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Evaluation of groundwater quality in and around Ariyalur of Tamilnadu using Geographical Information System

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Abstract: *A study has been carried out in Ariyalur region of Tamilnadu for premonsoon to assess the quality of groundwater using geographical information techniques. A total of 71 groundwater samples were collected and pH, TDS, EC were measured in the field. Samples were also measured for major ions (Ca, Mg, Na, K, HCO_3, Cl, SO_4, NO_3) using standard techniques. The ground water quality information maps of the entire study area have been prepared using GIS spatial interpolation technique for all the above parameters. The results obtained in this study and the spatial database established in GIS will be helpful for monitoring and managing ground water pollution in the study area.*

I. Introduction

Groundwater is used for agricultural, industrial, drinking purposes throughout the world. In the past few decades, the increase in demand for fresh water due to overexploitation and also rapid growth of population. There are significant amount of studies conducted to determine potential sites for groundwater exploration in diverse geological using remote sensing and GIS techniques (Kamaraju 1997; Srivastava et al. 1997; Srivastava and Battacharya 2000). The knowledge of the occurrence, replenishment and recovery of potable groundwater assumes special significance in quality-deteriorated regions, because of scarce presence of surface water. (Todd 1980).Geographic information system (GIS) is an efficient and useful tool in solving, where spatial data are significant. The widely used application is for assessment of quality and developing solution for water resources related problems (Chaudhary et al. 1996), stretching hydrological systems both natural and man-made to limits within the country. The anthropogenic quality deteriorations take place due to mismanagement of solid and liquid wastes as a result of rapid growth in population, industrial, domestic, municipal and mining activities of a particular place and agricultural activities stretching of hydrological system sendurai and Ariyalur block which is located in the extreme of the Ariyalur region (Devaraj et al 2016). The present study aims to determine the groundwater quality using geographical information techniques.

