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SPATIAL VARIATION OF GROUNDWATER QUALITY AND INTER ELEMENTAL CORRELATION STUDIES IN LOWER BHAVANI RIVER BASIN, TAMIL NADU, INDIA

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ABSTRACT

The paper deals with the spatial variation of various groundwater quality parameters and their interrelationship in lower Bhavani River basin, Tamil Nadu, India. Biotite hornblende gneiss and charnockite are the basement rocks in this region. Groundwater occurs under water table conditions in the weathered mantle of crystalline rocks. Interpretation of the analytical results of fifteen groundwater samples spread over the basin indicates that groundwater of the area is mainly alkaline and hard in nature. Magnesium is the second dominant cation next to sodium, which is highly responsible for the higher total hardness in groundwater. Higher concentrations of geochemical parameters are noticed in the eastern part of the basin. Concentrations of geochemical parameters exceed the maximum allowable limits for drinking at few locations. Thus, it is suggested that groundwater of these locations need to be treated before using for drinking purposes. Groundwater of the area is, however, suitable for irrigation.

INTRODUCTION

Groundwater quality of an area can be understood by analyzing the water for various physio-chemical parameters. Subramani et al. (2005a) have studied the spatial and seasonal variations of various geochemical elements in Chithar River basin, Tamil Nadu, India. They have classified the groundwater into various types based on its suitability for drinking and irrigation purposes. Usha Natesan (2004) has applied the geographical information system (GIS) for assessing the quality of groundwater in Pernampet Block of North Arcot Ambedkar district in Tamil Nadu.

Groundwater level monitoring, pump-test analysis and determination of groundwater quality parameters at selected sites are some of the previous works carried out in lower Bhavani River basin, Tamil Nadu by the Central Ground Water Board (CGWB 2000) and the Tamil Nadu Public Works Department (PWD 2002). However, spatial variations of concentrations of various geochemical elements in groundwater and their correlations were not included. Thus, in the present study, an attempt has been made to understand the spatial variation of groundwater quality parameters and their interrelationship.

STUDY AREA

Bhavani river is one of the important tributaries of Cauvery river, which originates in the Silent Valley range of Kerala State. The lower Bhavani River basin lies between 11º15' N and 11º45' N latitude and 77º00' E and 77º 40' E longitude. The area comprises hilly regions and plain terrains with a maximum and minimum altitudes of 1487m and 215m above mean sea level respectively. The terrain is sloping towards south-east. The study area includes reserve forests, built-up lands, agricultural fields and barren lands. Tanks are mainly rain-fed and remain dry throughout the year except during rainy season. The Bhavani river flows from west to east in the study area and confluences with Cauvery river at Bhavani town. The major crops are paddy, banana, groundnut and sugarcane. Bhavani, Gobichettipalayam, Sathiyamangalam and Anthiur are the major settlements in this region. The area experiences dry climatic conditions with a maximum temperature of 40ºC during April and May and a minimum temperature of 22ºC during November and December. The average annual rainfall is about 762mm. The Archean basement of the study area (GSI 1995) consists of fissile hornblende biotite gneisses (mainly in plains) and charnockites (mainly in hills).

MATERIALS AND METHODS

Sampling and analytical techniques: The groundwater samples from 15 open wells in the study area (Fig. 1) were collected during July 2004. Field parameters like pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured immediately after sampling using digital meters. Collected samples were transported to the laboratory on the same day, and analyzed for determination of concentrations of chemical parameters such as sodium, potassium, calcium, magnesium, chloride and total hardness (TH) as per the standard methods (APHA 1995).

Data interpretation techniques: The study area map was prepared manually from the Survey of India toposheets on 1:50000 scale. The prepared hard copy maps were scanned and digitized using surfer (v.8.0) GIS software. Zonation maps for TDS and TH were prepared by fixing proper limits. Spatial variation maps for various major ions such as sodium, potassium, calcium, magnesium and chloride were prepared using the same software. Statistical correlation matrix was prepared for the eight parameters using SPSS (v.6.0) software. Further, water quality parameters were compared with the international standards for understanding the suitability of water for drinking and irrigation. Wilcox (1955) and US salinity (Richards 1954) diagrams were also prepared for the study of irrigation water quality.

