CHAPTER 2
REVIEW OF LITERATURE

2.1 General

Hydro chemical studies are concerned with the chemical nature of ground water, which can be interpreted to identify processes in both past and present periods that are responsible for the evolution of ground water bodies. There is a considerable progress in the application of hydrochemistry in hydro-geological investigations during the last decade. The hydro-chemical parameters such as physical, chemical and bacteriological characteristics of water determine its usefulness for domestic, agriculture and industrial activities. It can also be used to interpret ground water flow rates, flow direction and aquifer boundary conditions.

Chemical analysis of water has been carried out routinely for more than a century. However, the successful correlation of water chemistry with hydrologic and geologic environments is a more recent development.

Y. Sathyababu et al. (1989) found that pollution of ground water is due to over crowded urbanization and industrialization. The resulting ground water through precipitation by leaching of aerosols and gases can pollute ground water.

Ghazali (1992) noticed that the pollution of the water has extremely serious implications. Nearly two thirds of all ailments in India, such as jaundice, cholera, diarrhoea, dysentery and typhoid are caused by consumption of polluted water. These water borne diseases claim nearly 15 lakhs lives annually in India. Though 70 % of the ailments emanates from water, one third of the total beds in the hospitals are occupied by people suffering from water related diseases. Safe drinking water constitutes only two percent of the earth's total water supply (Sapru, 1989).

D.D. Ozha et al (1994) noticed that in recent years it has been seen that there has been a significant impact on hydro-environmental conditions due to changes in agricultural practices, industrial developments and urbanisation. These factors have influenced the surface and ground water.
Pradeep K Jain et al. (1998) found that the important factors that influence the water quality for irrigation are total dissolved solids concentration, percent sodium and sodium absorption ratio. Excessive amount of salt in general and sodium in particular affect the soil permeability, soil structure, and create toxic condition for plants, particularly those sensitive to sodium.

Davina V. Gonsalves and Joe D'Souza (1999) have conducted a study on the ground water in Goa city (India) in order to assess the impact of tourism industry on the quality with respect to physico-chemical and microbial parameters.

Shubha Srivastava et al. (1999) investigated the status of water pollution in and around Hazaribagh Township in South Bihar region (India). The analytical work was made during pre and post monsoon seasons. The report obtained during the study narrated the presence of high levels of hardness, iron and biological oxygen content than the standard limits of drinking water. Therefore the treatment of water prior to use for domestic purposes from the pollution control point of view was suggested.

Dubey et al. (1999) conducted a pilot study on the ground water quality in core zone of Malanpur industrial complex near Gwalior of Madhya Pradesh (India) in order to ascertain the current status of ground water quality in the industrial region. The study revealed that the values obtained for various chemical parameters for drinking purposes were satisfactory as per standards except sodium, turbidity and microbial quantity since they have exceeded the standard limits. As the study has reported on ground water quality in an adjoining industrial area, the data generated would help in assessing the impact of industrialization on the environment through regular monitoring process in future.

Babar and Kaplay (1999) carried out an analysis on ground water quality around Pingalgad Nala in Parbhani District of Maharashtra (India) in order to ascertain the quality of water for domestic needs. The analytical report obtained indicated that the problem of health in urban and rural areas needs detailed chemical analysis of water of the wells located near streams and rivers where
drainage outlets are made. The preventive measures are necessary to save the people from danger of the health hazards in these areas.

The chemistry of ground water in Sangamner area of Maharashtra (India) was carried out by Deshmukh and Pawar (1999) to determine the suitability of water for domestic and irrigation purposes. The analytical data obtained showed that the quality of ground water in irrigated land region was unsatisfactory. However, the quality of ground water from non-irrigated land (area without drainage) was fit for domestic as well as agricultural purposes.

The need for geochemical approach for evaluation of ground water quality and geochemical principles to predict the major and minor elemental pollutants that percolate into the ground water reservoir and their interactions with soil-water and rock-water. These interactions start with the dissolution of atmospheric gases in the rain water and continue with carbonate and silicate mineral equilibria, redox reactions, ion exchange and adsorption or desorption process. Surface active colloids and organic matters present in the aquifer play an important role in attenuation of pollutants. In conclusion, the author has stressed the relevance of geological expertise in protection and monitoring of our environment (Raymahashay, 1999).