Geological Setting

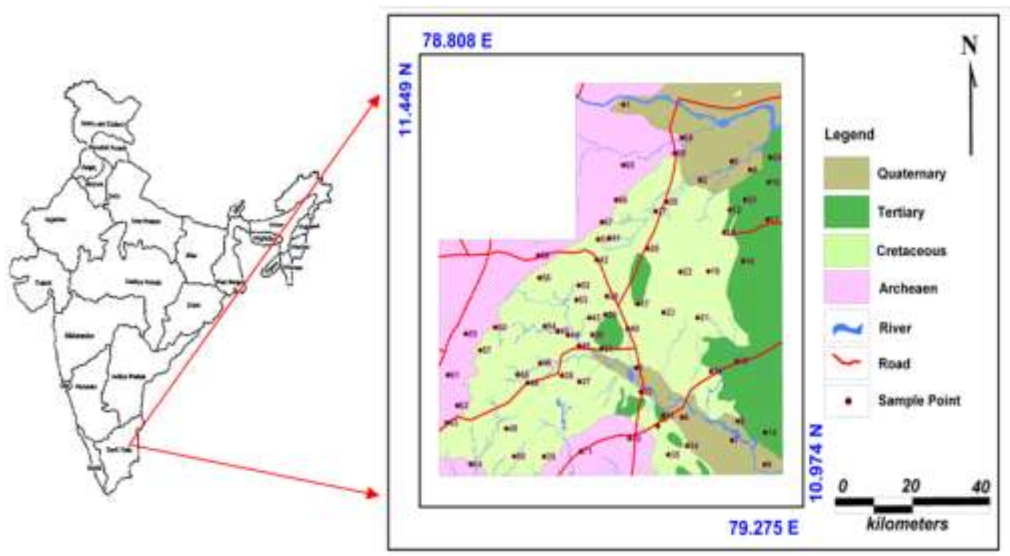

Fig 1: Sample location and Geology map of the study area

The Ariyalur group is more widely exposed than the other two groups. Sastry et al. (1972) divided the Ariyalur group into four formations, namely Sillakkudi, Allankurichchi, Ottakkovil and Kallamedu in upward succession. The Ariyalur Group unconformably rests over the Trichinopoly Group (Table 1) developed by extension during the Mesozoic breakup of the Gondwana land (Prabhakar and Zutshi, 1993; Blankford (1862). The study area fall in a part of Ariyalur region, Ariyalur district in Tamilnadu South India (Fig 1) which lies between the latitudes North 11˚449' & 10 ˚974' East longitudes 78˚808' & 79˚275'. The study area covers about 1.774 sq. km. The predominant soil is red loam and black soil. The average annual normal rainfall of the state is about the 966.90 mm. The temperature of the study area ranges from 21° C in the month of January to 40°C in the month of June. The mean elevation of the area is 50 AMSL. In the north and west part, river Vellar and Marudaiyar flows in the study area which consists of hills and finally joins in the Bay of Bengal. The topography is mostly plain area, while western limestone bearing area is undulating in nature.

Table 1.Lithostatigraphy of Ariyalur Group (Modified after Sastry et al. 1972)

Group	Formation	Lithology	Age
	Niniyur		Danian
ARIYALUR	Kallamedu	Unfossiliferous fine to coarse grained sandstones interbedded with siltstone, sandy clay, ferruginous clay and marl	Maastrichtian
	Ottakovil	Fossiliferous calcareous sandstone interbedded with sandy clay	
	Kallankurichchi	Fossiliferous calcareous conglomeratic sandstone interbedded with sandy clay, sandy fossiliferous limesone, fossiliferous limestone and marl	
	Sillakkudi	Unfossiliferous calcareous sandstone, Fossiliferous calcareous gritty sandstone, Fossiliferous calcareous and stones interbedded with sandy clay and thin band of sandy limestone	Campanian
Trichinopoly			Late Turonian to santonian

II. Methodology

Groundwater samples were collected during the year 2013 in (August) from the bore wells which were almost uniformly distributed over the study area. A total of 71 groundwater samples were collected in the study area representing the entire district (Fig 1). Sampling and analysis were carried out using standard procedures (Ramesh and Anbu 1996; APHA 1995). Five hundred milliliters of water samples were collected in polyethylene bottle. Then, it was sealed and brought to the laboratory for analysis, stored properly (4°C), and filtered with 0.45µm filter paper before analysis. pH and electrical conductivity (EC) were determined in the field using Field Analysis Kit (Eutech Handheld Instruments). The collected groundwater samples were analyzed for major cations and anions. Calcium, magnesium, bicarbonate and chloride were determined by titrimetric method. Sodium and potassium were analyzed through flame photometry (ELICO CL 378). The range of flame photometry is 1–100 ppm with an accuracy of ±1 digit. Silica, phosphate, and sulfate were determined by spectrophotometry (ELICO SL 171 minispec). The range of spectrophotometry is 340–1,000 nm with an accuracy of ±2.5 nm. The reliability of the results was determined by the ionic balance of groundwater samples and a 5–10 % of percentage error was noted.

III. Results and discussion

The results of maximum, minimum, and average values of groundwater chemical constituents are given in Table 2. The relative abundance of cations in the groundwater is in the order Ca^{2+} >Na^+> Mg^{2+}> K^+ and that of anions is HCO^-_3 >Cl^- > NO_3^-> SO_4^{2-} (Table 2).

Table: 2 Maximum, Minimum and Average of the chemical constituents in groundwater samples (All values in mgl^{-1} Except EC in µs/cm and pH.)

Parameter	Minimum	Maximum	Average	WHO (2004)
Ca^{2+}	14	380	113	100
Mg^{2+}	9.6	139.2	55.9	50
Na^+	11	346.7	72.3	200

K^+	0.2	68.5	9.05	20
Cl^-	30.45	868.5	208.88	250
HCO_3^-	130.6	1134.6	494.469	125-350
SO_4^{2-}	0.3	10.97	2.59	250
NO_3^-	-5.96	120.2	18.767	50
PH	6.42	7.81	7.06	6.5-8.5
EC	440	14430	2657.099	1400
TDS	248	5983	1166.69	500-1000

pH

pH is a measure of the hydrogen ion (H+) availability (activity). The hydrogen ion is very small and it is able to enter and disrupt mineral structures so that they contribute dissolved constituents to groundwater. pH of the water is an indicator of its quality and geochemical equilibrium for solubility calculation (Hem 1985). The spatial variation map in the study area shows that North West region which is less than 7 (Fig. 2) and that of above 7 it is noted in southern and western part indicating the pH values are in safe which is suitable for drinking water.

