CHAPTER 3

LITERATURE REVIEW

3.1.0 INTRODUCTION

Groundwater is a large source of fresh water available on earth; water is widely distributed and plays a vital role in both environment and human life. It is a renewable natural resource having several inherent advantages over surface water like wide distribution, negligible evaporation loss and low risk of contamination. Dependence of groundwater has increased rapidly in many regions because of limited surface water sources, non perennial rivers and frequent failure in monsoon. Therefore, groundwater resources are often over exploited to meet the increasing demand thereby giving a heavy stress to aquifer system. To maintain this system proper management has to be adopted. Hence to arrive at a suitable methodology review of the work done in the specific field of research is essential. This review in general helps us to find out the status of the work carried out globally and locally, in previous and present context. It also helps us to identify the gaps of the work done and to frame a standard methodology for the objective chosen.

3.2.0 HISTORY OF GROUNDWATER RESEARCH

The importance of groundwater has been studied scientifically for decades. Darcy (1856) first studied motion of water through a geological
medium. Later similar type of works was done by Chamberlain (1885), Slitcher (1899), and King (1899). During earlier periods well-documented works on geohydrology (Meinzer 1923) and study of change in groundwater storage over time (Meinzer and Steams 1928; Meinzer 1932) were also carried out in detail. Additional contribution to groundwater flow and movement were put forth by Hubbert (1940) and Jacob (1940). Simultaneously research in water chemistry has attained its momentum (Piper 1944; Stiff 1950; Chebotarev 1955; Hem 1959; Back 1960; Garrels and Christ 1965). Further, advancements of studies in groundwater were done by advent of computers using numerical modelling and integrated approaches.

3.3.0 HYDROGEOLOGY

Management of groundwater rules a better understanding of characterisation of aquifer system, fluctuation in groundwater level, flow and recharge mechanisms. Importance of hydrogeology was well documented by Vendie Chow (1964). Later detailed works on groundwater assessment, evaluation and management in relation to hydrology and water resources engineering were initiated by several authors (Walton 1970; USDI 1975; Todd 1980; Matthan 1982; Prince 1985; Gars Kumar 1987; Karanth 1987; Ramesham 1987; Ward and Robinson 1989 and Ragunath 1990). Hall and Heath (1984) have carried out significant studies in the field of urban and basic groundwater hydrology. Hydrogeological studies and targeting of groundwater gained importance in later stages (Altovsky 1959; Brown and others 1972;
SAMPLING

In any hydrogeochemical study collection of samples play a vital role in determining the quality of the data produced. Methods adopted for sampling techniques were discussed by various authors (Schoeller 1967; Palm Quist 1973; Pickens and others 1979). Standard analytical techniques and sample
collection are important in order to obtain a good result (APHA 1996; Ramanathan 1992; Ramanathan and others 1993, 1996; Ramesh and Anbu 1996).

3.5.0 HYDROGEOCHEMISTRY

Demand for freshwater continues to grow in human population. Diversion of freshwater to supply agricultural, industrial, domestic and municipal needs stretches hydrological systems both natural and man made to limit within the country. A continuous supply of freshwater may already be in scarce and may vary both seasonally and geographically. Study of quantity of water alone is not sufficient to hard water management problems because their use for various purposes depends on its quality alone. Chemical parameters present in groundwater were mainly used as a tool to match its suitability for various uses. Hence, hydrogeochemical characters of groundwater and groundwater quality in different aquifer over space and time proved to be an important technique in solving the problems. Hydrogeochemical evaluation and related studies was done in detail by Back and Hanshaw (1965), Collins (1975), Johnson (1975), Mason Moore (1985), Sastri and Lawrence (1988), Stuyfzand (1989), and Lavitt and others (1997). Detailed work on water utility and quality assessment of groundwater in Naini industrial area in U. P. was done by Rahul Mohan and others (2000), they found that the dominated facies was \( \text{Na}^{2+}, \text{Mg}^{2+}, \text{and} \ HCO_3^- \) and is unsafe for domestic purpose. But they found it suitable for domestic purpose. Similar works on quality studies was also done by several authors (Wilcox 1955; Hem 1970; WHO 1971; Craig and Anderson
1979; Jagannatha Sarma and Narayanaswamy 1981; Jansvoma 1985; ISI 1983; William Alley 1993; Ramanathan and others 1998, 1999 and Ballukraya and Ravi 1999). Early studies of water quality were carried out by Davis and Dewiest (1966). Later excellent work on hydrogeochemistry was carried by (Back and others 1966; Gibbs 1970; Desai and others 1979; Chandrasekaran 1988; Sastri and Lawrence 1988; Jankowski and Jacobson 1989; Razak and Dazy 1990; Hem 1991; Jain 1996, 1997; Madan Mohan and others 1996; Panigrahy and others 1996; Ramanathan and others 1996; Atwia and others 1997; Fischer and Mullican 1997; Ballukraya and Ravi 1999; Anandhan and others 2000; Ramappa and others 2000 and Ramanathan and others 2000). Srinivasamoorthy and others (2005) studied geochemical facies identification and utilisation of groundwater based on its quality and regional flow system.

