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Original Research Paper

Quality Evaluation and Irrigational Suitability of Groundwater in a Lateritic Terrain, Vettikavala Block, South Kerala, India

G. S. Vidhya and R. B. Binoj Kumar
Department of Geology, University of Kerala, Kariavattom, Trivandrum, Kerala

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ABSTRACT

The geochemical characteristics of groundwater in the lateritic terrain of Vettikavala block, South Kerala was evaluated during the pre-monsoon and post monsoon seasons to assess its appropriateness for domestic and irrigational purposes. One hundred and one water samples from shallow open wells were collected and analysed for pH, EC, TDS and all major cations and anions. The results point out that certain areas with acidic pH are unsuitable for drinking and other domestic purposes. Piper diagram reveals that most of the samples were HCO_3 dominated, since dissolution plays an important role and also no major shifting was noticed during both the seasons suggesting a static regime. Irrigational suitability assessed by percent sodium reveals that 10% of the waters in the area are unsuitable.

INTRODUCTION

Water subsists virtually in each accessible environment on or near the earth's surface. Chemistry of groundwater has an imperative role that makes it as an interesting and multifaceted topic. Chemical processes in the groundwater environment are both multifaceted and fascinating. Characterizing and predicting these processes is one of the most challenging problems in groundwater science. Groundwater chemistry is relevant to all users of groundwater resources, whether it be for drinking, irrigation or industrial purposes. Chemistry of groundwater is central and the type and concentration of salts in groundwater depend on the geological environment and movement of groundwater. The present study focuses attention on the groundwater scenario of a lateritic aquifer and its suitability for domestic and irrigation purposes.

STUDY AREA

The study area wrap the Vettikavala block of Kollam district, Kerala state with an area of 204 km^2 (Fig. 1). As per the CGWB categorization the block is affirmed as semi-critical. The area receives an average annual rainfall of 30 cm. The area has an undulating topography with hills, valleys and low lying plains. This is an agrarian block with more focus on paddy cultivation. The study area is well drained by a network of first and second order streams and shows sub dendritic type of drainage pattern. Ittikara River is the major stream flowing across the study area.

GEOLOGY OF THE AREA

Geology of the area is relatively homogeneous comprising of precambrian crystallines. Among the crystallines the charnockites, biotite-gneisses and other unclassified gneisses cover major portions with laterites cappings. Nearly 90% of the area is characterized by lateritic soil. These are mostly reddish brown to yellowish. Laterite forms the major phreatic aquifer. Groundwater extracted from these aquifers is the main source of water supply for agriculture and domestic purpose in this area.

MATERIALS AND METHODS

Groundwater samples were collected from 101 dug wells during post and pre-monsoon periods. Water samples were collected in polythene bottles that were previously cleaned and rinsed with the sample water. The pH and electrical conductivity were measured in the field and then the samples were brought to the laboratory for the analysis of all major cations and anions. The methods used for the analyses were standardized as per procedures laid down by APHA (1985).

RESULTS AND DISCUSSION

Suitability of water for domestic use: The pH of an aqueous solution is controlled by inter-related chemical reactions that produce or consume hydrogen ions (Hem 1959). The pH of the analysed samples varies from 4.5-6.8 during pre-monsoon, and during post monsoon it varies from 3.7-6.7 showing an acidic trend with mean ranges of 5.75 and 5.19 respectively.

In general, pH distribution does not show any specific trend during pre-monsoon. The lowest value during this season was noted in the south eastern part of the study area. During post monsoon, pH value of less than 4.5 was noticed in most parts of the study area. Generally, pH of water is influenced by geology of the area and in the study area most of the wells are constructed in lateritic aquifers. The acidic nature of water causes rusting of pipes, minor intestinal problems and alters the taste of water. Low pH value can cause gastrointestinal disorders (Rajesh et al. 2001).

