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# GROUND WATER QUALITY MONITORING OF MINE AREA USING REMOTE SENSING AND GEOGRAPHIC INFORMATION TECHNIQUES

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## ABSTRACT

Ground water quality in Chalk Hills, Salem has special significance and need more attention since the area is rich in mineral deposits like Magnezite, Dunites, Peridotites and Talc. Continuous exploitation of natural resources beyond threshold limit causing imbalance in natural ecosystem resulting in large-scale disaster. The continuous extraction of minerals from the study region, result in disturbance of groundwater resource. The objective of the study is to investigate and monitor the groundwater quality in the Chalk Hill region. The present study emphasizes on the ground water quality, sources of contamination, variation of ground water quality and its spatial distribution. Various thematic maps for the research are prepared using SOI toposheets No. 58 I /1, 58 I /2, 58 I /5, 58 I /6 and fused data of IRS-ID PAN and LISS-III imagery on 1:50,000 scale using ARC/INFO software. Physio-chemical analysis of the groundwater samples were collected at 30 predetermined well locations forms the attribute database for the study, based on which the spatial distribution maps of major water quality parameters has prepared. Water Quality Index (WQI) was then calculated by weighted arithmetic mean method which has revealed that the ground water pollution in the study area. Appropriate methods for improving the water quality in affected areas have been suggested.

**Key words:** Hydrogeomorphology , Mafic intrusive; Biodegradability; Methaemoglobinaemia , Spatial distribution ,Brackish Water.

## 1. INTRODUCTION

Water is a dynamic renewable natural resource. Its availability with good quality and adequate quantity is very important for human life. Ground water is an important source of water supply. As a result of population, urbanization, deforestation and mining excessive withdrawal of ground water without proper recharge takes place results in the shortage and contamination of the subsurface water. So it is very important to estimate quality and quantity of ground water resource and also need proper planning for continued utilization of water. The quality of ground water is equally important as that of quantity. Remote sensing and GIS are the effective tools for water quality mapping, monitoring, modeling and detecting the environmental changes. For predicting subsurface water resources availability, Remote Sensing plays a major role. Remotely Sensed data by its wide area coverage and multispectral nature has helped in identification and mapping of most of the factors with selective ground checks in a cost-effective manner.GIS is useful in preparing various thematic maps like land use / land cover map, geomorphology map. Spatially integrating these maps with field data helps in identifying the ground water quality . Groundwater with low pH values can cause gastrointestinal disorder and this water cannot be used for the drinking purposes. Contamination of groundwater by heavy metals has been given much attention due to their low biodegradability and toxic effects (Numberg 1982; Ramesh et al. 1995; Howari et al. 2005; Samuel Obiri 2007). TDS values are considered important in determining the usage of water and groundwater with high TDS values are not suitable for both irrigation and drinking purposes (Davis and DeWiest 1966; Fetters 1990; Freeze and Cherry 1979). Presence of Fluoride ion in the groundwater above 1.5 ppm can cause fluorosis and the monitoring of the fluoride levels in the groundwater gains significance (Woo et al. 2000; Subba Rao and Devada 2003). The presence of nitrate, nitrite and phosphate in the groundwater above the permissible limit is not conducive for the drinking purpose (Julia Pachero et al. 2001; Lee et al.2003; Rajmohan and Elango 2005). Groundwater quality suitability for drinking and agricultural purposes was attempted by Subramani et al. (2005) in Chithar river basin, Tamilnadu and identified locations of contamination by using geographic information system approach. Srinivasamoorthy et al. (2005) studied groundwater quality in Mettur Taluk of Salem district and identified higher NO3 and PO4 pollution levels. Similar studies were also attempted by Stamatis et al. (2006), Pachero et al. (2001), and Antoniou (2002).

## 2. Objective

- Prepare the digital data base using toposheets which is obtained from Geological Survey of India (GSI) for the mine area.
- Prepare various thematic maps such as Geomorphology, Geology, Soil, Land use and Land cover using Remote Sensing and GIS Technique.
- Validate the result using secondary hydro geological data.
- Examine the ground water quality of the area based on the Physio – Chemical characteristics and to evaluate the ground water quality.
- Recommendations for future work and provide guidelines for groundwater prospecting.

## 3. Study Area

Salem is Geologist's paradise, surrounded by hills and the landscape dotted with hillocks. One of the world's best Magnesite deposit occur in the state is in Chalk hills . The study area chalk hills is located at the foothills of shervarys at a distance about 10 km northeast of salem falls under toposheet numbers 58 I/1, 58 I/2, 58 I/5, 58 I/6 of Survey of India with latitude 11 ° 43'05" N and longitude 78°09'45" E. It comprised of variety of minerals like magnezite , chromite and ultra mafic intrusive of dunite , perdolite and pyroxenite. The northern belt with an area of 14.4 sq km and southern belt with an area of 2.8 sq km occupying the chalk hills region. The Mine Lease area of 19.028 hectares falls under the study region. The study region mainly of forest , barren land , wet and dry cultivable land falls in zone II moderately stable in seismic zone. The region does not have bird sanctuaries, biosphere reserves, National parks, Breeding and Green pastures and other sensitive areas. Monthly mean Temperature for the study period is found to be 39.2$^{o}$C and the maximum and minimum temperature ranged from 35$^{o}$C to 28$^{o}$C. Salem city has the altitude of 1,523 meters and Rainfall of 960mm.

**Fig .1 Location map of the study area**

**Fig .2 Satellite Image of study area**

## 4. MATERIALS AND METHODOLOGY

The project was carried out in three stages in that first stage is pre field work which includes literature survey , data collection, image interpretation and spatial database creation, second stage is ground truthing of the thematic maps and field work (for collection of well data, hydrological data etc.) and the third stage is integration and analysis.

### 4.1 Pre-field

- ***Literature Survey and data collection:***

Detailed literature survey was carried out to understand the methodology and analytical framework of the project. The satellite images and toposheets were collected from NRSA and Survey of India.

- ***Image interpretation and creation of spatial database:***
  IRS-ID LISS-III image was interpreted to prepare various thematic maps which mainly include Land use , Geomorphology, Geology and Soil map. The SOI topographical maps and other maps were used for preparation of base maps. The thematic maps so prepared by interpretation were digitized in Arc Info and Arcview platform. This analog to digital conversion was done for overlay analysis of all the thematic maps.