Nitrate being a component of groundwater plays a significant role on human health when if exceeds 45 mgL$^{-1}$. Ozha and others (1993) studied about the nitrate concentration in some districts of Rajasthan, their health hazards and nitrate removal. Similar studies of nitrate in groundwater were also carried out by Handa (1974), Kakar (1985), Lakshmanan and others (1986), Bel and others (1989), Bulusu and Ponde 1990), Ternlamche (1991), Kato and Ogura (1992), Mukherjee (1994), Pandey and Mukherjee (1994), Lerner Barrett (1996) and Hegde and Puranik (1997).

The use of groundwater were categorised based upon its chemistry. Studies on groundwater for agricultural utility based upon carbonates were discussed by Eaton (1950). Diagrams for utility purpose were developed by
USSL (1954) and Doneen (1948) including permeability plots. Impact of intensive agriculture on geochemistry of groundwater recharged in regional aquifer was studied by Alexandar and others (1995). Similar types of studies where initiated in Hataprabha irrigation project by Nandakumar and Murthy (1997). They noticed significant variation in $\text{Ca}^{2+}$ and $\text{Na}^{2+}$ in command and non-command areas. Similar works on impact of agriculture in groundwater was done by Sondhi and Ramprakash (2000) and Puranik and Abbi (2000).

The impacts of mining and agricultural and other anthropogenic activities have also proved to affect the quality of groundwater (Joshi and others 1982; Kakar and others 1989; Krishnaswamy and others 1993; Lakshmanan and others 1986; Miller and others 1977; Singh 1971 and Krishnappa and Shinde 1980 and Anandhan (2000).

An increased usage of groundwater has depleted the source and excess concentration of certain ions has made water unfit for use. Thereby, polluting the groundwater due to input from the industries and its implications on land resources have led to serious problems in the water quality. The groundwater quality also helps in the pollution study (Hariharan 1968; Todd and MC.Nulty 1976; Baweja and Karanth 1980). Hydrogeochemical studies were also done in conjunction with pollution status in coastal environment (Ramanathan and others 1996). Public health and agriculture were adversely impaired due to consumption of contaminated water. Augmentation of water supply sources in addition to borewells in contaminated land will also yield non-satisfactory result. Moody (1990) studied groundwater contamination in aquifers of USA.
Similar studies were also carried out in India by Gurunadha Rao and others (2000); Sondhi and Ramprakash (2000). Pollution due to textile effluent on groundwater quality was attempted in Kerala by Shahul Hameed and others (1997). Pollution studies and their impact on human health, its status in India were also studied in detail by Baireja and Karanth (1980), Aller and others (1985), Rao and Rao (1990), Karanth (1991), CGWB (1992) and Erajfey and Abu-Jaber (1999).

