CHAPTER III

REVIEW OF LITERATURE
3.1 Introduction

The literature review related to present study gives the information regarding the historical background of study, the present status of research in that field, and recent developments in the subject. It also provides a unique source of information about the groundwater contamination and its effects on human health in the rural, industrial and newly formed urban sectors, which has become path indicator for the studies and therefore forms the strong foundation of present study. In view of this, the present chapter includes the information on:

- Effect of environment on the human health,
- Water related health problems,
- Health issues related to groundwater quality.

3.2 Environment and health

Environment is the creator as well as the destroyer of any biological and living beings on the earth. It also puts both positive and negative impressions at the every stage of life between birth and death. As far as humans are concerned, the relation between the surrounding environment and human health was studied by many researchers for centuries (Skinner 2007). The atmosphere, hydrosphere and lithosphere are considered as the major environmental units and collectively all affecting the health of people by its beneficial and harmful means.

Raucher (1996) studied the relevance of safe drinking water act of United States for public health. Also, old water purification techniques and their legal aspects were put forward in this review paper. Heizer et al. (1997) studied the intestinal effects of
sulfate in drinking water on normal human subjects. Pehlivan (2003) studied the effect of hot springs and hydrogeochemical changes on human health. By analyzing chemical properties and comparing those values with World Health Organization (WHO) the conclusion was drawn that hot and mineralized spring can cause positive or adverse effects on human health. Use of modern tools and techniques in the studies related to health is on rise. For example, McLafferty (2003), Ricketts (2003) and Cromley (2003) reviewed the use of Geographical Information System (GIS) for management of health care system. Hu and Balakrishnan (2005) have studied the relative importance of ingestion, inhalation and dermal contact as routes of exposure for health hazards that are environmentally pervasive. He also enlisted the well recognized hazards in India, like obesity, type II diabetes and associated cardiovascular morbidity that has begun to result from dietary shifts and the spread of sedentary lifestyles etc. Population exposures with respect to newer hazards such as air pollutants (particles, sulfur oxides, carbon monoxide, oxides of nitrogen, ozone, and polycyclic aromatic hydrocarbons), toxic metals (lead, arsenic, mercury in air, water, and food) and organics (pesticides, solvents) still remain understudied.

Fetter (1999) investigated Chloride is minor constituent of the earth’s crust. Rain water contains less than 1 ppm Chloride. Chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt, and saline intrusion (WHO, 1993). Its concentration in natural water is commonly less than 100 mg/L unless the water is brackish or saline. High concentration of chloride gives a salty taste to water and beverages and may cause physiological damages. Water with high chloride content usually has an unpleasant taste and may be objectionable for some agricultural purposes.

Vera et al. (2006) reviews the historical development of population health indicators like environmental, socioeconomic, early life conditions, individual actions and medical. Rapant et al. (2006) studied the environmental and health risk due to abandoned mining area, Zlata Idka, Slovakia. Geochemical analysis indicates that
arsenic (As) and antimony (Sb) is enriched in soils, groundwater, surface water and stream sediments as compared to their crustal abundances presented in Table 3.1. Cutchin (2007) highlighted the need for developing new models for epidemiologic studies of environment and health. His findings suggest a number of geographic perspectives on health and environment that could create useful connections between geography and public health, via social epidemiology.

<table>
<thead>
<tr>
<th>Element</th>
<th>Ion</th>
<th>Percent by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O)</td>
<td>O^{2-}</td>
<td>45.00</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>Si^{4+}</td>
<td>27.20</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>Al^{3+}</td>
<td>8.00</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>Fe^{2+} and Fe^{3+}</td>
<td>5.80</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Ca^{2+}</td>
<td>5.06</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Mg^{2+}</td>
<td>2.77</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Na</td>
<td>2.32</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>K^{+}</td>
<td>1.68</td>
</tr>
<tr>
<td>Titanium (Ti)</td>
<td>Ti^{4+}</td>
<td>0.68</td>
</tr>
<tr>
<td>Hydrogen (H)</td>
<td>H^{+}</td>
<td>0.86</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Mn^{2+}, Mn^{3+}, Mn^{4+}</td>
<td>0.14</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>P^{5+}</td>
<td>0.10</td>
</tr>
<tr>
<td>All other elements</td>
<td>-</td>
<td>0.77</td>
</tr>
<tr>
<td>Total</td>
<td>-</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: (Rapant 2006)

3.3 Review of elemental nutrition and its physiology

The essential nutrients are divided into six general categories: water, proteins, carbohydrates, fats, vitamins and minerals. Amongst all these, minerals are inorganic substances that are essential for the proper functioning of the body. Minerals are divided into two general categories:
- Electrolytes and
- Trace elements.

