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ORIGINAL ARTICLE

GROUNDWATER QUALITY STUDY FOR IRRIGATION PURPOSE IN LOWER TAMIRABHARANI RIVER BASIN, TAMIL NADU, INDIA

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ABSTRACT

The present study area is located in Lower Tamirabharani river basin, Tamil Nadu and India. 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, 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 all 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. 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. Percentage of sodium plotted on Wilcox diagram indicates that out of 48 samples, 19 samples belong to Excellent to good category, 16 samples belong to good to permissible category, 6 samples belong to Permissible to doubtful category and 3 samples fell under unsuitable category. Analytical data of PI values plotted on Doneen's diagram revealed that 19 samples fall in Class I, 27 samples belong 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 adsorbed by the soil.

Keywords: SAR *(Sodium Adsorption Ratio)*; Tamirabharani River; Tamil Nadu.

1.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.

Standard urban groundwater problems like inadequately controlled groundwater abstraction, excessive urban infiltration and excessive subsurface contaminant load are initiated by the requirement of water supply, wastewater or solid waste disposal (Pokrajac 1999). Lateral contamination of groundwater aquifers from stationary sources occur in several situations. Streams, lakes, drainage channels, waste-water disposal sites or stagnant ponds which contain contaminated water may get connected to groundwater aquifers laterally. If so, they cause the spread of the contaminant into the adjoining aquifers. In such situations, it is proposed to locate wells near the contaminated water bodies. This is essential to predict the spread of the contaminants to the adjoining aquifers. Such predictions are useful to decide the safe distance for the location of wells or to predict water quality in adjoining wells which already exist (Basak and Murty 1977).

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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). This paper investigates the possible chemical processes of groundwater rock interaction in hard rock terrain.

2.MATERILAS AND METHODS

Study Area

The major portion of the study area falls in Thoothukudi 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 covering an area of 1255.28 Sq km (Fig.1). Easter part of the study area is coastal zone of the Bay of Bengal. Western part of the study area is underline by the Archaean crystalline rocks.

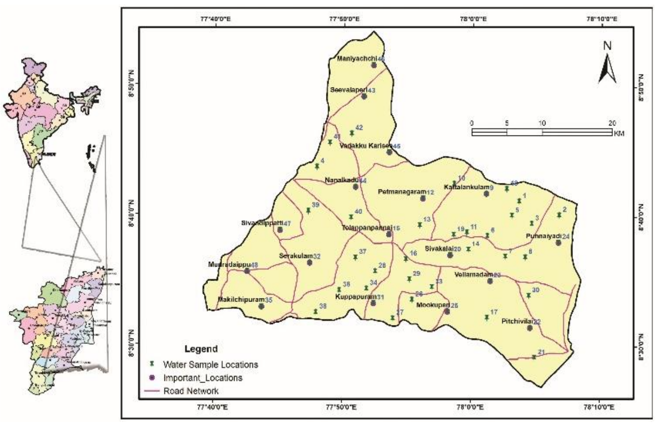

Fig.1. Study Area of Lower Tamirabharani River basin and Sample Locations

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. 48 groundwater samples 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), Wilcox diagram (1955) and Doneen diagram (1961; 1964) respectively.

3.RESULTS AND DISCUSSION

Water Quality Analysis for Irrigation Purpose

The hydro-chemical analysis data 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, 2010) 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, 2010). The alkalinity values varies from 52 to 2520 mg/l. 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 sodium concentration in the groundwater from 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 some of the domestic applications (WHO, 2013). calcium, magnesium, nitrate, total dissolved solids and total hardness in the groundwater are inter-related.

Most of the samples showed normal values of calcium, magnesium and total hardness well within permissible limits (WHO, 2010) 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, nitrate, total dissolved solids and total hardness ions. The chloride contents range from 24 to 1560 mg/I. 81.25% of samples falls within the permissible limit for drinking purpose (WHO, 2010). 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.