Electrical conductivity ranges from 45.1-509μS/cm in pre-monsoon and 32.2-582 μS/cm in post-monsoon, indicating that majority of the groundwater belong to low to medium conductive class, and within permissible limits. TDS was found in the range of 31.9-361 mg/L during pre-monsoon and 16.6-205 mg/L during post-monsoon, suggesting less dissolution of salts in the area and within permissible limit as per BIS (1991). TDS was found to be < 300 mg/L for both the seasons. Total hardness (TH) of water is characterized by contents of calcium and magnesium. TH in the study area have a maximum value of 175mg/L and 110mg/L during pre-monsoon and post-monsoon in that order. The calcium concentration was observed with maximum values of 17 and 48.96mg/L in both the seasons, which is beyond permissible limit. The magnesium concentration was observed with values ranging from 2-21.82mg/L and 2-18mg/L during pre and post monsoon respectively. The major anions identified were chloride, bicarbonate, sulphate, phosphate and nitrite. All the anions were found to be within permissible limit recommended by BIS. The mean and range values of all the parameters are given in Table 1.

Chemical classification and water types: The Piper trilinear diagram (Piper 1944) is the most widely used graphical representation of groundwater quality, and it helps to understand the geochemistry of shallow aquifers. The diagram is based on the ionic concentrations of the anions and cations and it brings about the chemical relationships more accurately than with the other possible plotting methods. Chemical composition of the analysed samples of the study area is represented in the Piper diagrams (Figs. 2a and 2b) for post monsoon and pre monsoon seasons respectively. The different water types obtained from the diagram for both seasons belong to $Ca^{2+}Cl^-$, $Ca^{2+}Na^+HCO_3^-Cl^-$, Na^+Cl^-, $Ca^{2+}Na^+Cl^-$, $Na^+HCO_3^-Cl^-$ and $Ca^{++}HCO_3^-Cl^-$. Only marginal shifting was noticed during both the seasons and it indicates a static regime than a dynamic one. It can be noticed that majority of the water samples in both the seasons belong to $Ca^{2+}Na^+Cl^-$ and $Ca^{++}Na^+HCO_3^-Cl^-$ types and this indicates HCO_3^- dominance and it is related to the process known as dissolution. Chandresekharam (1989) has opined that the

Table 1: Water chemistry of the studied samples in comparison with the drinking water quality standards.

Parameter		Pre-monsoon values	Post-monsoon values	BIS standard	
				Higheste desirabl	Maximum permissible
pH	Range	4.5-6.8	3.7-6.7	6.5 –8.5	Norelaxation
	Mean	5.75	5.19		
EC (μS/cm)	Range	45.1-509	32.2-582		
	Mean	156.39	137.91		
TDS (mg/L)	Range	31.9-361	16.6-205	500	2000
	Mean	110.78	71.26		
Hardness (mg/L)	Range	10-175	15-110	300	600
	Mean	47.47	42.47		
Ca^{2+} (mg/L)	Range	2.04-48.96	2.0-18.20	75	200
	Mean	5.33	4.68		
Mg^{2+} (mg/L)	Range	2-30	2-18	30	100
	Mean	8.29	7.62		
Cl^- (mg/L)	Range	0-63.9	10.65-248.5	250	1000
	Mean	27.06	33.53		
Na^+ (mg/L)	Range	4-46	1-44		200
	Mean	13.82	12.50		
K^+ (mg/L)	Range	0-30	0-26		40
	Mean	4.03	2.35		
NO_3^- (mg/L)	Range	0-5.69	0-1.14	45	100
	Mean	1.17	0.70		
SO_4^{2-} (mg/L)	Range	0-25.78	2.77-3.80	200	400
	Mean	5.66	3.29		
PO_4^- (mg/L)	Range	0-.17	0-1.29		5
	Mean	0.05	0.11		

