Spatial analysis of groundwater quality in Varahanadi Watershed, Tamil Nadu, using GIS techniques.

Geology

* Ramamoorthy.P	Department of Geology, University of Madras,Chennai-600025. *Corresponding author
Rammohan.V	Department of Geology, University of Madras,Chennai-600025.
Subramani.T	Department of Geology, Anna University, Chennai-600025.

ABSTRACT   *The present study involves the groundwater quality analysis of Varahanadi watershed to assess their suitability for domestic, drinking and irrigation purposes. Fifty nine ground water samples were collected during pre-monsoon and post-monsoon seasons and analyzed for various water quality parameters. Groundwater samples were collected from both bore well and open well to monitor the hydrochemistry of various ions. The quality of ground water in the study area is almost fresh water, hard to very hard category and slightly acidic to slightly alkaline nature. It was observed that the bed rock of the study area has influenced the groundwater quality resulting in higher concentrations of Ca2+, Mg2+, Na+, SO42-, Cl-, HCO3- and NO3- in the study area.*

Introduction:

Rapid growth of population, extension of irrigation and increasing tendency of industrialization have contributed towards rising demand for groundwater in the Varahanadi watershed, Variation of groundwater quality in an area is a function of physical and chemical parameters that are greatly influenced by geological formations and human activities. The study area covers an area of about 512 square Kilometers (Fig.1). Physiographically the area is a plain terrain with small elevated uplands. GIS is an effective tool for storing large volumes of data that can be correlated spatially and retrived for the spatial analysis and integration to produce the desirable output(Shankar.K et al 2010).GIS tool is widely used for assessment of water quality and developing solutions for water resources related problems(Chaudhary et al.1996).
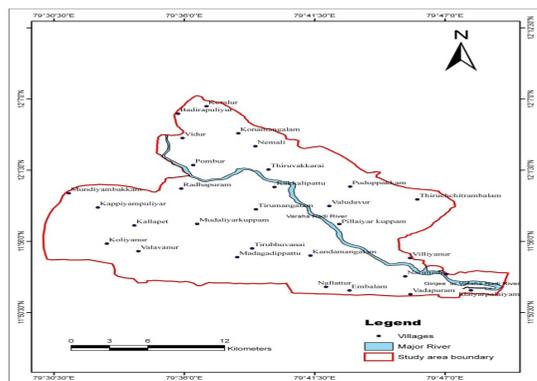

Figure: 1 Location map of the study area

Geological setting:

The study area is categorized by different geological formations, reflecting the various geological eras. It is enclosed by the hard crystalline rock masses of Precambrian age and sedimentary rocks of upper Gondwana, Cretaceous, Tertiary and Quaternary age.

Data used and Methodology:

Survey of India (SOI) topographic maps (No.57P/12, 57 P/16, 58 M/9, 58 M/13 of scale 1:50,000) were used for preparation of the base map. Fifty nine groundwater samples were collected in the study area during December 2011, and June 2012. The samples have been collected from bore well and open well. Before collection from the bore well, the water was left to run for 5 min to get a representative sample. The samples were analyzed using standard analytical methods (American Public Health Association 1985; Brown et al. 1973) for major ions (i.e.,Ca^{2+}, Mg^{2+}, Na^+, CO_3^{2-}, HCO_3^-,SO_4^{2-},Cl^-,NO_3^- EC, total dissolved solids (TDS), pH). In order to study the quality of water, the obtained chemical data was evaluated in terms of its suitability for domestic and irrigation purposes. The results were evaluated in accordance with the drinking water quality standards given by the World Health Organization (WHO) (Table.1). Followed by water quality analysis, thematic maps were generated using GIS software.

Geographical Information system:

The GIS is a system of collecting, storing, analyzing and disseminating information about areas of earth. Geocoded spatial data objects that have an orientation and relationship in two or three dimensional space. The object is classified as a point, line or a polygon and is tied to a geographic coordinate system.