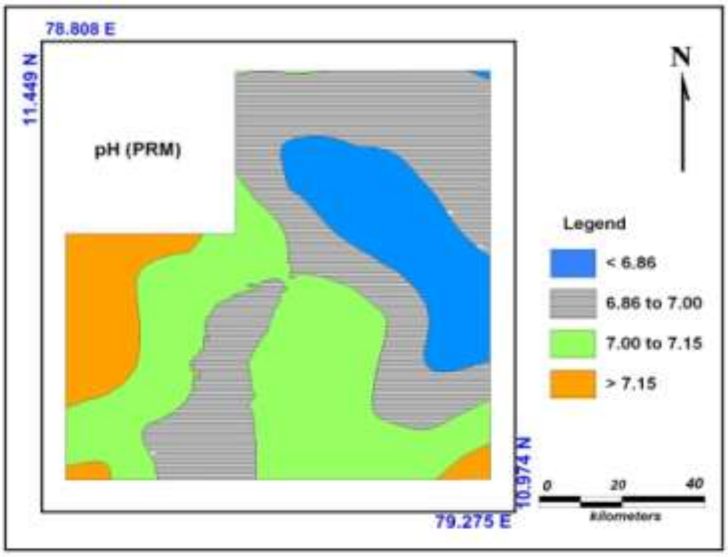

Fig. 2 Spatial distribution of pH according to WHO standard (2004)

Electrical Conductivity

The Electrical conductivity (EC) is a measure of the total salt content of water based on the flow of electrical current through the sample. In the study area EC varies between 440 -14430 µs/cm with an average of 2657 µs/cm, Groundwater below 1400 µs/cm is portable for drinking purpose (WHO 2004) (Table 2). Higher concentration of EC is observed in (2694 mg/l) North West direction around downstream of vellar river and along cement industries where the lower concentration is observed in the north east to south east region (Devaraj et al. 2016) (Fig. 3).

Total Dissolved Solids

Total dissolved solids (TDS) are defined as the quality of dissolved material in water, and mainly depend on the solubility of rocks and soils contact in water (Prasanna et al. 2010). TDS varied from 248 to 5983 mg/l (Table 1).The groundwater can be classified as non-saline (TDS =<1000 mg/l) to slightly saline (TDS with 1000 to 3000 mg/l) (Freeze and Cherry, 1979). From the spatial variation map it was observed that high concentration is noted in north west direction (Fig. 3) indicating the dissolution of rock in ion particle mixed with fresh water, dissolution or weathering of the rock and solids and dissolving nature of limestone, gypsum and other salts, when the source water passed over or percolates through them (Chebotarev, 1985 and Taghizadeh Mehrjardi et al. 2008)

