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Original Research Paper

Assessment of Groundwater Quality for Drinking and Agricultural Purposes in Vamanapuram River Basin, South Kerala, India

Veena M. Nair and R. B. Binoj Kumar
Department of Geology, University of Kerala, Kariavattom Campus, Trivandrum, Kerala, India

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ABSTRACT

Groundwater quality determination is essential for assessing its suitability for drinking and agricultural purposes. In the present study 104 open well water samples were collected during both pre and post-monsoon seasons to evaluate the groundwater quality of Vamanapuram river basin. Samples were analysed for different physico-chemical parameters such as pH, EC, TDS, salinity, Na^+, K^+, TH, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-} and HCO_3^- following standard procedures. The acquired values were compared with BIS standards to recognize their aptness for domestic use. From the Piper plot dominant hydrochemical facies identified is Na-Cl for both seasons. Alkalies (Na and K) exceed alkaline earths (Ca and Mg) and strong acids (Cl and SO_4) exceed weak acid (HCO_3) in both seasons. To determine the suitability of water for agricultural use, chemical indices like sodium adsorption ratio, percent sodium, residual sodium carbonate and permeability index were calculated. RSC and PI have revealed that all samples are safe for irrigation. As per Wilcox's diagram and USSL classification, majority of samples are suitable for irrigation except those from the coastal area of Anchuthengu which is unsuitable for drinking as well as irrigation purpose.

INTRODUCTION

Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sectors. Groundwater quality in an area degrades due to natural as well as anthropogenic activities. Overexploitation of groundwater resources also leads to degradation of its quality. Thus, groundwater quality assessment studies, are as important as its quantity. In the present study, an attempt has been made to characterize the groundwater quality of Vamanapuram river basin with respect to its chemical composition.

STUDY AREA

The Vamanapuram river basin, which spreads over the districts of Thiruvananthapuram and Kollam of Kerala State, is taken as the study area. It lies between 8°38'0' and 8°49'0' N latitudes and 76°45'30' and 77°7'30' E longitudes covering an area of 691.46 km^2 (Fig. 1). The Vamanapuram river originates from the Chemunjimotta hills (altitude 1860m) of the southern side of Western Ghats in Kerala. The Upper Chittar and Manjaprayar are the tributaries of this river. Flowing westwards for about 80 km, the Vamanapuram river meanders its way to the Anchuthengukayal through Attingal town.

The major rock types observed in the area include garnet-biotite-sillimanite gneiss ± graphite, garnet biotite gneiss, quartzofeldspathic gneiss and charnockite.

MATERIALS AND METHODS

A total of 104 open well samples were collected covering the entire study area during the post-monsoon month of August 2009 and the pre-monsoon month of May 2010. The samples were analysed for important parameters such as pH, EC, TDS and major cations like Ca, Mg, Na, K as well as major anions like HCO_3, Cl, NO_3, SO_4 and PO_4 following the standard analytical methods (APHA 1995). The obtained values were compared with Bureau of Indian Standards to recognize their aptness for domestic use (BIS 1991).

RESULTS AND DISCUSSION

The pH of the post monsoon water samples varies from 4.2 to 7.6 with an average of 5.59 and in the pre monsoon samples from 4.5 to 7.8 with an average 5.72 indicating an acidic trend for the groundwater in a good number of locations. Most of the TDS values fall within the highest desirable limits of BIS, except at a few places along the coastal regions. However, pre monsoon coastal samples show sporadic increase in TDS compared to post monsoon samples. The general order of the dominance of cations is $Na > Ca > Mg > K$ and anions is $Cl > HCO_3 > SO_4 > NO_3 > PO_4$. In the case of calcium, the value ranges from 2.004 to 106.2 ppm during post monsoon, and 2.004 to 218.3 ppm in pre-monsoon. Mg content varies from 1.18 to 127.6 ppm in pre-monsoon and from 1.2 to 56.9 ppm in post-monsoon. Values exceeding the BIS limit were observed only near Anchuthengu coast. Total hardness is due to Ca and Mg and the water with high