**Figure 3 :Flow chart showing the methodology**

**4.2 Field Work**

The work had carried out for the four seasons of March 2009 to February 2010. Fieldwork was conducted in and around 7 km radius of the study area , water samples of 30 numbers and soil samples of 4 numbers were collected from predetermined well locations based on the land use change and drainage network of the study area .The water samples for the collected seasons were analyzed for various Physio-chemical parameters adopting standard protocols. Meteorological data for the study area were collected from Indian Meteorological Department (IMD ), Chennai. The selected water quality parameters like pH, Electrical conductivity, Chlorides, Sulphates, Nitrates, Total hardness, Total Dissolved Solids, Fluorides, Alkalinity, Sodium, Potassium and Phosphates were measured by carrying out physicochemical analysis (APHA, 1998).

**4.3 Geo-referencing and Generation of thematic maps**

Toposheets of 1:50,000 scale was scanned and raster file for study area had created. These are geo referenced and edge matched based on the longitudinal & latitudinal coordinates. For the study area Base map, Landuse / Landcover map, Geomorphology map, Drainage network map and Slope map were prepared to a certain scale.

**4.3.1 Drainage and Drainage Pattern**

The drainage map of the Chalk hill region with different tributaries has been drawn from the SOI topographical maps of 1:50,000 scale and updated from the satellite data as shown in figure 4. The dendritic pattern is observed in the massive igneous rocks, complex metamorphosed rocks of the shear zone, and volcanic hills. Parallel drainage is also observed in this region.

**Figure 4 : Drainage map of the study area**

**4.3.2 Geomorphological Setup**

The storage capacity of the rock formations depends on the porosity of the rock. In the rock formation the water moves from areas of recharge to areas of discharge under the influence of hydraulic gradients depending on the hydraulic conductivity or permeability. In other words, at a given location, the occurrence of ground water depends on the storage capacity and the rate of transmission. The framework in which the ground water occurs is as varied as that of rock types, as indicated as their structural deformation and geomorphic history, and as complex as that of the balance among the Lithological, Structural and Geomorphic parameters. The combined units in which the lithology, landform, structure and recharge conditions are unique are called ‘Geomorphic units’. The ground water prospects are expected to be uniform in a hydro geomorphic unit. Different geomorphic units and their influence on groundwater regime have been shown in Table 1 below.

**Figure 5 : Geomorphology map of the study area**

**Table 1: Geomorphic units and their influence on groundwater regime**

## 5.0 GROUND WATER QUALITY DATA GENERATION

Appropriate number of ground water samples was collected based on the Land use /Land cover pattern in the study area and the selected water quality parameter were measured by carrying out physio chemical analysis (APHA, 1998). Samples for estimating Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were collected separately in BOD (glass) bottles. Water temperature was recorded on the spot using thermometers.

**Water Quality Index**

The main objective of water quality index is to turn complex water quality data into information that is understandable and useable by the public. Water Quality Index based on some very important parameters can provide a simple indicator of water quality

**Water Quality Index is calculated from the following equation**

To determine the suitability of the groundwater for drinking purposes, WQI is computed. (Srivastava, A. K et al. 1994) Water Quality Index (WQI) is a very useful and efficient method. For assessing the quality of water the following formula was adopted

$$[WQI = \sum Wn\ qn / \sum Wn]$$

where,

$W_n$ Weightage factor (W) is computed using the following equation

$$[W_n = K / S_n]$$

and K, Proportionality constant is derived from,

$$[K = 1 / (\sum^{n}_{n=1} 1/S_i)]$$

$S_n$ and $S_i$ are the WHO / ICMR standard values of the water quality parameter.

Quality rating (q) is calculated using the formula,

$$[q_{ni} = \{[(V_{actual} - V_{ideal}) / (V_{standard} - V_{ideal})] * 100\}]$$

where,

$q_{ni}$ = Quality rating of ith parameter for a total of n water quality parameters

$V_{actual}$ = Value of the water quality parameter obtained from laboratory analysis

$V_{ideal}$ = Value of that water quality parameter can be obtained from the standard tables.

$V_{ideal}$ for pH = 7 and for other parameters it is equalent to zero

$V_{standard}$ = WHO / ICMR standard of the water quality parameter

**Table 2: Ground water quality of the mine area**

**Table 3: Water Quality Parameter ,their ICMR / WHO standards and assigned unit weights**

**Table 4: Standards for drinking water**

**Table 5: Ground Water Classification based on TDS**

## 6.0 RESULTS

Water Quality index is calculated to determine the suitability of water for drinking purpose. Water quality index values revealed that the ground water at nine locations of the study area was of good quality with the WQI ranging in between 0-50 and therefore can be used for human consumption. Six samples were of poor quality with WQI ranging in between 50-75 and they need treatment before using. Such areas require special care to provide adequate drainage and introduce alternative salt tolerance cropping.

**Table 6: Water Quality Index Categories**

The analytical result of the ground water is compared with the standard guideline value recommended by World Health Organisation ( WHO, 1971,1983) for drinking and for public Health purposes. The table 4 shows the most desirable limits value . The concentration of cations such as $Na^{+}$, $Ca^{2+}$ , $Mg^{2+}$ are within the desirable limit for drinking purpose except few sample.

### 6.1 The pH values

The pH level is a measure of the acid content of the water. Most forms of aquatic life tend to be very sensitive to pH. Since most of the human body consists of (50-60%) water, the pH level has profound effect on all body chemistry, health and disease. The pH values of groundwater is alkaline ranging from 7.12 to 7.96 with an average value of 7. 4.

**Figure 6 : pH Values of Ground Water Samples**

### 6.2 Total Dissolved Solids

This is a measure of the solid materials dissolved in water. This includes salts, some organic materials, and a wide range of other things from nutrients to toxic materials. TDS consists of oxygen demanding wastes, disease causing agents, which can cause immense harm to public health .

Exposure to high doses can affect the central nervous system, provoking paralysis of the tongue, lips, and, face, irritability, dizziness. The presence of synthetic organic chemicals (fuels, detergents, paints, solvents etc.) imparts objectionable and offensive tastes, odors and colors to fish and aquatic plants even when they are present in low concentrations(Sawyer et al., 2003; Nollet, 2000).

To ascertain the suitability of groundwater for any purposes, it is essential to classify the groundwater depending upon their hydro chemical properties based on their TDS values (Cayroll 1962; Freeze and Cherry 1979).TDS values of the stations are found to be ranging from 477 to 1950 with the mean value of 1222 and the desirable limit is 500 – 1500.

