Chapter 2: REVIEW OF LITERATURE

2.1 Water- the precious resource

Water is the most common and precious natural resource without which there would be no existence of life on earth. The demand of water for various uses like drinking, irrigation, power generation for industries, fisheries, navigation and recreation is ever increasing due to rapidly increasing population associated with increased urbanization, rise in standard of living, industrialization and agricultural behavior. The quality of water is a vital concern for human being since it is directly related to the human health and hence the establishment of stable community. However, the quality of water varies widely with respect to its various uses and the water quality suitable for one purpose may not be satisfactory for another. In general, a water sample is suitable for drinking purpose if it has no color, turbidity and odor and has no objectionable taste. At the same time it should be free from pathogenic micro-organism and chemical substances that are hazardous to the human health. However mere sense does not guarantee a water sample to be safe for drinking. The fresh water supply in the earth for drinking is very limited. On the other hand, explosive population growth has exerted tremendous pressure on the water bodies. The factors such as massive industrialization, rapid urbanization and wide spread applications of various chemicals, pesticides, insecticides, herbicides in the agricultural fields have added considerable number of pollutants to the water resources (Pionke et al. 1990). The geochemical characteristics of an area also influence the rate of presence of concentrations of various chemical substances in the water bodies of a particular area (http://whqlibdoc.who.int). The most common and widespread health risk associated with drinking water is microbial contamination, because microbial contamination of major urban system has the potential to cause large outbreaks of waterborne diseases. Water related diseases are rare in developed
countries because of the availability of efficient provisions for adequate water supply and waste water disposal system. But in developing and underdeveloped countries contamination of drinking water by domestic and industrial wastes as well as human and animal excreta is a common feature (Crocker and Scott, 2000). Diseases related to contamination of drinking water constitute a major burden on human health. Faecal pollution leads to introduction of a variety of intestinal pathogens, bacteria, virus and parasites causing diseases starting from mild gastroenteritis to serve and fatal dysentery, cholera and typhoid. Naturally occurring micro-organisms in drinking water may cause a variety of infections in skin and in the mucous membranes of the eye, ear, nose and throat (http://nhmrc.gov.au). Moreover water can serve as an efficient transmitter of human pathogenic micro-organisms of sewage origin.

Chemical contamination of drinking water either naturally or 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 behave as cumulative poisons showing the adverse health effects after a long period of exposure (Plant et al. 2005). The use of various structurally complex synthetic compounds in the field of industry and agriculture has added many potentially toxic chemicals in the aquatic environment (Randhawa et al. 2009). The major toxic contaminants of water are As, F−, Pb, Hg, Cd, Cu, Ni, Zn, NO3− and NO2−, Se, Ag, Ba, Be, CN−, pesticides, poly nuclear aromatic hydrocarbons, phenols etc. There are other chemical constituents, which are non toxic, but affect the aesthetic and organoleptic quality of water. These include Al, Cl−, Cu, hydrogen sulphide, Fe, Mn, DO (dissolved oxygen), Zn, SO42− etc (Oates and Cohen, 2009). The need to monitor drinking water quality has been universally recognized and is a necessary safeguard against a large number of health hazards.
2.2 Drinking Water quality

Water is a very essential commodity to the human beings. Water, the universal solvent, can dissolve toxic and hazardous substances and suspended particles even in its natural state, causing water pollution, affecting the lives of many people throughout the world. The contamination of natural water is being increased day by day as the organic and inorganic pollution load is going to be increased day by day. Drinking water quality is considered as a very serious issue in all over the world and more attention has been given with the problem in the developing countries (WHO, 2004). However water quality parameters by means of physical, chemical and bacteriological examination are used as a tool for the evaluation of water quality pollution and also to provide guidelines for the provision of safe drinking water to the citizens. Diminution in pollution or improvement in water quality used for human consumption depends upon reliable analytical measurements (Lepom et al., 2009). The world health organization (WHO), has introduced a set of guideline values for drinking water quality (WHO, 2004) to ensure the physical, chemical and biological composition of water within the limits, so as not to cause undesirable effect to human being over a long time of consumption. Water conforming to such standards is known as potable water. The primary purpose of the Guidelines for Drinking-water Quality is the protection of public health. Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable. Safe drinking water, as defined by the Guidelines (WHO, 2008), does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Those at greatest risk of waterborne disease are infants and young children, people who are debilitated or living under unsanitary
conditions and the elderly. Safe drinking-water is suitable for all usual domestic purposes, including personal hygiene. Although the Guidelines describe a quality of water that is acceptable for lifelong consumption, the establishment of these Guidelines, including guideline values, should not be regarded as implying that the quality of drinking-water may be degraded to the recommended level. Indeed, a continuous effort should be made to maintain drinking-water quality at the highest possible level. The standards given by ISI (Indian Standard Institute) and EPA (Environment Protection Agency) standards of USA are also useful to determine the water quality parameters. The drinking water guideline values given by WHO/BSI are given below in Table 1 and Table 2.