Groundwater always contains measurable quantities of dissolved substances, which are called salts. The salts present in the water, besides affecting the growth of the plants directly, also affect the soil structure, permeability and aeration, which indirectly affect the plant growth. The total concentration of soluble salts in irrigation water can thus be expressed for the purpose of classification of irrigation water (Table 1) as follows: less than 250 µScm-1 were classified as low salinity area. These area's crops yield is low. Second and third categories of groundwater suitable for all crop cultivation and respectable yield. Final class of the groundwater must be not suitable for irrigational purposes due to very high salinity.

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 adsorbed 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.

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

(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 (Table 1). Based on the table, the groundwater of the study area falls under the category of little danger except four samples (7,20,21,46). 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;

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

(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 (Table 1). 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.

Table 1. Chemical Composition of Groundwater (Ionic concentrations are expressed in mg/L and EC in μScm^{-1})

Station	Ca	Mg	Na	K	Fe	HCO3	CO3	SO4	Cl	F	pH	EC*	TDS	K. Ratio	RSC*	SAR*	Na%	TH
Pullaveli	716	178	880	90	3.5	2817.26	0.00	280	1380	3.2	6.28	8740	6118	0.76	-4.18	7.63	44.62	3580
Pazhayakayal	182	50	254	27	1.8	638.03	0.00	120	424	1.2	6.92	2480	1736	0.84	-2.71	4.30	47.14	910
Agaram	95	29	151	17	1.5	493.57	0.00	52	176	2.5	7.34	1452	1016	0.92	0.97	3.48	49.61	476
Arasankulam	49	18	78	10	0.3	305.25	0.00	36	64	2.8	7.56	719	503	0.86	1.08	2.42	48.13	246
Sakkamalpuram	58	20	90	11	0.3	299.19	0.00	64	88	3.5	7.58	844	591	0.87	0.40	2.62	48.33	288
Siruthondanallur	71	23	112	13	3.8	458.34	0.00	27	92	1.6	7.47	1062	743	0.89	2.06	2.95	48.90	356
Sethukkuvaithan	27	13	48	7	0.2	222.08	0.00	6	32	0.4	7.64	424	297	0.88	1.25	1.93	48.84	136
MelaAuthoor	48	17	70	9	4.2	285.86	0.00	28	64	0.4	7.59	638	447	0.80	0.88	2.20	46.16	238
Kattalankulam	62	21	96	12	0.3	386.81	0.00	28	84	0.6	7.44	896	627	0.86	1.50	2.67	47.92	312
Pandaravilai	220	59	359	38	2.5	712.18	0.00	150	624	2.2	6.89	3530	2471	0.99	-4.14	5.55	51.18	1100
Perunkulam	53	19	77	10	1.6	317.46	0.00	36	64	1.2	7.52	708	496	0.80	1.03	2.31	46.24	264
Petmanagaram	54	19	85	11	1.4	325.41	0.00	32	80	1.0	7.46	792	554	0.87	1.05	2.53	48.13	272
Srivaikundam	51	18	81	10	0.5	284.09	0.00	40	84	2.0	7.53	754	528	0.87	0.60	2.48	48.34	256
Mottachikudiyiruppu	47	17	71	9	1.8	282.74	0.00	32	64	1.4	7.42	651	456	0.82	0.85	2.25	46.79	236
Tholappanpannai	38	15	75	9	0.3	247.33	0.00	28	72	1.8	7.47	689	482	1.03	0.89	2.59	52.49	192
Sivaganapuram	78	25	112	13	0.3	433.21	0.00	65	96	0.2	7.33	1060	742	0.82	1.15	2.82	46.66	392
Manakkadu	184	50	266	29	2.4	717.79	0.00	90	424	2.8	7.02	2598	1819	0.87	-1.54	4.48	48.01	920