Most of the groundwater samples are within the maximum permissible limit for drinking as per the WHO international standard .The stations Karungali and Reddipatti have the TDS values of 477 and 1947 respectively. At Reddipatti, it is found that the concentration of all ions are high especially the values of Na, Mg and Cl are found to be high. Since the station are within 5km from mine area, the penetration/percolation of the saline water into the adjacent aquifers is high and hence only the saline water dominates the geochemistry of these samples. But in Karungali the concentration of ions like Na, Ca, Mg and K are low. Hence the station is present in forest area and the ground water quality is also good. In all these stations there is more concentration of ions during the summer season and less ionic concentration during winter may be due to the leaching of salts from the soil and also by anthropogenic activities.

Higher concentration of TDS is observed in the groundwater near to the mine area. As per the TDS classification (Fetters 1990) most of the groundwater samples collected belong to brackish type (TDS>1,000 mg/l) , but the station like Karungali belong to fresh water type. The groundwater classifications of Freeze and Cherry 1979 and Davis and Dewiest 1966 are presented in Table5.

**Figure 7 : TDS Values of Ground Water Samples**

## 6.3 Total Hardness

The classification of groundwater (Table 4) based on Total Hardness (TH) shows that a majority of the ground water sample fall in very hard water category and the allowable limit of TH for drinking is 500 mg / lit (Sawyer and McCartly 1967). TH of the groundwater was calculated using the formula given below (Hem1985; Ragunath 1987).

**[TH (as CaCO3) mg/l = ($Ca^{2+}$ + $Mg^{2+}$ ) meq/l X 50 ]**

The hardness values range from 291mg/l to 1,097 mg/l with an average value of 599 mg/l.

**Figure 8 : Total Hardness Values of Ground Water Samples**

## 6.4 Chloride

The chloride ion concentration varies between 25mg/l to 348 mg/l with the average values of 217 mg/l. Most desirable limits and maximum allowable limit for chloride is 200mg /l to 600mg/l .Seven stations are below the desirable limit value and remaining stations are within the prescribed range.

**Figure 9 : Chloride Values of Ground Water Samples**

## 6.5 Nitrate

The nitrate concentration in groundwater samples range from 2mg/l to 74 mg/l with an average value of 35.33 mg/l. The concentration of nitrogen in groundwater is derived from the biosphere (Saleh et al. 1999). Nitrogen is originally fixed from the atmosphere and then mineralized by soil bacteria into ammonium. Under aerobic conditions nitrogen is finally converted into nitrate by nitrifying bacteria (Tindall et al. 1995). The high concentration of nitrate in drinking water is toxic and causes blue baby disease/ methaemoglobinaemia in children and gastric carcinomas (Comly 1945; Gilly et al.1984). As most of the study area is intensively irrigated,the fertilizers used for agriculture may be the source for the elevated concentration of nitrate in a few locations.

**Figure 10 : Nitrate Values of Ground Water Samples**

## 6.6 Sulphate

Sulphate is unstable if it exceeds the maximum allowable limit of 400 mg/l and causes a laxative effect on human system with the excess magnesium in groundwater. Only two samples exceed the prescribed value. However, all the station in the study area are within the maximum allowable limit of magnesium (150 mg/l) suggested for drinking.

### 6.7 Fluoride

Fluoride is one of the main trace elements in groundwater, which generally occurs as a natural constituent. Bedrock containing fluoride minerals is generally responsible for high concentration of this ion in groundwater (Handa 1975; Wenzel and Blum 1992; Bardsen and others 1996). The concentration of fluoride in groundwater of the study area varies between 0.2 mg/l and 1.3 mg/l with an average value of 0.71 mg/l. However, all samples examined exhibit suitability for drinking.

**Figure 11 : WQI Values of Ground Water Samples**

## 7.0 CONCLUSION

The results indicate that certain parameters such as nitrates, TDS, chlorides and fluorides were beyond the permissible limits in areas, which are near to mine area. The overall view of the water quality index of the present study zone showed a good result with most of the area having a WQI of < 50 in. But few areas like Reddipatti, Vinayagampatti and Vellalapatti had a higher WQI value indicating the deteriorate water quality. The analysis of the results drawn at various stages of the work revealed that

- Groundwater from the study area is neutral to alkaline in nature. The abundance of major ions in the groundwater was in the order of Na > Ca > Mg >K = Cl > HCO3 > SO4 > NO3.
- Hydrochemistry of the study area is dominated by alkali and strong acids. As per comparison with WHO and ISI standard, 65% of groundwater in study area is suitable for domestic and drinking purpose with few abnormalities.
- Higher TDS and EC values were observed in northeastern and northwestern part of the study area dominated by agricultural practices and industrial dominance. Higher concentration was noted in postmonsoon season following summer.
- Total hardness shows an increasing trend during postmonsoon and summer seasons. As per the classification of water for domestic and irrigation purposes, water is fit for irrigation purposes with minor exceptions irrespective of seasons.

## REFERENCES

1. APHA (1995). *Standard methods for the examination of water and wastewater* (19th ed.). Washington, DC:American public Health Association. Apodaca, L. E., Jeffrey, B. B., & Michelle, C. S. (2002).
2. Asadi S.S., Padmaja Vuppala and Anji Reddy(2007) Remote sensing and GIS Technique for Evaluation of Ground water Quality in Municipal Corporation of Hydrabad (Zone V ) India, international journal of Environmental research Public Health , 4(I), 45 -52.
3. Antoniou V (2002) Natural and human environment of Athens basin. Paper presented at the 6th Geographical conference of the Hellenic Geographical Society, Thessaloniki, I, 311–318.
4. Cayroll D (1962) Rain water as a chemical agent of geologic process a view USGS Water Supply 1533:18–20.