Table 1: Drinking water guidelines for physical and bacteriological water quality parameters prescribed by WHO/BSI

<table>
<thead>
<tr>
<th>Parameters</th>
<th>WHO (DL- PL)* ppm</th>
<th>BIS (DL- PL)* ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour in Hazen units</td>
<td>5-25</td>
<td>5-25</td>
</tr>
<tr>
<td>Odour</td>
<td>Agreeable- Agreeable</td>
<td>Agreeable- Agreeable</td>
</tr>
<tr>
<td>Turbidity in NTU</td>
<td>5-10</td>
<td>5-10</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Faecal Coliform Bacteria</td>
<td>Must not be detectable in 100 ml sample</td>
<td>Must not be detectable in 100 ml sample</td>
</tr>
</tbody>
</table>

* DL: desirable limit; *PL: permissible limit, *ppm: parts per million
Table 2: Drinking water guidelines for chemical water quality parameters prescribed by WHO/BIS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>WHO (DL- PL)* ppm</th>
<th>BIS (DL- PL)* ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5-8.5 - No relaxation</td>
<td>6.5-8.5 - No relaxation</td>
</tr>
<tr>
<td>TH</td>
<td>300-600</td>
<td>300-600</td>
</tr>
<tr>
<td>Na</td>
<td>200 - No relaxation</td>
<td>200 - No relaxation</td>
</tr>
<tr>
<td>K</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Mg</td>
<td>30-100</td>
<td>30-100</td>
</tr>
<tr>
<td>Ca</td>
<td>75-200</td>
<td>75-200</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>200-400</td>
<td>200-400</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>45-100</td>
<td>45-100</td>
</tr>
<tr>
<td>F⁻</td>
<td>1.0-1.5</td>
<td>1.0-1.5</td>
</tr>
<tr>
<td>As</td>
<td>0.01- No relaxation</td>
<td>0.01- No relaxation</td>
</tr>
<tr>
<td>Fe</td>
<td>0.3-1.0</td>
<td>0.3-1.0</td>
</tr>
<tr>
<td>Mn</td>
<td>0.1-0.3</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>Pb</td>
<td>0.05- No relaxation</td>
<td>0.05- No relaxation</td>
</tr>
<tr>
<td>Cd</td>
<td>0.01- No relaxation</td>
<td>0.01- No relaxation</td>
</tr>
<tr>
<td>Cu</td>
<td>0.05-1.5</td>
<td>0.05-1.5</td>
</tr>
<tr>
<td>Zn</td>
<td>5.0-15.0</td>
<td>5.0-15.0</td>
</tr>
</tbody>
</table>

* DL: desirable limit; *PL: permissible limit, *ppm: parts per million

2.3 Water quality parameters; Problems related to drinking water quality
Water quality parameters are considered as a tool for the evaluation of water pollution and also to provide guidelines for the provision of safe drinking water to the citizens. Various investigations show that, most of the infectious...
diseases are water borne and these diseases cause morbidity and mortality. The mortality rate especially among the infants is very high in developing countries like India. The public more or less is not well aware of the impact of water quality on human health. Reduction in pollution and improvement in quality of water used for human consumption depends upon reliable analytical measurements. Therefore, analytical water quality parameters are utmost important and are paying a key role for water pollution assessment. The importances as well as the impact of the water quality parameters are stated below.