Piramayapuram	51	18	74	9	0	349.24	0.00	22	48	1.6	7.48	684	479	0.80	1.66	2.27	46.13	256
Varatharajapuram	51	18	75	10	3.0	292.86	0.00	30	76	1.4	7.54	691	484	0.80	0.74	2.29	46.36	256
Sivakalai	10	6	22	4	0	76.56	0.00	6	24	0.4	7.29	196	137	0.96	0.26	1.36	51.74	48
Therikudiyiruppu	11	9	32	5	0	101.52	0.00	12	32	0.6	7.35	264	185	1.11	0.39	1.77	54.78	56
Pitchivilai	842	208	942	96	1.8	3166.26	0.00	320	1560	1.2	6.35	9360	6552	0.69	-7.24	7.53	42.34	4210
Vellamadam	71	23	130	15	0.3	333.75	0.00	24	196	1.0	7.42	1242	869	1.04	0.02	3.43	52.58	356
Punnaiyadi	73	23	127	15	0.2	434.68	0.00	90	88	0.2	7.36	1214	850	1.00	1.56	3.32	51.54	364
Mookuperi	85	26	125	14	0.3	454.01	0.00	76	112	2.2	7.44	1185	830	0.85	1.04	3.03	47.47	424
Sundapuram	224	60	305	33	1.5	774.97	0.00	130	524	1.0	6.85	2990	2093	0.82	-3.39	4.67	46.69	1120
Thoppur	74	24	110	13	0.2	359.48	0.00	40	144	1.2	7.41	1039	727	0.84	0.22	2.84	47.39	372
Kulathukudiyiruppu	72	23	113	13	0.2	385.52	0.00	40	128	2.6	7.3	1070	749	0.89	0.81	2.96	48.82	360
Athinathapuram	54	19	89	11	0	343.06	0.00	85	36	1.4	7.28	825	578	0.90	1.34	2.63	49.07	272
Athalikulam	118	34	193	21	0.6	521.01	0.00	60	280	1.0	7.06	1872	1310	0.96	-0.20	4.02	50.58	592
Kuppapuram	94	28	166	19	0.2	314.16	0.00	68	288	1.2	7.42	1596	1117	1.03	-1.86	3.85	52.26	468
Serakulam	138	39	212	23	1.2	522.62	0.00	90	336	1.6	7.01	2060	1442	0.91	-1.54	4.10	49.27	690
Udayarkulam	144	41	230	25	0.8	566.39	0.00	110	340	0.4	6.94	2240	1568	0.95	-1.24	4.36	50.28	720
Vallakulam	50	18	76	10	0	291.28	0.00	27	76	1.8	7.67	696	487	0.83	0.83	2.34	47.22	248
Makilchipuram	66	22	89	11	0	408.98	0.00	29	68	0.2	7.42	833	583	0.77	1.64	2.44	45.12	328
Ariyanayagipuram	54	19	85	11	3.6	293.07	0.00	36	96	1.8	7.42	793	555	0.87	0.52	2.53	48.16	272
Kalvi	82	26	128	15	0.3	425.11	0.00	56	144	2.8	7.44	1224	857	0.90	0.74	3.16	48.90	412
Athichanallur	49	18	72	9	0	327.93	0.00	25	48	1.8	7.28	658	461	0.80	1.48	2.24	46.31	244
Achimadam	87	27	122	14	0.2	436.94	0.00	80	120	2.2	7.35	1155	809	0.80	0.59	2.92	46.23	436
Saithunganallur	118	34	196	22	1.4	558.89	0.00	40	276	2.6	7.37	1904	1333	0.98	0.48	4.10	51.15	588
Maruthakulam	69	23	96	12	0	438.26	0.00	36	64	1.2	7.42	896	627	0.79	1.90	2.56	45.73	344
Ulakudi	40	16	63	8	0	248.69	0.00	22	60	1.6	7.54	569	398	0.83	0.80	2.14	47.33	200
Karaimanakkadu	52	18	76	10	0	332.08	0.00	30	56	0.8	7.48	696	487	0.80	1.33	2.29	46.19	260
Nanalkadu	45	17	69	9	0.3	309.14	0.00	22	48	0.6	7.35	632	442	0.83	1.43	2.23	47.06	226
Kaliyavoor	65	22	92	11	0	362.07	0.00	90	52	1.8	7.4	856	599	0.80	0.93	2.52	46.02	324
Fatimakovai	26	12	47	7	0	204.47	0.00	6	36	0.2	7.62	410	287	0.90	1.07	1.92	49.32	128
Keelanatham	28	13	52	7	0	218.58	0.00	9	40	0.2	7.74	462	323	0.93	1.14	2.05	50.11	140
Palayanchettikulam	45	17	72	9	0.2	266.10	0.00	28	72	1.0	7.38	659	461	0.87	0.75	2.33	48.19	224

EC* – Electrical conductivity, RSC* – Residual Sodium Carbonate, SAR* – Sodium Adsorption, Ratio, TH* - Total Hardness

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. 2 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.