Spatial analysis with GIS:

This includes preparation of spatial distribution map of groundwater quality parameters .The groundwater samples collected from Open wells and Bore wells were located in the physical environment using global positioning system (GPS) and transferred on GIS environment (ArcGIS 9.3). The following thematic maps are prepared in the GIS environment. Electrical conductivity (EC), Total hardness(TH),pH, total dissolved solids (TDS), Ca^{2+}, Mg^{2+}, Na^+, Cl^-, NO_3^-, HCO_3^- and SO_4^{2-}.

Table:1 Shows No.of samples in the study area exceeding the permissible limits prescribed by WHO for drinking purposes

Parameters	WHO international standard (1971,1983)	No.of samples exceeding permissible limits		
	Most desirable limits	Maximum allowable limits	Post-monsoon	Pre-monsoon
pH	7- 8.5	9.2	Nil	Nil
TDS(mg/l)	500	1500	2	2
EC(μS/cm)	1000	1500	20	18
TH(mg/l)	100	500	9	3
Na(mg/l)	-	200	9	19
Ca(mg/l)	75	200	1	Nil
Mg(mg/l)	50	150	1	Nil
Cl(mg/l)	200	600	3	3
SO_4	200	400	Nil	Nil
NO_3	45	-	17	12
F(mg/l)	-	1.5	Nil	2

Results and Discussion:
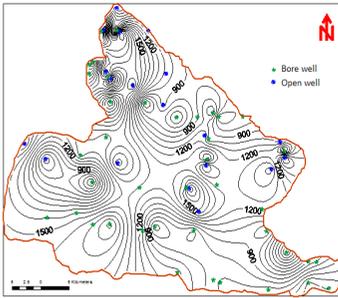
Electrical conductivity (EC)
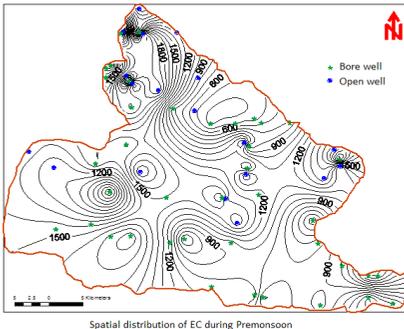
Fig:2 Spatial distribution of EC (Post-monsoon)

Fig:3 Spatial distribution of EC (Pre-monsoon)

In the study area the electrical conductivity (EC) values range from 330 to 3380 μS/cm and 310 to 3280 during post-monsoon and pre-monsoon respectively. Almost 30% of ground water samples fall within the maximum allowable limits as per WHO (1971,1983).The large variation in EC is mainly caused by anthropogenic activities and subsurface geochemical processes. The highest value of EC(3380 & 3280 μS/cm) is observed in Badirapuliyur and Siruvai where groundwater is unfit for irrigation.

pH:
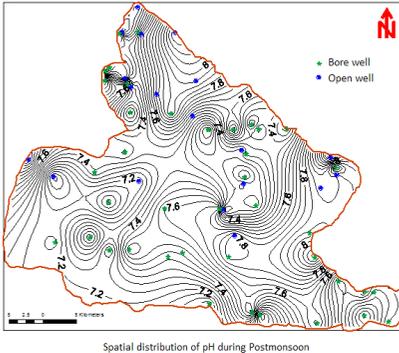
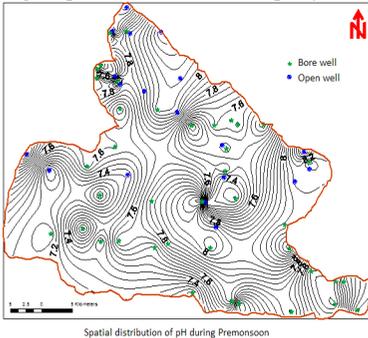**Fig:4 Spatial distribution of pH (Post-monsoon)**

Fig:5 Spatial distribution of pH (Pre-monsoon)

The pH values of groundwater in the study area fall in the ranges

from 6.96 to . It indicates an slightly acidic to slightly alkaline nature. The pH values of groundwater samples are within the maximum allowable limits. pH value range between 6 to 10 will not be a problem for domestic and industrial purposes.