2.3.1 Temperature
Temperature plays an important role in the physical, chemical and biological qualities of water (Park and Fayer, 2007). Temperature is also very important in the determination of various water parameters such as pH, conductivity, saturation level of gases and various forms of alkalinity etc. The speed of a chemical reaction in water increases as the temperature of the water increases which may reduce the solubility of gases and amplifies the taste (pleasant taste at 7°C to 11°C) and odour. At the same time the coagulation properties of suspended impurities and disinfection of water by bacteria are also influenced by the temperature of the water. Cool water is generally more palatable than warm water, and temperature has an impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems.

2.3.2 Odour
Odour of water (no odour in pure state) may due to natural or man made activity like decomposition of organic matters (plants, algae and other organisms), which liberates gases like ammonia, methane, hydrogen sulphide etc (WHO 2008). The presence of organic and inorganic compounds like
phenols, acetones, urea, insecticides, pesticides, herbicides, sulphides, halogens, metals like Fe, Cu, Pb, Zn etc. and pharmaceuticals, originate from municipal and industrial waste may also give odour to the water environment. Odour may also develop during storage and distribution due to microbial activity. Taste and odour in drinking-water may be indicative of some form of pollution or of a malfunction during water treatment or distribution (WHO 2008). It may therefore be an indication of the presence of potentially harmful substances.

### 2.3.3 Colour

Colour plays an important role in determining the suitability of water for drinking, cooking, batching and other domestic and industrial use (World Health Organisation, 2001). Colour of natural water indicates the presence of humic acids, fulvic acids, metallic ions such as Fe and Mn, suspended matters, phytoplankton and industrial effluents from textile, leather, food, pulp and paper industries. The appearance of reddish colour in groundwater generally occurs due to presence of Fe in three states as insoluble Fe hydroxides. Highly coloured polluted water has an objectionable taste due to humic substances, originating from decay and aqueous extraction of vegetation into surface water. Most people can detect colours above 15 true colour units (TCU) in a glass of water. Levels of colour below 15 TCU are usually acceptable to consumers, but acceptability may vary (WHO 2008). High colour could also indicate a high propensity to produce by-products from disinfection processes. No health-based guideline value is proposed for colour in drinking-water.

### 2.3.4 Turbidity

Turbidity is an optical property that causes scattering of light due to presence of suspended particle like clay, silt, organic matter, plankton and other micro-organism in water (Lechevallier et al. 1981). Surface water is comparatively more turbid during monsoon season as compared to groundwater (water
filtered through layers like sand, soils etc.) due to different activities like washing and wading of cattles, discharges of effluents from industries, surface runoff which carries the topsoil from the catchment area to the water body. The degree of turbidity of a water course may be used as a measure of the intensity of pollution. According to EPA the maximum turbidity value was fixed at 1 NTU (Nephelometric Turbidity Unit). Turbidity is an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration. No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter. The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. Particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. In all cases where water is disinfected, the turbidity must be low so that disinfection can be effective.

2.3.5 Dissolve oxygen (DO)

Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement) and as a waste product of photosynthesis is measured in the form of dissolve oxygen. Concentration of total dissolved oxygen in high amount can be harmful to aquatic life. Fish in waters containing excessive dissolved gases may suffer from "gas bubble disease" which may block the flow of blood through blood vessels causing death. External bubbles (emphysema) can also occur and be seen on fins, skin and on other tissue. Aquatic invertebrates are also affected by gas bubble disease but at levels higher than those lethal to fish. Adequate dissolved oxygen is necessary for good water quality (http://tellus.ssec.wisc.edu). Factors affecting the solubility of dissolved oxygen include water temperature, atmospheric pressure, and
salinity. As the dissolved oxygen levels in water drop below 5.0 ppm, aquatic life is put under stress (http://www.kywater.org/ww/ramp/rmdo2.htm).

2.3.6 pH

pH (the negative logarithm of hydrogen ion concentration) is a measure of hydrogen ion activity which can determine the acid–base equilibrium of dissolved components (Beka et al., 2009). The pH of natural water (pH = 6.5-8.5, WHO 1993, BIS 1991) which is controlled by the carbon dioxide-bicarbonate-carbonate equilibrium system may be changed due to exposure of air, biological activity and temperature changes (Trivedy & Goel 1986). A water solution having pH <7.0, 7.0 and >7.0 may be considered as acidic, neutral and basic respectively. pH less than 6.5 or greater than 9.2 would markedly impair the potability of the water (WHO 2008). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters, the optimum pH required often being in the range 6.5–9.5.