A case study on ground water pollution due to improper treatment and disposal arrangement by Maharashtra Distilleries was conducted by Biradar et al. (1999). The investigators arrived at the conclusion that among the various physico-chemical parameters analyzed, a few parameters, namely, dissolved oxygen, alkalinity, biological oxygen demand were affected by percolation of distillery effluents stored in katcha lagoon and thereby the water quality was made unsuitable for drinking, domestic and irrigation purposes.

S.A. Abbasi et al. (1999) conducted a study on water quality in and around an industrialized suburb of Pondicherry (India). The study recommended that no new industry can be permitted in this area. Only non-polluting industries may be permitted as of now. The disposal of liquid and solid effluents on land must be stopped forthwith.
S.K. Dash et al. (1999) recommended that residual sodium carbonate (RSC) less than 1-25 fall under good category. Samples of negative residual sodium carbonate value indicate that there is excess of alkaline earths over alkalinity and the waters are suitable for irrigation purpose. Soil permeability is affected by the use of irrigation water when it contains higher value of Total dissolved solids, sodium and bicarbonates. Chloride is the most troublesome anion for irrigation in the sense that it is more toxic than sulphates for the plants.

Krishna Rao et al. (1999) have carried out an analytical work on the influence of tank irrigation on ground water quality in the Vizianagaram District of Andhra Pradesh (India). The results obtained revealed that the ground waters quality deteriorates due to leaching of agro-chemicals in ayacut area by registering very high concentration of salinity, sodium, potassium and sulphates.

Very recently, Chandrasekhar et al. (2000) have succeeded in assessing the ground water pollution through remote sensing and GIS techniques for Anekal Taluk of Bangalore urban District of Karnataka (India). The main objective of remote sensing technique used was to protect ground water quality from every activity of the society, which causes pollution, and to determine ground water pollution potential.

S.Srinivasa Gowd et al. (2000) noticed that the concentration of sodium is important in classifying irrigation waters because it reacts with soil affecting permeability. Sodium saturated soils, alkaline soils formed on account of excess sodium in soil with carbonate as predominant anion or saline soils formed due to excess presence of sodium with either chloride or sulphate as predominant anion, stunt the growth of plants.

Srinivasa Gowd et al. (2000) noticed that irrigation water is also rated based on the classification given by Richards (1954). Sodium absorption ratio below 10 falls under excellent category for irrigation. According to U.S. salinity lab, carbonate of less than 1.25 meq/l in water is probably safe for irrigation. Water with residual sodium carbonate more than 2.5 meq/l is unsuitable for irrigation.
Joseph (2001) conducted detailed investigation on ground water chemistry in the valley of De Yabucoa alluvial aquifer South Eastern Puerto Rico of U.S.A. The valley is surrounded by the hills of son Lorenz Batholith on three sides by Caribbean Sea but on the fourth side, the study area has tropical marine climate and the valley is the major source of water for public and industrial supplies in the area. The water samples collected from public supplies, industrial, abandoned wells and observation wells were analyzed for important physico-chemical parameters as well as metal nutrients like ferrous and Manganese constituents. The investigation revealed that the aquifer system in the valley of De Yabucoa region indicated high level of iron and manganese concentration as high as 28 and 3.6 mg/L respectively. The investigator predicted from the report that the longest contributor of ferrous iron to the ground water appears to be iron oxide phase. Illuminat is probably the sole significant source of manganese. In addition to iron and manganese, the ground water in the aquifer locally contains high total dissolved solids (TDS) content that exceeds the drinking water standard. The high concentrations of TDS have caused some water supply to be taken out of service. Further, the author identified the high levels of calcium (Ca$^{2+}$), magnesium(Mg$^{2+}$) and bicarbonate (HCO$$_3^-$). As water moves through the aquifer and approaches the ocean, it becomes rich in sodium (Na$^+$), potassium(K$^+$) and chloride (Cl$^-$).

A. Abdul Jameel (2002) studied the ground water quality in Tiruchirapalli, TamilNadu (India). The study reveals that in all areas of water collection, there is no proper drainage. There is regular addition of large quantities of sewage and detergents from the residential locations. They contain both sanitary and non-sanitary components. They are absorbed by the soil and move with the ground water. Large scale exploitation of ground water lowers the water levels and dries the soil. This makes the maximum adsorption of the domestic sewage and industrial effluents causing the ground water pollution.

