Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 10, October 2021 :3684 – 3691

Research Article

Hydrochemical Characterization And Suitability Of Groundwater In Hard Rock And Marine Environments Of Lower Tamirabharani River Basin Tamil Nadu, India

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ABSTRACT

The present work is employed in Lower Tamirabharani river basin, Tuticorin district, Tamil Nadu and India. Most of the study area is underline by the Archaean crystalline rocks. The study area is associated with active agricultural activities region. The 48 groundwater samples were collected and analysed for major cations and anions. The irrigational parameters like; EC, Kelley's ratio, SAR values, Mg-hazards, HCO3 and RSC have been worked out to know the suitability of the groundwater for irrigational purpose. The plotting of SAR values in USSL diagram indicates that most of the samples have low SAR value. Out of 48 samples, two samples lies in C1-S1 field, 22 samples in C3-S1, 5 samples fell in C4-S2, two samples occur in C4-S3 and 17 samples in C2-S1, field (Fig. 3 and table 3) The C2-S1 and C2-S1 field in USSL diagram is considered as good water category for irrigation use. This implies that no alkali hazard is anticipated to the crops. 22 Location (45.83%) samples occurred within C3–S1 category Analytical data of PI values plotted on Doneen's diagram revealed that 19 samples fall in Class I, 27 samples belongs to under class-II and 2 samples fall under Class III. The sodium or alkali hazard limit for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil.

Key words: Groundwater; SAR; Sodium Percentage; Lower Tamirabharani river basin; Tamil Nadu.

Introduction

Groundwater plays an important role in Indian agriculture. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil (Michael, 1990). Groundwater always contains small amount of soluble salts dissolved in it. The kind and quality of these salts depend upon the sources for recharge of the groundwater and the strata through which it flows. The excess quantity of soluble salts may be harmful for many crops. Hence, a better understanding of the chemistry of groundwater is very essential to properly evaluate groundwater quality for irrigation purpose. Paddy crops, vegetables, fruits and food crops are the common agricultural produce of the people in the study area. The canal and tank waters are not available at many places in the study area or in case if available, they may not be able to supply adequate water for irrigating crops even at critical stages of crop growth. Under these circumstances, the groundwater becomes the main source of irrigation.

The more dependency on groundwater has led to aquifer stress in many places due to over exploitation, declining of water level, etc. At the same time, the aquifer stresses activate the hydrochemical process and will change the concentration of various ions of groundwater.

Geochemical processes in groundwater involve the interaction of country rocks with water, leading to the development of secondary mineral phases. The principles governing the chemical characteristics of groundwater were well documented in many parts of the world (Garrels and Christ, 1965; Stumm and Morgan, 1970; Swaine and Schneider, 1971; frappe et al., 1984; Herczeg, et al., 1991; Som and Bhattacharya, 1992; Pawar, 1993; Wicks and Herman, 1994; Kimblin, 1995).

Study Area

The major portion of the study area falls in Tuticorin district and parts of Tirunelveli District in Tamil Nadu. It lies between 8°26’35” and 8°54’09” N latitudes, and 77°38’50” and 78°8’22” E longitudes which covers an area of 1255.28 Sq km (Fig.1). Eastern part of the study area is coastal zone of the Bay of Bengal. The coastal zone includes recent age of coastal sand, calcareous sandstone with and without shells, clay, and kankar. The calcareous sandstone is seen at Kurumbur, Kayamoli, Ammanpuram and a few other places. Western part of the study area is underline by the Archaean crystalline rocks.The Archaean complex includes ridges of quartzite, charnockite, calc-granulite and the basement peninsular gneiss.