2.3.7 Total Hardness (TH)

In general practice, hardness is defined as the sum of the Ca and Mg concentrations, both expressed as Ca carbonate, in milligrams per liter. Water hardness, is one of the most important parameter in terms of water quality as well as fish health point of view. Water hardness has a major effect on pH and its stability. It will affect the toxicity of many common substances, including some fish disease treatments (http://www.fishdoc.co.uk/water/hardness.htm). It also has a major effect on fish osmoregulation, a process vital to fish health. Hard water is not suitable for bathing, washing and laundering. Hardness prevents the corrosion in the pipes by forming a thin layer of scale, and reduces the entry of heavy metal from the pipes to the water. Though hardness is not harmful to health, it has been suspected to be plying some role in heart disease (http://www.ijpqa.com).
2.3.8 Sulphate (SO$_4^{2-}$)

Sulphate is a major anion in hard water reservoirs (http://www.kywater.org). It can be obtained naturally or as a result of municipal or industrial discharges. When naturally occurring, they are often the result of the breakdown of leaves that fall into a stream, of water passing through rock or soil containing gypsum and other common minerals, or of atmospheric deposition. Point sources include sewage treatment plants and industrial discharges such as tanneries, pulp mills, and textile mills. Runoff from fertilized agricultural lands also contribute sulphates to water bodies. Sulfur is an essential plant nutrient. Aquatic organisms utilize sulfur and reduced concentrations have a detrimental effect on algal growth. The most common form of sulfur in well-oxygenated waters is sulphate. When sulphate is less than 0.5 ppm, algal growth will not occur (http://www.kywater.org). Sulphates are not considered toxic to plants or animals at normal concentrations. In humans, concentrations of 500-750 ppm cause a temporary laxative effect (http://www.kywater.org). However, doses of several thousand ppm did not cause any long-term ill effects. At very high concentrations sulphates are toxic to cattle. Problems caused by sulphates are most often related to their ability to form strong acids which changes the pH. Sulphate ions also are involved in complexing and precipitation reactions which affect solubility of metals and other substances.

2.3.9 Nitrate (NO$_3^-$)

Nitrate is a natural constituent of plants and is found in vegetables at varying levels depending on the amount of fertilizer applied and on other growing conditions. According to the WHO, most adults ingest 20-70 mg of nitrate-nitrogen per day with most of this coming from foods like lettuce, celery, beets & spinach (http://www.dnr.state.wi.us/org/water/dwg/nitrate.htm). When foods containing nitrate are eaten as part of a balanced diet the nitrate exposure is not thought to be harmful. Infants who are highly exposed to
nitrate may faced the disease like methemoglobinemia (blue baby syndrome) because the skin appears blue-gray or lavender in color caused by a lack of oxygen in the blood (http://www.dnr.state.wi.us/org/water/dwg/nitrate.htm). Some scientific studies have found evidence suggesting that women who drink nitrate-contaminated water during pregnancy are more likely to have babies with birth defects. Nitrate ingested by the mother may also lower the amount of oxygen available to the fetus. People who have heart or lung disease, certain inherited enzyme defects, or cancer may be more sensitive to the toxic effects of nitrate than others. In addition, some experts believe that long-term ingestion of water high in nitrate may increase the risk of certain types of cancer.