The municipal solid waste dumps have an impact on ground water quality due to leaching. Dispersion is spatial homogenization of concentration and attenuation occurs with time and distance. (T. Usha Madhuri et al. 2003).
Jayashri Jastab et al. (2002) recommended that specific conductance, (expressing Total dissolved solids) sodium content and sodium absorption ratio are the important factors in irrigation water classification. To assess the suitability for irrigation in terms of sodium hazards. The sodium absorption ratio has to be considered together with specific conductance. A low sodium absorption ratio (2-10) indicates minimum danger from sodium, medium hazards at sodium absorption ratio between (7-18), high (11-26). The lower the ionic strength of the solution, the greater the sodium hazard for a given sodium absorption ratio. Maximum 60 % for sodium is recommended for irrigation water as per BIS.

B. Guruprasad (2003) carried out water quality study at Tadepallimandel of Guntur District in Andhra Pradesh (India). The study showed that the reasons for high values of some of the physico-chemical parameters may well be ascribed to unscientific storage and usage of manures and fertilizers. Septic tanks of buildings may also be one of the causative agents, and the ground water source gets polluted once the effects of pollutants may persist for longer duration. The reclamation of surface water is easier than the reclamation of subsurface water. Hence prevention of ground water pollution due to any cause is necessary.

B. Guruprasad (2003) noted that ground water is usually free from pathogens, when found approximately within 30 feet. Except soluble metal compounds, almost all bacteria are filtered out. If free carbon dioxide is excessive, it may corrode the pipe and this can be neutralized by adding lime. The preventive measures may be adequate drainage system with proper treatment of sewage before disposal and removal of faulty septic tanks and cesspools.

B. Guruprasad et al. (2004) carried out an analysis on ground water quality at Machilipatnam town (India). The study indicated that, the salinity of ground water increased, as a result of over exploitation of ground water from thin sandy aquifer and shallow occurrence of water table below ground level. Hence it requires enactment of legislation to regulate the use of water in the particular site.
S. Lalitha et al. (2004) carried out an analysis on ground water quality near Thanjavur of Tamil Nadu (India), in order to ascertain the quality of water for domestic needs. The experimental analysis reveals that the quality of water in this area is good except a few samples. The poor quality of water and low quality may be attributed to seepage of domestic water into ground water. So a knowledge and awareness about the maintenance and proper disposal of domestic waters can be created among the people, so that the future generations may be saved from the attack of water borne diseases.

A study conducted by Moti R. Sharma (2004) in Hamirpour area in Himachal Pradesh denoted that the water in the area is highly alkaline, very hard and the chloride content is low. Most of the areas of the District is suitable for drinking purposes.

Sanjay Gupta et al. (2004) conducted a study on chemical analysis of ground water of Sanganur area in Rajasthan (India). The study reveals that high values of sulphates and TDS in drinking water are generally not harmful to human beings but high concentration of these may affect persons who are suffering from kidney and heart diseases.

Sanjay Gupta et al. (2004) recommended that ground water is one of the earth's renewable resources which occur as a part of hydrological cycle. The quality of ground water is the resultant of all the processes and reactions that act on the water from the moment it condenses in the atmosphere to the time it is discharged by a well. Therefore determination of ground water quality is important.

V. Ravinder et al. (2005) conducted a study on the ground water of Warangal, Andhra Pradesh (India) in order to assess the impact of pollution on the quality due to dumping of municipal solid wastes. The study revealed that the municipal solid waste dumping in low lying areas had an impact on ground water quality due to leaching. Leachate percolates through soil and contaminates the ground water. If necessary precautions are not taken while dumping municipal solid waste on the low lying areas, consequences can be very serious, in terms of damage to the natural resources such as water and soil.
K. Karunakaran et al. (2005) have carried out physico-chemical characteristics of ground water in Salem corporation in Tamil Nadu (India). The study showed that the ground water in the study area contains mainly chlorides of sodium and magnesium. High values of sodium, magnesium and chlorides are generally not harmful to human beings. But high concentration of magnesium may affect persons suffering from Kidney and heart diseases.