5. Comly HH (1945) Cyanosis in infants caused by nitrates in well water. J Am Mwd Assoc 129(129):12–144.
6. Davis, S. N., & DeWiest, R. J. (1966). Hydrogeology. New York: Wiley.
7. Freeze, R. A., & Cherry, J. A. (1979). Groundwater. New Jersey: Prentice-Hall.
8. Fetter, C. W. (1990). Applied hydrogeology. New Delhi, India: CBS Publishers & Distributors.
9. Gilly G, Corrao G, Favilli S (1984) concentrations of nitrates in drinking water and incidence of gastric carcinomas. First descriptive study of the Piemonate Region, Italy. Sci Total Environ 34:35–37
10. Handa BK (1975) Geochemistry and genesis of fluoride containing groundwater in India. Groundwater 13(3):275–281
11. Hem, J. D. (1985). *Study and interpretation of the chemical characteristics of natural water* (3rd ed.). U.S. Geological Survey Water-Supply Paper, 2254, 263.
7. Howari, F. M., Abu-Rukah, Y., & Shinaq, R. (2005). Hydrochemical analyses and evaluation of groundwater resources of North Jordan. Water Resources, 32(5), 555–564.
8. Lee, S. M., Min, K. D., Woo, N. C., Kim, Y. J., & Ahn, C. H.(2003). Statistical models for the assessment of nitrate contamination in urban groundwater using GIS. Environmental Geology, 44, 210–221.
9. Numberg, H. W. (1982). Yoltametric trace analysis in ecological chemistry of toxic metals. Pure and Applied Chemistry, 54 (4), 853–878.
10. Obiri, S. (2007). Determination of heavy metals in water from boreholes in Dumasi in the Wassa West District of western region of Republic of Ghana. Environmental Monitoring Assessment, 130, 455–463.
11. Pachero J, Marin L, Cabrera A, Steinich B, Escolero O (2001) Nitrate temporal and spatial atterns in 12 water-supply wells, Yucatan, Mexico. Environ Geol 40:708–715.
12. Ragunath HM (1987) Groundwater, 2nd edn edn. Wiley Eastern Ltd.,New Delhi, p 563.
13. Rajmohan, N., & Elango, L. (2005). Nutrient chemistry of groundwater in an intensively irrigated region of Southern India. Environmental Geology, 47, 820–830.
14. Ramesh, R., Shiv Kumar, K., Eswaramoorthi, S.,& Purvaja, G. R.(1995). Migration and contamination of major and trace elements in ground water of Madras city, India. Environmental Geology, 25, 126–136.
15. Sawyer GN, McMcartly DL, Parkin GF (2003) Chemistry for environmental engineering and science, 5th edn edn. McGraw Hill, New York, p 752.
16. Saleh A, Al-Ruwih F, Shehata M (1999) Hydrogeochemical process operating within the main aquifers of Kuwait. J Arid Environ 42:195–209.
17. Subramani, T., Elango, L., & Damodarasamy, S. R. (2005a). Groundwater quality and its suitability for drinking and agricultural use in Chithar River basin, Tamil Nadu, India. *Journal of Environmental Geology, 47*, 1099–1110. doi:10.1007/s00254-005-1243-0.
18. Srinivasamoorthy K, Chidambaram S, Prasanna MV, Vasanthavihar M, Peter J, Anandhan P (2008) Identification of major sources controlling groundwater chemistry from a hard rock terrain—a case study from Mettur taluk, Salem district, Tamilnadu, India. J Earth Syst Sci 117:49–59
19. Srivastava, A. K.; Sinha, D. K. Water Quality Indexfor river Sai at Rae Bareli for the pre-monsoon periodand after the onset of monsoon. *Indian Journal ofEnvironmental Protection*. **1994**, *14*, 340-345.
20. Subba Rao, N., & John Devada, D. (2003). Fluoride incidence in groundwater in an area of Peninsular India. Environmental Geology, 45, 243–251.
21. Woo, N.-C., Moon, J.-W., Won, J.-S., Hahn, J.-S., Lin, X.-Y., &Zhao,Y.-S. (2000).Water quality and pollution in the HunchunBasin, China. Environmental Geology Health, 22, 1–18.

**List of Tables**

**Table 1: Geomorphic units and their influence on groundwater regime**

| Geomorphic unit / Landform | Description | Influence on ground water regime |
|---|---|---|
| Structural Hills(SH) | Linear to acute hills | Mainly act as runoff zone |
| Residual Hills(RH) | A group of hills occupying comparatively smaller area than composite hills. | Limited prospects along valleys and limited recharge potential to the surrounding plains. |
| Inselberg (I) | An Isolated hill of massive type abruptly rising above surrounding plains. | Mainly act as runoff Zone |
| Valleys(V) | Low lying depressions and negative landforms of varying size and shape associated with stream / nala courses. | Favorable zones for ground water accumulation. |
| Pediment Inselberg Complex (PIC) | Pediment dotted with a number of inselbergs which cannot be separated and mapped as individual units. | Inselbergs form runoff zones. Pediment contributes for limited to moderate recharge |
| PediplainWeathered (PP) – Shallow (PPS) | Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments | Pediplains form good aquifers depending on their composition. In hard rocks, they form very good recharge and storage zones depending upon the thickness of weathering / accumulated material, its composition and recharge conditions. |

**Table 2: Ground water quality of the mine area**

| Sl. No | Sample Station | Ph | Chloride | Alkalinity | Ca | TH | Mg | TDS | F | Nitrate | WQI Values | WQI Rating |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Kullakavandanur($S_1$) | 7.26 | 225 | 377 | 180 | 680 | 55 | 1271 | 0.83 | 62 | 57 | Poor |
| 2 | Tekkampatti($S_2$) | 7.96 | 219 | 450 | 161 | 663 | 62 | 1212 | 0.76 | 64 | 61 | Poor |
| 3 | Karungali ($S_3$) | 7.27 | 25 | 304 | 78 | 302 | 26 | 477 | 0.56 | 4 | 37 | Good |
| 4 | Chinnathirupathi ($S_4$) | 7.5 | 272 | 381 | 132 | 534 | 34 | 1115 | 0.63 | 28 | 46 | Good |
| 5 | Gorimedu ($S_5$) | 7.21 | 177 | 516 | 168 | 670 | 60 | 1152 | 0.71 | 66 | 51 | Poor |
| 6 | Tyagampatti($S_6$) | 7.55 | 128 | 632 | 173 | 670 | 57 | 1270 | 0.6 | 19 | 47 | Good |
| 7 | Reddipatti($S_7$) | 7.37 | 348 | 509 | 247 | 1003 | 72 | 1947 | 0.98 | 62 | 69 | Poor |
| 8 | Kuduvampatti($S_8$) | 7.44 | 305 | 371 | 199 | 564 | 65 | 733 | 0.61 | 29 | 46 | Good |
| 9 | Mannarpalayam($S_9$) | 7.12 | 287 | 516 | 196 | 583 | 59 | 1513 | 0.76 | 13 | 51 | Poor |
| 10 | Sanikavandanur($S_{10}$) | 7.45 | 115 | 371 | 114 | 451 | 40 | 1049 | 0.4 | 24 | 33 | Good |
| 11 | Mungilpad($S_{11}$) | 7.25 | 192 | 550 | 161 | 643 | 58 | 1325 | 0.68 | 16 | 48 | Good |
| 12 | Mettupatti($S_{12}$) | 7.74 | 157 | 605 | 182 | 693 | 57 | 1561 | 0.36 | 31 | 37 | Good |
| 13 | Adikkanur($S_{13}$) | 7.27 | 51 | 258 | 63 | 291 | 31 | 683 | 0.6 | 2 | 39 | Good |
| 14 | Vinayagampatti($S_{14}$) | 7.25 | 35 | 425 | 90 | 340 | 40 | 600 | 1.13 | 21 | 69 | Poor |
| 15 | Chettichavadi($S_{15}$) | 7.92 | 265 | 655 | 75 | 331 | 34 | 1501 | 0.2 | 74 | 31 | Good |