Though electrolytes are consumed in relatively large quantities, the trace elements are needed in very small amounts. Electrolytes are the more important of the minerals and include sodium, potassium, chloride, calcium, magnesium, and phosphorous. Sodium is the primary electrolyte of the blood and the fluid that bathes the tissues (extra cellular fluid). Low blood sodium can result in confusion, seizures, erratic heart rhythm and possibly death. Potassium is the main electrolyte present inside the cells. Potassium deficiency results in weakness, erratic heart rhythm and death. Calcium and phosphorus are the main mineral components of the human bones and teeth. Calcium deficiency results in thinning of the bones (osteoporosis) that develop the fractures. The recommended daily allowance (RDA) of calcium is approximately 800 milligrams in children and 1000-1200 milligrams in adults. Chloride is almost always present in association with sodium and its deficiency is always related to sodium deficiency. The review paper of Burch et al. (1975) provides substantial information on the physiology and biochemistry of zinc, manganese, and copper in human context. Magnesium deficiency is relatively common, but only very severe deficiencies result in heart-rhythm problems (Satoh and Romero 2002). Most electrolytes are widely abundant in nature and more than adequately present in a balanced diet. The best sources of calcium are the dairy foods.

A review of literature on the trace element composition of groundwater indicates that in comparison with major element data, the trace element data is limited. Klusman and Edwards (1978) have studied the occurrence of toxic metals in the groundwater. Gibbs (1977) studied the transport of transition metals in the river water. Salbu and Roaldset (1982) have studied trace elements distribution in fresh waters. Solubility controls on trace elements in basaltic aquifer of Columbia Plateau have been evaluated by Deutsh et.al. (1982). Robinson (1983) studied natural control on heavy metals absorption. Occurrence and speciation of arsenic is given by Maher (1983). Laxen (1985)
documented adsorption mechanism of Cd, Pb and Cu during precipitation of hydrous ferric oxide in natural waters. Lin-Hua and Atkinson (1985) reported dissolved iron in Chalk aquifer. Larocque and Rasmussen (1998) have given an overview of trace metals in the environment, from mobilization to remediation. The occurrence of total iron in urban river has been studied by Kayabali et al. (1999). Lee et al. (2003) have studied that the rare earth elements as indication of groundwater environment changes in a fractured rock system. The chemical analyses of thermal waters from Slovenia (including trace and rare earths) have been carried out by Kralj (2000, 2004). The studies related with acid available particulate trace metals associated with suspended sediments in the Humber River were carried out by Neal (1999). However, there is negligible data available on the trace element composition of groundwaters from Deccan Volcanic Province. The first documentation on trace element content of groundwater from basaltic aquifers was done by Handa (1986). Later on Pawar and Nikumbh (1999) published data on trace element composition of groundwaters from basaltic aquifers. Edmunds et al. (2002) is of the opinion that, the hydrogeochemistry (several major ions as well as some trace elements) reflects the weathering of basaltic mineral assemblage, and their concentration increases with residence time.

The trace elements include iron, zinc, copper, manganese, fluoride, iodide, sulfur, molybdenum and a few relatively unimportant minor elements. Iron is the most important of all the trace elements because it is essential in the structure of hemoglobin, the red blood cell molecule that carries oxygen to the tissues. Iron deficiency-mainly from prolonged or extensive bleeding, such as in women with heavy periods causes anemia (Manahan 2003). Fluoride is crucial for healthy development of teeth in very young children and is added to majority of city water supplies. The deficiencies of most of the other minerals have never been demonstrated in humans, but animal studies have shown that these deficiencies are possible. Similar to electrolytes, trace elements are present in more than adequate amounts in a balanced diet. With all of these considerations in mind, the nutrients sometimes found in drinking water at potentially significant levels of particular interest are:
• Calcium – important in bone health and possibly cardiovascular health
• Magnesium – important in bone and cardiovascular health
• Fluoride – effective in preventing dental caries
• Sodium – an important extra-cellular electrolyte, lost under conditions of excess sweat
• Copper – important in antioxidant function, iron utilization and cardiovascular health
• Selenium – important in general antioxidant function and in the immune system
• Potassium is important for a variety of biochemical effects but it is usually not found in natural drinking waters at significant levels.