2.2 Physical Parameters

pH

The pH measurement has got some environmental and public health significance. pH in the 6.5 to 8.5 has no direct adverse effect on health. However a lower value below 4 will produce sour taste and higher value above 8.5 a bitter taste. High pH induces the formation of trihalomethanes, which causes cancer in human beings (Kotaiah, 1994).

The pH has been categorized under secondary drinking water standard as it does not pose a health risk. (Environmental Pollution Act, 1989).

K.C. Prakashan et al. (2003) reported that higher value of pH increases the rate of scale formation in the water heating apparatus and reduces the potentiality of chlorine. T. Jeyakumar et al. (2005), found that the lower pH starts corrosion in metals.

K. Veerabhadran et al. (2004) noted that the pH of the natural water is governed by the carbon di oxide-Bicarbonate-Carbonate equilibrium.

Electrical Conductivity

Electrical conductivity is a measure of salinity, which greatly affects the taste and thus has a significant impact on the user. (Pradeep K. Jain 1998).

Conductivity is due to the presence of large proportion of inorganic salts (Total concentration of ionize substances). If the Electrical conductivity of water is greater than 15 μmhos/cm, such water generally causes corrosion (Mahesa et al. 2004).
Total Dissolved Solids (TDS)

If Total Dissolved Solids value is higher than 500 mg/L, it causes gastrointestinal irritation (BIS 1991).

A. Abdul Jammeel (2002) reported that higher concentration of dissolved solids may be aesthetically unsatisfactory for bathing and washing. Membrane separation technique is efficient to decrease the solids content.

T. Usha Madhuri et al. (2003) showed that assessing the quality of water in a solid waste dump yard shows that parameter like Total Dissolved Solids is not within the standard due to leaching.

According to WHO, the acceptable limit for Total dissolved solids is 500 mg/L which may extend to 1500 mg/L in case of non availability of any available waste source.

S. Murugesan et al. (2005) found that a high total dissolved solids level above 1000 mg/L may cause corrosion of pipes and plumbing system. To reduce Total Dissolved Solids to acceptable limits a water softener with a reverse osmosis (R/O) is used.

T. Jeyakumar et al. (2005) indicated that total dissolved solids indicate the nature of the water quality or salinity. Total dissolved solids greater than 500 mg/L is not desirable for drinking purpose.

2.3 Chemical Parameters

Chloride (Cl\(^{-}\))

Chloride is present in all natural waters at greatly varying concentration depending on the geochemical conditions. The presence of chloride in natural water can be attributed to dissolution of salt deposits, discharge of effluents from chemical industries, oil well operations, sewage discharge irrigation drainage, contamination from refuse leachates and sea water intrusion in coastal areas. Each of these may result in local contamination of both surface and ground water.
A.J. Dhembare et al. (1998) indicated that high concentration of chloride in water is often found in conjunction with sodium concentration and the salty taste of water due to high chloride has deleterious effects on metallic pipes and structures as well as agricultural plants.

A. Abdul Jammel (2002) noted that excessive chloride content may give a salty taste if present with sodium.

C.K. Jain et al. (2003) found that chloride concentration from season to season and higher concentration leads to adverse health effects on humans. Maximum concentration is due to black cotton soil terrain.

S. Lalitha et al. (2004) and K.G. Kesavan et al. (2004) remarked that discharge of domestic sewage is the main source of chloride in water.

Sulphate (SO$_4^{2-}$)

K. Vijayaram et al. (1989) noted that the sulphates comparatively have less effect on taste of water than chlorides and carbonates.

V. K. Garg et al. (1999) found that sulphate content more than 200 mg/L is objectionable to domestic purpose. Water containing more than 500 mg/L sulphates tastes bitter and beyond 1000 mg/L it has purgative effect.

Mor et al. (2003) indicates that the sulphate is a naturally occurring anion found almost in all types of water. The sulphate may be present in sedimentary rocks in minor quantities in igneous rocks and largely recycled from atmosphere.

Nitrate (NO$_3^{-}$)

Recent study in Australia has found evidence that elevated nitrate in ground water may be a human teratogenic leading to prenatal death due to congenital malformations in a region that had more than 45 mg/L nitrate in drinking water (Scragg et al. 1982).