Ballukraya and Ravi (1997) studied pollution of groundwater from waterways of Chennai city. They stated that desilting of Buckingham canal is main cause for pollution of aquifer across Adayar and Coovum and Buckingham canal. Similar works were also carried out by Sehagal and Ramasesam (1984) and Somasundram and others (1993), Ramesh and others (1995) have also attempted pollution studies based on heavy metal concentration in groundwater of Chennai city. Similar work were also done by Handa (1978 b), Paliwal (1983), Kashyap and Sharam (1994), Gurunandha Rao and others (1995), Subha Rao and others (1996, 1998) and Puja Mehrotra and Sanjeev Mehrotra (2000).

Statistical analysis is a very useful tool for identifying groundwater quality of the region. Statistical association does not establish any cause and effect relationship but the relationship of cause and effect can be deducted. Correlation and factor analysis are generally used in parametric classification on modelling studies (Balasubramaniam and others 1989). Factor analysis and cluster analysis were used in groundwater chemistry interpretation by Ashely
and Lloyd (1978). Similar types of works relating to statistical analysis for the groundwater chemistry analysis was done by Anderson (1958); Dalton and Upchurch (1979); Lawrence and Upchurch (1982) and Razak and Dazy (1990).

### 3.6.0 REMOTE SENSING


Change detection techniques, both visual and digital, have been very useful in addressing many phenomena. Amongst them, the change in land use has taken the biggest dimension since its interpretation is found to be of very much helpful in planning several development processes. Works of Singh (1986), weeda & Grootenhuis (1986), Sharma et al (1989), Dhinwa et al (1992) and Mouat et al (1993), have touched several aspects of this phenomena of land use change.

Remotely sensed data contain more information about the lithology, geomorphology, vegetation that could be of additional use in hydrological studies (Stefouli, 1983). So this is a fact that the growth, distribution and
change in type and pattern of vegetation represent a host information about the character of groundwater supporting them. Srinivas (1986) has given a detailed account on estimating regional water potential by means of satellite derived land cover data.

Some studies estimated the relationship between the land surface temperature and vegetation abundance (Jing Jiang and Guangjin Tian, 2010). Landuse is a product of interactions between a society's cultural background, and its physical needs on the one hand, and the natural potential of land on the other (Balak Ram and Kolarkar 1993). In order to improve the economic condition of the area without further deteriorating the bio environment, every bit of the available land has to be used in the most rational way. This requires the present and the past landuse/land cover data of the area (Chaurasia et al., 1996) has emerged as a central issue within the scientific community concerned with global environmental change (Kumar and Turner, 1994).

To improve the economic condition of the area without further deteriorating the bio environment, every bit of the available land has to be used in the most rational way. Land-use, land-use change and forestry (LULUCF) contribute to ongoing anthropogenic climate change (Meyer and Turner, 1992; Dale, 1997; Watson et al., 2000; McGuire et al., 2001; Achard et al., 2002; Houghton, 2003), and have consequently received increasing research attention over the last decade (White et al., 2000; Bondeau et al., 2007; Muller et al., 2007; Rokityanskii et al., 2007; Running, 2008; Smith, 2008; Strassmann et al., 2008; van Minnen et al., 2008; Zomer et al., 2008). LULUCF can also
make a significant contribution to the reduction of GHGs, by increasing the carbon storage of terrestrial ecosystems (carbon sequestration), by conserving existing carbon stocks (e.g. by avoiding deforestation or land degradation), and by providing renewable energy (biomass production) (Bloomfield and Pearson, 2000; Schlamadinger et al., 2007; Andersson et al., 2009). Such LULUCF activities are expected to provide a significant and cost effective way by which atmospheric CO$_2$ concentration can be reduced, at least in the short- to medium-term (Lal, 2003; Pacala and Socolow, 2004; Nabuurs et al., 2007) (Elena Cantarello, 2011). Temporal changes in land cover have become possible in less time, at lower cost and with better accuracy through remote sensing technology (Kachhwaha, 1985).

3.7.0 MODELING

An area of groundwater research that is presently receiving great attention in India is numerical modelling of aqueous system. Quantity of water flowing through an aquifer is much affected by aquifer parameters. Numerical flow and transport models have been used for mapping wellhead protection areas especially to model complex aquifer. In general most of the widely used groundwater flow models assume porous media flow, which is the flow associated with granular aquifer and fractured rock aquifer.