RESULTS AND DISCUSSION

The intensity of acidity or alkalinity and the concentrations of hydrogen ions in groundwater are based on the pH values. It has no direct adverse affect on health, however, a lower value (pH < 4.0) will produce sour taste, and higher value (pH > 8.5) an alkaline taste. The acceptable range of pH is normally 6.5 to 8.5 (BIS 1983). It is observed that the groundwater samples of the basin are mainly alkaline in nature with a pH varying from 7.6 to 8.6. The average value of pH during July 2004 is 8.18.

The electrical conductivity (EC) value is an index to represent the total concentration of soluble salts in water. It is used to measure the salinity hazard to crops as it reflects the TDS in groundwater. The EC values in the study area range from 660 µS/cm to 2800 µS/cm with an average value of 1665 µS/cm. Majority of the July 2004 groundwater samples (12 samples) fall in the category of permissible (EC- 700 µS/cm to 2000 µS/cm) for irrigation (Ragunath 1987), and one sample fall in the category of good water (EC- 250 µS/cm to 700 µS/cm). Two samples, however, exceed the permissible limit and represent the doubtful category (EC- 2000 µS/cm to 3000 µS/cm). The higher values of EC may be due to the long residence time and the existing lithology of the region (Ballukraya & Ravi 1999).

Total dissolved solids (TDS) in groundwater range between 360 mg/L and 1560 mg/L. Most of the groundwater samples (13 samples) are within the maximum allowable limit for drinking (< 1500 mg/L) based on their TDS values (WHO 1983). According to Freeze & Cherry (1979), twelve samples represent the freshwater category (TDS < 1000 mg/L), and three samples the brackish water

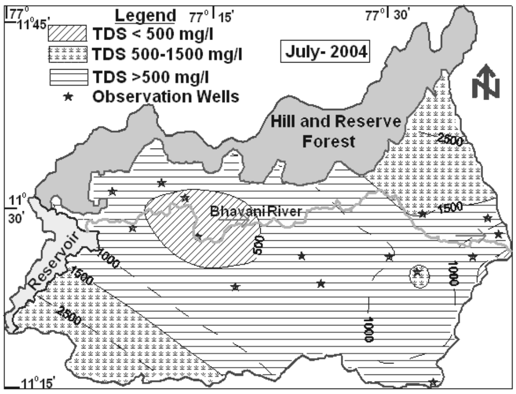

Fig. 1: TDS zonation map.

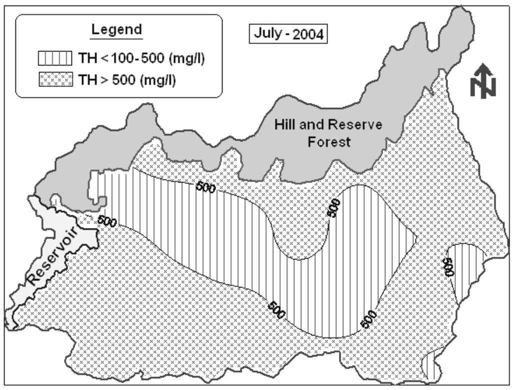

Fig. 2: TH zonation map.

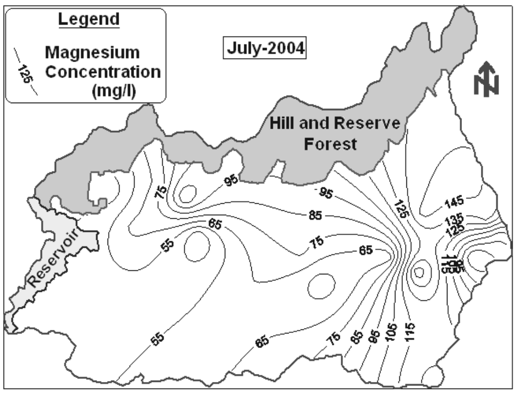

Fig. 3: Spatial variation of magnesium ion concentration in groundwater.

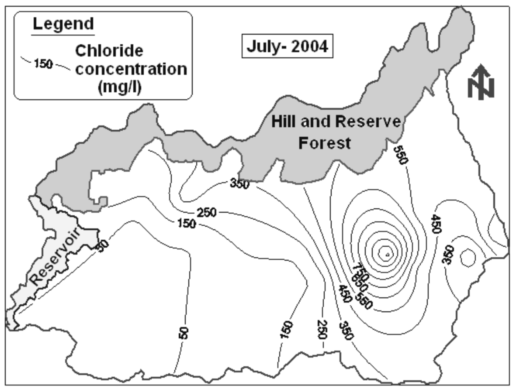

Fig. 4: Spatial variation of chloride ion concentration in groundwater.

category (TDS- 1000 mg/L to 10000 mg/L). The TDS zonation map (Fig. 1) indicates that groundwater in 20% of the total area (approximately) is unsuitable for drinking.