K. Vijayaram et al. (1999) found that the nitrate concentration in ground water is due to the tannery and sewage discharges which leach soil nitrate into it. Ajmal and Raziuddin (1986) found that when present in considerable quantity, nitrate causes cyanosis among infants and higher quantity causes gastric problems.
Deepanjanmasumdar et al. (2000) noted that nitrate is one of the several inorganic pollutants contributed by nitrogenous fertilizers, organic manures, human and animal wastes and industrial effluents through the biochemical activities of micro-organisms.

Sushil kumar et al. (2002) found that nitrate is the most oxidized state of the versatile element nitrogen and represents a highly stable product. It is very difficult to remove nitrates from water because it is chemically non reactive in dilute aqueous solutions.

B.Guruprasad (2003) remarked that the presence of too much nitrates causes methemoglobinemia in infants. Much of the nitrate to the ground water reaches with the percolating water through the soil. Nitrate is very loosely bound to the soil particles and easily leaches out.

S.Lalitha et al. (2004) noted that higher concentration of nitrate is due to the decomposition and percolation of organic matter into the ground water.

Biological oxidation of nitrogenous substances from sewage is the main source of nitrate.

Calcium (Ca$^{2+}$) and Magnesium (Mg$^{2+}$)

A.Abdul Jameel (2002) predicted that calcium and magnesium are of great neurochemical importance. Symptoms of cathartic and diuretic action are observed if excess of these ions are consumed. They are also the sources for the hardness.

A.J.Dhembare et al. (1998) suggested that physiologically calcium is needed for the body in small quantities, though water produces only a small proportion of the body's requirement of calcium. High concentration of magnesium has a laxative effect especially on new users of a supply. It may act like 'milk of magnesia' and the water becomes unpalatable before toxic concentrations of magnesium are needed.

K.G.Kesavan et al. (2005) found that calcium is one of the most abundant substances of the natural water. Being present in high quantities in the rock, it is leached from these to contaminate water. Disposal of sewage and industrial waste water is also important sources of calcium. It has no hazardous effects on
human health. Calcium is not desirable in washing, laundering and bathing due to its suppression of formation of lather with soap, and scale formation in boilers is also another problem associated with high calcium content.

**Total hardness (TH)**

The degree of hardness in mg/L has been classified in terms of equivalents of CaCO$_3$ concentration (APHA, 1985; Kotaiah, 1994) as:

- **Soft**: 0-50
- **Medium**: 50-100
- **Hard**: 150-300
- **Very Hard**: >300

A. J. Dhembare et al. (1998) remarked that the hardness is defined as the sum of polyvalent cations present in the water and the most common divalent cations are calcium and magnesium.

B. Guruprasd et al. (2004) studied that water reflects the nature of the geological formations with which it has been in contact.

G. Achuthan Nair et al. (2005) noted that the principal natural sources of hardness in water are sedimentary rocks, seepage and runoff from soils. Hard water normally originates in areas with thick top soil and limestone (Sawyer and Mccaity, 1967).

### 2.4 Water Quality Index (WQI)

Horton (1965) devised and implemented the first water quality index, and a great deal of consideration has been given to the development of index methods (Shoji et al. 1978; Brown et al. 1970; Landwehr et al. 1974, Inhaber 1974, 1976, 1977; Thom and Ott 1976; Joung et al. 1978) which allow measurements of constituents to be transformed into a common measurement unit; for example, an aggregated measuring score on a water quality index scale for overall classification (Warner and Preston, 1974; Munn, 1975; Clark et al. 1980). For most water quality index designers, the critical issue is to construct a water quality index in a simple way so that the right information can be
extracted from the measurements in order to illustrate their spatial variation and seasonal fluctuation (Ott, 1980).

Hsiang-te Kung et al. (1992) studied that there have always been difficulties in the technical interpretation of Water quality indices. For instance, a WQI score of 1.0 is often defined as a "normal status" for a given water body, but this score can be calculated from at least three possible situations. First, all measured constituents may just reach legally permissible standards, causing the very rare case of "threshold status". Second, the measures of toxic constituents may be far lower than permissible standards while the concentration of eutrophic and scenic parameters may be above permissible standards, indicating little deterioration of water quality. Finally, one of the heavy metals may have a higher measure than the legally permissible standard although the measurements of the other constituents may be lower than the legally permissible, yielding a definitely toxic-polluted status.