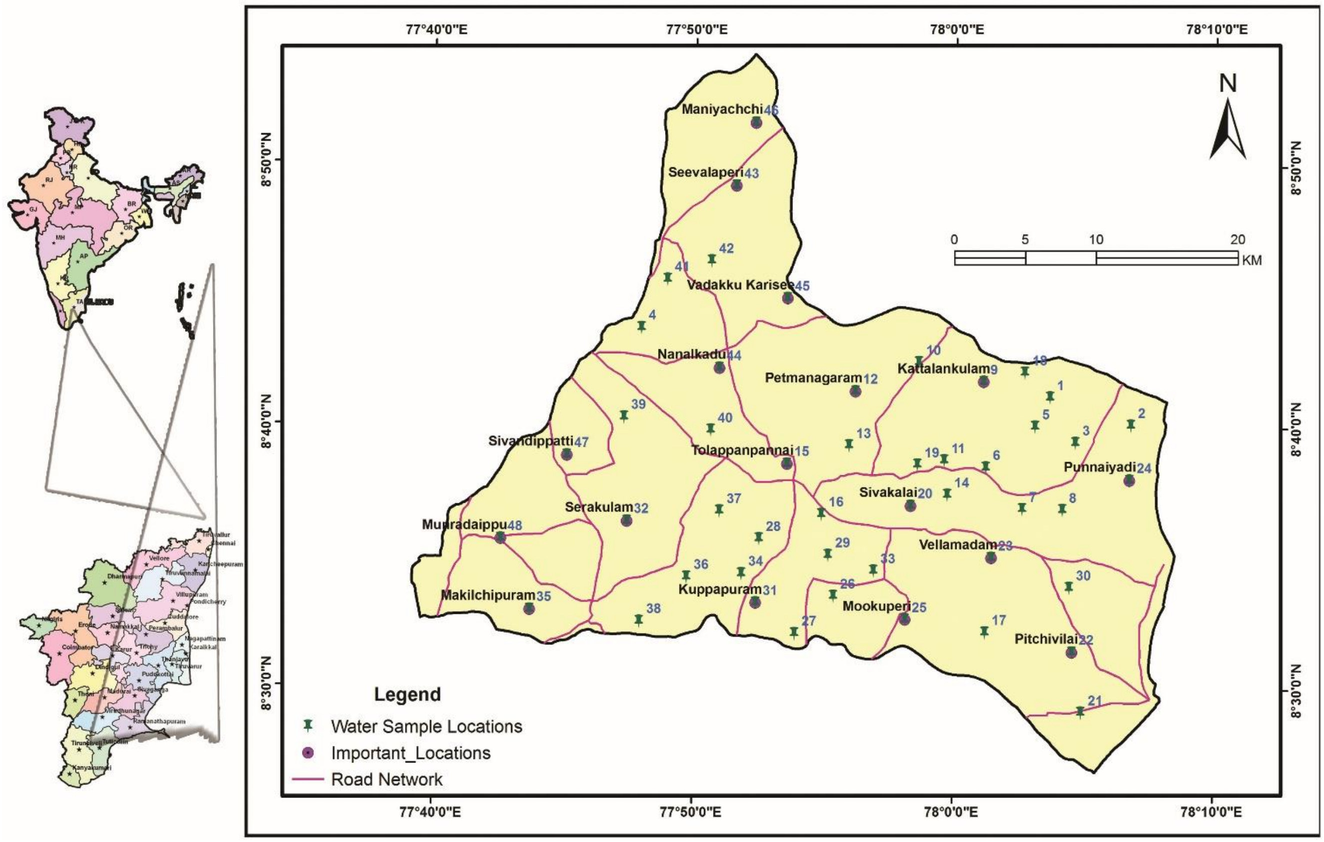

Fig.1.Study Area of Lower Tamirabharani River Basin and Sample Locations

Methodology

The base map was prepared using toposheet nos. 58 L/1, 2, and 58 H/13, 14 on 1:50,000 scale. Their attributes are added and analyzed in ArcGIS software. Totally 48 groundwater samples were collected from open and bore wells of various locations which are extensively used for drinking and also irrigation purposes in the Lower Tamirabharani river basin area. The locations of groundwater sampling stations are shown in the Fig. 1. pH and Electrical Conductance were measured within a few hours by using Elico pH meter and conductivity meter. Ca and Mg were determined titrimetrically using standard EDTA method and chloride was determined by silver nitrate titration (Vogel, 1968) method. Carbonate and bicarbonate were estimated with standard sulphuric acid. Sulphate was determined a gravimetrically by precipitating $BaSO_4$ from $BaCl_2$. Na and K was determined by Elico flame photometer (APHA, 1996). For determination of suitability for irrigation use SAR, Na% and PI were calculated and plotted on USSL diagram (Richards, 1954; Hem, 1985), and Doneen diagram (1961; 1964) respectively. The analyzed hydrochemical parameters of cations and anions is presented in the figure - 2