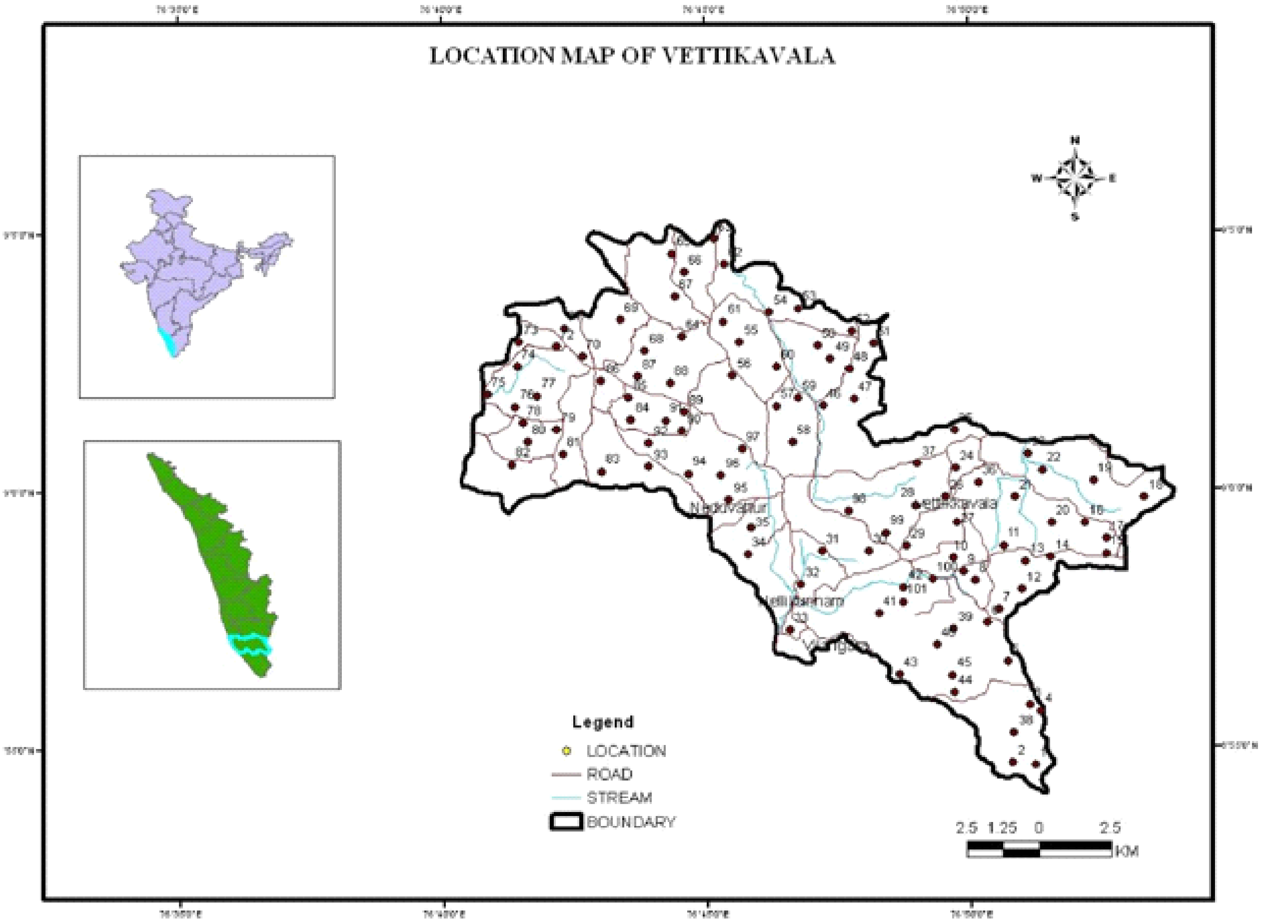

Fig. 1: Location map of Vettikavala.

groundwater from the lateritic terrain shall normally be of HCO_3 nature as the groundwater has high HCO^-_3 ions than SO_4^{2-} and Cl^- ions.

Evaluation of Groundwater Quality for Irrigation

Percent sodium: The irrigation water containing a high proportion of sodium will increase the exchange of sodium content of the soil, affecting the soil permeability, and the texture makes the soil hard to plough and unsuitable for seedling emergence (Trivedy & Goel 1984). If the percentage of sodium is above 60 with respect to (Ca+Mg+Na), it is undesirable for irrigation since it affects the permeability of the soils (Karanth 1987). Agricultural utility data chart is given in Table 2.

The calculated values of percent sodium of samples in post-monsoon range from 12 to 80, and in pre-monsoon from 12 to 82. A maximum of 60% sodium in groundwater is allowed for agricultural purposes.

The data chart for % Na shows that the groundwater in major part of the area ranges from good to permissible class (20-60%) in both the seasons; while rest of the samples fall in doubtful to unsuitable class (60-80%). The electrical conductivity and total dissolved solids of the groundwater have remained less than 500 throughout the year. The percent sodium, TDS and EC are well within limits. The general quality of groundwater in majority of the area is categorized as good for irrigation.