Sendroy (1945) reviewed the mineral metabolism in the human context. His studies are focused on physiology of essential minerals like Ca, metabolism with respect to kidney stone formation and in vitro dissolution. Shils (1988) in his review paper brought out the role of magnesium in human health and disease. The study covers the Mg requirements, Mg deficiency, Mg depletion in various disease state, Mg alteration and possible disease development, Mg repletion, hypermagnesemia and Mg toxicity. Potassium is the major intracellular cation and is required for normal cellular function. Severe potassium deficiency is characterized by hypokalemia, and its adverse consequences include cardiac arrhythmias, muscle weakness, and insulin resistance. More subtle deficiency signs of potassium are increased blood pressure, increased sensitivity of blood pressure to sodium intake (“salt sensitivity”), increased risk of kidney stones and increased bone turnover. Sodium chloride is required to maintain fluid and electrolyte balance, extra-cellular volume and serum osmolality. Sierakowski et al. (1979) studied the RDA of major elements like Ca and Mg. Assuming a daily water intake of 2 liters, one can calculate that as much as 330 mg, or 41% of the calcium RDA can be obtained by drinking very hard water. In addition, on the basis of data, 2 liters of very hard water will supply 106 mg of magnesium, which is more than 60% of a recommended dietary magnesium supplement therapy for preventing
calcium oxalate stones. The review paper of Smil (2000) focuses on phosphorous and gives enormous information on importance of phosphorous in life forming. Schoppen et al. (2004) investigated the possible beneficial effects of consuming a sodium rich carbonated mineral water on lipoprotein metabolism and to determine whether consumption of this water influences endothelial dysfunction (ED) in postmenopausal women. Logan (2006) studied dietary sodium intake and its relation to human health. The study pinpointed that; the kidney is the primary long-term effector that efficiently regulates sodium and water excretion.

Anderson (1997) documented that normal dietary intake of Cr for human is suboptimum and is essential nutrient for sugar and fat metabolism. The estimated safe and adequate daily dietary intake (ESADDI) for Cr is 50 to 200 μg. Most of diet contains 60% of the minimum suggested intake, so insufficient dietary intake of Cr results in symptoms of diabetes and cardiovascular diseases. So, remaining 40% of Cr can be available from drinking water especially from groundwater.

Iodine is the nutrient element for human being which is also available from environment. It is a nutritionally essential element, especially important in thyroid hormone synthesis. Ma et al. (1993) studied the iodine deficiency within mountainous region of China and examined the iodine content of soil and water. Stewart and Pharoah (1996) studied the iodine deficiency with symptoms of diseases like endemic goiter, stillbirths, abortions, congenital abnormalities, endemic cretinism, and impaired mental function. Zein et al. (2000) studied the population based iodine deficiency study in Yemen.

Fluoride inhibits enzymes that breed acid-producing oral bacteria whose acid eats away tooth enamel. This observation is valid, but some scientists now believe that the harmful impact of fluoride on other useful enzymes far outweighs the beneficial effect on caries prevention. Fluoride ions bind with calcium ions, strengthening tooth enamel as it forms in children. Many researchers now consider this more of an assumption than fact, because of conflicting evidence from studies in India and several other
countries over the past 10 to 15 years. Nevertheless, agreement is universal that excessive fluoride intake leads to loss of calcium from the tooth matrix, aggravating cavity formation throughout life rather than remedying it, and so causing dental fluorosis. Severe, chronic and cumulative overexposure can cause the incurable crippling of skeletal fluorosis. Valenzuela-Vasquez et al. (2006) concluded high fluoride concentration is associated with high bicarbonates, pH and temperature. Muralidharan et al. (2002) studied the high fluoride concentration found in arid regions of Rajasthan state in India and the conclusion was drawn as causative minerals like calcite and dolomite have accelerated the leaching of fluoride to the groundwater. Madhavan and Subramanian (2001) studied the fluoride concentration in rivers of South Asia. The study reveals that fluoride levels in various types of environmental samples show wide variations from a low of 1.2 μg/m³ in the air samples over Delhi to a very high value of over 18,000 μg/L in a hot spring in the Western Ghats region, due to which the surface water samples in the mountain streams generally show higher F levels. Large rivers with large run-off show higher levels of fluoride and hence greater fluoride flux to the oceans. Higher fluoride exposures due to enhanced application of rock phosphates adversely affect the health of our aquatic environment, in addition to decreasing the per capita availability of safe drinking water.

P. D. Sreedevi (2006) investigated association of hydrogeological factors in temporal variations of fluoride concentration in a crystalline aquifer in India. Decrease in calcium would be followed by increase in fluoride ions. However, if pH is constant, enrichment in bicarbonate ions is usually accompanied by enrichment in fluoride ions, as also reported by Kakar et al. (1988) and Dev Burman et al. (1995).