All units except ph and water quality index are in mg/l

**Table 3: Water Quality Parameter ,their ICMR / WHO standards ,and assigned unit weights**

| Parameter | Standard ($S_n$&$S_i$) | Weightage |
|---|---|---|
| Ph | 8.5 | 0.1356 |
| Chloride | 250 | 0.0046 |
| Calcium | 500 | 0.025 |
| Alkalinity | 120 | 0.0096 |
| Nitrates | 50 | 0.0231 |
| Total Hardness | 300 | 0.00385 |
| TDS | 1000 | 0.0012 |
| Magnesium | 30 | 0.061 |
| Fluoride | 1.5 | 0.7714 |

**Table 4: Standards for drinking water**

| Parameter | INDIAN STD 10500 – 1983 | | ICMR | | WHO | |
|---|---|---|---|---|---|---|
| Physical | P | E | P | E | P | E |
| Turbidity | 10 | 25 | 5 | 25 | 5 | 25 |
| Chemical | P | E | P | P | P | E |
| pH | 6.5- 8.5 | 6.5- 9.2 | 7.0- 8.5 | 6.5- 9.2 | 7.0- 8.5 | 6.5- 9.2 |
| Total solids | - | - | - | - | 500 | 1500 |
| Total Hardness | 300 | 600 | 300 | 600 | - | - |
| Calcium | 75 | 200 | 75 | 200 | 75 | 200 |
| Magnesium | 30 | 100 | 50 | 150 | 50 | 150 |
| Iron | 0.3 | 1.0 | 0.3 | 1.0 | 0.3 | 1.0 |
| Manganese | 0.1 | 0.5 | 0.1 | 0.5 | 0.1 | 0.5 |
| Chlorides | 250 | 1000 | 250 | 1000 | 200 | 600 |
| Sulphates | 150 | 400 | 200 | 400 | 200 | 400 |
| Nitrates | 45 | - | 20 | 50 | - | 50-100 |
| Na + K | - | - | - | - | 200 | - |
| Fluoride | 0.6 – 1.2 | - | 1.0 | 2.0 | 0.5 | 1.0- 1.5 |

P= PERMISSIBLE LIMIT E = EXCESSIVE LIMIT

NOTE : all the units are in mg / lit except pH

**Table 5: Ground Water Classification based on TDS**

| Sl.No | TDS (mg/l) | Nature of water |
|---|---|---|

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| | | |
|---|---|---|
| 1. | <1000 | Fresh water |
| 2. | 1000- 10,000 | Brakish water |
| 3. | 10,000- 1,00,000 | Saline water |
| 4. | >1,00,000 | Brine water |

**Table 6: Water Quality Index Categories**

| Water Quality Index | Description |
|---|---|
| 0 – 25 | Excellent |
| 26 – 50 | Good |
| 51- 75 | Poor |
| 76 – 100 | Very Poor |
| >100 | Unfit for drinking |

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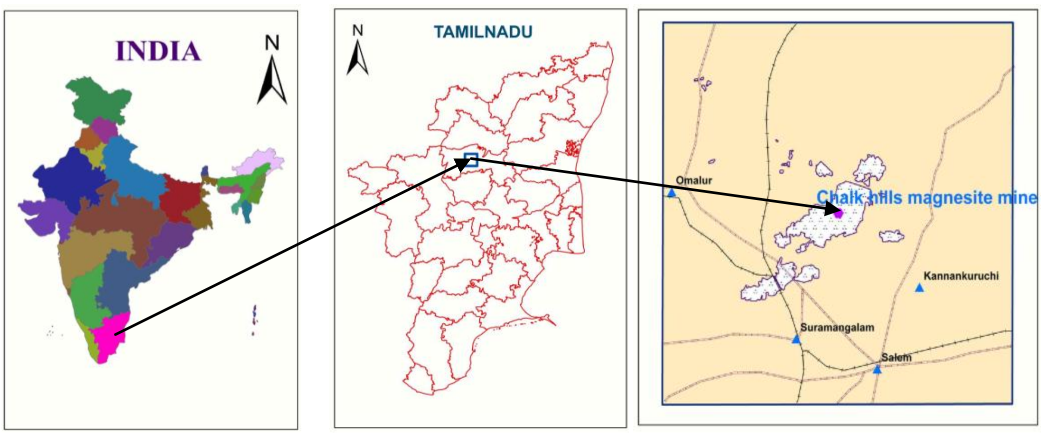
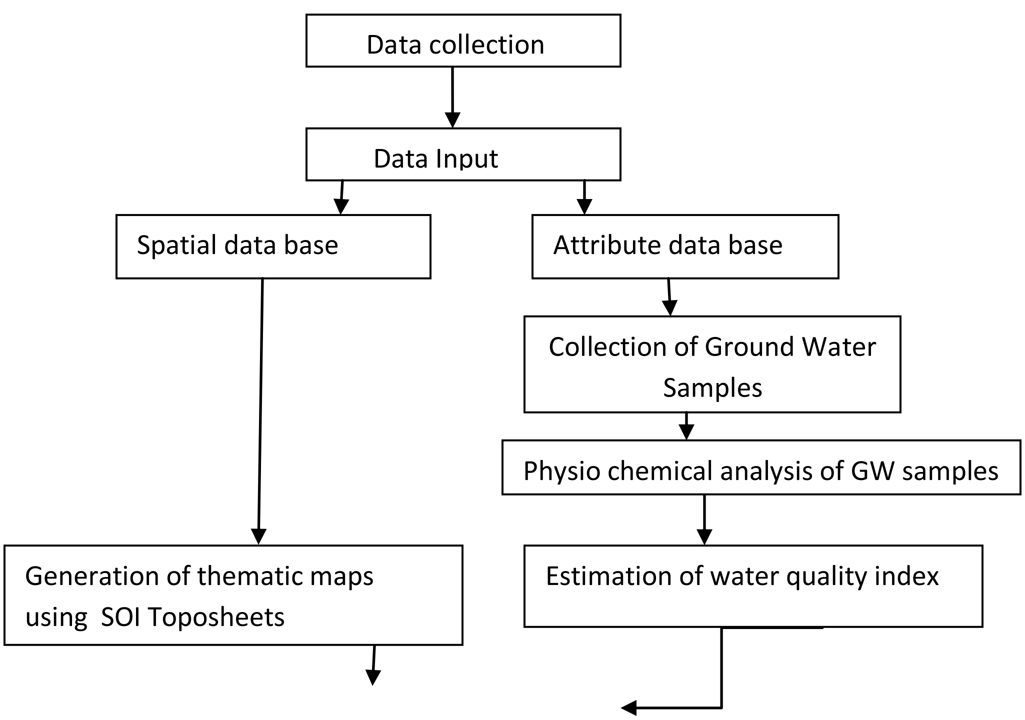