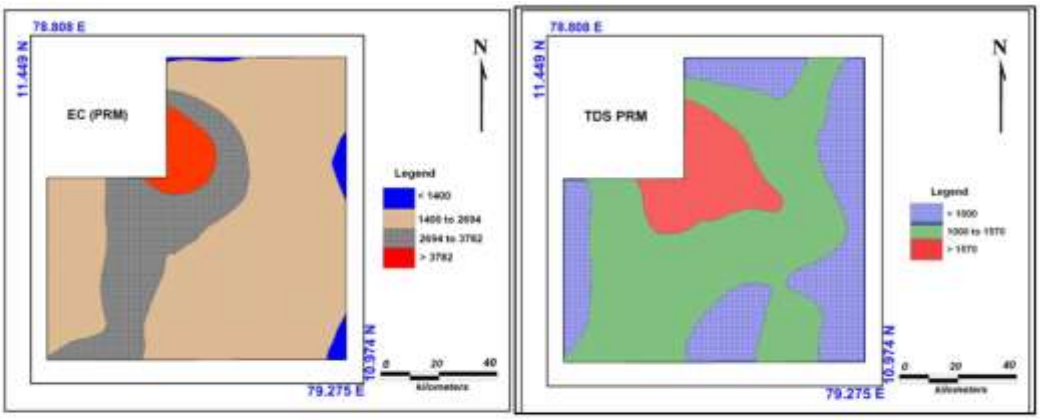

Fig 3: Spatial distribution of EC and TDS of the study area

Calcium

The Calcium ions present in ground water is particularly derived from leaching of limestone, dolomites, gypsum and anhydrites whereas the calcium ion is also derived from Cation exchange process (Garrels, 1976). Generally Calcium is found more in Terrestrial water than in saline waters. Source of calcium in the study area is from the sedimentary rock (Herman Bower, 1978).The study area almost less than 100 ppm is classified an good region which is suitable for drinking water. Ca above 100 ppm is observed in parts of northern and southern regions (Fig.4).