Saxena et al (2002) focused on inferring the chemical parameters for the dissolution of fluoride in groundwater. The decomposition, dissociation and dissolution are the main chemical processes for the occurrence of fluoride in groundwater. During rock–water interaction, concentration of fluoride in rock, aqueous ionic species and residence time of interaction are important parameters. The decomposition, dissociation and
dissolution are the main chemical processes for the occurrence of fluoride in groundwater. During rock–water interaction, concentration of fluoride in rock, aqueous ionic species and residence time of interaction, etc are also important parameters. Fluoride content in groundwater is mainly due to natural contamination, but the process of dissolution is still not well understood (Handa 1975; Saxena and Ahmed 2001). In addition, the source of contamination is not a point source and often unknown. Thus, in addition to mitigation of excess fluoride, inferring the responsible conditions and the parameters for its dissolution and enrichment in time and space as well as monitoring them through an adequate monitoring network are essential (Ahmed et al 2002).

Ahmed et al (2002) have carried out repeated sampling of water in a small watershed in a granitic aquifer and found a cyclic variation of fluoride with a high value after the monsoon recharge and a lower value before the monsoon.

Cabrera et al (2001) have discussed the presence of excess fluoride causing dental and skeletal hazards. Many theories have been advocated depending upon its occurrence with respect to geology, geomorphology, climate, etc. It is difficult to determine a satisfactory single solution for its occurrence in groundwater and its variation in time and space.

Sievers et al. (2001) studied the molybdenum metabolism in infancy. The essential trace element molybdenum (Mo) is bound to and required for the function of molybdoenzymes, e.g. sulfite and xanthine oxidase. The study concludes that, Mo given orally is well reabsorbed in premature infants, and predominantly excreted in the urine. Dietary recommendations should prevent excessive intakes in infancy.

Cook and Monsen (1976) studied the food iron absorption in the human subject and concluded that all sources of animal proteins are not equivalent in their effect on non heme iron absorption. Solomons (1986) studied the nutrient requirement of Fe and Zn and its interaction in the diet. The study concludes that the Fe/Zn ratios in human
diets, foods and therapeutic nutrient supplements in order to reduce the zinc-inhibiting effects of iron. Although when zinc and iron are taken with meals, a damping of their interaction is observed in absorption experiments, the epidemiological observations with infant foods suggest that it is still significant in a dietary context. If one can justify the need for a high, chronic level of iron, then supplementation (ratio balancing) with zinc would seem a logical solution.

Klevay (1998) in his review paper concluded that RDA should be essential for copper because bone disease and cardiovascular disease from diets low in copper have been studied in animals for decades. Men and women fed diets close to 1 mg of copper per day, amounts quite frequent in the US, responded similarly to deficient animals with reversible, potentially harmful changes in blood pressure control, cholesterol and glucose metabolism and electrocardiograms. Women supplemented with trace elements including copper experienced beneficial effects on bone density. These data exceed similar data on magnesium, selenium and zinc and are sufficient for establishing an RDA. Skinner (2007) enlists element wise recommended daily allowances (RDA) for adults (Table 3.2).

**3.4 Review of health issues related to water quality**

Water is the largest single constituent of the human body and is essential for cellular homeostasis and life. Water provides the solvent for biochemical reactions. It is also the medium for material transport and has unique physical properties (e.g. high specific heat) to absorb metabolic heat and is essential to maintain blood volume to support cardiovascular functions and renal filtration. Approximately 60% of the adult human body is composed of water. Nearly all of the life-sustaining chemical reactions require an aqueous (watery) environment. Water also functions as the environment in which water-soluble foodstuff is absorbed in the intestines and the waste products are eliminated in urine. Another essential role of water is to maintain body temperature through evaporation, as in sweating. Severe dehydration will result in cardiovascular collapse and death. On the other hand, water toxicity (too much water) is also possible,
resulting in dilution of important electrolytes (mineral salts) that may lead to erratic heart rhythm and death. The estimated water requirement of an average adult is two liters per day.