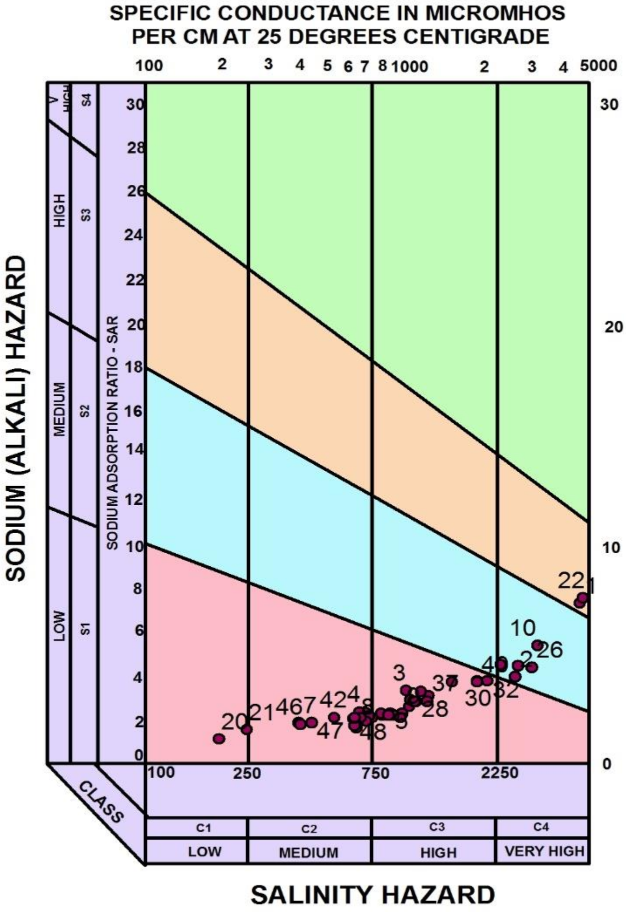

Fig. 2 USSL Diagram of Lower Tamirabarani river basin

Table 2. Classifications of groundwater samples based on USSL

Sl. No.	Class	Water Class	Number of Samples	
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	-	-

Wilcox's Diagram

Another method for determination of suitability for agricultural use in groundwater is by calculating Na^+ percentage (Wilcox, 1955), because Na^+ concentration reacts with soil to reduce its permeability (Todd, 1980). Percentage of sodium values of groundwater samples indicate that most of the groundwater samples show excellent to permissible category for irrigation use, except few samples which are under Unsuitable category (Table 3).

Percentage of sodium plotted on Wilcox diagram indicates that out of 48 samples, 19 samples belong to Excellent to good category, 16 samples belong to good to permissible category, 6 samples belong to Permissible to doubtful category and 3 samples fell under unsuitable category (Fig. 3).