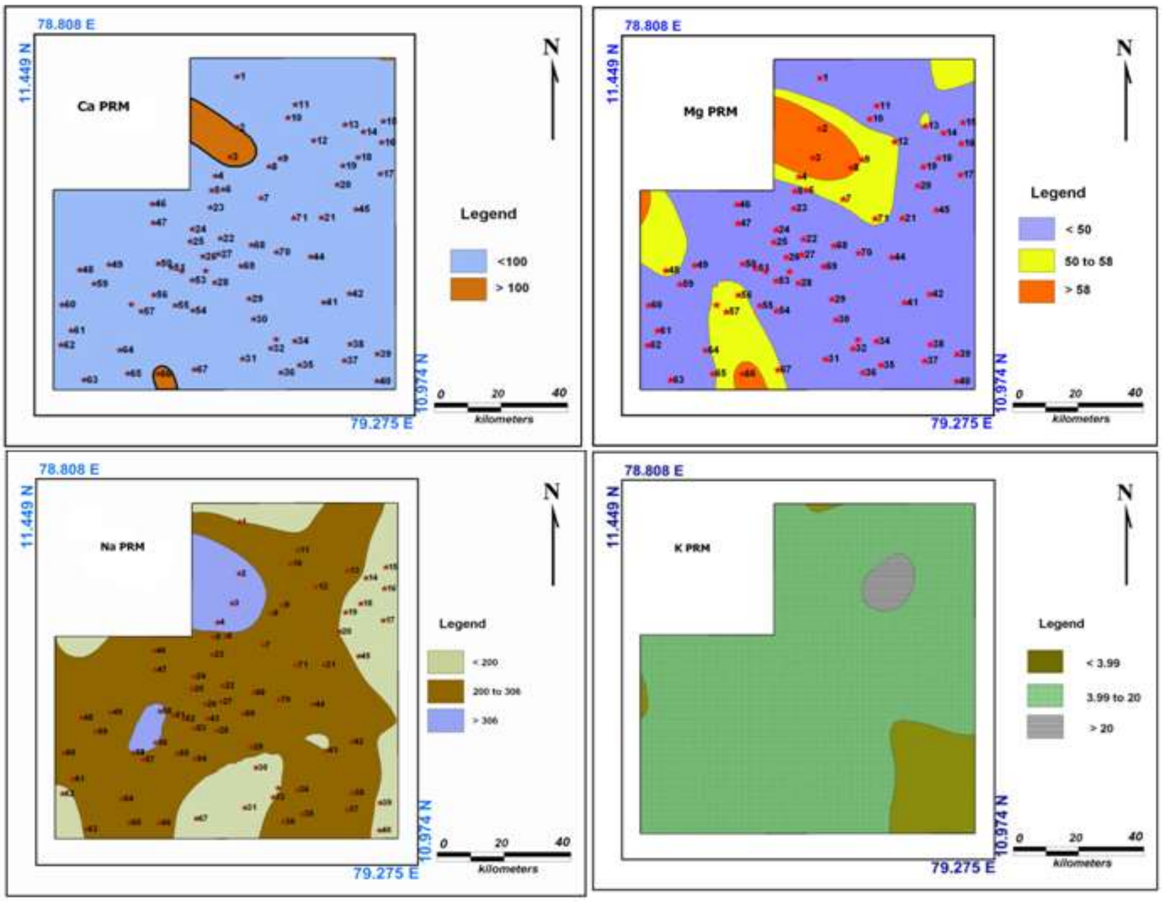

Fig.4 Spatial distribution of cations in the study area

Magnesium

Magnesium in groundwater are mainly due to the leaching of Magnesium bearing minerals from Mafic and Ultramafic rocks like Pyroxenite, Peridotite, Dunite, Anorthosite and Gabbro or even hypersthene present in Charnockite. Higher concentration of Mg which is above 58 mg/ l is noted in parts of northern and southern region as that of Ca in the study area (Fig. 4), and the region serves as a safer region for good quality drinking water.

Sodium

Sodium is the important and most abundant alkali metal which is highly mobile and soluble in groundwater. The concentration of sodium in groundwater sample in the study area varies from 11 to 346 ppm. Sodium concentration in most of the sample ranges from 200 to 306 ppm which is observed in central part of region. The higher concentration is noted along the northern and west part with the concentration above 306 ppm values (Fig 4).

Potassium

Potassium in groundwater is generally lesser due to its lesser mobility (Herman Bouwer, 1978). It plays a vital role as implant metabolism. K^+ occurs in less quantity in groundwater which may be due to ion exchange or weathering process (Chidambaram 2000). The Potassium has been compared with WHO (2004) (Table 2). Potassium less than 20 ppm in most of the samples is observed in the entire study area (Fig 4). The spatial distribution of above range 20 ppm in the northern region.

Chloride

Chloride represents the major sum of alkalinity. Chloride in water is the measure of its capacity of neutralization. In the study area is mostly covered with less than 250 ppm. Some of the samples which is above WHO (2004) standard is spatially distributed in North-Western part (Fig.5). Chloride concentration exceeding permissible limit except some groundwater samples, Chloride in ground water originates from both natural and anthropogenic sources. High chloride content indicates heavy pollution. It can be due to the uses of inorganic fertilizer, landfills leachates, and septic tank effluent drainage (Freeze and Cherry, 1979).

