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Suitability Assessment of Groundwater for Irrigation Purpose in Veppanthattai Block, Perambalur District, Tamil Nadu

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ABSTRACT

Groundwater is a major water source for agricultural irrigation in Veppanthattai block. Forty-five groundwater samples were collected at various standard locations from the study area in the year of 2015 at pre-monsoon, post monsoon and monsoon seasons periodically. The concentrations of physicochemical parameters like pH, Electrical Conductivity (EC), total dissolved solid (TDS), Total Hardness (TH), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, NO_3^{-} and PO_4^{3-} were analyzed. The results of the concentrations were interpreted and compared with different irrigation standards namely EC, Percent Sodium (%Na), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Permeability Index (PI), Kelly's Ratio (KR), Ion Exchange as chloro-alkaline indices (CAI-I and CAI-II), Chloride classification and Magnesium ratio.

Keywords**:** Groundwater, Veppanthattai, Irrigation, Season, Physicochemical parameters

1. INTRODUCTION

Groundwater plays an important role in Indian agriculture. In the study area, the groundwater is the main source of irrigation. Irrigation is the application of water for the farming of crops, trees, grasses and like. Irrigation water quality is a kind and amount of salt present in the water and their belongings on crop development. The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt receiving ability of the plants, climate and drainage characteristics of the soil [1].

Groundwater forever contains few soluble salts suspended in it. The variety 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 to many crops. Hence, a better understanding of the chemistry of groundwater is important to properly evaluate groundwater quality for irrigation purposes [2].

To assess the overall irrigational water quality of the study area, nine irrigation standards have been considered namely Sodium adsorption ratio (SAR), Percentage Sodium (%Na), Residual Sodium Carbonate (RSC), Kelley's Ratio (KR), Permeability index (PI), Magnesium Ratio (MR), Ion Exchange (CAI – I &CAI – II), Electrical conductivity (EC), Chloride classification. All these parameters mean values are represented in Table 1.