**Fig .1 Location map of the study area**

**Fig .2 Satellite Image of study area**



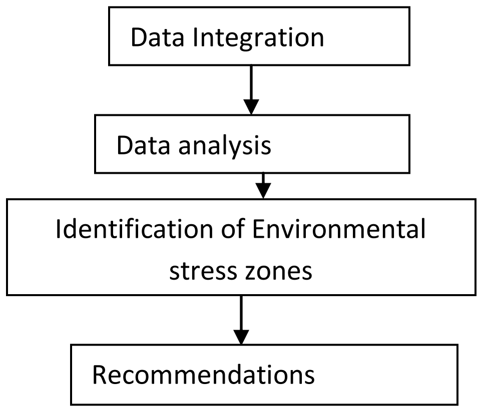



**Figure 3 :Flow chart showing the methodology**

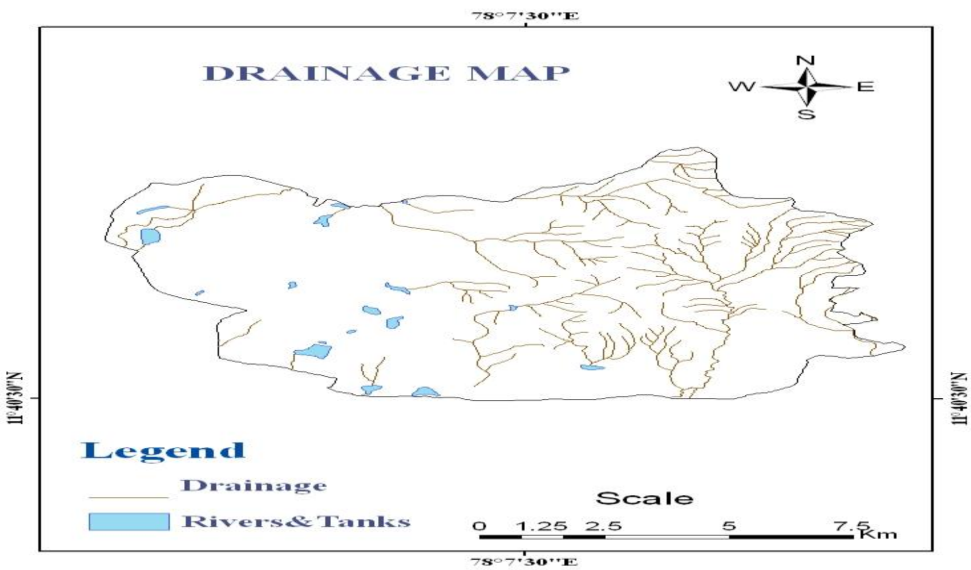



**Figure 4 : Drainage map of the study area**

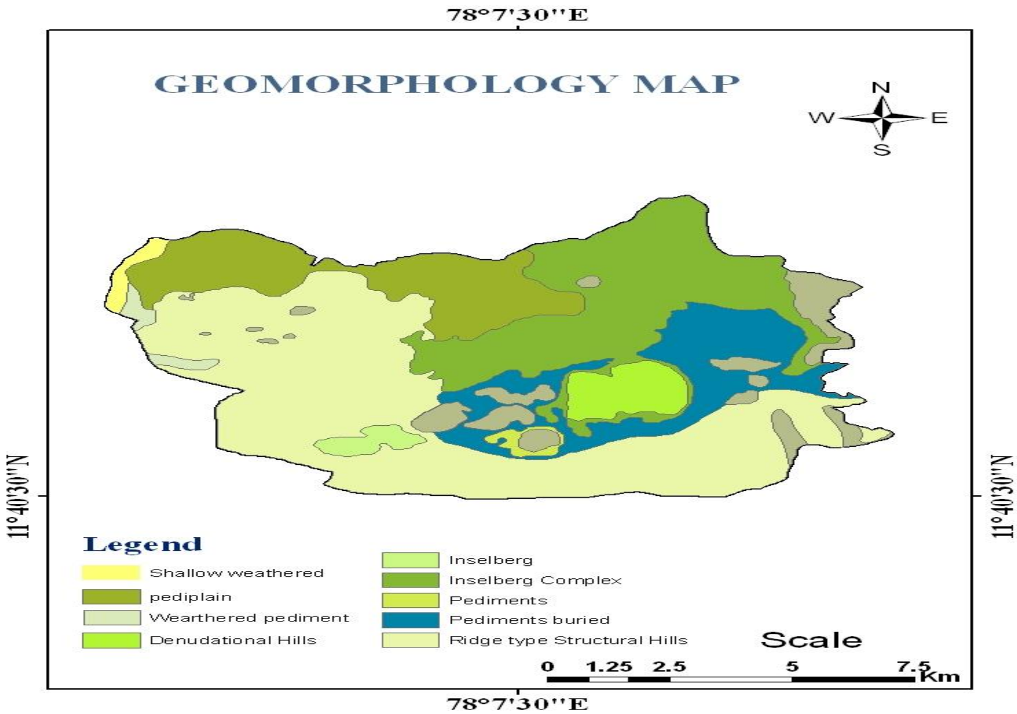