Suitability of water through U.S.S.L diagram: The classification of irrigation proposed by the US Salinity Laboratory (1954), based on the salinity and sodium hazards is much in vogue. Salinity hazard is a measure of electrical conductivity while sodium hazard is in terms of sodium adsorption ratio (SAR). For calculation of SAR, the ionic concentrations are expressed in epm.

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

Table 2: Agricultural utility chart.

No:	RSC		SAR		%Na		No:	RSC		SAR		%Na	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon		Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
1	-1.26	-2.07	2.00	0.477	55	22	52	-0.45	-0.33	1.17	1.392	55	61
2	-1.67	-1.73	0.65	0.401	28	20	53	-0.98	-0.65	0.20	0.259	12	18
3	-0.30	-0.62	2.40	0.441	67	26	54	-0.68	-0.43	0.82	0.794	42	46
4	-0.27	-1.03	1.03	0.256	51	14	55	-0.47	-0.93	0.34	0.059	25	13
5	-1.024	-2.07	0.87	0.416	34	16	56	-0.68	-0.72	1.34	1.381	50	50
6	-0.37	-1.12	0.95	0.358	48	20	57	-0.27	-0.78	2.70	2.778	73	68
7	-0.38	-0.37	0.68	0.368	39	26	58	-0.47	-0.42	0.61	1.492	37	60
8	-0.35	-0.45	0.87	0.736	48	40	59	-0.18	-0.52	0.55	0.667	40	35
9	-0.80	-1.05	0.59	0.216	29	13	60	-0.47	-0.53	1.10	1.103	50	50
10	-0.60	-0.55	1.52	1.239	53	51	61	-0.38	-1.21	0.68	0.324	40	18
11	0.26	-0.43	0.96	0.794	55	43	62	-0.73	-1.15	0.64	0.520	37	27
12	-1.38	-1.13	1.60	1.286	47	43	63	0.14	-1.23	0.30	0.312	23	18
13	-0.98	-0.57	2.39	2.465	63	67	64	-1.35	-1.03	0.53	0.511	28	26
14	-0.27	-1.05	0.63	0.324	41	17	65	-0.18	-0.17	0.63	0.522	38	36
15	-0.32	-1.20	0.38	0.204	24	12	66	-0.86	-0.37	0.29	0.588	16	35
16	-0.57	-0.60	0.25	0.267	18	19	67	-0.27	-1.25	1.03	0.653	51	28
17	-1.00	-0.67	0.50	1.477	26	55	68	-0.29	-0.57	1.32	1.816	57	59
18	-0.42	-1.45	1.66	1.18	61	43	69	-0.35	-1.02	1.11	0.636	52	30
19	-0.58	-0.77	0.24	0.47	18	25	70	-1.07	-0.88	1.40	1.741	49	57
20	-0.70	-0.92	1.34	1.046	50	43	71	-1.03	-1.33	0.73	0.754	37	33
21	-0.65	-0.67	0.51	0.431	31	25	72	-0.52	-0.07	0.52	0.611	29	37
22	-0.37	-0.75	0.66	1.292	39	49	73	-0.27	-0.62	2.22	1.830	69	59
23	-0.47	-0.37	0.82	0.588	45	36	74	-0.82	-1.15	0.57	0.910	27	34
24	-0.55	-0.75	1.23	0.985	53	44	75	-0.15	-0.60	0.91	0.334	39	22
25	-0.29	-0.97	0.66	0.486	40	24	76	-0.65	-1.03	1.29	1.180	53	45
26	-0.40	-1.79	0.77	0.511	39	20	77	-0.29	-0.20	0.36	0.550	26	39
27	-0.27	-2.33	2.86	1.362	73	39	78	-0.12	-0.90	1.10	1.148	49	44
28	-0.25	-0.70	0.34	0.253	29	17	79	-1.37	-1.12	1.98	1.175	60	53
29	-0.35	0.05	1.82	2.304	64	68	80	-0.77	-0.53	0.41	0.515	23	32
30	-1.15	-4.90	0.31	0.259	17	9	81	0.21	-0.85	2.89	1.291	82	46
31	-0.17	-0.45	1.74	1.48	65	57	82	-0.09	-0.63	0.34	0.482	26	28
32	-0.55	-0.43	0.34	0.556	23	36	83	-0.27	-0.41	0.31	0.522	25	34
33	-0.75	-0.73	1.23	1.362	49	51	84	-0.37	-0.75	0.66	0.369	39	21
34	-0.50	-0.92	0.55	0.550	31	27	85	-0.54	-0.68	0.22	0.469	19	25
35	-0.05	-1.25	0.78	0.402	54	20	86	-0.09	-0.55	0.87	0.688	50	37
36	-0.57	-0.05	1.49	2.809	59	80	87	-0.50	-0.47	1.23	1.377	56	58
37	-0.58	-1.20	0.67	0.307	45	22	88	-0.55	-0.73	0.68	0.389	39	24
38	-0.57	-0.55	0.32	0.360	25	21	89	-0.25	-1.08	0.78	0.301	47	17
39	-0.48	-0.85	0.45	0.410	27	23	90	-0.65	-0.02	0.25	0.416	22	36
40	-0.38	-1.02	1.85	0.847	60	35	91	-0.27	-0.68	1.03	0.800	54	40
41	-0.57	-0.55	0.25	0.413	18	26	92	-0.28	-0.38	0.80	0.344	42	21
42	-0.78	-1.03	0.44	0.449	25	25	93	-0.32	-0.70	0.51	0.379	31	22
43	-0.10	-0.55	0.47	0.550	36	33	94	-0.88	-1.23	0.21	0.469	17	24
44	-0.58	-0.48	0.30	0.305	23	26	95	-0.68	-1.22	0.93	1.137	42	43
45	-0.18	-0.28	0.71	0.515	44	32	96	-0.48	-1.28	0.64	0.358	35	20
46	-0.42	-0.58	1.04	0.355	49	24	97	-0.08	-0.60	0.52	0.293	38	20
47	-0.66	-1.70	0.46	0.397	26	19	98	-0.09	-0.60	1.13	0.587	56	32
48	-2.34	-1.35	0.88	0.661	28	25	99	-0.77	-0.40	1.93	2.442	59	70
49	-0.67	-1.20	0.30	0.562	23	25	100	-0.29	-1.00	0.36	0.220	26	15
50	-0.18	-1.55	0.55	0.550	36	24	101	-0.290	-0.35	0.73	0.371	41	28
51	-0.37	-0.62	0.73	0.505	46	31							

