kumar et al., 1998). Therefore, the incidence of fluorosis is a matter of much concern, as it is directly related to drinking water fluoride (Singh et al., 1997). Several studies have enlightened the seriousness of this problem (Choubisa and Sompura, 1996; Stanely et al., 1997; Addiscot, 2006; Thomson et al., 2006). Prevalence of dental and skeletal fluorosis due to fluoride and its preventive strategies were studied by many authors (Susheela, 1987: Kumar, 2000; Gopalakrishnan, 2000; Jain et al., 2000). They have revealed the realities, the magnitude and severity of fluorosis caused by high levels of fluoride in drinking water and in other sources.

Fluoride concentrations in the drinking water of Dungapur District of Rajasthan were also estimated (Choubisa et al., 1995). High levels of fluoride were recorded in the ground water of an industrial area of Jeedimelta, Andhra Pradesh (Gupta and Saxena, 1997; Prasad and Chandra, 1997). Suresh et al., (1996) studied fluoride concentration in Bhopal water resources. Groundwaters at and around
Chitrakoot and in Alwar District of Rajasthan were found to be rich in fluoride contents (Tripathy et al., 1996; Kumar and Saini, 1998).

Nitrogen is essential to maintain life balance in natural ecosystem. However, nitrogen in the form of nitrate is hazardous to man and animal (Prasad et al., 1998). The magnitude of risk posed to human health from nitrate contamination of ground water is still a matter of debate. In the twin city of Hyderabad and Secunderabad, water of dug wells and tube wells has been found mean nitrate contents of 119 mg/L and 35 mg/L respectively (Lakshmanan, Rao and Vishwanathan, 1986). Nitrate concentrations up to 136.4 mg/L were recorded in the ground water of sub urban regions of Madraj city (Rengraj et al., 1996). Presence of high nitrate contents of dug well water from Cuddapah Town (Andhra Pradesh) were attributed to domestic sewage pollution, improper drainage systems and irrational location of dug wells with respect to septic tanks (Kumaraswamy, 1991).

According to information available, states of India having high nitrate content in drinking water are Tamil Nadu, Haryana and Rajasthan (Pandey et al., 1986). Joshi et al., (1995) carried out water quality assessment in 27 villages of Nagpur District during the period 1990-92 under an “Integrated water and waste management” project where nitrate content ranges from 1.2 to 164 mg nitrogen per litre in bore wells and 1.3 to 150 mg N/L in dug wells. It was observed that 20 out of the 30 dug well samples and 14 out of 23 samples from hand pumps had nitrate exceeding the BIS limit of 10 mg N/L. Ground water of Uttar Pradesh and Rajasthan was found to be rich in nitrate contents (Ozha et al., 1993).

Large scale of nitrogenous fertilizer was found to be responsible for high level of nitrate in the natural water of Delhi (Bhatia and Deve, 1980). Nitrate is formed by biochemical activities of micro-organisms or added in chemically synthesized forms to lithosphere enters hydrosphere with relative ease, as all these environmental components are dynamically interconnected. Due to high solubility of nitrate in water and its low retention by soil particles makes it a major component of ground water. Ammonium compounds of manures, sewage and animal waste are also oxidized to nitrate. Nitrate enters the human body through the use of ground
water for drinking and causes a number of health disorders, viz., methemoglobinemia in case of infants, gastric, cancer, goiter, birth malformations, hypertension, etc. when present in high concentration in drinking water. In the fatal methemoglobinemia case in infant due to nitrate toxicity, infant blood was found to turn chocolate brown and the well water analyzed was found to contain 150 mg nitrate N/L (Johnson et al., 1987).

The high nitrate level in urban areas may be attributed to bad sanitary practices as per WHO observations. With the increase in the use of nitrogenous fertilizers in India and huge amount of organic wastes generated by the massive population, ground water nitrate pollution in many regions of India has assumed alarming proportions and may aggravate in the coming years (Majumdar et al., 2000).

Degradation of ground water quality due to heavy metals in industrial areas of India was studied by Tyagi et al. (2000). Metal contamination of ground water in Guwahati, Assam has been reported by Jain et al., (2000). Heavy metals viz. iron; lead and arsenic originated from industrial effluents are found in ground water of Faridabad District of Haryana (Khurshid et al., 1997). A study reported the presence of toxic metals like Cr, Cd, Se, Sb, Hg in drinking water sources are not uncommon (Rao et al., 1994, Tripathi et al., 1996). In Delhi, drinking water has been found contaminated with heavy metals (Zeheeruddin et al., 1996). According to Chandra et al., (1991), in the “Maha Kumbhamela” area of Allahabad, tube well water is polluted due to presence of cadmium in high concentration. The pollution effects caused due to heavy metals is increasing (Ramanibai and Ravichandran, 2001).