RESULTS AND DISCUSSION

The Maximum and Minimum values of hydro-chemical parameters of groundwater samples are presented in Table 1.The pH values are in the range of 6.28 to 7.74 indicating an acidic to alkaline nature. As per the (WHO, 2020) standards, all the samples fall within the recommended limit except 1, 22 samples (6.5 to 8.5) for human consumption. The conductivity value of the samples varies from 196 to 9360 µScm^{-1}. The TDS value varies from 137.2 to 6552 mg/l. Number of samples showed abnormal values of Conductivity and TDS (1, 2, 10, 17, 20, 22 samples) falling within the permissible limits (WHO, 2020). The alkalinity values vary from 52 to 2520 mg/l.
The sodium concentration in the groundwater of the study area varies between 22 to 942 mg/l. It can be observed from the tables that sodium concentration in the groundwater from some of the wells are very high and unsuitable for domestic applications when compare with WHO standard. Calcium, magnesium, total dissolved solids and total hardness in the groundwater are inter-related.

Parameters	WHO standards (2020)	Study area	
		Minimum	Maximum
pH	6.5–8.5	6.28	7.74
TDS (mg/L)	500–1,000	137	6552
Calcium (mg/L)	100	10	842
Magnesium (mg/L)	50	6	208
Chloride (mg/L)	250	24	1560
Sulfate (mg/L)	250	6	320
Sodium (mg/L)	200	22	942
Potassium (mg/L)	20	4	96
Bicarbonate (mg/L)	125–350	76.56	3166.26
Iron (mg/L)	0.1	0	4.2
Fluoride (mg/L)	1.0	0.2	3.5

Table – 1 Maximum and Minimum values of hydrogeochemical parameters

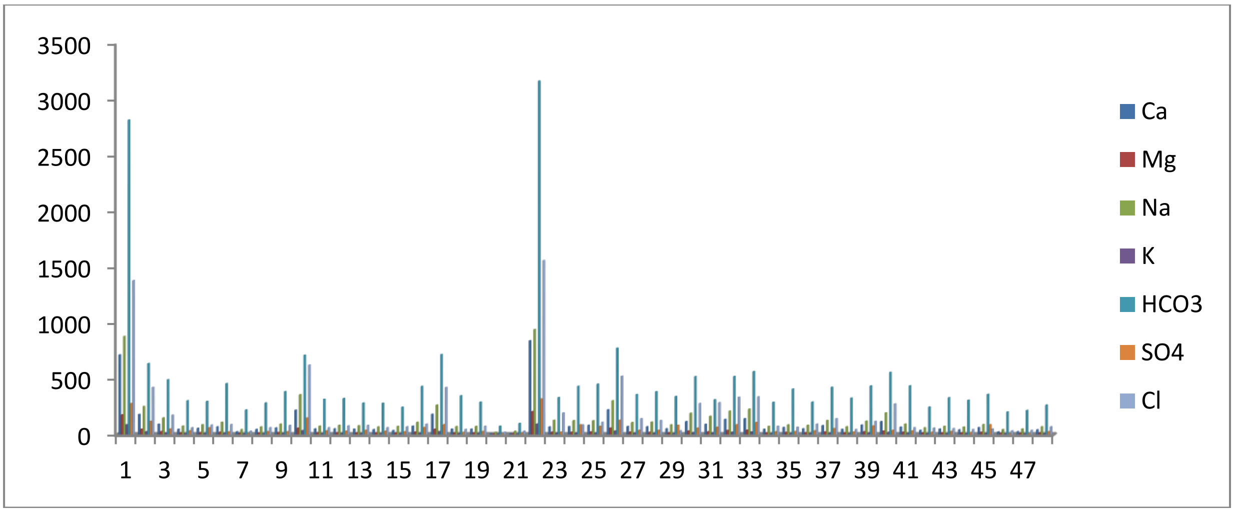

Fig. 2 ; Bar Diagram of Major Cations and Anions

Most of the samples showed normal values of calcium, magnesium and total hardness well within permissible limits (WHO, 2020) and thus the groundwater is not much hard. Based on the WHO standard 1, 2, 10, 17, 22, 26 and 30 samples are high concentration or contamination of groundwater for calcium, magnesium, total dissolved solids and total hardness ions.
The presence of carbonates, bicarbonates and hydroxides are the most common source of alkalinity in natural water. Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil. The chloride contents range from 24 to 1560 mg/I. 81.25% of samples falls within the permissible limit for drinking purpose (WHO, 2020). Iron (Fe) concentration of the groundwater ranging from 0 to 4.2 mg/l, but most of the samples fell in not potable category. Fluoride ionic concentration of the present investigation reveals that 56% of the samples fell in potable zone.