B. Gruprasad (2003) recommended that parameter selection has great importance for the calculation of Water quality Index. Since various parameters depend on the intended use of water, physico-chemical parameters namely turbidity, pH, electrical conductivity, total hardness, total alkalinity, chloride, sulphate, fluoride, nitrate and iron were used to estimate water quality index.

2.5 Classification Of Water

S.K. Dash et al. (1998) conducted a study on ground water quality in a part of Sundargarh District, Orissa, India, in order to find out the classification of water based on piper's diagram, USSL classification and permeability Index.

Studies were conducted on the Ground water classification of Malaprabh sub basin, Karnataka, India, by C.K. Jain et al. (2000). The grouping of samples according to their hydro chemical facies clearly indicate predominance of Ca-Mg-Cl-SO$_4$ Hydro chemical facies followed by Ca-Mg-HCO$_3$ and Na-K-Cl-SO$_4$ facies during the survey.

Abhay kumar singh (2002) carried out the quality analysis of surface and subsurface water of Damodar River basin, with the classification of water. He
found that Na-Ca-HCO$_3$ is the common hydro chemical facies in sub surface water.

N.B.Y Reddy et al. (2005) carried out an analysis on Hydro chemistry of ground waters in and around Tadpatri Area, Anantapur District, Andhra Pradesh, India, in order to predict the type of water. Hydro chemistry of the ground waters of Tadpatri area reveals that the waters are of Carbonate type with Ca, Mg and Na as Cations, and they are of moderately hard nature.

Omkar Singh et al. (2005) conducted detailed investigation on ground water in some parts of Udhampur District (J&K), India, for the classification of water based on piper's diagram and USSL classification. The results obtained revealed that the hydro chemical classification using piper's diagram indicates majority of samples under the Ca$^{2+}$, Mg$^{2+}$, HCO$_3^-$ hydro chemical facies and USSL classification indicates the study area under C3S1 (High salinity-Low sodium adsorption ratio) zone.

M.A.Sivasankaran et al. (2005) have studied the geochemical characteristics of ground water in Pondicherry region, India, for the classification of ground water. The study reveals that the mean of dominant cations and anions of ground water of Pondicherry region are in the order of HCO$_3^>$Cl$>$SO$_4$ and Na$>$Ca$>$Mg$>$K (meq/L) respectively by using piper's diagram.

2.6 Statistical Modelling

Singh (1996) made a systematic study of correlations among 14 water quality parameters by considering 35 locations in Jhunjhunu District of Rajasthan and obtained neither perfect positive nor perfect negative correlation between any two parameters. Correlation co-efficient obtained is greater than and equal to 0.6 between 9 pairs of parameters with 0.858 between calcium and total hardness, high correlation between carbonates and bicarbonates and low correlation between sodium and magnesium, magnesium and potassium and sodium and potassium.

Singh and Choudhary (1996) attempted to obtain some correlation among physico-chemical parameters of Nagpur and concluded saying that large
positive correlation between chloride and total dissolved solids, and electrical conductivity and total dissolved solids are obtained.

D. Mohapatra et al. (2001) carried out the correlation study on Physico-Chemical characteristics of ground water in Paradip areas, India, and found that sodium and chloride had a high positive correlation (0.954). Chloride is the most dominant anion in the water samples.

Savangi et al. (2001) conducted the correlation study of some water quality parameters of ground water around Sargipali Lead-Zinc mines, India, and recommended that, correlation coefficient study, which helps in determining the correlations among the numerous water quality parameters facilitate the periodic monitoring process. Since by knowing the values of ten important parameters, other parameters can be inferred from the existing correlation and thus it gives a rough idea about the water quality.

Mariappan, P. et al. (2002) studied the correlation coefficients of some physico-chemical parameters of drinking water ponds in the eastern part of Sivagangai District, TamilNadu, India, and recommended that the correlation coefficient determination will greatly ease the tasks of rapid monitoring of water quality parameters at any cost.

Punam Tyaj et al. (2003) conducted a study on correlation among physico-chemical parameters of ground water in and around Pithampur Industrail area, India, and observed that the Electrical conductivity has strong positive correlation with major cations Na\(^+\), K\(^+\),Ca\(^{2+}\),Mg\(^{2+}\) and major anions Cl\(^-\),HCO\(_3\)^-,SO\(_4^{2-}\), that is as the concentration of electrical conductivity increases the concentration of these ions also increases.