2.3.10 Fluoride (F⁻)

F⁻ is a fairly common element that does not occur in the elemental state in nature because of its high reactivity. It accounts for about 0.3 g/kg of the earth's crust and exists in the form of fluorides in a number of minerals, of which fluorspar, cryolite, and fluorapatite are the most common. It can cause significant effects on human health through drinking water. Different forms of F⁻ exposure are of importance and have shown to affect the body's F⁻ content and thus increasing the risk of fluoride-prone diseases. F⁻ has beneficial effects on teeth at low concentrations of 1ppm by preventing and reducing the tooth decay (Rao 2003). Concentrations lower than 0.5ppm of F⁻ however have shown to intensify the risk of tooth decay. F⁻ can also be quite detrimental at higher concentrations exceeding 1.5-2.0 ppm of water (Rao 2003). High concentration of F⁻ poses a risk of dental fluorosis as well as skeletal fluorosis and osteoporosis. Skeletal fluorosis is a significant cause of morbidity in certain regions of the world (Sajidu 2008).
2.3.11 Sodium (Na)

Na is present in abundance or in less quantity in natural water; sea water contains relatively high levels of sodium about 10 g of sodium per litre (www.pcrwr.gov.pk/wq_phase3_report/chap2.htm). The principal cation present in the extra-cellular fluid (ECF) has several physiological roles including acid-base balance; generating transmembrane gradients (which allow cells to take up nutrients) maintenance of ECF volume and osmotic pressure and in the electro-physiology of nerve and muscle cells. Deficiency of sodium in the body might appear as mental apathy, low blood pressure, fatigue, depression, dehydration etc., whereas over dose can cause adema, hypertension, stroke, headache, kidney damage, stomach problem and nausea (http://www.pcrwr.gov.pk/wq_phase3_report/chap2.htm).

2.3.12 Potassium (K)

The element K plays an important role in human body. Vital functions of K include its role in nerve stimulus, muscle contractions, blood pressure regulation and protein dissolution. Daily intake of 2-3.5g K in diet may be very helpful for a human being (http://www.lenntech.com/periodic/water/potassium/potassium-andwater.htm). It protects the heart and arteries, and may even prevent cardiovascular disease. K content in drinking water varies greatly depending on its source and it tends to be larger in mineral waters than ordinary tap water (http://www.epa.gov/EPA-PEST/2006/June/Day-14/p8939.htm). The total amount of K (in between 110 & 140 g) lies in a human being is mainly depends upon muscle mass (contains most K, after red blood cells & brain tissue) whereas its opponent Na is present in intracellular fluids. K shortages may lead to depression, muscle weakness, heart rhythm disorder & confusion (http://www.lenntech.com/periodic/water/potassium/potassium-andwater.htm). K loss may be a consequence of chronic diarrhoea or kidney disease, because the physical potassium balance is regulated by the
kidneys. When kidneys operate insufficiently, K intake must be limited to prevent greater losses. Potassium alum may cause stomach complaints and nausea at concentrations as low as 2 g, and may be corrosive and even lethal in higher concentrations (http://www.lenntech.com/periodic/water/potassium/potassium-andwater.htm). Potassium carbonate is lethal to adults at doses above 15 g (http://www.lenntech.com/periodic/water/potassium/potassium-andwater.htm).

2.3.13 Calcium (Ca)

In order of abundance it is the fifth element which is commonly present in all water bodies where it usually comes from the leaching of rocks. Disposal of sewage and industrial waste materials are also important sources of Ca. Ca is very essential for nervous systems and for formation of bones (http://www.indiamart.com/petrus-terbonova/pcat-docs/essential_20vitamins_10479474.pdf). Ca in an aquatic environment is an important macronutrient. It is also needed in large quantities by molluscs and vertebrates. The concentration of Ca in potable water ranges from 75 ppm to 200ppm (WHO 1993, BIS 1991). Ca has no hazardous effects on human health (http://www.epa.gov/ttn/atw/hltheff/calciumc.html). Ca concentrations upto 1800ppm has been found not to impair any physiological reaction in man (Trivedy and Goel. 1986).

2.3.14 Magnesium (Mg)

The Mg, like Ca, is a common element present in water environment has the property to produce hardness in water. It was reported that the Mg concentration may vary from zero to several hundred milligrams per liter, depending on the source and treatment of water. About 19g of Mg per 70kg human body weight is involved in the synthesis of protein as well as acts as co-factor in 300 enzymatic reactions (http://www.acu-cell.com/acn.html).
2.3.15 Arsenic (As)