Study Area

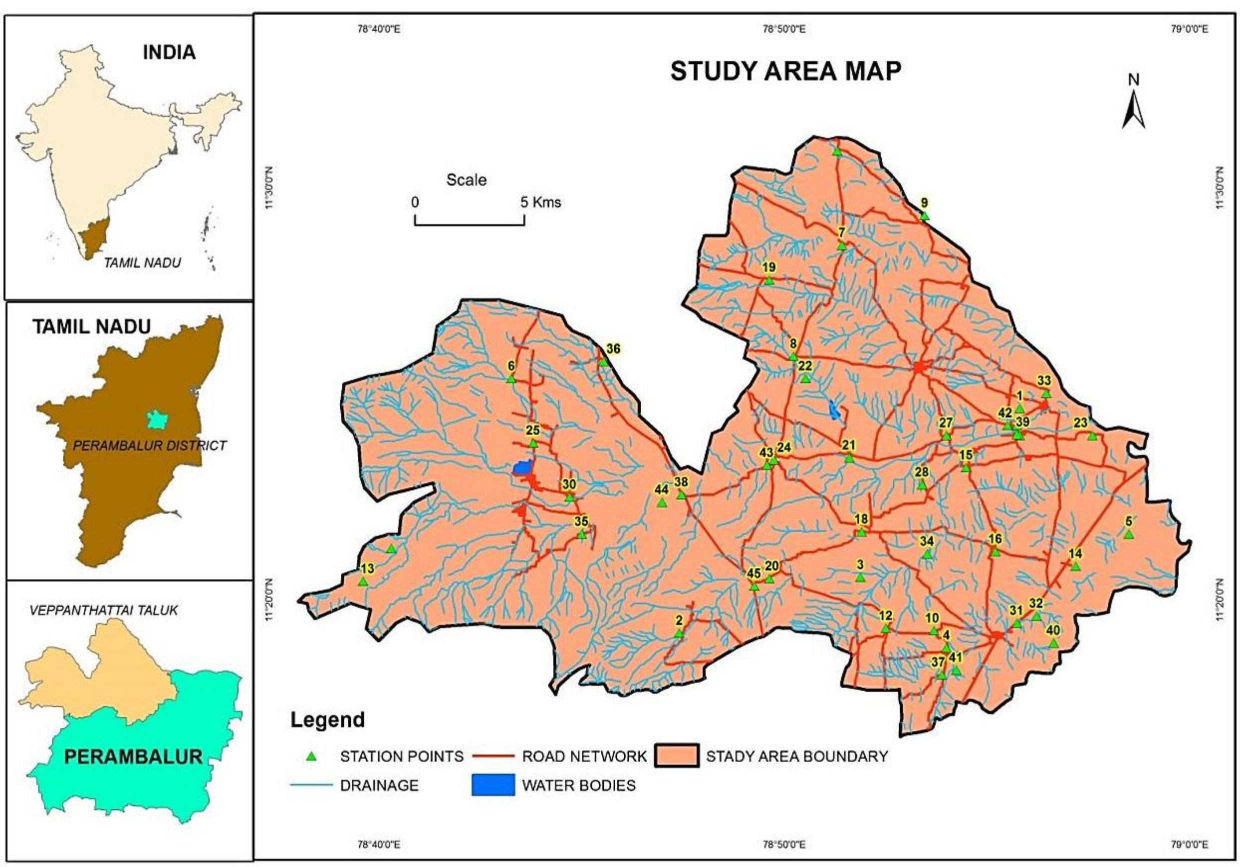

Figure 1. Location map of the Study area

Perambalur District Located and spread between 10.54' and 11.30' degree Northern latitude and 78.40' and 79.30' degree of the Eastern longitude. It is an inland district without the coastal line. The District has Vellar River in the North and it has well marked natural divisions. The pachamali hill situated on the North boundary of Perambalur is the most important hill in the district. It is bounded on the North by Cuddalore and Salem Districts, South by Tiruchirappalli, East by Ariyalur District, West by Tiruchirappalli and Salem Districts. The density of population in the district is 322 per Sq.Km. Perambalur District is centrally located in Tamil Nadu and is 267 K.M away, in the southern direction, from Chennai. The District has an area of 3691 Sq.Km.

Veppanthattai is one of the prominent block in Perambalur district of the state of Tamilnadu. This area is located 13 km away from Perambalur on the way to Attur. The area faces Krishnapuram on the northern side, Esanai on the southern side and Valikandapuram in the eastern side.

2. MATERIALS AND METHOD

45 groundwater samples were collected from study area for investigation. They were collected in cleaned 2 L polyethene bottles from respective bore wells. Each bottle was rinsed with distilled water for avoiding any possible contamination. The analysis was carried out systematically in the laboratory using instrumental techniques. Standard books and manuals were followed for the analysis. Concentrations are expressed in milligrams per liter (mg/L) except pH but EC in μS (then converted into meq/l for irrigation) [14-20].

pH meter (Systronicsdigital model 335) was used to determine the hydrogen ion concentration. Conductivity meter was used for analysis of EC. Total Alkalinity (TA) was estimated volumetrically by neutralizing with Standard HCl. Total Hardness (TH) and Calcium Hardness (CH) as $CaCO_3$ were determined volumetrically by using standard EDTA soln. Phosphate and Nitrates were determined by using a colorimeter. Flame photometer was used for analysis of Na and K. Sulphate and Dissolved Oxygen (DO) were estimated by precipitation method by using BOD bottle and Chloride, volumetrically by using standard $AgNO_3$ Solution.

3. RESULT AND DISCUSSION

The results of the irrigation quality standards are expressed in Table 1. And the discussions are as follows.

Sodium adsorption ratio (SAR)

The most useful parameter for determining the suitability of groundwater for irrigation purposes is the sodium adsorption ratio (SAR) values. The sodium adsorption ratio (SAR) values were calculated for each sample by the following equation given by Richards [3]. The concentrations are expressed in meq/l. The Groundwater categorization based on sodium adsorption ratio is expressed in Table 2.

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

The sodium adsorption ratio (SAR) values range from 1.018 to 2.105 (mean 1.624), 1.223 to 2.318 (mean 1.839) and 0.958 to 2.144 (mean 1.572) at post monsoon, pre-monsoon and monsoon season, respectively. Based on the SAR all the samples are suitable for irrigation.