### Table 3.2: Elements, recommended daily adult allowances (RDA)

<table>
<thead>
<tr>
<th>Element</th>
<th>RDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron (B)</td>
<td>(1.7 – 7.0 mg)</td>
</tr>
<tr>
<td>Bromine (Br)</td>
<td>0.3 – 7.0 mg</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>800 – 1300 mg</td>
</tr>
<tr>
<td>Caesium (Cs)</td>
<td>0.1 – 17.5 μg</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>130 μg</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>15 – 32 μg</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>1 – 2 mg</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>1.5 – 4.0 mg</td>
</tr>
<tr>
<td>Iodine (I)</td>
<td>70 – 150 μg</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>10 – 18 mg</td>
</tr>
<tr>
<td>Lithium (Li)</td>
<td>730 μg</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>3.5 mg</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>3.5 mg</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>160 μg</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>(35 – 700 mg)</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>800 – 1300 mg</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>3500 mg</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>70 μg</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>(21 – 46 μg)</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>0.13 – 12.69 μg</td>
</tr>
<tr>
<td>Vanadium (V)</td>
<td>(12.4 – 30.0 μg)</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>8 – 15 mg</td>
</tr>
</tbody>
</table>


Source: (Skinner 2007)
3.4.1 Surface water and its health implications

Generally, 80% human diseases are water-born. Water born diseases are increasing as the lack of proper sanitation of drinking water and its sources (lakes, ponds, dams and rivers). Eutrophication, leakage of safety tanks, sewage pollution, agro and chemical based industry induced water pollution are the basic sources of human pathogens. Ingestion of this untreated biologically contaminated surface water may cause serious diseases. Various pathways are shown with the help of flow-chart (Fig. 3.1).

**Figure 3.1: Sources & pathways of disease causing pathogens from environment to humans** *(Source: Pruss-Ustin et al. 2008)*

Ramaiah et al. (2004) found the presence of disease causing bacterial species like *Pseudomonas aeruginosa*, *Salmonella sp.*, *Escherichia coli* O157 and *Vibrio cholerae* in huge amount in Mumbai ballast water. Rajamani (2005) studied the biological
management of complex interconnected system of plant, soil, groundwater and river to avoid the deterioration of water on the land. Rosborg et al. (2006) examined 20 municipal water treatment plants for treated water from Sweden for their qualitative analyses and correlated to human health implications. As also, different treatments modify the water quality and raise various health problems. HCO₃ from drinking water seems important, since neutralization of the diet net acid load can improve the calcium and phosphorus balances and reduce the bone resorption rate.

Ludwing et al. (2003) discussed the water sanitation facts in developed and under developed countries with public health protection. Masironi and Shaper (1981) discussed the cardiovascular disease epidemiological studies of human health effects of water from different sources. The correlation was made for cardiovascular mortality and hardness of drinking water. In addition, geographic variation of cardiovascular disease was correlated with respect to water quality of the area under study. Stambuk-Giljanovic and Stambuk (2005) suggested the information subsystem of drinking water total hardness and its influence on human health. The processed database with above system can serve as a methodological platform for the study of environmental factors influencing human health.

The observations link sulfate in drinking water at concentration exceeding 500-700 mg/L as a cause of diarrhea, but in-vitro study by Heizer et al. (1997) have not reported such effects. The in-vitro study conducted in normal adults, to determine the effect of various drinking waters of different known sulfate concentrations on bowel function. The study concluded that ingestion of sulfate in drinking water at a concentration of 1200 mg/L, which is higher than reported to occur in US municipal water sources, caused a measurable but clinically insignificant increase in stool mass and decrease in stool consistency and appearance time, but no change in stool frequency and no complains of diarrhea.

Eni Devalsam et al (2011) worked on impact of urbanization on sub-surface water quality in Calabar Municipality and said that 50.1 percent of urban growth influenced
water quality. Urbanization affects the quality and quantity of underlying sub-surface water by radically changing patterns and rates of recharge, initiating new abstraction regimes and adversely affecting groundwater quality (Foster et al, 1998).

Higher fluoride levels are obtained in discharge areas than in recharge areas with a trend of fluoride enrichment along the direction of flow (Gaciri and Davies 1993). The latest information shows that fluorosis is endemic in at least 25 countries across the globe. In the Indian context, the fluoride is dissolved in groundwater mainly from geological sources.

Raymond A. Duraiswami et al (2009) revealed that Runoff has increased many fold in urban areas due to increase in paved areas, training of streams and construction of storm water drains. The recharge is therefore continuously decreasing; resulting in depleting groundwater reserves beneath large cities, especially those situated on water divides. Urbanization also affects the natural water cycle and groundwater recharge. Water is often scarce, water demand in cities is large and, in many cases, increasing with time.