The outcome of experimental findings of As poisoning due to drinking of As contaminated water show the presence of almost all the stages of As clinical manifestation (Hotta, 1989). After the ingestion of As into the human body, about 50% of the As is excreted in the urine (Das, 1995; Das et al., 1995), with small portions through the faeces, skin, hair, nails and lungs. Thus As in urine, faeces, skin, hair, nails and lungs have been used as an indicator of the As hazard to the population (Borgono and Greiber, 1971; Goldsmith et al., 1972; Yamamura and Yamauchi, 1980). People drinking As contaminated water generally show skin lesions, which are a late manifestation of As toxicity. Long term exposure to As contaminated water may lead to various diseases such as conjunctivitis, hyperkeratosis, hyperpigmentation, cardiovascular diseases, disturbance in the peripheral vascular and nervous systems, cancer of the skin, lung, liver, urinary bladder and kidney skin, gangrene, leukemomalnosis, nonpitting swelling, hepatomegaly and splenomegaly (Jack et al. 2003; Tchounwou et al. 2003; Bunnell 2007; Jie and Waalkes 2008; Xia et al. 2009).

2.3.16 Iron (Fe)

Fe is the 4th most abundant element on the earth’s crust (Malyszko 2009). Occurs mainly in the divalent and trivalent (ferrous and ferric) forms in water (http://wgbis.ces.iisc.ernet.in/energy/water/paper/Tr-115/chapter5.htm). The form and solubility of Fe in natural water are strongly dependent upon the pH and the oxidation–reduction potential of the water: under reducing conditions Fe exists in the ferrous state (Fe II). On exposure to air or addition of oxidants, a ferrous ion is oxidized to the ferric state (Fe III) and may hydrolyse to form insoluble hydrated ferric oxide. Fe in water can cause staining of laundry and porcelain. A bittersweet astringent taste is detectable by some persons at level above 1 ppm (WHO/BIS Permissible limit of Fe in drinking water). Fe is an
essential element in human nutrition (http://www.nutrientdataconf.org/PastConf/NDBC14/5-1_Nielsen.pdf). It is contained in a number of biological significant proteins as haemoglobin and cytochromes. Fe also promotes the growth of "iron bacteria" which derive their energy from the oxidation of Fe (II) to Fe (III) and in the process deposit a slimy coating on the piping. Regarding the health aspect it is found that Fe deficiency caused anemia. It has also been reported that children have been known to develop Fe toxicity by higher Fe intake symptomized by fatigue, anorexia, dizziness, nausea, vomiting, headache, weight loss, shortness of breath and possibly a graying color to the skin (http://www.prr.hec.gov.pk/Thesis/1118.pdf).

2.3.17 Manganese (Mn)

The very reactive element Mn is found in nature is used extensively in industry for the manufacture of glass, ceramics, batteries, paints, varnishes, inks, dyes and fireworks (http://www.answers.com/topic/pyrolusite). It occurs in two forms (divalent and trivalent) and it is rarely found in natural surface waters in concentrations above 1.0 ppm. (World Health Organization, Geneva 1994). However, in ground waters subject to reducing conditions Mn can be leached from the soil and occur in high concentrations. Mn often accompanies Fe in ground waters (http://www.oregon.gov). At high concentrations in water it will cause an unpleasant taste, deposits on food during cooking, stains on sanitary ware, discolouration of laundry, deposits on plumbing fittings and cooking utensils, and will foster the growth of micro-organisms in water supply systems (http://www.usfa.dhs.gov/downloads/pdf/publications/Water_Supply_Systems_Volume_II.pdf).

2.3.18 Lead (Pb)

Pb is a toxic metal that is harmful to human health. High levels of Pb contamination (stored in brain, bones, kidneys and other major organs) in a child can result in convulsions, major neurological damage, organ failure,
coma, and ultimately death (http://emedicine.medscape.com/article/410113-overview). Moderate to low levels of exposure may result in hearing loss; inhibit growth, learning disabilities, cramps, irritability, fatigue, vomiting, constipation, sleep disorder, poor appetite, and trouble sleeping. The drinking water quality can have a great impact on the Pb level of water. If the water is soft or corrosive, this type of water can accelerate the leaching of Pb and Cu and other metals from household plumbing and water fixtures (http://www.water-research.net/lead.html). The signs of this type of problem would include: greenish rings (Cu) around basins, metallic or bitter taste to the water especially in the mornings, and frequent leaks/ evidence of corrosion of the household plumbing.