Finite element simulation of phreatic flow domain using recharge distribution coefficients was done by Sulekha and Rastogi (1997). They have carried out recharge from rainfall, seepage from canal and irrigation return flow
over normal input to lager aquifer system. It is in fact very difficult to correctly determine the quantity of net recharge into aquifer. Pumping and others sources contributing to aquifer are generally difficult to estimate with exactness. Non-steady flow in subsurface, surface and their hydrology has been investigated for seepage loses and groundwater flow (Neuman and Witherspoon 1971; Pinder and Gray 1977; Yeh 1981 and Rastogi and Prasad 1992). Flow modelling of groundwater aquifer system was done by several people like Bear (1988), McDonald and Harbaugh (1988), Franz and Guiger (1990), Khublarian (1990), Gurunadha Rao and others (1995) and Wilson Guiger and Thomas Franz (1996). Finite element based groundwater flow realization (GFR) models was used by Rai (2002) for understanding the dynamic behaviour of groundwater flow in the region of Schoneiche disposal sight and found fruitful result.

Basin wise water balance modelling with emphasis on spatial distribution of groundwater recharge was done by Sophocleous and McAllister (1998). They formulated budget, using minimal daily weather input data and soil plant-water system. They characterised spatial distribution of hydrologic components of water balance with in the basin. Work on numerical stimulation of ground water flow to understand the hydrodynamics in Bukeleru river basin in Nalgonda district, a granitic terrain was done by Thangarajan (1999). This study indicates that the phreatic aquifer can sustain the present reduce cost of adhoc experimentation. Two dimensional study state sea water intrusion problem was approached through non-linear solute transport modal by Rastogi and Ukaranda (2002) and determined the influence of Field parameters like
discharge, hydraulic conductivity on sea water intrusion and found fruitful result. Aquifer modelling of Ganga-Mahawa subbasin has been attempted to integrate all available information and provided a tool that could be used for predictive simulation by Ala-Eldin and others (2000).

Solute transport modelling studies (Dhar and others 1994) for the preliminary assessment of the impact of red mud packing on the aquifer system was done in Orissa. Similar pollutant migration studies were also done by Subba Rao and others (1997) and Zhuo Yong Sheng (1997). They attempted underground stimulation model for groundwater pollution. They coupled unsaturated and saturated models successfully and provided new approach to solute transport modelling. Similar works were done by Bear (1988).

Computerised geochemical models are powerful tools for understanding chemical state of natural waters and for predicting behaviour of such waters under variety of such hypothetical conditions. Helgesan and others (1970), Plummer and others (1976), Shannon and others (1977), Sposito and Mattigod (1979), Wolery (1979), Runnels and Lindberg (1981), Felmy and others (1984), Parkhurst and others (1990) and many others have developed a variety of geochemical models for describing and deducing the chemical behaviour of complex and mixed waters. A brief review of existing geochemical studies has been given by Nordstrom and others (1979), Jenne (1981), Plummer and others (1983), Runnels (1987) and Plummer (1990). Several earlier workers have also used geochemical models for solubility equation studies in groundwater (Wolery 1979, 1983; Sanford and Konikow 1989; Plummer and others 1990;
Global problems approaches and priorities of chemical modelling were discussed in detail by Jenne (1978). Implication of computer programme in calculation of equilibrium distribution of inorganic species of major and minor elements in natural waters using chemical analysis and insitu measurements of EC, pH were discussed in detail by Truesdell and Jones (1973). Mixing of water from different aquifer with water from deep bedrock aquifer in groundwater discharge area having an intermediate composition was explained by dilution of calcite precipitation using Mix2 chemical equilibrium model (Wallid 1981), in drainage basin of Holocene age, Canada. Simulation of calcite dissolution and porosity changes in saltwater mixing zone in coastal aquifers was done by Sanford and Konikow (1989). They found that there is an increasing porosity and permeability by enhanced dissolution, using geochemical model PHREEQC. The same model was used by Elangovan and others (1999) to find out diequilibrium indices of calcite along with other minerals such as Calcite, Aragonite, Dolomite, Hematite, Goethite, Fe (OH)₃ and Strontionite. Saturation index of minerals were also adopted in studies of groundwater in Salem district (Srinivasamoorthy, 2004).

