Nature Environment and Pollution Technology © Technoscience Publications	Vol. 7	No. 3	pp. 423-428	2008

Geochemical Studies of Groundwater Present in Upper Thirumanimuthar Sub-basin, Tamil Nadu, India

B. Gurugnanam, M. Suganya, M. Suresh and K. Dharanirajan*
Department of Earth Sciences, Annamalai University, Annamalai Nagar-608 002, T.N., India
*Institute for Ocean Management, Anna University, Chennai, T.N., India

Key Words:
Groundwater
Geochemical studies
Piper trilinear diagram
Kalley's ratio
Sodium adsorption ratio
Magnesium hazards
Sodium percentage

ABSTRACT

Geochemical analysis of groundwater is employed to evaluate the postmonsoon 2005 water quality of upper Thirumanimuthar subbasin. Thirty two representative groundwater samples were collected from dug and bore wells. The samples were analysed to monitor the water chemistry of major ions. The results were evaluated in detailed and compared with WHO water quality standards. An overall assessment of the water samples indicated that all parameters are within the permissible limit except in some locations. According to the USSL diagram most of the samples falls in $C_3 - S_1$ class, which indicates its suitable nature. Piper trilinear diagram interpretations were made to know the chemical type of the groundwater. It reveals that the subsurface water is alkaline earth (Ca+Mg) exceeds alkalies (Na+K) type.

INTRODUCTION

Groundwater is an important natural resource, which plays a significant role in human development. Development provides opportunities for pollution of groundwater. The hydro-chemical characteristics of water determine its usefulness for municipal, commercial, industrial, agricultural and domestic water supplies. The study of water quality involves a description of occurrence of various constituents in water and relation of these constituents to water use. The present study was undertaken to carry out quality assessment of water of upper Thirumanimuthar subbasin and to ascertain its suitability for drinking and irrigational purposes.

STUDY AREA

The Thirumanimuthar subbasin of Cauvery river covers nearly about 2030 km^2. The upper Thirumanimuthar subbasin extends between east longitude of 78°07' to 78°21' and north latitude of 11°37' to 11°49' (Fig. 1). It covers an area of 340.952 km^2. The hills cover an area of 112.834 km^2 and the plain area occupies about 228.118 km^2. Physiographically, Salem has an extensive area of hills and forests with undulating plains. The minerals like magnestie, bauxite, iron ore, limestone and chromite are the major contribution made to the state by the district. Magnestie, gneiss and dolerite are the major rock types of the study area.

MATERIALS AND METHODS

In order to assess the groundwater chemistry, groundwater samples were collected during the month of postmonsoon in 2005. A total of thirty two representative water samples were collected (Fig. 1) from dug and bore wells. The ground water samples were collected in clean 1000 mL polythene bottles. The bottles were rinsed before sampling, tightly sealed after collection and were labelled in the field. The samples were analysed for physico-chemical parameters (pH, EC), major cations (Ca,

Mg, Na, K) and major anions (CO_3, HCO_3, SO_4, Cl) as per standard procedures. In the present study the specifications as proposed by Kelley et al. (1940), U.S. Salinity Laboratory Staff (1954), Wilcox (1955) and Paliwal (1972) have been used to asses the suitability of water for irrigational purposes. The calculated values of these specifications are given in Table 2. The major cations and anions have been plotted on the Piper trilinear diagram and projected onto a common diamond-shaped field (Fig. 2). USSL diagram has been worked out, correlating EC against SAR (Fig 3).

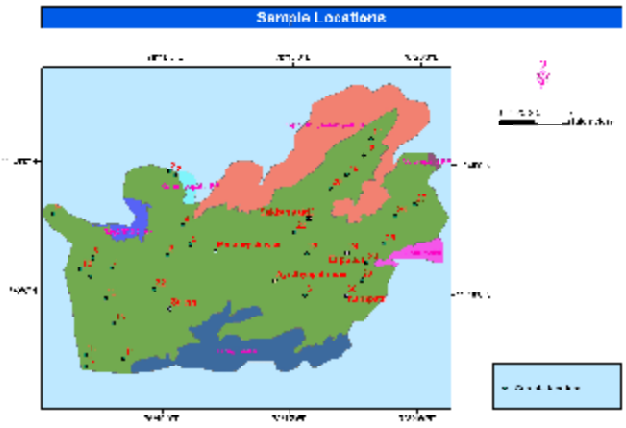

Fig. 1: Sample location map of the study area.

RESULTS AND DISCUSSION

Hydrogeochemistry: The average chemical composition of water of upper Thirumanimuthar subbasin is presented in Table 1. The analytical results show that groundwater is alkaline in nature as the pH range is 8 to 12. The high pH value is noticed in 2 locations. Bicarbonate is the most dominant anion followed by chloride, carbonate and sulphate.