Sodium content in groundwater of the area varies from 27 mg/L to 310 mg/L with an average value of 145 mg/L. Five out of fifteen samples exceed the maximum allowable limit of 200 mg/L for drinking as per WHO (1983) standard. Concentration of potassium ion in groundwater ranges from 6 mg/L to 50 mg/L with an average value of 22 mg/L.

Total hardness (TH) varies from 340 mg/L to 720 mg/L. Acceptable limit of TH for drinking is 500 mg/L (WHO 1983). According to Sawyer & McCartly (1967), the groundwater of the area is hard to very hard in nature (most of the samples having TH > 150 mg/L). The TH zonation map illustrates that groundwater in 50% of the area (approximately) is unsuitable for drinking (Fig. 2).

The groundwater quality data reveal that the calcium ion concentration in groundwater varies from 48 mg/L to 140 mg/L, and the magnesium ion concentration from 35 mg/L to 154 mg/L with the average values of 79 mg/L and 87 mg/L respectively. All the groundwater samples exhibit the acceptability for drinking purposes based on the concentration of calcium and magnesium ions,

Table 1: Statistical correlation matrix of groundwater quality parameters.

Parameters	pH	TDS	TH	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-
pH	1							
TDS	0.09	1						
TH	0.62	0.65	1					
Na^+	0.42	0.56	0.42	1				
K^+	-0.34	0.16	0.1	-0.17	1			
Ca^{2+}	-0.22	0.32	0.18	-0.27	0.36	1		
Mg^{2+}	0.55	0.78	0.72	0.86	-0.14	-0.05	1	
Cl^-	-0.21	0.49	0.13	0.35	0.67	0.32	0.29	1

except one sample having slightly higher concentration of Mg^{2+} (> 150 mg/L). Magnesium is the second dominant cation in the study area next to sodium. The spatial variation of Mg^{2+} concentration is illustrated in the Fig. 3, where the higher values are noticed in the eastern part of the basin.

The chloride ion concentration varies between 23 mg/L and 1300 mg/L. The average value is 362 mg/L. Only two samples exceeded the maximum allowable limit of 600 mg/L. The concentration increases towards east in the basin (Fig. 4).

Alkali/sodium hazards to crops are generally ascertained based on the sodium absorption ratio (SAR) and percent sodium (% Na) values of groundwater samples (Karanth 1987). The SAR values range from 0.39 to 3.87 with an average value of 1.81. All the samples fall in the field of low sodium (S1) class (Richards 1954). The % Na ranges from 15.7% to 52.87% with an average value of 34.67%. All the samples were within the maximum allowable limit (< 60%) for irrigation (Wilcox 1955).

The statistical correlation matrix of various physio-chemical parameters of groundwater namely, pH, TDS, TH, Na^+, K^+, Ca^{2+}, Mg^{2+} and Cl^- was prepared using SPSS software (Table 1). It is observed that TH exhibits positive correlation with pH and TDS. Sodium and magnesium ions also exhibit positive correlations with pH and TDS. The magnesium ion concentration in groundwater is greatly responsible for the higher values of TH in the study area. This is clearly indicated by the R^2 value (7.2) in the Table 1. Rock-water interaction is the main source for the higher concentrations of magnesium ions in the groundwater (Subramani et al. 2005b). Sodium and magnesium ions are themselves having good positive correlations. TDS in groundwater of the area is mainly governed by the concentrations of magnesium, sodium and chloride ions.

CONCLUSIONS

1. The abundance of major cations in groundwater of the study area during July 2004 is as follows: Na > Mg > Ca > K.
2. Concentrations of geochemical elements in groundwater increase towards east in the basin.
3. Groundwater of the area is alkaline and hard in nature.
4. Higher concentrations of TH in groundwater are mainly due the higher ionic concentrations of magnesium. Magnesium ions may be contributed to groundwater from the existing rocks by weathering and rock-water interaction processes.
5. Groundwater of the area is suitable for irrigation but not suitable for drinking at few places. Hence, it is suggested that groundwater of those places need to be treated before using for drinking purposes.

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