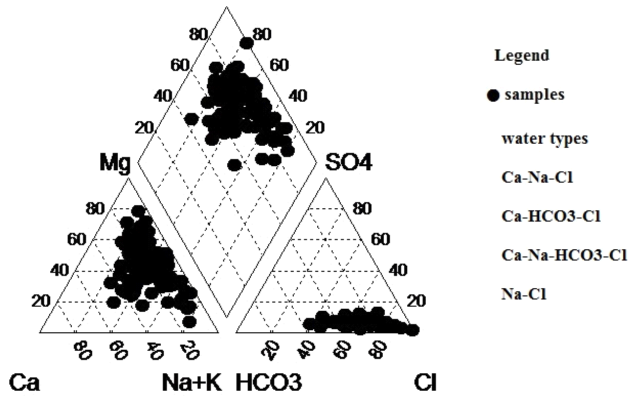

Fig. 2a: Piper Trilinear diagram (post-monsoon).

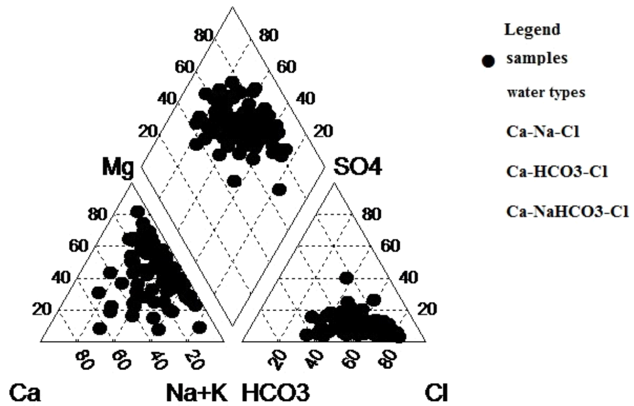

Fig. 2b: Piper Trilinear diagram (pre-monsoon).

