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Original Research Paper

Assessment of Groundwater Quality for Irrigational Use in Cumbum Valley, Madurai District, Tamilnadu, India

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ABSTRACT

The suitability of groundwater for irrigation uses was assessed in Cumbum valley covering a total area of about 1485.62 km^2 The study area is located in Uttamapalyam taluk and a small part of Periyakulam Taluk of Madurai district, Tamil Nadu. Fifty five groundwater samples were collected from open wells in the various locations in the study area. The samples were analyzed for major cations and anions and other parameters viz., EC, Kelley's ratio, SAR values, Mg-hazards, HCO_3 and RSC have been worked out to know the suitability of the groundwater for irrigational purpose. Piper trilinear diagram interpretations were made to know the chemical type of the groundwaters. It reveals that the subsurface water is alkaline earth (Ca+Mg) then alkalies (Na+K) type. The groundwater samples fall under class-I of Doneen's classification and use in good to permissible zone according to Wilcox classification. According to the SAR values plotted in the USSL Staff diagram, most of the groundwater samples belong to C_3-S_1 (41.82%) class indicating that the groundwater could be used for all types of crops on soils of medium to high permeability.

INTRODUCTION

Natural water is never pure and always contains some quantities of dissolved gases and solids. The quality of water that we ingest as well as the quality of water in our lakes, streams, river and oceans is a critical parameter in determining the overall quality of our lives. Water quality is determined by the solutes and gases dissolved in it, as well as the matter suspended and floating on the water. The water quality is a consequence of the natural, physical and chemical state of the water as well as any alteration that might have occurred as a consequence of human activity. The usefulness of water for a particular purpose is determined by the water quality. If human activity alters the natural water quality so that it is no longer fit for a use for which it had previously been suited, the water is said to be polluted or contaminated.

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 well documented in many parts of the world (Garrels & Christ 1965, Stumm & Morgan 1970, Swaine & Schneider 1971, Kimblin 1995, Raju 1998).

In the present study, groundwater samples have been collected and analyzed for major cations and anions. The irrigational parameters viz., EC, Kelley's ratio, SAR values, Mg-hazards, HCO_3 and RSC have been worked out to understand the suitability of the groundwater for irrigational purpose.

STUDY AREA

Study area located in the whole taluk of Uttamapalyam and a small part of Periyakulam taluk, situated in the western corner of Madurai district of Tamil Nadu. It lies between latitudes 9°34' N to 10°10' N and longitudes 77°10' E to 77°31' E and falls within the Survey of India toposheets 58 F/8, 58 G/1, 58 G/2, 58 G/5 and 58 G/6. The extent of the area is about 1485.62 km^2. The length of the valley along NE-SW direction is about 60 km and its width is about 28 km (Fig. 1).

MATERIALS AND METHODS

Fifty five water samples were collected during the year 2009 from different dug wells, which are almost uniformly distributed over the study area. Before a well water sample is taken, the well should be pumped for some time so that the sample will represent the groundwater from which the well is field. All bottles should be rinsed with the water to be sampled before the sample for analysis is collected. If water samples are collected in glass bottles, sufficient air space may be provided, but if polythene bottles are used they may be provided, completely filled. Groundwater samples analyzed in the laboratory for major cations and anions, EC, and pH. pH and electrical conductance were measured within a few hours by using Elico pH meter and conductivity meter respectively. 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.