Table 1. Variation of irrigation Quality Standard during different seasons

Irrigation standard	unit		Post monsoon	Pre monsoon	Monsoon
SAR	meq/l	MIN	1.018	1.223	0.958
		MAX	2.105	2.318	2.144
		MEAN	1.624	1.839	1.572
%Na	%	MIN	22.47	24.62	21.45
		MAX	38.91	38.96	38.75
		MEAN	31.72	32.9	31.38
RSC	meq/l	MIN	-7.36	-6.46	-5.53
		MAX	1.20	0.97	0.99
		MEAN	2.25	2.29	-2.05
KR	meq/l	MIN	0.23	0.26	0.22
		MAX	0.53	0.53	0.51
		MEAN	0.37	0.41	0.37
PI	meq/l	MIN	38.39	40.26	37.78
		MAX	57.11	58.77	56.51
		MEAN	47.94	48.34	48.40
MR	meq/l	MIN	40.68	41.30	41.98
		MAX	47.48	48.74	48.28
		MEAN	44.63	44.59	45.35

CAI - I	meq/l	MIN	-0.44	-0.69	-0.79
		MAX	0.69	0.71	0.66
		MEAN	0.28	0.31	0.14
CAI - II	meq/l	MIN	-0.19	-0.27	-0.31
		MAX	1.21	1.11	0.93
		MEAN	0.32	0.35	0.18
EC	µS/cm	MIN	1098.88	1314.18	1034.38
		MAX	1909.69	2181.35	1746.80
		MEAN	1441.30	1610.57	1303.03
Cl classification	meq/l	MIN	3.55	3.11	2.57
		MAX	13.71	16.52	12.32
		MEAN	7.01	8.21	5.54

Table 2. Groundwater classification based on sodium adsorption ratio (Richards 1954)

S.No	Sodium Adsorption Ratio (meq/l)	classification
1	<6	Suitable
2	.6-9	Not Suitable
3	>9	Completely not suitable

Percentage Sodium (%Na)

Percentage Na^+ is also widely utilized for evaluating the suitability of water quality for irrigation [4]. The % Na^+ is computed with respect to relative proportions of cations present in water, where the concentrations of ions are expressed in meq/l, using the following formula. The Groundwater type based on sodium percentage is shown in Table 3.

$$\%\mathbf{Na^+} = [(\mathbf{Na^+} + \mathbf{K^+})/(\mathbf{Ca^{2+}} + \mathbf{Mg^{2+}} + \mathbf{Na^+} + \mathbf{K^+})] * \mathbf{100}$$

Table 3. Groundwater classification based on sodium percentage

S. No	Na%	classification
1	<20	Excellent
2	20 - 40	Good
3	40 - 60	Permissible
4	60 - 80	Doubtful
5	>80	Unsuitable

The values of % Na^+ are varying between 22.47-38.91% (mean 31.72), 24.62-38.96% (mean, 32.90%) and 21.45-38.75% (mean 31.38%) in post monsoon, pre-monsoon and monsoon season, respectively. All the sampling stations are under excellent to good categories in three seasons.

Residual Sodium Carbonate (RSC)

In water having a high concentration of bicarbonate, there is a tendency for calcium and magnesium to precipitate as carbonates. An experimental parameter termed as residual sodium carbonate (RSC) was used to calculate this effect. The RSC (expressed in meq/1) is calculated as follows [5]. The Classification of RSC is shown in Table 4.

$$\mathbf{RSC} = \left(\mathbf{HCO_3^-} + \mathbf{CO_3^{2-}}\right) - (\mathbf{Ca^{2+}} + \mathbf{Mg^{2+}})$$

Table 4. Groundwater classification based on Residual sodium carbonate

S.No	Residual sodium carbonate (meq/l)	classification
1	<1.25	good
2	1.25 - 2.50	Doubtful
3	>2.50	Unsuitable

The values of RSC in groundwater varies from -7.36 to 1.20 (mean = 2.25), -6.46 to 0.97 (mean -2.29) and -5.53 to 0.99 (mean -2.05) in post monsoon, pre-monsoon and monsoon season, respectively. All the Samples are under good category in three seasons.

Kelley's Ratio

The Na^+ measured against Ca^{2+} and Mg^{2+} was considered to calculate Kelley's ratio [6] values are expressed in meq/1. A Kelley's index of more than 1 indicates an excess level of sodium in water and hence, water with Kelley's index less than one is considered suitable for irrigation.

$$\mathbf{Kelley's ratio = Na^+/(Ca^{2+} + Mg^{2+})}$$

The values are varying between 0.23 – 0.53 (mean 0.37), 0.26 – 0.53 (mean 0.41) and 0.22 – 0.51 (mean 0.37) in post monsoon, pre-monsoon and monsoon season, respectively. According to Kelley's ratio, all the groundwater samples in the study area show suitable for irrigation.