Gossel et al (1999) said that many large cities rely mostly on surface water supply. As urban population grows, conjunctive use of surface water and groundwater is likely to become increasingly common, and water management is to be enhanced As a result, urban groundwater is emerging as a distinct branch of hydrogeology.

3.4.2 Review of groundwater and its health hazards

Nkhuwa (2003) studied threats of chronic epidemics of cholera in complex geologic structure composed of strongly folded and overthrustsed Neo- proterozoic schist and quartzite that are dominated by thick and extensive sequence of dolomitic marbles. This fragile geologic environment gave way to deterioration of groundwater by contaminants provoking the problem of cholera cases. Datta (2005) pinpointed the ethics required to avoid groundwater deterioration due to rapid growth in population,
urbanization, industrialization and competition for economic development. The study highlights the following points to sustainable use of groundwater like:

- Promoting action to make more freshwater available and
- Protecting groundwater reserves and preventing further degradation by contamination.

Patnaik et al. (2002) have studied water pollution generated from major industries. Similarly, waste effluents discharged into streams may enter the aquifer body downstream, which also affects the groundwater quality. Abbasi et al. (2002) have studied the impacts of wastewater input on the water quality. Jagdap et al. (2002) and Sunitha et al. (2005) classify the water in order to assess the water quality for various sources in and around Jaipur and many villages.

Kamaleshwar pratap (2000) studied groundwater assessment and concluded that the occurrence and movement of groundwater in an area is controlled by various factors. The influence of all factors need not be the same in the area. Therefore, each parameter is assigned a weightage depending on its influence on the movement and storage of groundwater. The area being underlain by hard crystalline rocks, the lithological control is less compared to the topographical control.

P. R. Salve et al (2008) revealed Assessment of Groundwater Quality with Respect to Fluoride and concluded that Though fluoride enters the body through food, water, industrial exposure, drugs, cosmetics, etc drinking water is the major contributor (75–90% of daily intake) (Sarala and Rao 1993). The studies carried out by various researchers on groundwater quality with respect to fluoride across India, including Gujarat, are reported elsewhere (Shaji et al. 2007).

vulnerability issues, which strengthens the grounds for scholarly interpretation, while providing a practical basis for intervention.

P. Balakrishnan et al (2011) studied Groundwater quality mapping using geographic information system (GIS): A case study of Gulbarga City, Karnataka, India. GPS technology proved to be very useful for enhancing the spatial accuracy of the data integrated in the GIS. Groundwater quality mapping various physico-chemical parameters like chloride, nitrate, TDS, and hardness were analyzed in the groundwater samples used for drinking purposes. The main sources of nitrate and other pollutants of urban groundwater is sewage and nitrate can reach the aquifer by sewer leakage and, on-site disposal systems such as septic tanks.

A GIS-based study was carried out by Barber et al. (1996) to determine the impact of urbanization on groundwater quality in relation to land-use changes. Nas and Berktay (2010) have mapped urban groundwater quality in Koyna, Turkey, using GIS. Ahn and Chon (1999) studied groundwater contamination and spatial relationships among groundwater quality, topography, geology, landuse, and pollution sources using GIS in Seoul. GIS has been useful in establishing the spatial relationship between pollution level and its source in this study.

Robinson et al (2006) studied the spatial and the non-spatial database formed is integrated for the generation of spatial distribution maps of the water quality parameters. For spatial interpolation Inverse Distance Weighted (IDW) approach in GIS has been used in the present study to delineate the locational distribution of groundwater pollutants. Groundwater mining can also threaten long-term water security and has emerged as salient public policy issue (Alley et al 1999, US Bureau of Reclamation, 2003). In the particular method the experimental variogram measures the average degree of dissimilarity between un-sampled values and a nearby data value (Deutsch and Journel, 1998) and thus can depict autocorrelation at various distances. From analysis of the experimental variogram, a suitable model (for example
spherical and exponential) was derived by using weighted least squares and the parameters (for example range nugget and sill).

Singh and Lawrence (2007) prepared a groundwater quality map in GIS successfully for Chennai city, Tamil Nadu, India. Preparing groundwater quality maps taking into consideration, multiple contaminants and spatial variability of these contaminants, groundwater quality assessment in Dhanbad district, Jharkhand, India was much more difficult due to the spatial variability of multiple contaminants and wide range of indicators that could be measured. Considering the above aspects of groundwater contamination and use of GIS in groundwater quality mapping, the study was undertaken to map the groundwater quality in Gulbarga city, Karnataka, India.

Stefanoni and Hernandez (2006) studied that the co-regionalization. (expressed as correlation) between two variables, that is, the variable of interest, groundwater quality in this case and another easily obtained and inexpensive variable, can be exploited to advantage for estimation purposes.