The quality of drinking water in some identified villages of Delong Block, Orissa recorded the total iron content in most places beyond the stipulated limit of WHO (Rao et al., 1998). According to Jain et al., (1996), the ground water of Hardwar District of UP has been found unfit for domestic applications. The study of bore well water in Priparya Township has recorded higher values of turbidity, total alkalinity, calcium hardness, magnesium hardness and manganese and has suggested for proper treatment of domestic and municipal sewage which has been responsible for such situation (Kataria, 2000). Khurshid et al., (1998) showed that the chemical nature of
surface water from Eloor to Cochin harbour has established that wastewater disposal has been a major source of water contamination by trace metals. Similar results have been reported by a number of investigations (Saha et al., 1999; Agarwal et al., 2000; Pradhan et al., 1998; Nayak and Sawant, 1996; Dixit et al. 2003).

Ground water in an industrial area of Tuppa in Maharashtra has been found to be contaminated by industrial effluents (Kaplay et al., 1998). In this study, the ranges of various parameters are: Temperature: 23-29°C, pH: 7.19-7.91, Chloride: 12.24-271.22 mg/L, total alkalinity: 290-1165 mg/L (CaCO₃), calcium: 56.11-1042.08 mg/L, magnesium: 26.37-777.99 mg/L, sodium: 121-1075 mg/L, Potassium: 0.06-4.2 mg/L.

Arvinda et al. (1998) reported that industrial effluents have been responsible for pollution of the river Thunga-Bhadra, Karnataka. The quality of Morna river water at Akola found to be unsatisfactory due to the presence of sulphate, nitrate and pathogenic bacteria at high levels (Musaddiq, 2000). Study of Padma river water at Kozhencherry (Koshy and Nayar, 2000) has reported that the pollution rate has been increasing every year due to anthropogenic activities. Water from major rivers in Tamilnadu was shown to be unsuitable for drinking and other domestic purposes due to contamination by pathogenic organisms (Sujatha, 2001). Similarly, river water quality was monitored in many investigations (Shrivastava, 1993; Kaur et al., 1996; Mogal and Desai, 1998; Bhuvaneswaran et al., 1999).

Monitoring of river Ramganga water at Barielly suggested greater pollution load during “mass bathing” (Chandra et al., 1996). Well water in Varanasi City was found to contain radioactive substances, which found their pathway from the effluents of an industry (Ketri Copper Mine). The contamination level was observed after rain (Choudhry, 1990). Ground water quality in Patiala City was studied extensively and a high content of chromium, identified to be of industrial origin was recorded (Sharma et al., 1989; Mittal et al., 1994). The surface and ground water quality in Mandiakudar with respect to physico-chemical characteristics has found the water, except from ponds, suitable for drinking purpose (Adak and Purohit, 2001). Suresh et al., (1996) studied fluoride concentrations in Bhopal water
resources. The water of Kolar reservoir located in the same city was found to be severely affected by various domestic and industrial effluent streams flowing to the dam water at different points (Kataria et al., 1996).

The bacteriological quality of drinking water in and around Vijaipur was assessed (Jain et al., 1993). Gyananath et al., (2000) investigated bacteriological contamination of the Godavari river water at Nanded during “Holimela”. Similar investigation was carried out in the ground water of Karnataka (Krishna and Sankar, 2000). Bacteriologically the quality of water was found to be much degraded and unsafe for public health. Pollution level and quality status of water in parts of Cochin for domestic purposes has also been assessed (Khurshid et al., 1998). The bacteriological contamination of ground water was studied by Bobby Cruz et al., (2000) in Trichirapalli City. Similar works were carried out by Lal and Bhattacharyyya (1989); Malik et al., (1995); Joshi et al., (1996); Sarma and Bhattacharyya (1997) and Gaur et al., (2000). Water from some community ponds at Rourkela was not safe for human consumption (Naik and Purohit, 1996).

Mahapatra and Singh (1998) reported the concentrations of inorganic anions in drinking water from different sources in Cuttack within the permissible limits. Contamination of drinking water with fluoride, total hardness and coliform bacteria has posed a serious problem in Agra (Shrivastava and Choudhary, 1997). Groundwater at and around Chitrakoot and in Alwar District of Rajasthan was found to be rich in fluoride contents (Tripathy et al., 1996; Kumar and Saini, 1998). Ground water quality in sub urban areas of Madras city was found to be degraded (Rengaraj et al., 1996). Water quality was reported to be suitable for both domestic and irrigation purposes in Sundargarh district and Armoni Town of Maharastra (Das and Sahoo, 1999; Patil et al., 2001). Latif and Jha (1998) showed that the tube well water was suitable for drinking purpose over municipal supply water in Doarbanga. Water quality in coastal regions of Andhra Pradesh was observed to be unsuitable for various uses (Jain et al., 1997; Naidu et al., 1998).