**Figure 5 : Geomorphology map of the study area**

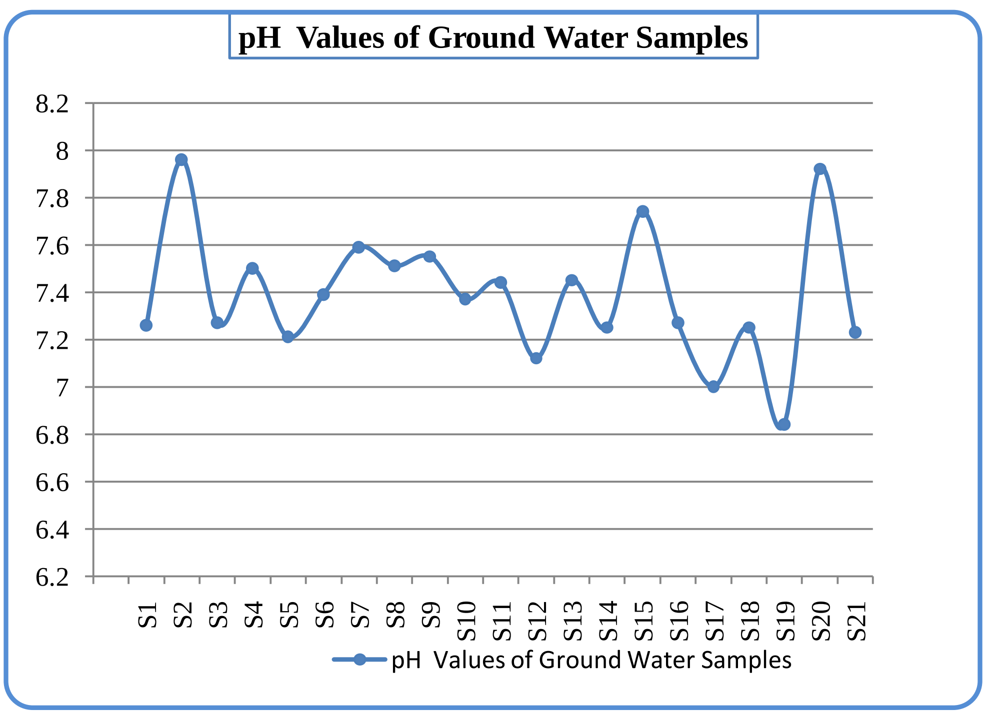



**Figure 6 : pH Values of Ground Water Samples**

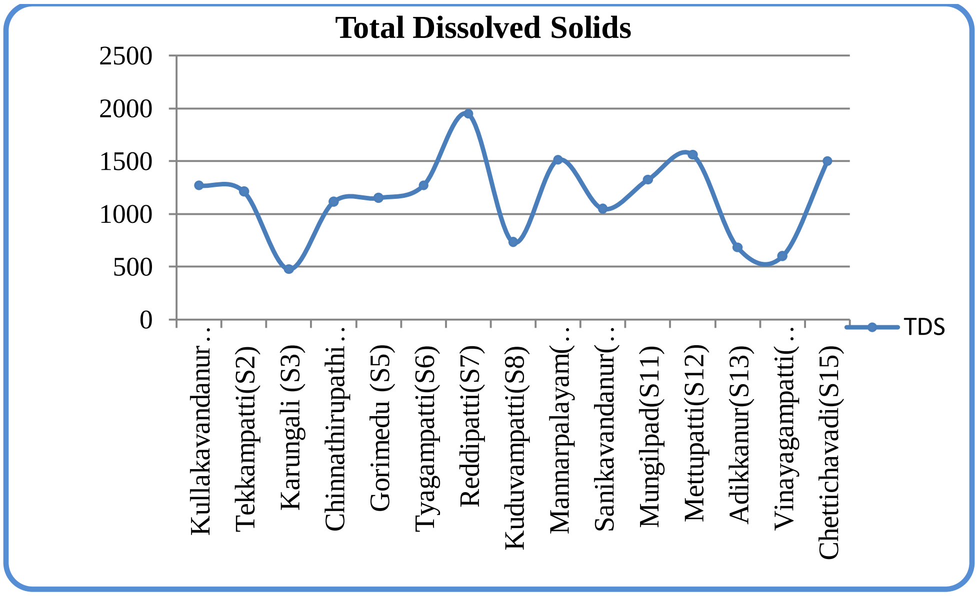



**Figure 7 : TDS Values of Ground Water Samples**

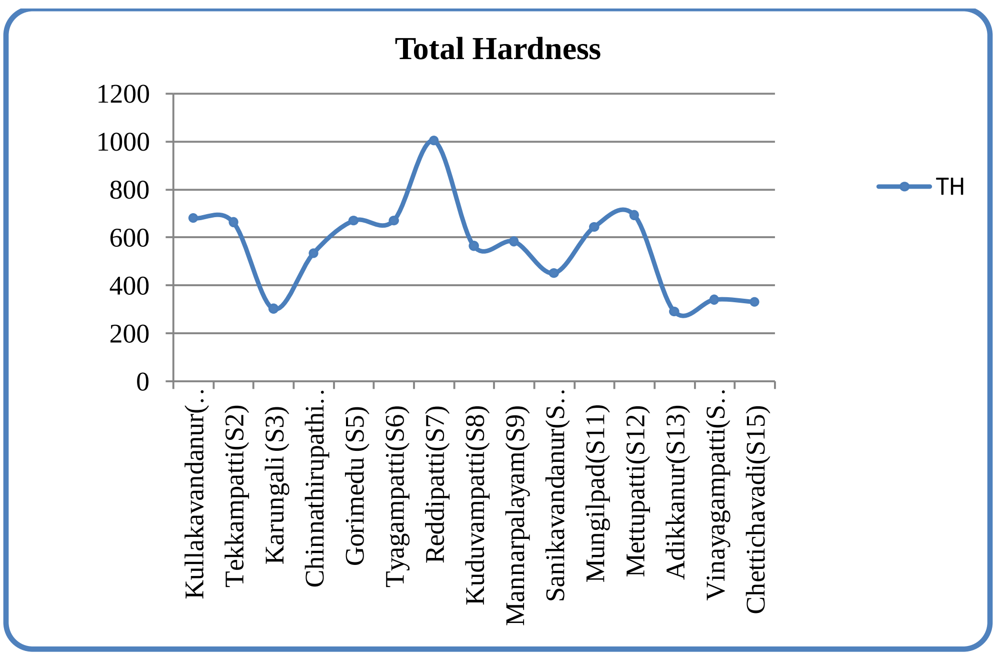