Kaza Somasekhara Rao et al. (2004) remarked that the main objective of statistical investigations is to establish relationships which make it possible to predict one or more variables in terms of others. For this purpose, regression analysis is employed.

K. Karunakaran et al. (2005) carried out a study on the Physico-chemical characteristics of ground water in Salem Corporation, India, and predicted that compared to other water quality parameters electrical conductivity and total
dissolved solids are easily determinable, hence knowing the electrical conductivity and total dissolved solids values, one can determine the other significant parameters like sodium, magnesium and chloride without spending more time in the experimental analysis of these parameters.

**S.V. Mahajan et al. (2005)** conducted a correlation and regression study for Vapi area of Gujatat, India, and indicated that the strong correlation always exists among the water quality parameters. A systematic calculation and interpretation of correlation coefficient gives an idea of rapid water quality monitoring methods.

**V.V. Nageswara Rao et al. (2005)** carried out the statistical analysis of ground water quality parameters in the industrial areas of Hyderabad, Andhra Pradesh, India. They found that the significant positive correlation between electrical conductivity and total dissolved solids and between electrical conductivity and hardness is due to the presence of ions like chlorides, magnesium, nitrate and total dissolved solids, which mainly contribute to the electrical conductivity of water.

### 2.7 Geographical Information System

A Geographic Information System (GIS) is a computer based information system that enables capture, modelling, manipulating, retrieval analysis and presentation of geographically referenced data.

Work of GIS began in late 1950s, but first GIS software came only in late 1970s from the lab of the ESRI. Canada was the pioneer in the development of GIS as a result of innovations dating back to early 1960s. Much of the credit for the early development of GIS goes to Roger Tomilson. Evolution of GIS has transformed and revolutionized the ways in which planners, engineers, managers etc., conduct the database management and analysis.

**Kharad et al. (1999)** from L&T Information Technology Ltd., developed a GIS based ground water assessment model. This model allows assessing the ground water more efficiently, accurately and at a fast pace. Ground water
assessment is based on the water fluctuation method and is calculated based on the norms recommended by GEC 1984.

**Ramalingam et al. (1999)** applied GIS and remote sensing to delineate areas favourable for recharge and to recommend suitable recharge structures. Different thematic maps were prepared and overlaid with suitable rank and weights. Recharging structures are recommended based on the field conditions and weights.

**Rajamohan (2000)** utilised GIS techniques for ground water quality assessment in Madurai Corporation. In order to assess the ground water quality, 105 wells were identified throughout the Madurai Metropolitan region and water samples have been collected during summer as well as winter seasons in the year 1997-1998. The estimated data of 105 locations for each parameter have been converted into contour maps by using GIS (ARC-VIEW). Total dissolved solids, total hardness, chlorides and fluorides have been integrated through GIS and three priority classes (High, Medium, Low) have been derived.

**Mohammed Ismail et al. (2000)** used GIS techniques for mapping the spatial variability of ground water in Erode District. In his study, the ground water quality of 40 wells randomly distributed in Erode District was selected. MAPINFO was used for zoning the ranges of pH, bicarbonates, chloride, calcium and magnesium. The frequency distribution of the parameters were randomly classified into four ranges. Based on these ranges, the thematic maps for pH, bicarbonate, chloride, calcium and magnesium for open wells and bore wells are prepared and presented.

**Arun et al. (2003)** developed an integrated remote sensing and GIS based methodology and tested for the evaluation of ground water resources of Silai watershed, Bankura District, West Bengal.

**Arora et al. (2003)** highlighted the use of Geographical Information System in development of conceptual ground water model. Various layers of information such as canal network recharge zones, subsurface geology and digital terrain model (DTM) of Hanumangarh and Srinagar Districts were
developed in GIS and were then transferred to finite differences grid for developing mathematical ground water flow model of the area.

S.S.Asadi et al. (2005), assessed the ground water quality in the zone III of Municipal Corporation of Hyderabad to demonstrate its spatial distribution using advance techniques of remote sensing and geographical information system.

V.Radhika (2005) applied GIS Technique to find the delineation of potable ground water for the Tirunelveli District with the standard norms.