Burrough and McDonnell (1998) Studied Inverse distance weighting (IDW). In interpolation with IDW method, a weight is attributed to the point to be measured. The amount of this weight is dependent on the distance of the point to another unknown point. These weights are controlled on the bases of power of ten. With increase of power of ten, the effect of the points that are farther diminishes. Lesser power distributes the weights more uniformly between neighboring points. In this method the distance between the points count, so the points of equal distance have equal weights

Wakida and Lerner (2005) studied non agricultural sources of groundwater nitrate. Urban sources of nitrate may have a high impact on groundwater quality because of the high concentration of potential sources in a smaller area than agricultural land.

Lin et al. (2004) studied the health problems induced by geochemical factors from China. The distribution of the endemic diseases has geographical characteristics.
Among the most harmful and widely distributed of the endemic diseases are: Kaschin-Beck disease, Keshan disease, iodine deficiency, endemic fluorosis and hepatic carcinoma. The geographical environments have a close relationship to endemic diseases and are influenced by climate, geology, landform, soil, food and drinking water. Drinking water is the key issue, since polluted water, or water lacking in or having an excess of certain minerals and elements, as well as water containing certain organic components, has been shown to be harmful to human health. Research has shown that some diseases can be reduced or eliminated by paying attention to the way drinking water is obtained, as well as by improving the nutritional values of the food by eliminating negative components. Ozsvath (2009) in his review paper on environmental fluoride and human health, explains that fluoride in the diet can help prevent dental caries and strengthen bones, but there are a number of adverse effects with chronic ingestion at high doses can have on human health, including dental fluorosis, skeletal fluorosis, increased rates of bone fractures, decreased birth rates, impaired thyroid function and lower intelligence in children. Chronic occupational exposure to fluoride dust and gas is associated with higher rates of bladder cancer and variety of respiratory ailments. Acute fluoride toxicity and even deaths from the ingestion of sodium fluoride pesticides and dental products have also been reported.

In India, the concentration of trace elements in the groundwater of the Ganga–Nim basin was ascertained by Khan and Abbasi (2004), Das et al. (2003) studied the groundwater quality in Guwahati for fluoride and various inorganic ionic species that appear in subsurface water. The conclusion was drawn from the study that the fluoride contents have positive correlation with Na⁺, K⁺, total alkalinity and depth of the source, and negative correlation with Mg²⁺, Ca²⁺ and total hardness. Negative correlation of fluoride with hardness and absence of any correlation with chloride indicate recharge of the aquifer by the Brahmaputra and/or rain. The sources of fluoride and nitrate were inferred to be the minerals from the Precambrian granites, which form the basement of the city and also outcrops at several places in the city.
Alarcon-Herrera et al. (2001) studied the fluorosis of Guadiana valley of Mexico wherein 84% wells exceeded the maximum permissible limit of fluoride in groundwater. A higher risk of increased dental damage is directly related to persons living in areas with higher fluoride levels in their drinking water. A positive correlation between the Dean Index of dental fluorosis and the occurrence of bone fractures also exists. A paradoxical behavior was observed between the occurrence of fractures and fluoride concentration in water.

### 3.5 Review of groundwater salinity

Groundwater salinity is one of the reasons for salt concentration rise in aquifers and this necessitates the background literature survey for groundwater salinity. Also, it is helpful to compare the outcome from present study.

Shirur taluka is a part of semi arid zone of Deccan Volcanic Province, India, facing the critical groundwater salinity problem that aggravates in drought period. In view of this the author decided to take review of inland salinity problem in the study area. The term salinity refers to the presence of excess salts/solutes in water by various geochemical and anthropogenic processes. Though the presence of high concentration of salts in irrigation water leads to the accumulation of salts in soil making it saline in nature, the problem of salinity in the area is typical of arid and semi-arid areas. The sodium plays a major role in the development of salinity in arid and semi-arid areas, as the rate of evaporation is high and precipitation is less. This leads to accumulation of sodium salts at the soil surface due to high rate of evaporation, which results in development of alkalinity in soil and enhances salinity process in ground water.