TH:

The TH as CaCO3 ranges from 74.9 to 739.6 mg/l and 84.9 to 939 mg/l during pre-monsoon and post-monsoon respectively. The majority of groundwater samples fall in hard to very hard water category. Nine samples of Post-monsoon and 3 samples of pre-monsoon season exceed the maximum allowable limit.
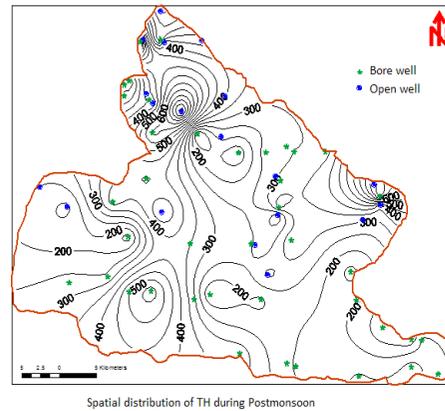

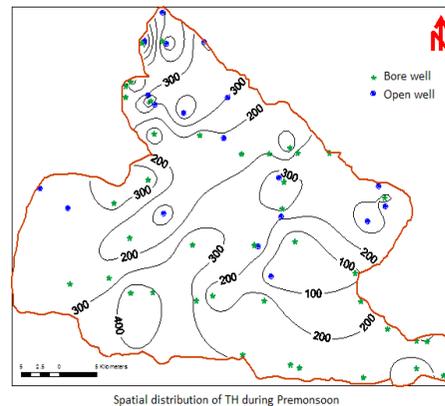**Fig:6 Spatial distribution of TH (Post-monsoon)**

Fig:7 Spatial distribution of TH (Pre-monsoon)

The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per WHO international standard. TH of the groundwater was calculated using the formula given below (Sawyer et al.2003).

TH (as CaCO3)mg/l = ($Ca^{2+}+Mg^{2+}$)meq/l x 50

TDS:

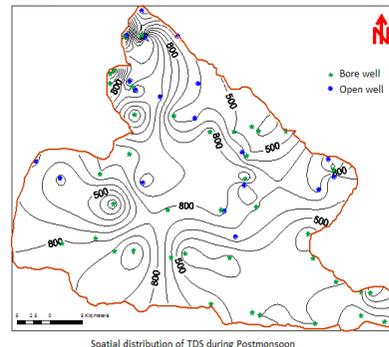**Fig:8 Spatial distribution of TDS (Post-monsoon)**
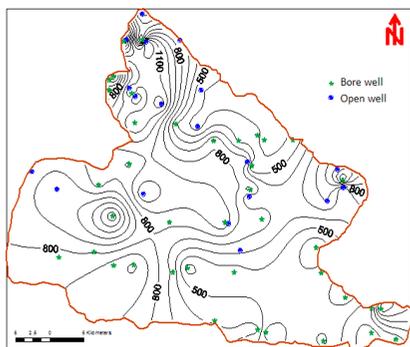
Spatial distribution of TDS during Premonsoon

Fig:9 Spatial distribution of TDS (Pre-monsoon)

To determine the fitness of groundwater of any purposes, it is necessary to classify the groundwater depending upon their hydrochemical properties based on their TDS values (Davis and Dewiest 1966; Freeze and Cherry 1979). 81.3 % of samples from Post-monsoon and 79.6 % of samples from Pre-monsoon belongs to fresh water category. The highest concentration of TDS is identified at Badirapuliyur.The study area shows that only 32.2% & 37.2% samples of Pre-monsoon and Post-monsoon is below 500 mg/l of TDS which can be used for drinking without any risk.

Calcium:

Calcium ion concentration groundwater samples of post-monsoon season is highest at Thiruchitrambalam and lowest at Korakkeni, Rajaputrapalayam, Sengameddu,Alapakkam areas. Calcium concentration ranges from 14 to 208 mg/l and 14 to 108 mg/l during Post-monsoon and pre-monsoon respectively. High concentrations for Ca^{2+} (208 mg/l) were observed at Thiruchitrambalam location.The major source of Ca^{2+} in this area is due to ion exchange of minerals from the rocks (Ramesh K, & Elango L., 2011).
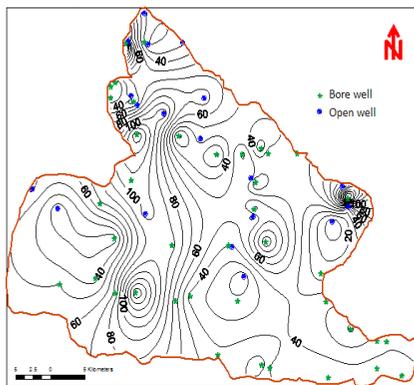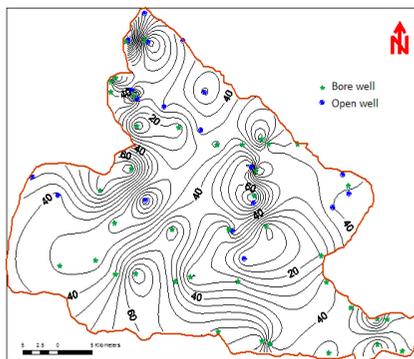

Spatial distribution of Calcium during Post monsoon

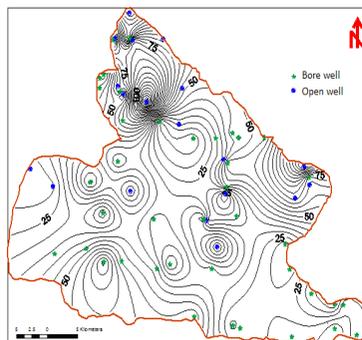**Fig:10 Spatial distribution of Calcium(Post-monsoon)**

Spatial distribution of Calcium during Premonsoon

Fig:11 Spatial distribution of Calcium(Pre-monsoon)
Magnesium:

Spatial distribution of Magnesium during Postmonsoon

Fig:12 SpatialdistributionofMagnesium(Post-monsoon)
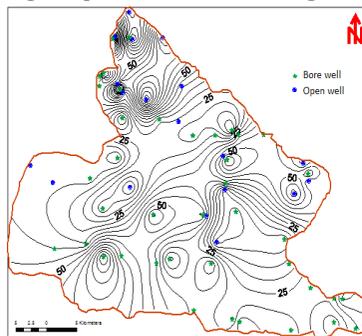

Spatial distribution of Magnesium during Premonsoon

Fig:13Spatialdistribution of Magnesium(Pre-monsoon)

Magnesium concentration in groundwater samples varies from 9.7 to 155.7 mg/l during post-monsoon and 6.1 to 126.5 mg/l during pre-monsoon. Maximum concentration of Magnesium was observed in Poonampundi during Post-monsoon. Maximum was observed in Badirapuliyur during pre-monsoon. The concentration of Mg 2+ in the groundwater is due to the exchange of minerals in soil and rock by water(Ramesh K & Gowri V.S 2012).
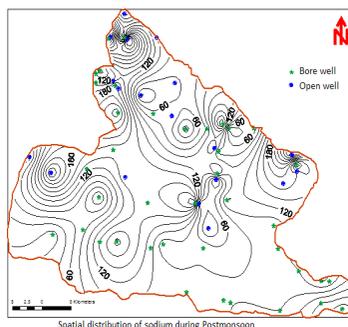
Sodium:

Spatial distribution of sodium during Postmonsoon

Fig:14 Spatial distribution of Sodium(Post-monsoon)

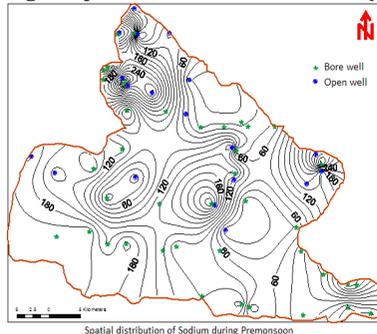Spatial distribution of Sodium during Premonsoon

Fig:15 Spatial distribution of Sodium(Pre-monsoon)

The possible source of sodium might be from deep percolating water from the top soil layers due to atmospheric precipitation that has been subjected to such concentration effects (Herman and Bower,1978).Maximum concentration of sodium is observed at Siruvai(441.8 mg/l) and Irumbai (347.3 mg/l)during Pre-monsoon and post-monsoon .Seventeen samples of pre-monsoon and 9 samples of post-monsoon exceeds the Permissible limit as per WHO (1971,1983)