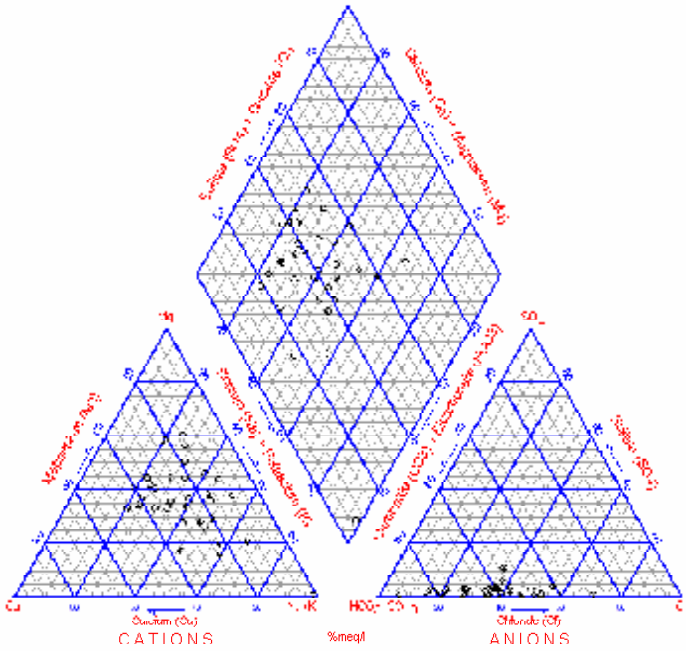

Fig. 2: Piper trilinear diagram.

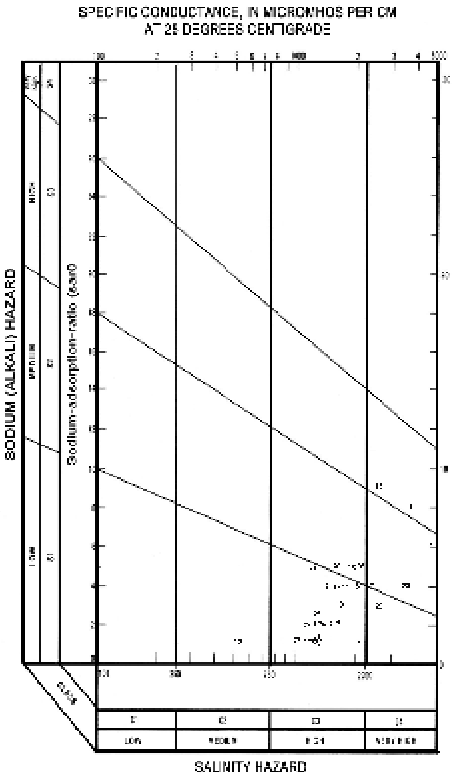

Fig. 3: USSL diagram.

The analytical results indicate that the chloride concentration varied from 71 to 1257 mg/L, being minimum at Pallapatty and maximum at Uthamasolapuram. It is due to the replacement of hydroxide to chloride in the hornblende biotite gneissic rocks (Kuroda & Sandell 1953). Chloride ions are the major contribution to the salinity of water. WHO (1984) has suggested 200 ppm of chloride as desirable limit and 600 ppm as maximum permissible limit in drinking water (Table 1).

Specific conductance, which is measurement of ionic strength of water varies from 500 to 8000 µS/cm. High EC values are noticed in the groundwater sample numbers 2, 15, 16 and 19 during postmonsoon period.

Calcium and magnesium concentrations range from 20 to 180 mg/L and 7 to 158 mg/L in postmonsoon period respectively, which are within the limiting values. Sodium concentration is noticed from 25 to 750 ppm with an average of 178 mg/L. Potassium contents range from 4 to 1803 mg/L with an average of 85 mg/L. High potassium values are noticed in the groundwater sample numbers 2 and 15. It is because of the potassium feldspars are resistant to attack by water (Hem 1985).

Irrigational quality of water: To understand the suitability of water for irrigational purpose, certain ratios are of fundamental importance and are described below:

The Kelley's ratio has been calculated for all the water samples of the study area and presented in Table 2. It varies from 0.2 to 1.4 epm (except in one sample 20.4) with an average of 1.23 epm. The ratio is less than unity in 25 water samples indicating their suitable nature for irrigational uses. The formula used in the estimation of this ratio is expressed as:

$$Kelley's \quad Ratio = \frac{Na}{Ca + Mg}$$

The water having excess of carbonate and bicarbonate over the alkaline earth mainly calcium and magnesium, in excess of allowable limits affects agriculture unfavourably (Eaton 1950). Table 2 shows that the ratio is less than 1.25 in 25 water samples. It indicates their suitable nature for irrigation. The rest are unfit for irrigation in postmonsoon season. The value of RSC (residual sodium carbonate) varies from 0.2 to 5.2 epm which is expressed by the following equation:

$$RSC = (CO_3 + HCO_3) - (Ca + Mg)$$

The relativity of sodium ion in the exchange reaction with soil is expressed in terms of a ratio known as 'Sodium Adsorption Ratio' (SAR). The SAR value of the water samples of the study area vary from 0.8 to 8.5 epm with an average of 4.11 epm. Out of 32 samples, 90 percent of the water samples fall under no problems category. SAR is expressed by the following equation:

Table 1. Range of chemical parameters of water samples and comparison with WHO drinking water standards.

Parameters	Minimum	Maximum	Average	WHO (1984) Highest Desirable limit	WHO (1984) Maximum PermissibleLimit
pH	8	12	8	7 – 8.5	6.5 - 9.2
EC, µS/cm	500	8000	2013	-	-
Ca, mg/L	20	180	89	75	200
Mg, mg/L	7	158	79	50	150
Na, mg/L	25	750	178	-	-
K, mg/L	4	1803	85	-	-
HCO_3, mg/L	183	1977	689	-	-
CO_3, mg/L	0	1266	41	-	-
SO_4, mg/L	10	40	20	200	400
Cl, mg/L	71	1259	271	200	600

Table 2: Irrigational specification values of groundwater in epm.

S.No	Location	RSC	SAR	Mg Hazards	Kelley'sRatio	SSP
1	Kombaipatty		1.3	56.9	0.3	21.36
2	Vinayagampatty		36.6	37.5	20.4	98.01
3	Vinayagampatty 2	1	1.4	55.1	0.3	23.3
4	Kondappanaikanpatty		1.6	80.8	0.3	25.24
5	Kannakurichi	1.8	3.8	80	0.8	45.14
6	Iyyanthirumaligai		1.3	73.1	0.2	20.24
7	Narasothipatty/Rettiur	0.2	4.1	67.2	0.8	47.03
8	Vellakalpatty		1.8	78.7	0.4	27.81
9	Karrupur		1.6	54.5	0.3	25.93
10	Reddiapatty		2.8	56.1	0.6	39.68
11	Suramangalam		1.4	62.7	0.4	28.92
12	Pallapatty		0.8	53.8	0.3	33.9
13	Annadhanapatty		8.5	79.6	1.1	52.9
14	Seelanaikanpatty		3.6	68.6	0.8	44.44
15	Uthamasolpuram		6.2	61.9	1.1	66.53
16	Jarikondalampatty	0.4	7.9	40	1.4	59.63
17	Adimalaipudur	5	3.8	53.2	0.9	47.19
18	Achankuttapatty		4.5	59.2	1	50.25
19	Kuppanur		3.7	60.2	0.6	39.33
20	Parrutikaddu	0.4	3.6	32.6	0.8	45.56
21	Sukkampatty	1.5	4.2	51.8	1	50.3
22	Valasaiyur		1.1	50.4	0.2	18.79
23	Kullampatty		3.1	76.4	0.6	39.5
24	Aripudur	0.2	2	50.6	0.5	33.18
25	Jalakandapuram	1.9	2.1	47.2	0.4	29.8
26	Kottathupatty		3.4	47.5	0.7	41.63
27	Annupur		1.2	48.8	0.3	24.07
28	S.Nattarmangalam	3.7	2.2	67.7	0.5	33.56
29	Krarumpura,	5.2	5.4	47.5	1.4	57.67
30	Karipatty	1.4	1.1	41.7	0.3	20.66
31	AVS		1.4	45.1	0.3	23.65
32	G.A.C		3.9	73.3	0.4	30.77
	Maximum	5.2	36.6	80.8	20.4	98.01
	Minimum	0.2	0.8	32.6	0.2	18.79
	Average	1.89	4.11	58.12	1.23	38.94

Table 3: Frequency distribution of SSP, RSC, Mg hazards and Kelley's ratio.