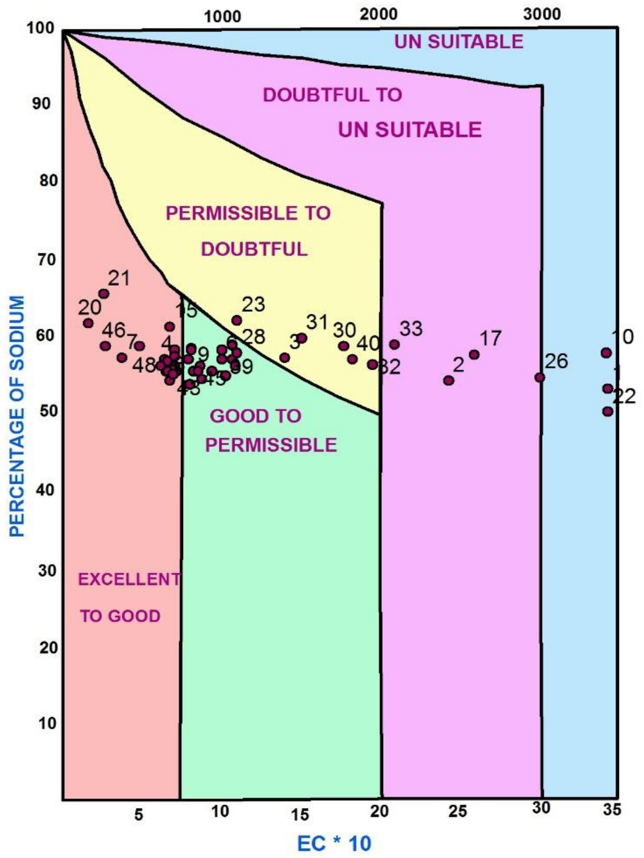

Fig. 3 Wilcox's Diagram of Lower Tamirabarani river basin

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

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

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

Classification of irrigation water for soils of medium permeability diagram (Fig. 4) reveals the most of the samples fall 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 4). The water sample fall under, Classes I and II in the Doneen diagram are generally good for irrigation purposes.

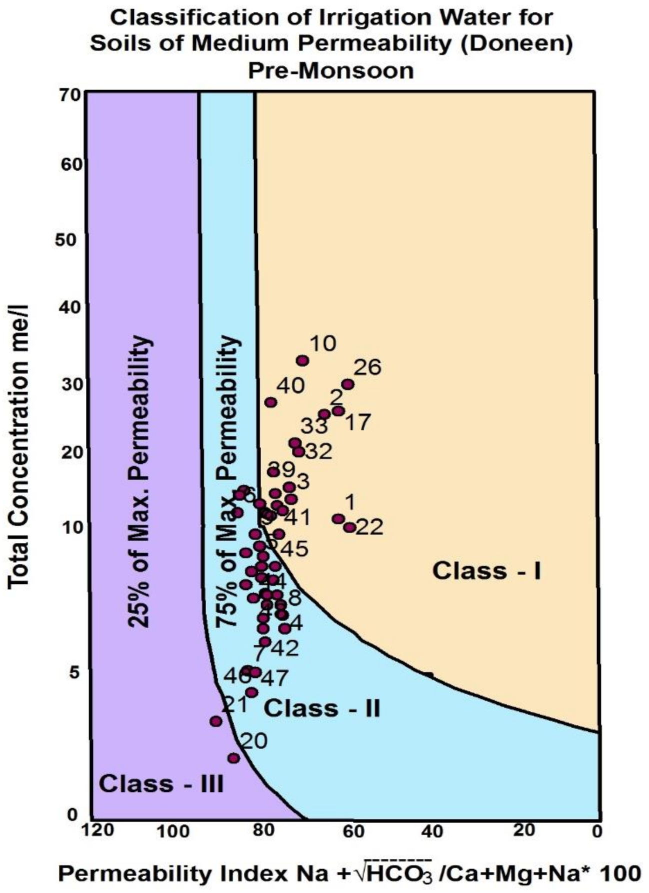

Fig. 4 Doneen's Diagram of Lower Tamirabarani river basin

Table 4. 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

4.CONCLUSION

In this study, the assessment of groundwater for irrigational uses has been evaluated on the basis of various guidelines. The saline area is demarcated using the EC groundwater quality data. The 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_2-S1 and C2-S_1 field in USSL diagram is considered as good water category for irrigation use. Percentage of sodium plotted on Wilcox diagram indicates that out of 48 samples, 19 samples belong to Excellent to good category, 16 samples belong to good to permissible category, 6 samples belong to Permissible to doubtful category and 3 samples fell under unsuitable category. Classification of irrigation water for soils of medium permeability diagram reveals the most of the samples fall under class-II.

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