Permeability index (PI)

The soil permeability is affected by long-term irrigation influenced by Na^+, Ca^{2+}, Mg^{2+} and HCO_3^- contents of the soil. The PI values indicate the suitability of groundwater for irrigation. The values are expressed in meq/l. It is calculated as follows [5]. The permeability index of less than 60 is considered suitable for irrigation. And more than 60 indicates the groundwater is unsuitable for irrigation.

$$PI = \left(Na^+ + \sqrt{HCO_3^-}\right) * 100/(Ca^{2+} + Mg^{2+} + Na^+)$$

The PI values range from 38.39 to 57.11(mean 47.94), 40.26 to 58.77 (mean 48.34) and 37.78 to 56.51(mean 48.40) at post monsoon, pre-monsoon and monsoon season, respectively. All the samples are below 60 (meq/l). It indicates that water is suitable for irrigation purposes in the study area.

Magnesium Ratio

In general, Ca^{2+} and Mg^{2+} maintain a state of equilibrium in most groundwater [7,8]. During equilibrium, more Mg^{2+} in groundwater will adversely affect the soil quality rendering it alkaline resulting in a decrease of crop yield. The values are expressed in meq/l. It is calculated as follows. Magnesium hazard was less than 50 can be safely used for irrigation.

$$\mathbf{MR = \left(Mg^{2+}\right) * 100/(Ca^{2+} + Mg^{2+})}$$

The Magnesium ratio (MR) values range from 40.68 to 47.48 (mean 44.63), 41.30 to 48.74 (mean 44.59) and 41.98 to 48.28 (mean 45.35) at post monsoon, pre-monsoon and monsoon season, respectively. All the samples are within the permissible limit.

Ion exchange

Ion exchange can be studied in terms of the chloro-alkaline indices (CAI-I and CAI-II) proposed by Schoeller (1967) [9,10]. When an exchange of Ca^{2+} or Mg^{2+} in groundwater with Na^+ or K^+ in aquifer materials takes place, both of the above indices are negative, while in the instance of a reverse ion exchange, both indices are positive [11]. The Schoeller indices are calculated using the following formulas, where all ions are expressed in meq/l. the CAI –I and CAI –II values are represented in Table5

$$\mathbf{CAI - I = Cl^{-} - (Na^{+} + K^{+})/Cl^{-}}$$

$$\mathbf{CAI - II = Cl^{-} - (Na^{+} + K^{+})/\ (HCO_3^{-} + SO_4^{2-} + CO_3^{2-} + NO_3^{-})}$$

85%,89% and 73% have positive Schoeller index values at post monsoon, pre-monsoon and monsoon season, respectively And rest are Negative Schoeller index. The positive index Indicating the possibility of ion exchange of Na^{+} and K^{+} of the water with Mg^{2+} and Ca^{2+}.

Table 5. Groundwater classification based on chloro-alkaline indices (CAI-I and CAI-II)

Sample No	Post monsoon		Pre-monsoon		Monsoon	
	CAI –I	CAI – II	CAI –I	CAI – II	CAI –I	CAI – II
GW - 01	0.574	0.822	0.504	0.540	0.539	0.636
GW - 02	0.694	0.879	0.665	0.746	0.658	0.723
GW - 03	0.484	0.397	0.497	0.482	0.543	0.442
GW - 04	0.610	0.627	0.614	0.690	0.540	0.484
GW - 05	0.524	0.308	0.245	0.133	0.407	0.231
GW - 06	0.082	0.029	0.442	0.339	-0.132	-0.046
GW - 07	0.669	0.724	0.667	0.746	0.614	0.459
GW - 08	0.345	0.297	0.278	0.201	0.136	0.071
GW - 09	0.568	0.533	0.488	0.491	0.584	0.622
GW - 10	0.620	0.647	0.708	0.860	0.520	0.523
GW - 11	0.189	0.090	-0.056	-0.025	0.004	0.001
GW - 12	0.675	0.783	0.569	0.582	0.594	0.602
GW - 13	0.471	0.390	0.511	0.479	0.371	0.238
GW - 14	-0.234	-0.137	-0.086	-0.057	0.061	0.049
GW - 15	0.259	0.156	0.129	0.063	0.039	0.017