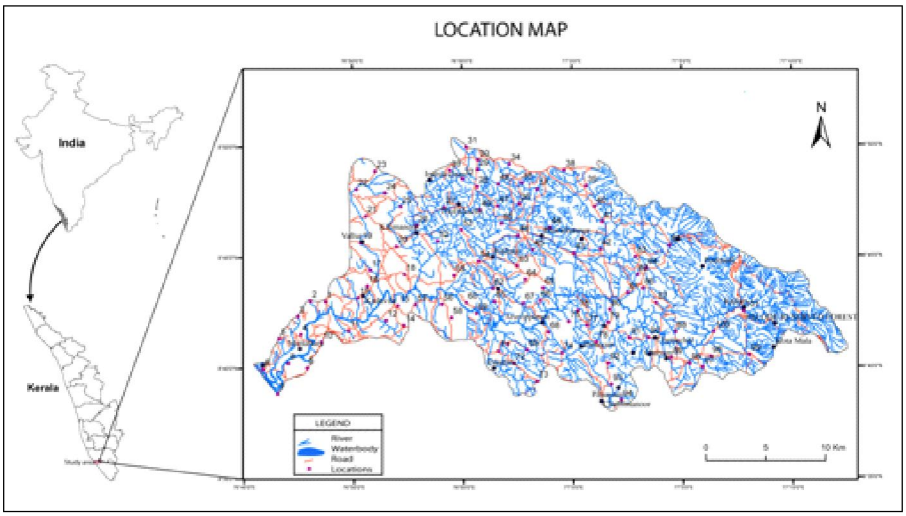

Fig. 1: Study area showing sampling stations.

hardness of 150-300 ppm and above may cause heart disease and kidney problems (Ramesh & Elango 2006). Total hardness ranges from 10-550 ppm during pre-monsoon and 10-500 ppm during post-monsoon. Chloride is one of the major anions found and its concentration ranges from 10.65 to 639 ppm in post monsoon and 7.1 to 1700 ppm in the pre-monsoon. The highest value is obtained near Anchuthengu fort close to the Arabian Sea. Apart from this in Attingal area, which is under the grip of urbanization, also show relatively high values of chloride during post monsoon indicating anthropogenic contamination. Bicarbonate content varies from 10 to 165 ppm in pre-monsoon and 5 to 150 ppm in post-monsoon. Bicarbonate is an important ion in the evaluation of irrigation water quality (Ramesh & Elango 2006). Nitrate and phosphate values show sporadic increase (0-37 ppm) at few places indicating anthropogenic input in post monsoon whereas the values are within limits in the pre-monsoon season. Sulphate values exceed BIS limit during both the seasons along the coastal region and this can also be attributed to anthropogenic contamination.

Mean and range values of the measured parameters in groundwater are compared with BIS values and are presented in Table 1.

Hydrochemical facies: Hydrochemical facies can be classified on the basis of dominant ions using the Piper's trilinear diagram (Piper 1953). The concentrations of major ionic constituents of groundwater were plotted in the Piper trilinear diagram to determine the water type (Fig. 2).

The plots of the chemical data on the Piper's trilinear diagram show that majority of water samples irrespective of season fall in the field of mixed Na-Cl type. However, pre-monsoon samples show minor representations also from mixed Ca-Mg-Cl, mixed Ca-Na-HCO_3 and Ca-Cl type. From the plot alkalies (Na and K) exceed alkaline earths (Ca and Mg) and strong acids (Cl and SO_4) exceed weak acid (HCO_3) in both the seasons.

Quality for irrigation use: In order to evaluate suitability of groundwater for use in agriculture, the sodium adsorption ratio (SAR), residual sodium carbonate (RSC), sodium percentage and permeability index were calculated.

The TDS, expressed in terms of EC, gives the salinity hazard of irrigation water. The relative proportion of sodium to calcium and magnesium is expressed as SAR. The SAR is used to predict the danger of sodium (Na) accumulation in the soil. It is defined by

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

In which the concentrations are expressed in milliequivalents per litre (Karanth 1989).

The interpretive guidelines for SAR are as follows after Herman Bower (1978).

SAR value	*Water Class*
< 10	Excellent
10 - 18	Good
18 - 26	Doubtful
> 26	Unsuitable

The calculated values of SAR for all post-monsoon samples in this area fall in excellent class, whereas in the case of pre-monsoon samples, out of 2 coastal samples, one falls in good category and one in doubtful category while all other samples fall in excellent type water class.

Table 1: Mean and range values of open well water samples.