The sodium or alkali hazard limit for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). There is a significant relationship between SAR values of irrigation water and the extent to which sodium is absorbed by the soil. If groundwater used for irrigation is high in sodium and low in calcium, the cation-exchange complex may become saturated with sodium. This can destroy the soil structure owing to dispersion of the clay particles.

$$\text{SAR} = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

(Ragunath., 1987)

A simple method of evaluating high sodium water is the SAR. Calculation of SAR for given water provides a useful index of the sodium hazard of that water for soils and crops. A low SAR (2 to 10) indicates little danger from sodium; medium hazards are indicated between 10 to 18; high hazards between 18 to 26 and very high hazards more than that. The lower the ionic strength of the solution, the greater the sodium hazards for a given SAR. The value of SAR in the groundwater samples of the study area ranges from 1.36 to 7.63. Based on the table, the groundwater of the study area falls under the category of little danger except four samples (7, 20, 21, and 46). High sodium water may produce harmful levels of exchangeable sodium in most soils and will require special soil management like good drainage, high leaching, and organic matter additions.

The sodium percentage is calculated as;

$$\text{Na\%} = \frac{Na+K}{Ca+Mg+Na+K} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

(Ragunath., 1987)

Where all ionic concentrations are expressed in Millieqivalent per litre.
The sodium percentage in the study area varies from 52.04 to 56.85 . As per the Bureau of Indian Standards, 1991 standards, a sodium percentage of 60 is the maximum recommended limit for irrigation water. The high sodium saturation in the water samples directly causes calcium deficiency.

USSL Diagram
The plotting of SAR values in USSL diagram indicates that all the samples have low SAR value. Out of 48 samples, two samples lies in C_1-S_1 field, 22 samples in C_3-S_1, 5 samples fell in C_4-S_2, two samples occur in C_4-S_3 and 17 samples in C_2-S_1, field (Fig. 3 and Table 2) The C_2-S1 and C2-S_1 field in USSL

diagram is considered as good water category for irrigation use. This implies that no alkali hazard is anticipated to the crops. 22 Location (45.83%) samples occurred within C_3–S_1 category. This category is suitable for irrigational purposes.If the SAR value is greater than 6 to 9, the irrigation water will cause permeability problems on shrinking and swelling types of clayey soils (Saleh et al. 1999). The C_3S_1 category, this class are could be used for all types of crops.

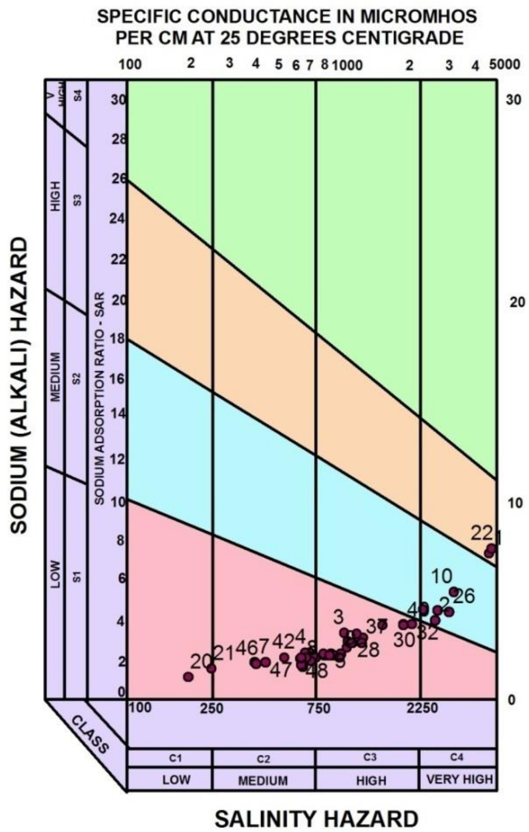

Fig. 3 USSL Diagram of Lower Tamirabharani river basin

Table 2. Classifications of groundwater samples based on USSL in Lower Tamirabharani river basin

Sl. No.	Class	Water Class	Number of Samples	
			May - 2013	**Total No.**
1	C1-S1	Good	20,21	2
2	C2-S1	Good	4,7,8,11,13,14,15,18,19,34,38,42,43,44,46,47,48	17
3	C3-S1	Good	3,5,6,9,12,16,23,24,25,27,28,29,30,31,32,35,36,37,39,40,41,45	22
4	C4-S1	Good	-	-