S.No	Water Quality Parameters	Range	Water Classes	No. of Samples
1	USSL Diagram	C2-S1	Good	1
		C3-S1	Good	20
		C4-S1	Good	1
		C3-S2	Moderate	3
		C4-S2	Moderate	3
		C4-S3	Bad	2
2	RSC	<1.25	Safe	4
		1.25-2.5	Marginal	5
		>2.5	Unsuitable	3
3	Mg Hazards	<50%	Suitable	9
		50-65	Marginal	13
		>65	Unsuitable	10
4	Kelley's Ratio	<1	Suitable	25
		1 to 2	Marginal	6
		>2	Unsuitable	1
5	SSP	<20	Excellent	1
		20-40	Good	18
		40-60	Permissible	11
		60-80	Doubtful	1
		>80	Unsuitable	1

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Wilcox (1955) has recommended another classification for rating irrigation water on the basis of soluble sodium percentage (SSP). The values of SSP have been determined for all the water samples and presented in Table 2. The ratio of the SSP values is 20.24 to 66.53 epm (except in one sample 98.01). The values of SSP are expressed by the following equation:

$$SSP = \frac{(Na + K)}{Ca + Mg + Na + K} \times 100$$

Table 3 shows the range of water quality parameters RSC, Mg hazards, Kelley's ratio and SSP in the water samples. Paliwal (1972) has used the ratio as an index of magnesium hazards for irrigation water. Table 2 reveals that the magnesium ratio for water samples of the study area varies from 32.6 to 80.8 in epm. High Mg ratio is noticed in 10 locations. It is found due to surface water and subsurface water are more reacted and pass through the limestone, kankar and granitic rock formations in the study area (Pandian & Sankar 2007).

$$Mg \quad Hazards = \frac{Mg \times 100}{Ca + Mg + Na + K}$$

Piper trilinear diagram: Hydrochemical facies are distinct zone that have cation and anion concentrations describable within defined composition categories. Piper (1944) developed a form of trilinear diagram which is an effective tool in segregating analytical data for critical study with respect to

sources of the dissolved constituents in groundwater. The plotting of hydrochemical data on trilinear diagram (Fig. 2) indicate the hydrochemical type of groundwater in the study area which shows most of the samples are alkaline earth (Ca+Mg) exceeds alkalies (Na+K) type.

USSL diagram: In order to study the suitability of groundwater for irrigational uses, the values of EC and SAR are compared and plotted on U.S. Salinity Laboratory diagram (Fig. 3) which gives direct indication of the salinity and alkali hazards. It is evident form the figure that the water quality belongs to C_3 - S_1 classes which fall in the zone of good water quality in most of the area, while few samples fall within C_2 - S_1, C_3 - S_2, C_{4-} S_1, C_4 - S_2 and C_4 - S_3 classes of poor water quality for irrigational use.

CONCLUSION

The water chemistry in upper Thirumanimuthar subbasin reveals that the water is suitable for drinking and irrigational uses**.** With reference to the WHO (1984) standards, the water is good for drinking purpose. The salinity and sodium hazards have been evaluated by using the Kelley's ratio. The ratio is less than unity in 25 water samples; it indicates their suitable nature for irrigational uses. As per the Eaton's interpretation, 4 water samples have RSC values less than 1.25 and 5 samples have RSC values between 1.25 and 2.5 which clearly indicates their marginal and suitable nature respectively for irrigational purposes. In the area of present investigation, 9 water samples have less than 50% magnesium hazards indicating their suitable nature for irrigation. With reference to the irrigation quality, the water is good for irrigation. The U.S. Salinity Laboratory Staff diagram indicate that the water belong to C_3 - S_1 class. Piper trilinear diagram was used to find out the hydrochemical type of groundwater in the study area which shows most of the samples are alkaline earth (Ca+Mg) exceeds alkalies (Na+K) type.

REFERENCES

Eaton, F.M. 1950. Significance of carbonate in irrigation water. Soil Science, 69(2): 123-133.

Hem, J.D. 1985. Study and interpretation of chemical characteristics of natural water, U.S. Geol. Surv. Water Supply Paper, 2254, pp. 264.

Kelley, W.P., Brown, S.M. and Leibig, G.I. Jr. 1940. Chemical effects of saline irrigation water on soils. Soil Science, 49: 95-107.

Kuroda, P.K. and Sandell, E.B. 1953. Chlorine in igneous rocks. Geological Society of America Bulletin, 64: 879-896.

Paliwal, K.V. 1972. Irrigation With Saline Water. I.A.R.I., Monograph No.2, (New Series), New Delhi, pp.198.

Pandian, K. and Sankar, K. 2007. Hydrogeochemistry and groundwater quality in the Vaippar river basin, Tamil Nadu. J. of GSI, 69: 970-982.

Piper, A.M. 1944. A Graphical procedure in the chemical interpretation of groundwater analyses. Trans. Geophy. Union, 25: 914-923.

U.S. Salinity Laboratory Staff 1954. Diagnosis and Improvement of Saline and Alkaline Soils, U.S.D.A. Handbook No.60, pp.160.

Wilcox, L.V. 1955. Classification and use of Irrigation water, U.S.D.A.Circ. 969, Washington, DC. p. 19.

WHO 1984. Guideline for Drinking Water Quality, VI. Recommendation, World Health Organization, Geneva.