Parameter		Values		BIS Standard	
		Pre-monsoon	Post-monsoon	Highest Desirable	Maximum Permissible
pH	Range	4.5-7.8	4.2-7.6	6.5-8.5	No relaxation
	Mean	5.72	5.59		
EC (µs/cm)	Range	31.6-4600	32.3-2450	-	-
	Mean	253.5	200.92		
TDS (ppm)	Range	16.7-3800	16.8-1290	500	2000
	Mean	142.5	105.34		
Salinity (ppt)	Range	0.003-14.5	0.02-1.50	-	-
	Mean	0.263	0.1226		
Total hardness (ppm)	Range	10-550	10-500	300	600
	Mean	57.45	54.135		
Na (ppm)	Range	1-3600	6-197	-	200
	Mean	81.75	28.1923		
K (ppm)	Range	1-800	0-29	-	-
	Mean	21.48	4.8942		
Ca (ppm)	Range	2.004-218.3	2.004-106.212	75	200
	Mean	13.91	9.9622		
Mg (ppm)	Range	1.188-127.6	1.210- 56.9762	30	100
	Mean	6.97671	6.9859		
Cl (ppm)	Range	7.1-1700	10.65-177.5	250	1000
	Mean	59.98	50.17		
NO_3 (ppm)	Range	0-5.12	0-37.607	45	100
	Mean	2.710769	7.97		
SO_4 (ppm)	Range	0-50	1.5709-79.724	200	400
	Mean	3.375962	9.9939		
PO_4 (ppm)	Range	0-1	0-3.703	-	5
	Mean	0.035	0.1075		
HCO_3 (ppm)	Range	10-165	5-150	-	-
	Mean	42.40385	29.75		

The analytical data plotted on the US Salinity diagram (Richards 1954) show that most of the samples during post-monsoon fall in the C1-S1 and C2-S1 field and one sample each falls in the C3-S1 and C4-S1 field (Fig. 3a). Groundwater in the low salinity and low to medium alkalinity can be used for irrigation on all types of soil with little danger of development of harmful level of exchangeable sodium (Ramesh & Elango 2006). One sample each falls in high salinity and very high salinity range which is unsuitable for irrigation.

In the case of pre-monsoon samples the plot shows that out of 104 samples, except 3 all other samples fall in C1-S1 and C2-S1 field of low salinity and low to medium alkalinity which is suitable for irrigation. One sample each falls in the C2-S2, C3-S3 and C4-S4 field (Fig. 3b).

Sodium concentration is important in classifying irrigation water because sodium reacts with soil to reduce its permeability (Todd 1980). Sodium content is usually expressed in terms of percent sodium also known as sodium percentage, defined by:

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

Where all ionic concentrations are expressed in milli equivalents per litre.

The calculated values of percent sodium of samples in post-monsoon range from 20.11 to 78.7 with an average of 55.81, and in pre-monsoon from 4.14 to 90.6 with an average of 66.7. A maximum of 60% sodium in groundwater is allowed for agricultural purposes (Ramakrishnan 1998).

The Wilcox (1955) diagram relating sodium percentage and electrical conductivity shows that most of the samples fall in the field of excellent to good in both seasons, however, 3 post-monsoon and 12 pre-monsoon samples fall in permissible to doubtful category, and in the case of 2 coastal samples both fall in unsuitable division in pre-monsoon, while in post-monsoon one falls in doubtful to unsuitable, and one in permissible to doubtful category (Fig. 4a & b).

Residual sodium carbonate (RSC): Residual sodium carbonate (RSC) exists in irrigation water when the carbonate plus bicarbonate content exceeds the calcium (Ca) plus magnesium (Mg) content of the water. Where RSC is high, extended use of that water for irrigation will lead to an accumulation of sodium (Na) in the soil.

RSC Hazard in meq/L:

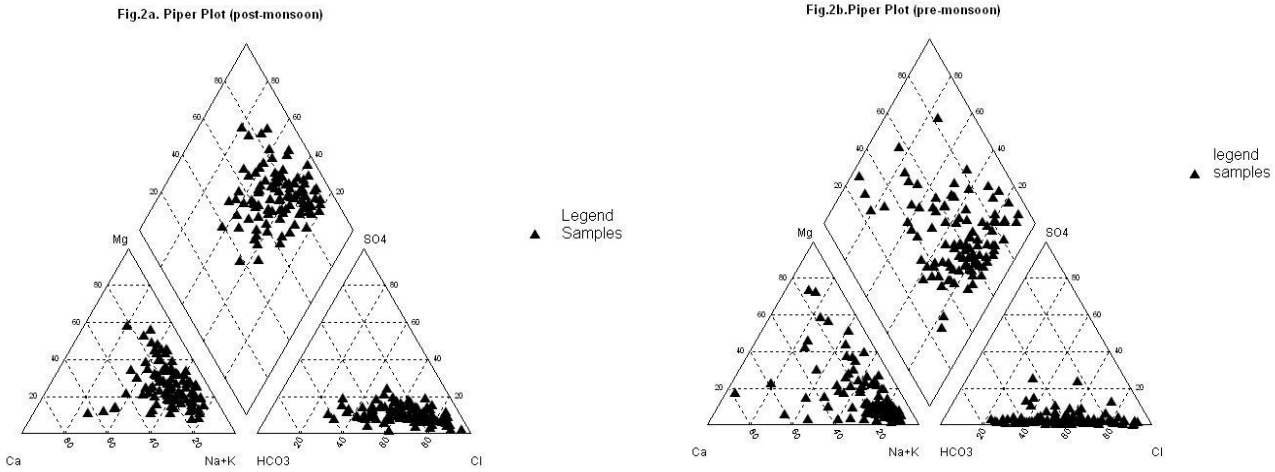

Fig. 2 a & b: Chemical facies of groundwater in Piper-diagram.

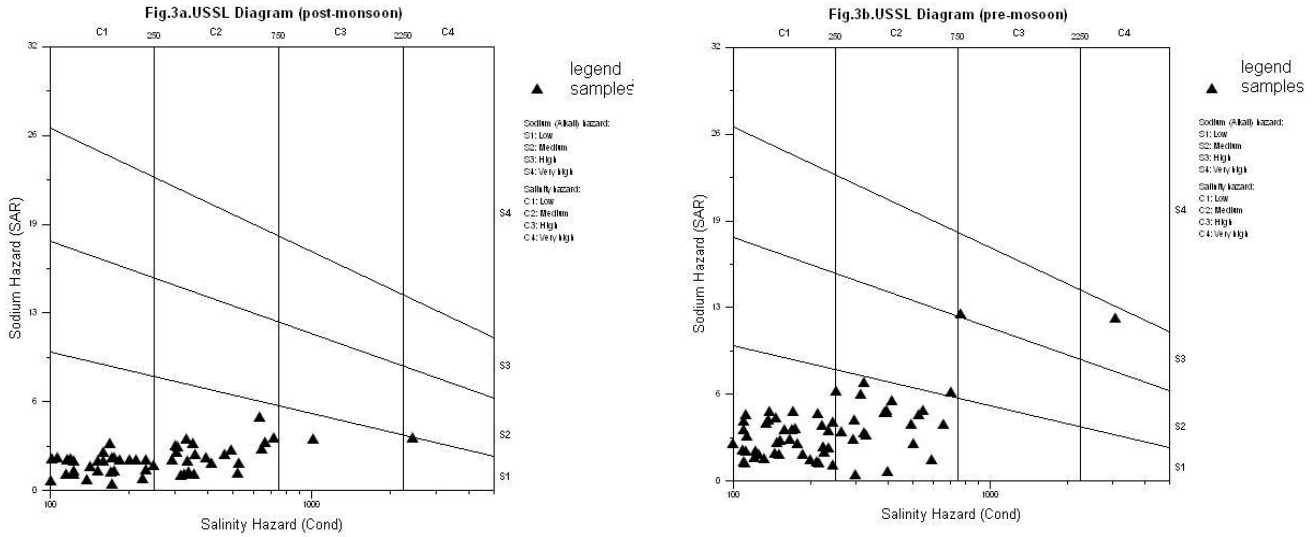

Fig. 3 a & b: Salinity and alkalinity hazard of irrigation water in US salinity diagram.

< 1.24	None
1.25 to 1.7	Increasing
1.7 to 2.1	Significant
2.1 to 2.5	High
> 2.5	Severe

The water samples in the area have a RSC value of less than 1.24 in both the seasons showing no RSC hazard (Eaton 1950).

Permeability index: The permeability index (PI), as developed by Doneen (1964), indicates the suitability of groundwater for irrigation. It is defined as follows:

$$PI = \frac{Na + \sqrt{HCO3} \times 100}{Ca + Mg + Na}$$

Where all the ions are expressed in meq/L.