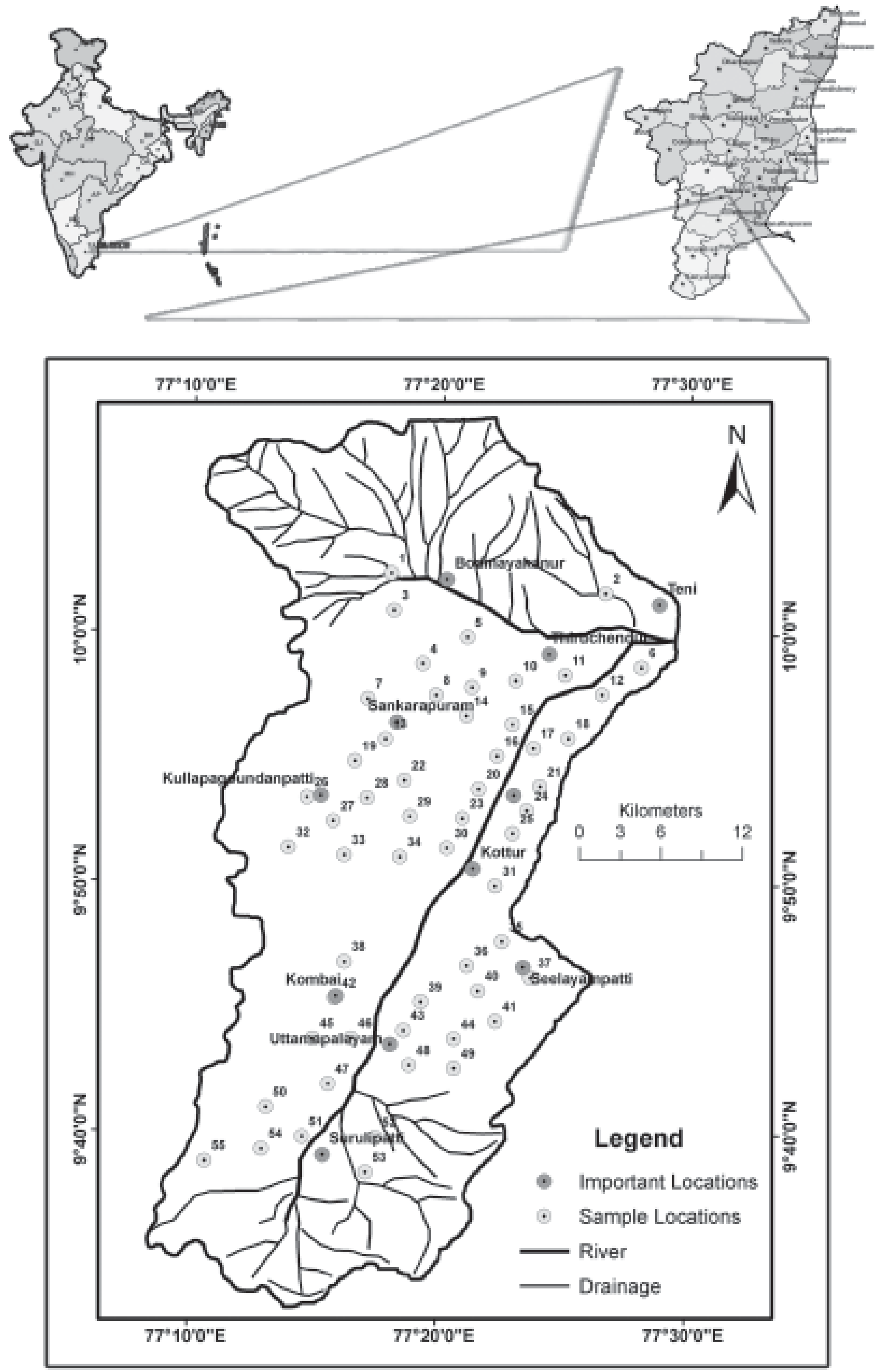

Fig. 1: Study area and groundwater sample locations.

Sulphate was determined a gravimetrically by precipitating $BaSO_4$ by $BaCl_2$. Na and K were determined by Elico flame photometer (APHA 1996). Sodium Adsorption Ratio (SAR) was calculated by dividing sodium with the root of half calcium and magnesium as described by Richard (1954).

RESULTS AND DISCUSSION

The results of the analysis are given in Table 1. The interpretation of the groundwater quality data for irrigation has been carried out as per guidelines given by Ayers (1977) and Christiansen et al. (1977).

Sodium Adsorption Ratio: The sodium or alkali hazard in groundwater 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.