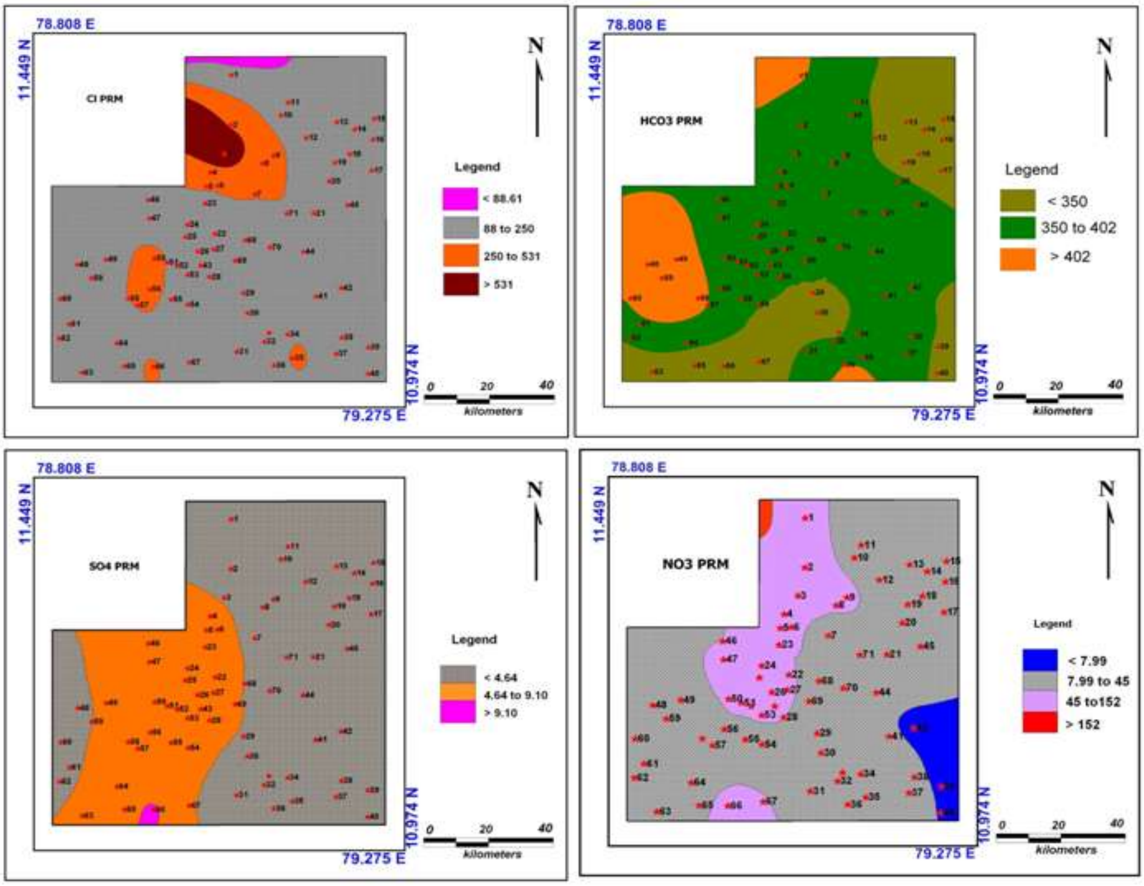

Fig 5: Spatial distribution of anions in the study area

Bicarbonate

Chapelle et al (1987) attributed HCO^-_3 concentration in natural water to the dissociation of H_2CO_3. Concentration is classified based on WHO (2004) standard, Bicarbonate sources of study area less than 350 ppm which is noted in North and Southern part and inferred to be good. Bicarbonate ions in groundwater are derived from carbon dioxide in the atmosphere, carbon dioxide in the soil and solution of carbonate rock, hence HCO^-_3 concentration in groundwater is mainly due to the weathering process (Stumm and Morgan 1996).Higher concentration above 402 ppm was noted in the north and west direction along the vellar river as is shown in study area (Fig. 5).

Sulphate

Sulphate is commonly found as minor concentration due to lesser break down of organic substances from weathering and Sulphate is naturally occurring anion in all kinds of natural waters (Miller 1979; Singh et al, 1994). The highest desirable limit of sulphate in groundwater is 200 mgl^{-1} and the maximum permissible limit is 400 mgl^{-1} (WHO 2004).The maximum and minimum concentration of SO_4 in the study area ranges from 0.3 to 10.97 mg/l (Table 2). Spatial distribution shows higher concentration along the South and west part of the of the study area (>4.64 ppm) (Fig 5). In the study area Sulphate are found to be within prescribed limit (30 ppm) for drinking within the study area.

Nitrate

NO_3 concentration in groundwater is mainly due to organic, industrial effluents, fertilizer or nitrogen fixing bacteria, leaching of animal dug and septic tanks leakage through soil water matrix to groundwater (Chidambaram, 2000). Higher NO_3 is noted in North west direction which is above 50 ppm (Fig 5) suggests that this part of Archean formation is higher. The lesser Nitrate with respect to 45 ppm contour as buffer along Vellar and Marudaiyar River indicating charging of connate water mixing with recent recharge.

IV. Conclusion

The chemical composition of the groundwater in the study area shows that HCO_3 are the dominant anions and Ca as the dominant cation. The study also brings out the fact that majority of the samples are within the permissible limit and can be used for domestic and agricultural purposes. The present study provides a guideline for solving water quality problem in Ariyalur region of Tamilnadu. The spatial distribution analysis of groundwater quality in the study area indicated that many of the samples collected are satisfying the drinking water quality standards prescribed by the WHO (2004). The sample which is non-potable for drinking purposes has been observed in the some parts of northern and southern region where the Vellar River flows. The results obtained gave the necessity of making the public, local administrator and the government to be aware on the crisis of poor groundwater quality prevailing in the area.

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