Doneen evolved a criterion for assessing the suitability of water for irrigation based on the permeability index. Accordingly water can be classified as Class I (> 75%), Class II (25-75%) and Class III (< 25%). Class I and II waters are considered good for irrigation with 75% or more maximum permeability while Class III are unsuitable with 25% of maximum permeability (Raju et al. 2009). In the present study out of 104 post-monsoon samples 86 samples fall in

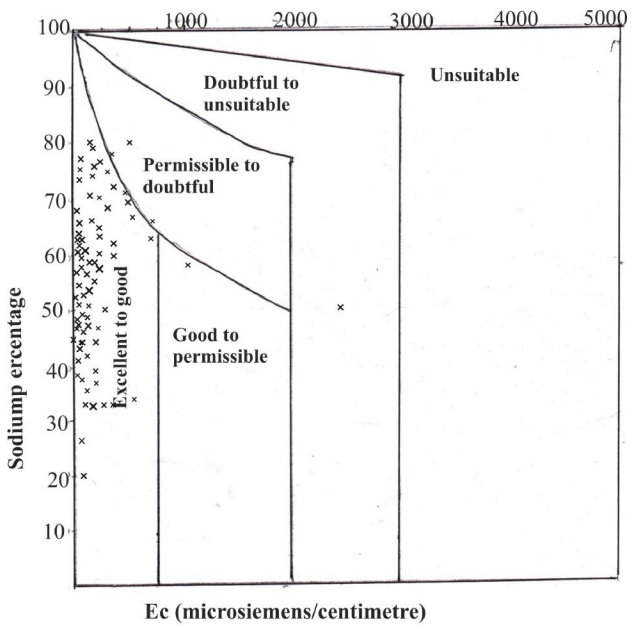

Fig.4a. Wilcox classification diagram (post-monsoon)

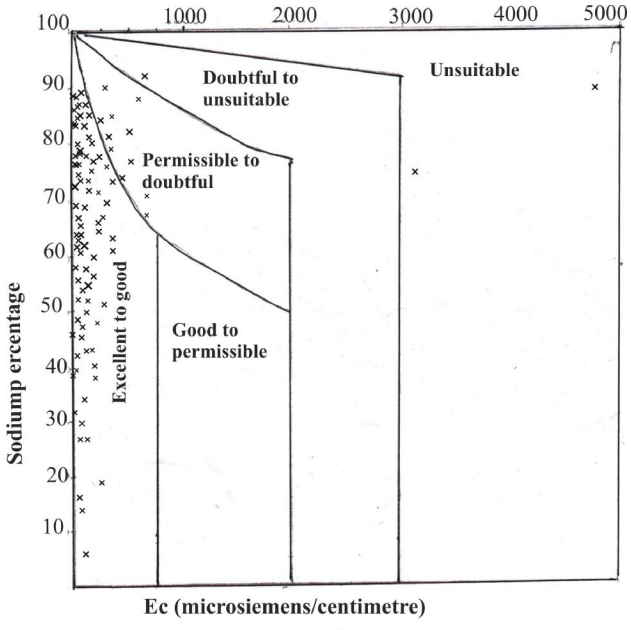

Fig.4b. Wilcox classification diagram (pre-monsoon)

Fig. 4a & b: Suitability of water for irrigation in Wilcox diagram.

Class I and 18 in Class II, while in pre-monsoon 93 samples in Class I and 11 samples in Class II.

CONCLUSION

The groundwater of Vamanapuram river basin was analysed for finding its suitability for domestic and irrigational purposes. Different physico-chemical parameters of groundwater for post-monsoon and pre-monsoon were analysed and compared with BIS standards and it was found that water is suitable for drinking purposes in both the seasons in the area except along the coastal regions. The concentration of all chemical parameters increases from inland to coastal areas in both the seasons. Piper plots show that majority of water samples of both seasons fall in the field of mixed Na-Cl type, with alkalies (Na and K) exceeding alkaline earths (Ca and Mg) and strong acids (Cl and SO_4) exceeding weak acid (HCO_3). Different physico-chemical properties of irrigation water were compared with the national and international standards set for irrigation. As per the SAR classification all post-monsoon samples fall under excellent category while in pre-monsoon except coastal samples others fall in excellent category. The plotting of values over the USSL diagram has indicated that majority of the samples of both seasons falls in the C1-S1 and C2-S2 field of low salinity and low to medium alkalinity. The Wilcox diagram reveals that majority of samples irrespective of season fall in the excellent to good category with minor representations in other fields. Likewise, the concentration of RSC in the study area is within the limit. PI calculation shows that water falls in Class I and Class II of Doneen classification. All these parameters indicate that the groundwater in the area except that along the coastal regions is good for irrigation purpose.

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