**Figure 8 : Total Hardness Values of Ground Water Samples**

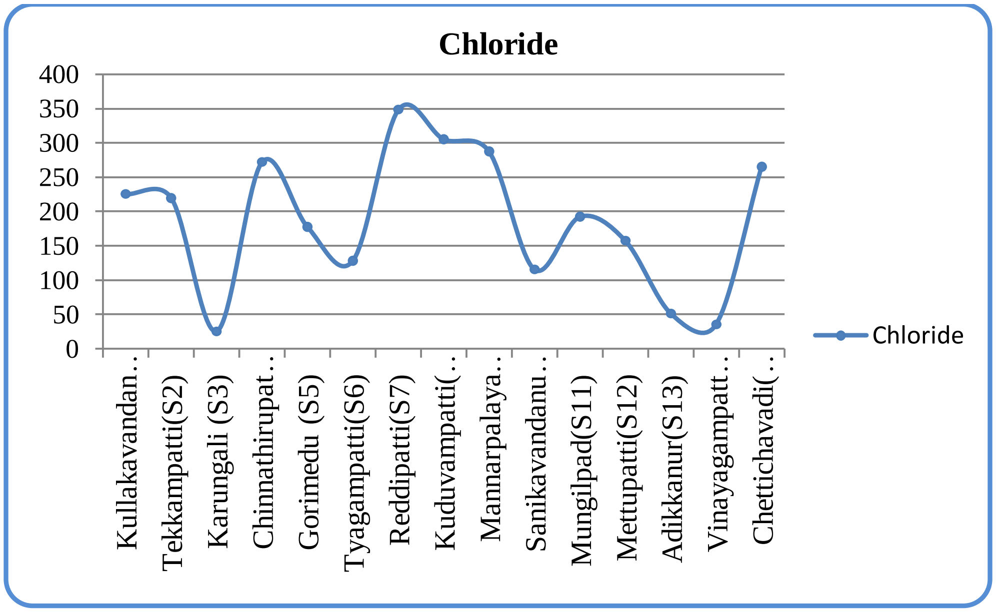



**Figure 9 : Chloride Values of Ground Water Samples**

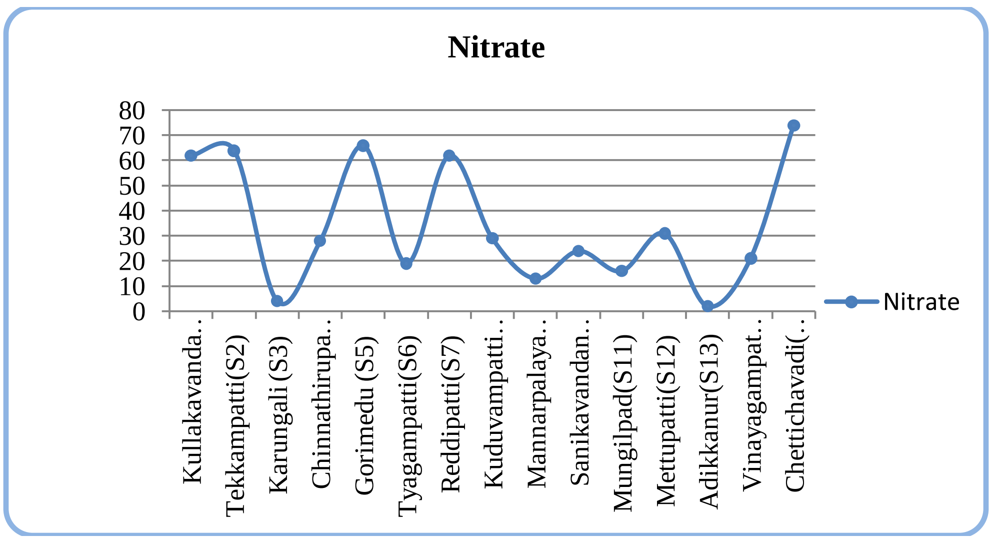



**Figure 10 : Nitrate Values of Ground Water Samples**

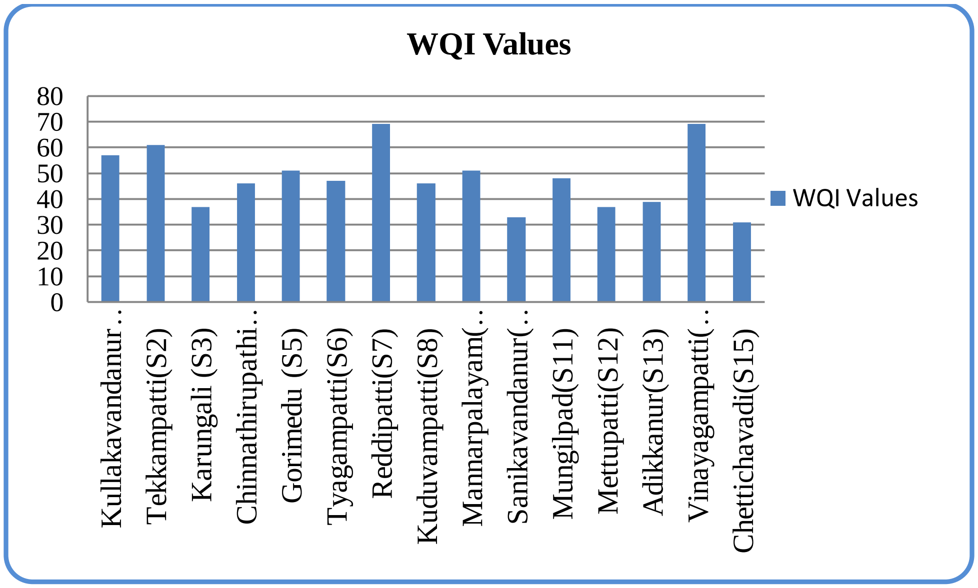



**Figure 11 : WQI Values of Ground Water Samples**