3.8.0 STUDY AREA

Groundwater contamination is observed in certain locations of the study area due to sea water intrusion. In several places along the coast either the ground water is naturally saline or it is artificially made saline by over
extraction and consequent intrusion of sea water into the land aquifers. Under MINAR's Scheme, TNPCB is monitoring the quality of water from 16 places of Cauvery River bed. As per the test, the quality of water is normal. In Kollidam, sampling station falling within the composite Nagapattinam district, TDS and Chloride content of water is exceeding the standard value, because of more water evaporation and influence of backwater. pH of water is slightly more than the standard. Disposal of sewage and drainage water into the Cauvery river are the main reasons to affect the biological quality of water.

An Extensive water sample analysis carried out in over half-a dozen villages of Sirkali taluk, in the aquaculture belt of Nagapattinam district by the Gandigram Rural University as reported in Indian Express dated October 9, 1994 has revealed a deterioration in the quality of the only source of potable water ground water. An independent study made by the Bhagawati Environment Development Institute recently has established that hardness, chloride and alkalinity levels of water collected at 17 different points in Sirkali taluk of Nagapattinam District spread over the seven villages of Niethalvasal, Mehendrapalli, Keelaiyur, Pudukuppam, Eranjimedu, Thirunagari and Radhanallur are in excess of the prescribed tolerance limits for drinking water. Prawn culture and shrimp farming are done in coastal districts of Chengalpattu, Cuddalore, Thanjavur, Nagapattinam, Tiruvarur, Pudukottai, Ramanathapuram, Tuthukudi and Kanyakumari.
There are about 1200 such aquaculture farms in Tamilnadu. The effluents let out of these farms containing bio-degradable wastes are not properly treated in many cases and hence they pollute groundwater in adjoining areas, even up to a distance of 6 km, affecting agriculture. Added to this, a majority of the prawn farms have been flouting environmental guidelines by discharging untreated effluents into the neighbouring Poromboke lands. There are about 648 Aquaculture units, which are occupying the areas of about 1484 hectares. The estimate on wastewater generation from these units is also not available.

Impact of Tsunami 2004 in coastal villages of Nagapattinam District was assessed by Kumaraperumal and et al (2007) and observed the seawater inundation distance of 2.2 km. They have also revealed that the pH and EC values are increased on soil irrespective of distance from the sea. The geoelectical cross section (GECs) for pre and the post tsunami by Chidambaram et al (2008) indicates that the lower resistivity values are noted in the north of Perunthottam. It is also suspected with a fresh water lens at a depth of 5-8 m, with resistivity ranging from 100-60 ohm meter, below Kulaiyar and it extends to south of Palayar. Groundwater quality studies were carried out six months after tsunami by Narasimha et al.(2005). Similar studies were carried out by Chidambaram et al (2006), Rengalakshmi et al (2007), Ravishanker et al (2008), Chidahambaram et al (2008), Martin et al (2008) and Chandrashekaran et al (2008). The impact in groundwater chemistry before and after tsunami and the process governing the water chemistry was carried by Chidambara et al (2010 and 2011) with a frequent six months monitoring data.
3.9.0 NEED OF THE STUDY

One will decipher, after having a quick look on the existing literature survey reveals that an extensive work on hydrogeochemistry integrating problems of sea water intrusion and hydro geochemical modelling does not literally prevail in this study area. Factors affecting the quality of groundwater in this coastal environment have not been deciphered yet. Hence this study aim to fill up those gaps incorporating and integrating all related factors to get a meaningful interpretation for groundwater quality in the study area. So the main objective of this study area framed as follows.

3.10.0 AIM AND OBJECTIVE

- To assess the quality aspects of groundwater for various purposes.
- To obtain seasonal variations of groundwater chemistry.
- To identify the land use pattern change.
- To find the probable factors responsible for the water chemistry variations.
- To assess the state of chemical saturation in groundwater.