GW - 16	0.555	0.602	0.464	0.386	0.308	0.182
GW - 17	0.235	0.179	0.126	0.112	0.285	0.217
GW - 18	0.661	0.991	0.695	1.114	0.654	0.926
GW - 19	0.343	0.373	0.388	0.434	0.240	0.189
GW - 20	0.190	0.138	0.269	0.224	-0.117	-0.054
GW - 21	0.204	0.164	0.358	0.359	0.040	0.028
GW - 22	0.172	0.159	-0.051	-0.040	0.016	0.011
GW - 23	0.549	1.212	0.495	0.792	0.188	0.197
GW - 24	0.448	0.468	0.440	0.398	0.283	0.241
GW - 25	0.311	0.317	0.216	0.176	0.010	0.007
GW - 26	-0.437	-0.189	0.005	0.003	-0.036	-0.022
GW - 27	0.475	0.446	0.497	0.569	0.160	0.128
GW - 28	-0.034	-0.020	-0.688	-0.268	-0.793	-0.311
GW - 29	0.150	0.084	0.094	0.045	-0.045	-0.017
GW - 30	0.249	0.191	0.120	0.098	0.106	0.102
GW - 31	0.149	0.116	0.102	0.066	-0.541	-0.173
GW - 32	0.499	0.553	0.458	0.504	0.109	0.078
GW - 33	0.387	0.766	0.463	0.874	0.472	0.772
GW - 34	0.309	0.304	0.369	0.468	0.291	0.280
GW - 35	0.419	0.407	0.466	0.506	0.313	0.250
GW - 36	-0.089	-0.071	0.061	0.047	-0.530	-0.241
GW - 37	0.350	0.316	0.422	0.537	0.076	0.059
GW - 38	-0.113	-0.076	0.407	0.467	-0.220	-0.144
GW - 39	0.430	0.530	0.479	0.669	0.391	0.395
GW - 40	0.087	0.063	0.120	0.113	-0.445	-0.256
GW - 41	-0.283	-0.149	0.284	0.269	0.193	0.157
GW - 42	0.089	0.066	0.113	0.087	-0.056	-0.036

GW - 43	0.053	0.037	-0.086	-0.062	-0.382	-0.168
GW - 44	-0.304	-0.182	0.142	0.136	-0.255	-0.183
GW - 45	0.140	0.123	0.382	0.512	0.257	0.275

Such ion exchange potentially explains the abundance of Ca^{2+} and deficiency of Na^{+} in groundwater and the negative index indicating the reverse ion exchange.

Electrical conductivity

Electrical conductivity is a good measure of salinity hazard to crops as it reflects the TDS in groundwater. The primary effect of high EC water on crop productivity is the incapability of the plant to compete with ions in the soil solution for water. The higher EC, the less water is available to plants [12]. The values are expressed in μS/cm. the groundwater type based on EC is shown in Table 6.

Table 6. Groundwater classification based on electrical conductivity

S.No	Electrical conductivity (μS/cm)	classification
1	<250	Excellent
2	250 - 750	Good
3	750 - 2000	Permissible
4	2000 - 3000	Doubtful
5	>3000	Unsuitable

The electrical conductivity values range from 1098.88 to 1909.69 (mean 1441.3), 1314.18 to 2181.35 (mean 1610.57) and 1034.38 to 1746.80 (mean 1303.03) at post monsoon, pre-monsoon and monsoon season, respectively. All the values are within the permissible limit for irrigation.

Chloride classification

Stuyfzand (1989) classified water on the basis of Cl^{-} ion concentration [13]. The values are expressed in meq/l. the Groundwater type based on chloride classification is shown in Table 7.

Table 7. Groundwater classification based on chloride classification.

S. No	1	2	3	4	5	6	7	8
Cl class (meq/l)	<0.14	0.14- 0.85	0.85- 4.23	4.23- 8.46	8.46 28.21	28.21 282.06	282.06 564.13	>564.13
classification	Extremely fresh	Very fresh	Fresh	Fresh brackish	Brackish	Brackish - salt	Salt	Hypersaline

Based on this classification; the groundwater of the area is 9%, 2% and 27% are fresh, 56%, 56% and 69% are fresh – brackish and the rest of the samples represent brackish water type in post monsoon season, pre-monsoon and monsoon season respectively.

4. CONCLUSION

The present study of the assessment of groundwater sample for irrigation has been evaluated on the basis of standard guidelines and it reveals that the electrical conductivity (EC) and MR values for irrigation standard are in the permissible category. SAR, Kelley's ratio and PI are under the suitable category. % Na falls in excellent to good category. Cl classification falls from fresh – brackish to brackish type and RSC is under the good category for all the samples in three seasons. Hence it is concluded that all the groundwater samples of the present study area are completely suitable for irrigation.A continuous monitoring program of water quality is required to check the suitability for irrigation purpose.

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