Darren et al. (2007) demonstrated that for dry land salinization to occur, it need not be necessary to have discharge zone saline in nature. Only the presence of large salt store does not necessarily lead to problems of dry land salinization if, clay-rich sediments at the site and the salt lies below the pasture root zone. Jalali (2006) revealed that the groundwater chemistry is primarily controlled by weathering of the minerals mainly
alumino-silicates. The evolution of groundwater may be controlled by more complex processes involving evaporation, precipitation and dissolution of carbonate minerals, besides cation exchange reactions between groundwater and clay minerals. Alyamani (2000) suggested that the groundwater salinity varies and is randomly distributed. The salinity problem seems to be due to intensive evaporation that led to precipitation of evaporates (e.g. calcite, dolomite, gypsum and probably halite). The intensive irrigation activity (mineral dissolution) recharges the groundwater with a marked increase in the salinity. The local hydrogeological setting plays a strong role in determining the risk of groundwater salinity as a consequence of irrigation practice. Subba Rao (2008) opined that various hydrogeochemical processes are involved in the development of groundwater salinity. The compositional relations and mineral saturation states indicated that the associated hydrogeochemical processes such as dissolution of oil salts, dissolution of NaCl and Ca\textsubscript{2}SO\textsubscript{4}, precipitation of CaCO\textsubscript{3} and ion exchange of Ca\textsuperscript{2+} for adsorbed Na\textsuperscript{+} have dominant control. Evapotranspiration causes the formation of salt layers by transfer of original salts from groundwater to soil / weathered zone. Such salts are the sources of ions to reach groundwater through infiltrating recharge water. Extensive irrigation, helps in recycling of saline groundwater, irrigation-return-flow and application of agricultural fertilizers are the major human activities, which are responsible for further increasing the concentration in groundwater. Salameh and Hammouri (2008) postulated that, the Permo-Triassic, Jurassic rocks, basaltic dykes and sills are the sources, which cause a drastic increase in the salinity of water in their study area. These rocks contain residual evaporates, contact metamorphism products, sills, dykes and secondary altered mineral assemblage of plagioclase, pyroxenes and Fe - Mn minerals also cause drastic changes in ionic ratios, saturation indices and groundwater changes in ionic ratios. Rajmohan and Elango (2004) concluded that the composition of groundwater depends on the recharge from lakes and rivers. In addition, control of silicate mineral weathering on the concentration of major ions in the groundwater aided by rock-water interaction, dissolution and deposition of carbonate and silicate minerals, ion exchange was brought out. Janardhana Raju (2007) pinpointed that, the seasonal variation in
groundwater quality due to agricultural and domestic activities through infiltration and percolation during monsoon. Thus, the overall quality of groundwater of an area is controlled by lithology apart from other local environmental conditions. Trabelsi (2007) related the origin of salinity to the existence of various salinisation processes such as: dissolution of gypsum and calcite dispersed through reservoir rock, ion exchange, intensive agricultural practices and sea water intrusion, enhanced by excessive withdrawal of groundwater. Manish Kumar et al. (2006) gave detailed account of the hydrochemical processes responsible for the quality of groundwater which included simple dissolution, mixing, evaporation and weathering of carbonate / silicate minerals and surface water interaction besides reverse ion exchange. Highly saline and brackish groundwater is associated with long history of evaporation and oxidation of sulphur gases in low-lying areas. Koc (2008) opined that poor planning of irrigation water led to heavy salt loads adversely affecting the environment in the Great Menderes River Basin. Duraiswami et al. (2009) studied the salinity model for the Karha river basin by remote sensing and GIS techniques.

Piper (1944) discovered a diagram named after him as piper diagram. Piper diagrams are a type of trilinear diagram broadly used in hydrogeology as they illustrate the hydrochemical characteristics of groundwater by representing the concentration of anions and cations in separate triangular diagrams. Geochemically similar waters are clustered in clearly defined areas, indicating water-mixture phenomena, precipitation, dissolution, etc.

Richards (1954) has given a formula called Sodium adsorption ratio (SAR). Sodium is a unique cation because of its effect on soil (when present in exchangeable form) as it causes adverse physico-chemical changes in the soil, particularly to the soil structure. A high salt concentration in the water leads to the formation of saline soil and the higher concentration of sodium leads to development of alkali soil. Usually SAR less than 3.0 will not be a threat to vegetation while SAR greater than 12.0 is considered sodic and threatens the survival of vegetation by increasing soil swelling (dispersion)
and reducing soil permeability (Kuipers et al., 2004). The compounding effects of discharging water with high SAR is that it produces soils that are unsuitable for agriculture, grazing and it creates hazards such as fugitive dust from wind and increased sediment loading of local streams and rivers from surface runoff and damages the stream channel integrity (Kuipers et al., 2004). The suitability of the groundwater for irrigation from the present area of study was judged by determining the SAR value and they were categorized under different classes.