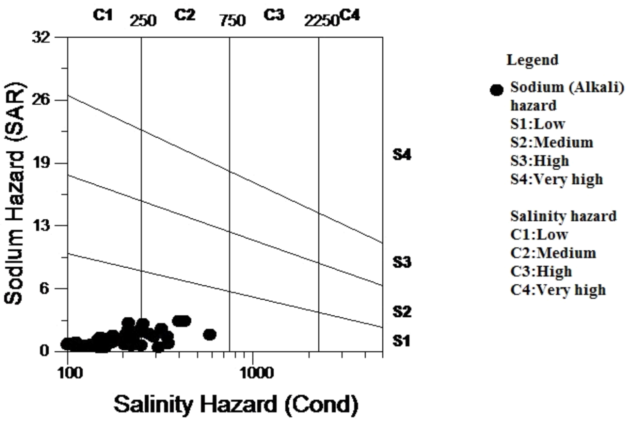

Fig. 3a: USSL diagram (post-monsoon).

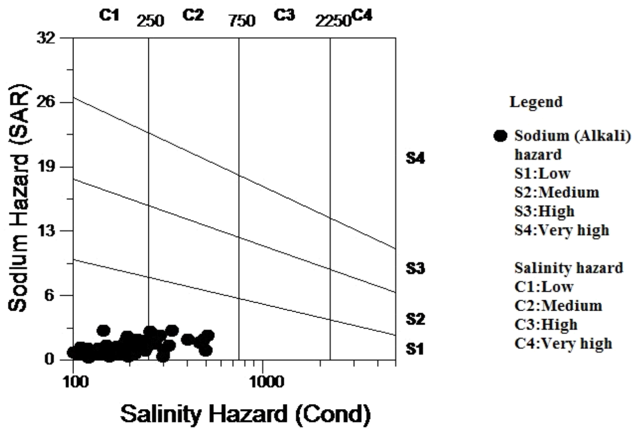

Fig. 3b: USSL diagram (pre-monsoon).

The classification of water for irrigation is determined graphically by plotting the values of specific conductance and SAR on the USSL diagrams. While C1, C2, C3, C4 and C5 type indicates salinity hazards, the S1, S2, S3 and S4 types indicate sodium hazard.

The results (Figs. 3a and 3b) show that most of the waters in the study area fall in C1S1 and C2S1 types during both the seasons. They are considered suitable to irrigate most of the crops.

Residual sodium carbonate: RSC index of water (Eaton 1950) is given by the equation:

$$RSC = [CO_3^- + HCO_3^-] - [Ca^{2+} + Mg^{2+}]$$

The units are expressed in epm. The water having excess of CO_3^- and HCO_3^- concentrations over the alkaline earths mainly Ca and Mg, in excess of allowable limits affects agriculture unfavourably (Eaton 1950). Lloyds & Heathcote (1985) have classed irrigation water based on RSC as (1) suitable (<1.25), (2) marginal (1.25-2.5) and (3) not suitable (>2.5). The RSC of <1.25 are safe for irrigation, and it indicates that Na^+ buildup is unlikely since Ca^{2+} and Mg^{2+} are in excess of what can be precipitated as CO_3^- (Ramakrisna 1988). The RSC of groundwater samples of the area for both the seasons fall under "suitable" type.

CONCLUSION

The seasonal variations of the ions were determined from the hydrochemical investigation of the groundwater. A major part of the study area during pre-monsoon and post-monsoon seasons shows pH of the order less than 6.8, indicating an acidic trend. The consumption of this water may lead to probable health hazards. The concentration of EC, TDS and other major ions of groundwater during both the seasons are within the limits and fit for domestic consumption. The Piper diagram shows that generally the area has basic type of water and chemically characterized by intermediate types. The irrigation suitability of the groundwater shown by percent sodium, shows that 90% of the area is considered good for irrigation, since most of the samples fall in good to permissible class. The plotting values over the USSL diagram have indicated that most of the samples fall in C1S1 and a few in C2S2 indicating low salinity/low sodium alkali hazard. Likewise, the value of RSC is also found to be within limits (<1.25 epm). In general, the groundwater in this lateritic terrain is considered good for irrigation and a periodical monitoring is essential to uphold quality of water at its optimal level.

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