Sulphate:
Source of sulphate is sulphur minerals and sulphides of heavy metals,which are of common in igneous and metamorphic rocks(Shankar et al 2010). In the study are sulpahtes are found to be within the maximum allowable limit for drinking purposes as per WHO. It ranges from 0.9 to 244.8 mg/l during post-monsoon and 2 to 242 mg/l during pre-monsoon. 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 (Subramani.T et al 2005).
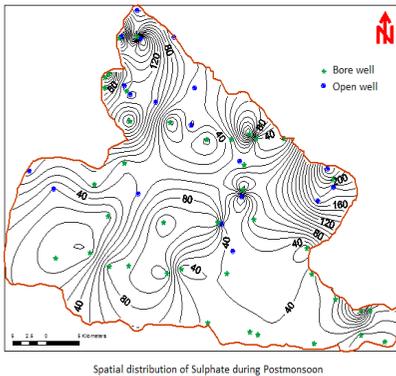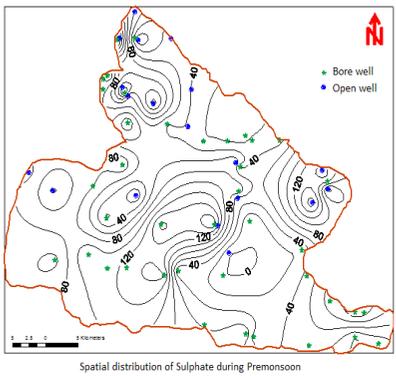

Spatial distribution of Sulphate during Postmonsoon

Fig:16 Spatial distribution of Sulphate (Post-monsoon)

Spatial distribution of Sulphate during Premonsoon

Fig:17 Spatial distribution of Sulphate (Pre-monsoon)

Chloride:

Spatial distribution of Chlorine during Postmonsoon

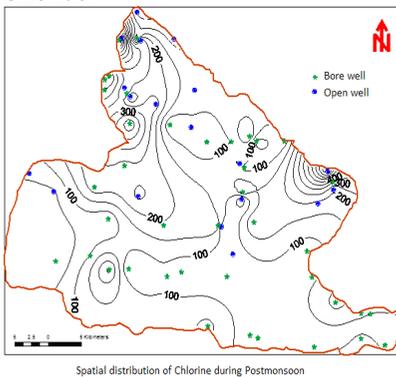**Fig:18 Spatial distribution of Chloride (Post-monsoon)**

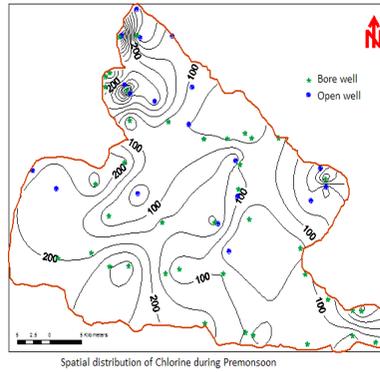Spatial distribution of Chlorine during Premonsoon

Fig:19 Spatial distribution of Chloride (Pre-monsoon)

The concentration of chloride ranges from 28.4 to 694.8 mg/l during pre-monsoon and 5.5 to 765.7 mg/l during post-monsoon. The main source of chloride in the groundwater is result of erosion and weathering of crystalline rocks and minerals such as Sodalite, apatite, micas and hornblende in the rock matrix(Sujatha .D & Rajeswara reddy.B.2003).The chloride concentration in the groundwater of the study area exceeds the maximum allowable limit of 600 mg/l in the Badirapuliyur,Siruvai and Irumbai.
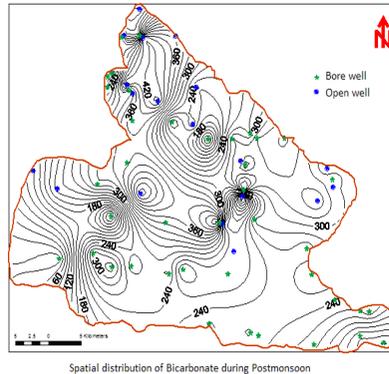
Bicarbonate:

Spatial distribution of Bicarbonate during Postmonsoon

Fig: 20 Spatial distributionofBicarbonate (Post-monsoon)

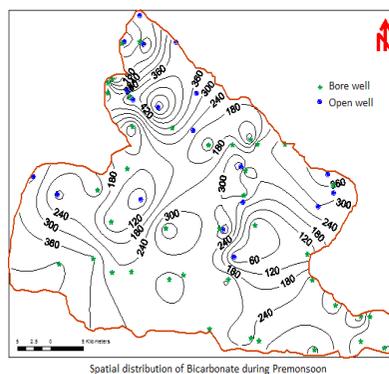Spatial distribution of Bicarbonate during Premonsoon

Fig:21 Spatial distribution of Bicarbonate (Pre-monsoon)

The main source of bicarbonates in the groundwater is the dissolved CO_2 in rain water when enters the soil dissolves more Carbon-di-oxide. Decay of organic matter and SO_4 reducing bacteria may also release CO_2 for dissolution. Water charged with CO_2 dissolve carbonate minerals When passing through soil and rocks to give bicarbonates(Shankar et al 2010). Water with a high concentration of bicarbonates, if used for sprinkler irrigation,may cause white deposits on fruits and leaves,which is undesirable(subrahmanyam and Yadaiah 2001).The concentration of Bicarnbonate ranges from 61 to 659 mg/l and 36.60

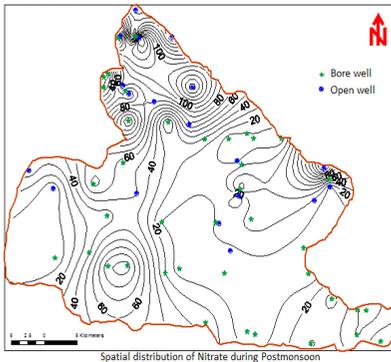to 481.90 mg/l during Pre-monsoon and Post-monsoon.

Nitrate:

Spatial distribution of Nitrate during Postmonsoon

Fig: 22 Spatial distribution of Nitrate (Post-monsoon)

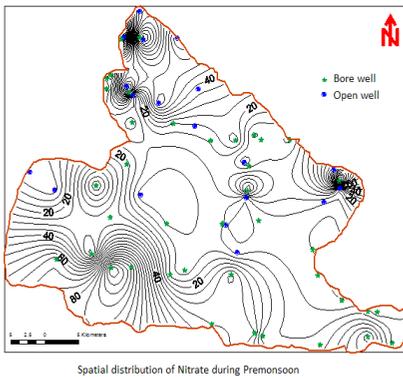Spatial distribution of Nitrate during Premonsoon

Fig: 23 Spatial distribution of Nitrate (Pre-monsoon)

The Nitrate concentration of study area varies from 0.2 to 143.8 mg/l during pre-monsoon and 0.6 to 170.5 mg/l during post-monsoon.The high concentration of nitrate is attributed to decaying organic matter,sewage wastes, and increased usage of fertilizers (Karanth 1989).The high concentration of nitrate in drinking water is toxic and causes blue baby disease/meth-aemoglobinaemia in children and gastric carcinomas (Comly 1945:Gilly et al.1984).Seventeen groundwater samples of post-monsoon and 12 samples of pre-monsoon exceed the permissible limits.

Conclusion:

The quality of groundwater in the study area is almost fresh water, hard to very hard category and slightly acidic to slightly alkaline nature. The geological formations have a great influence on the groundwater quality in the study area. The increase in concentration of ions in groundwater is due to evaporation, irrigation return flow, rock water interactions and intensive agricultural activities in most part of the study area. The concentrations of major ions in ground water are within the permissible limits for drinking except at some places. Most of the samples in the study area are apt for irrigation purpose except in Badirapuliyur and siruvai. The most serious pollution threat to groundwater is from nitrate concentration. About 32% of samples beyond the permisible limits by WHO for drinking prupose. Hence special care needs to be given to observe the interaction between geological formations and ground water in the study area.

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