2.3.19 Cadmium (Cd)

Pure Cd is a soft, silver-white metal found naturally in small amounts in soil (http://www.idph.state.il.us/envhealth/factsheets/cadmium.htm). Cd is not mined, but it is a by-product of the smelting of other metals such as Zn, Pb and Cu. The principal industries that use Cd are metal smelting, electronics, nuclear power, paint pigment production, and other metal working and refining companies. Cd is released into the environment from mining and metal processing operations, burning fuels, making and using phosphate fertilizers, and disposing of metal products (Assche 1998). People living near industry that conducts any of these activities may be exposed to Cd. Cd exposure at low levels usually does not produce immediate health effects, but can cause adverse health effects over long periods. Cd can enter the body from smoking tobacco, eating food and drinking water containing Cd (http://www.idph.state.il.us/envhealth/factsheets/cadmium.htm). Fruits and vegetables, especially grains, potatoes, and leafy vegetables like spinach, grown in soils with high levels of Cd may contain elevated levels of Cd. Shellfish and organ meats like liver or kidney also contain more Cd than other
foods (http://www.idph.state.il.us/envhealth/factsheets/cadmium.htm). Cd once entered into the body, is stored mainly in the bone, liver, and kidneys and it affects causing stomach irritation, vomiting, diarrhea, kidney damage and fragile bones (http://www.idph.state.il.us/envhealth/factsheets/cadmium.htm).

2.3.20 Copper (Cu)
Copper the reddish metal occurs naturally in rock, soil, water, sediment, and air (http://www.cdc.gov/ncidod/dpd/healthywater/factsheets/copper.htm). Its unique chemical and physical properties have made it one of the most commercially important metals. Since Cu is easily shaped or molded, it is commonly used to make pennies, electrical wiring, and water pipes. Moreover the Cu compounds are also used as an agricultural pesticide, and to control algae in lakes and reservoirs (http://www.cdc.gov). It is an essential element for all known living organisms, including humans. However, very large single or long-term intakes of Cu may cause health problems like vomiting diarrhea, stomach cramps and nausea (http://dnr.wi.gov/org/water/dwg/copper.htm).

2.3.21 Zinc (Zn)
Zn, the 23rd most abundant element is found naturally in many rock-forming minerals like Zn blende wurzite, smithsonite and hemimorphite (http://www.lenntech.com/periodic/elements/zn.htm). It also may be present in industrial discharges. Zn has lots of use like galvanization of steel, preparation of negative plates in electric batteries, vulcanization of rubber, wood preservatives, and antiseptics and in rat and mouse poison (Zn phosphide). Zn is an essential element in the diet. It is included in most single tablet as it has an anti-oxidant property (http://www.lenntech.com). Many foodstuffs contain certain concentrations of Zn and very low amount of the metal may cause loss of appetite, decreased sense of taste and smell, slow wound healing and skin sores. Zn-shortages can even cause birth defects. However large amount of Zn can cause eminent health problems, such as stomach cramps, skin irritations,
vomiting, nausea and anaemia, damage of the pancreas and disturb the protein metabolism, cause arteriosclerosis and respiratory disorder (http://www.lenntech.com).

2.3.22 Bacteriological Test (faecal coliform bacteria)

The biological contamination in drinking water is a major problem of public health in developing world. WHO estimates that about 1.1 billion people globally drink unsafe water and the vast majority of diarrhoeal disease in the world (88%) is attributable to unsafe water, sanitation and hygiene (WHO 2003). The most common and widespread health risks associated in drinking water in developing countries are of biological origin. Looking at the 20 leading risks factors for health burden in developing regions, unsafe water, sanitation and poor hygiene are third, behind underweight or practicing unsafe sex (WHO 2003). According to the WHO estimations more than 3 million children below age 5 die annually form diarrhoeal disease contracted through drinking water in developing world. Nonetheless, the inadequate availability of water, poor quality of water at source, ill-maintained water pipelines and sewer lines, unsafe disposing of human, animal and household wastes, unawareness about good sanitation and personal hygienic practices etc. are some key factors responsible for poor drinking water quality in rural areas of India.