Physico-chemical parameters of ground water in Kadur and its surrounding areas of Karnataka were recorded as: pH (6.7-8.9), conductance: (0.6-6.4) mscm⁻¹,
TPS (437-1630) mg/L, Total Hardness (96.5-1427.2) mg/L, Calcium hardness (60.3-1338.2) mg/L, Magnesium hardness (16-1143) mg/L, Chloride (20-400) mg/L, Sulphate (20-240) mg/L, Nitrate (1.1-10) mg/L, Fluoride (0.14-1.4) mg/L, Turbidity (0.2-17.1) NTU. The water quality in this area was not fit for domestic uses (Nalina et al., 2006). Phosphorous contamination of Kali river water in Dandeli, Karnataka was attributed to entry of agricultural run-off and to other human activities. The quality of same water was found degraded with respect to other physico-chemical parameters (Krishnamurthy and Bharati, 1995-97). Physico-chemical analysis of water from river Anjar (Kataria and Jain, 1995), usefulness of river Tawi (Jammu) water for drinking purpose with respect to trace metals (Dhar et al., 1989) and unsuitability of water from Rapti river at Gorakhpur for domestic, irrigation and other uses (Singh, 1995) have also been reported.

Correlations among various water quality parameters were worked out in various studies (Pallah et al., 1990; Kaul et al., 1992; Rao and Rao, 1994; Pradhan et al., 1997; Venkatachalam and Jebanesan, 1998, Jain et al., 2000; Tamlurkar et al 2006). Garg et al., (1990) investigated the seasonal variations in ground water quality in Roorkee City and showed that the tube well water was not affected very much by seasonal changes. Various drinking water samples in Burdwan District of West Bengal have showed the presence of arsenic, cadmium, manganese and zinc above guideline values (Nag and Das, 1992). Deo and Ali (1993) recorded the concentrations of iron, magnesium, copper, calcium, zinc, manganese, sodium, potassium, aluminium and strontium within the permissible limits in well water in the mining area of Keonjhar District. Various physico-chemical characteristics of surface and ground water and their correlation coefficients were studied by Venkatachalam et al., 1998 and Adak and Purohit, 2001.

Assuming the supplied water to be safe, it has been suggested that the number of water taps per 100 populations is a better indication of health than the number of hospital beds (Tebbutt, 1998). That is, safe drinking water is an unavoidable element of public health. This need of the people is still a far cry in many parts of India. Rapid population growth and relative lack of development, compounded with ignorance, poverty and inadequate infrastructural facilities have
made the supply of clean and safe drinking water to all the people a cry in India. The environmental problems resulting from sewage discharges, indiscriminate dumping of solid wastes, inadequate refuse collection system, unscientific agricultural practices, and large-scale deforestations etc. is significant in India for ages. Nowadays, these issues have received prominence in government agenda.

The physico-chemical characteristics of drinking water from ponds in India were studied by Jadhav 2006. Srinivas et al., (2001) studied the chemistry of rainwater in and around Hyderabad and Secunderabad. Similar studies have been reported by Das (1988), and Subba Rao et al., (1995). The water quality situation in Assam as well as in the Northeastern region is not better and more or less same as the rest of the country. The environmental monitoring and studies of water quality for human uses particularly for drinking purposes are in still in its infant stage in this region. Air and water quality assessment is of recent origin in the state and most of the studies have been confined to Guwahati and its suburbs.

The well water of Arunachal Pradesh has been found to have high bacteriological contamination (Das, 1989). The ground water of North Tripura district has been reported to be unsafe for drinking due to bacteriological and chemical contamination (Kumar et al., 1990). The surface water quality of Greater Guwahati has been studied with respect to trace metals and has been found contaminated with iron (Kakati and Bhattacharyya, 1990). Gogoi et al., (1991) reported the iron contamination of drinking water of Duliajan (Assam). The quality of wastewater and storm run-off of the IOC refinery at Guwahati have been proved to be degraded (Kakati and Bhattacharyya; 1990; Sarma and Bhattacharyya, 1995). The Bharalu river water at Guwahati was found to be contaminated by various waste disposals (Lal and Bhattacharyya, 1989). Sarma (1997) assessed the quality of drinking water from different sources in the Darrang District of Assam. Sarma and Bhattacharyya, (1995) studied the surface water quality of a few entrapped water sources in and around Guwahati city. Trace metal distribution in water bodies around Lakwa oil field (Assam) was studied and the contamination by trace metals viz. Zinc, Copper, Cobalt, Nickel and Lead was found to be significant (Baruah et al., 2001). Sarma (2002) assessed the drinking water quality in Goalpara District.
As per Northeastern Regional Institute of Water and Land Management (NERIWLM) all together 6777 habitations of northeastern states (including 2931 in Tripura) have been identified with having excess of fluoride, nitrate, iron and arsenic levels in the ground water, a major threat to the region. Assam has maximum sources of contaminated water with 28181 habitations followed by Tripura with 2931, 566 in Arunachal Pradesh, 136 in Nagaland, 124 in Meghalaya, 76 in Sikkim, 37 and 26 in Manipur and Mizoram respectively. In most of the cases the sources either going dry or lowering in the ground water table was seen, besides, systems were working below rated capacity due to poor operation and maintenance, increasing population resulting in lower per capita availability and slippage had also taken place due to seasonal shortage of water. All together 7067 habitations had been identified as arsenic affected while 29030 as fluoride affected. The Govt. of India has put highest priority for the years’ 2007-09 and suggested to tackle other problems by rain water harvesting and in situ remediation under submission on sustainability of water (www.sentinelassam.com).