5	C3-S2	Moderate	-	-
6	C4-S2	Moderate	2,10,17,26,33	5
7	C4-S3	Bad	1,22	2
8	C3-S3	Bad	-	-

Permeability Index (PI)

The soil permeability is affected by long term use of irrigation water. It is influenced by sodium, calcium, magnesium and bicarbonate contents of soil. Doneen (1964) has evolved a criterion for assessing the suitability of water for irrigation based on Permeability Index (PI):

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100$$

Na,Ca Etc. values in epm

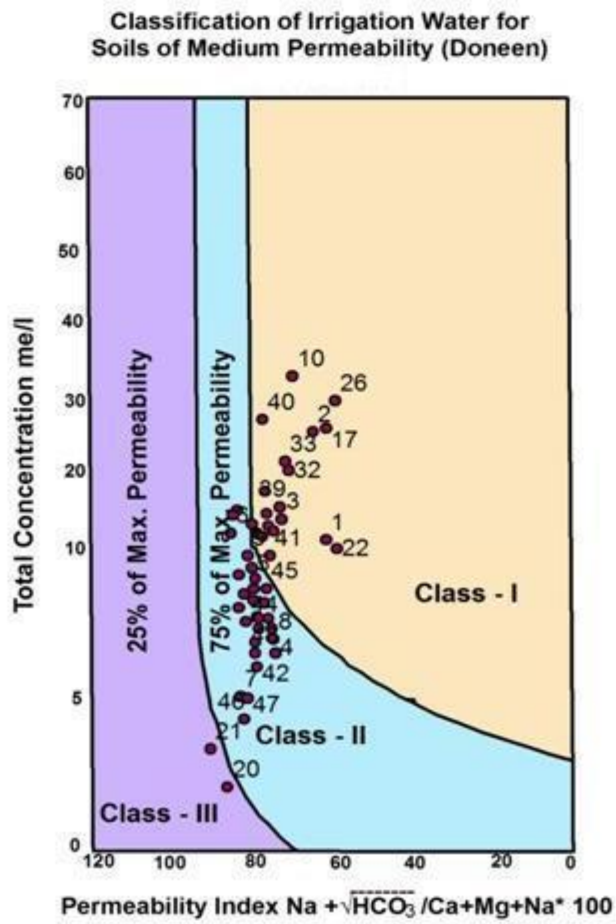

Fig. 4; Doneen's Diagram of Lower Tamirabharani river basin

Classification of irrigation water for soils of medium permeability diagram (Fig. 4) reveals the most of the samples fell under class-II. Analytical data of PI values plotted on Doneen diagram revealed that 19 samples fall in Class I, 27 samples belongs to under class-II and 2 samples fall under Class III (Fig. 4 and Table 3). The water sample fall under, Classes I and II in the Doneen diagram are generally good for irrigation purposes.

Table 3. Classifications of groundwater samples based on Doneen's in Lower Tamirabarani river basin

Category of Irrigation Water	Sample Locations	Total No. of Samples
Class - I	1,2,3,10,16,17,22,23,24,26,27,28,30,32, 33,37,39,40,41	19
Class - II	4,5,6,7,8,9,11,12,13,14,15,18,19,25,29,31,34,35,36,38,42,43,44,45,46,47,48	27
Class - III	20,21	2

Conclusion

In this study, the assessment of groundwater for irrigational uses has been evaluated on the basis of cations and anions concentration. The saline area is demarcated using the EC and it shows 72.92% of the samples suitable for irrigation purposes. With respect to SAR and sodium percentage, more than 91.67% of the samples are within the permissible limit and the groundwater is suitable for irrigation purpose. The pH values indicating an acidic to alkaline nature for human consumption. The conductivity and TDS values in study period, the number of samples showed abnormal values. The presence of carbonates, bicarbonates and hydroxides are the most common source of alkalinity in natural water. Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil. The plotting of SAR values in USSL diagram indicates that all the samples have low SAR value. Out of 48 samples, two samples lies in C_1-S_1 field, 22 samples in C_3-S_1, 5 samples fell in C_4-S_2, two samples occur in C_4-S_3 and 17 samples in C_2-S_1, field. The C_1-S1 and C_2-S_1 field in USSL diagram is considered as good water category for irrigation use. Classification of irrigation water for soils of medium permeability diagram reveals the most of the samples fell under class-II.

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