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \quad \text{(All ions in epm)}$$

A simple method of evaluating the high sodium in water is the SAR. Calculation of SAR value for a given groundwater provides a useful index of the sodium hazard of that water for soils and crops. Classification of water with reference to SAR is provided by Herman Bouwer (1978). A low SAR of 0 to 6 indicates no problem from sodium; increasing problem is between 6 to 9, and severe problem is above 9. The lower the ionic strength of solution, the greater sodium hazards for a given SAR. The value of SAR in the groundwater samples of the study area ranges from 0.1 to 6.99 during pre-monsoon (Table 2). All samples fall under the category of no problem except one sample, which falls under the increasing problem category.

Kelley's Ratio: Kelley et al. (1940) have suggested that the sodium problem in irrigational water could very conveniently be worked out on the basis of the values of Kelley's ratio, which is calculated as follows.

$$\text{Kelley's Ratio} = \frac{Na}{Ca + Mg} \quad \text{all ions in epm}$$

Groundwater having Kelley's ratio more than one is generally considered as unfit for irrigation. The Kelley's ratio has been calculated for all the water samples of the study area. It varies from 0.09 to 2.66 epm (Table 1). Groundwater having more than one is generally considered as unfit for irrigation. The Kelley's ratio has been calculated for all the groundwater samples of the study area.

Residual Sodium Carbonate: Residual Sodium Carbonate is defined as RSC = $(CO_3 + HCO_3) - (Ca + Mg)$ where all concentrations are expressed in epm. The water having excess of carbonate and bicarbonate over the alkaline earth, mainly calcium and magnesium, in excess of permissible limits affects irrigation unfavourably (Eaton 1950, Richards 1954). Table 3 shows that 96% of samples are safe for irrigation purpose and the rest are unfit for irrigation use in the pre monsoon season. The range of residual sodium carbonate in groundwater in the investigated area varies from 18.92 to 2.77 epm.

Magnesium Ratio: It is expressed as:

$$Magnesium\ Ratio = \frac{Mg \times 100}{Ca + Mg}$$

Where all the ions are expressed in epm. Excess of magnesium affects the quality of soils which is the cause of poor yield of crops. The magnesium ratio of premonsoon groundwater varies from 30 to 91.01 epm (Table 1). Magnesium ratios were found to be more than the permissible limit in all the water sample locations, except few locations. High Mg ratio is due to surface water and subsurface water more reacted and passage through the limestone, kankar and granitic rock formation in the study area (Pandian et al. 2007).

Chemical Relationship: The Piper's trilinear diagram (Piper 1944) is most useful to understand the chemical relationships among groundwater. The chemical quality data of the

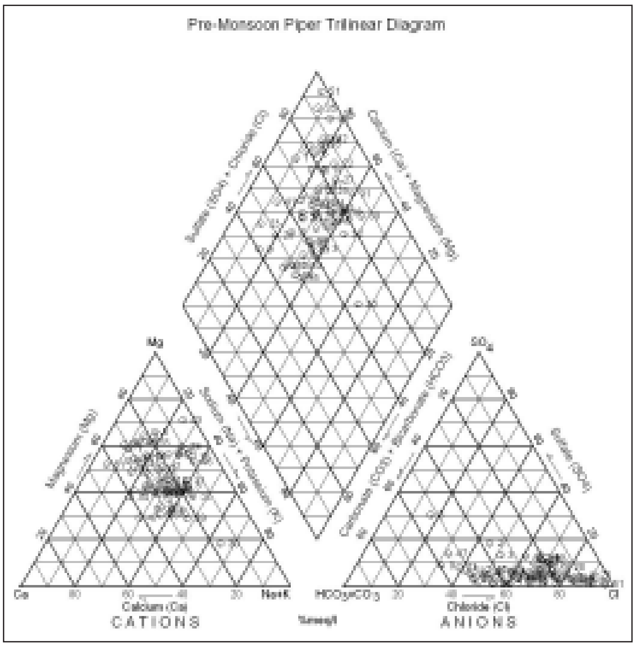

Fig. 2: Piper trilinear diagram.

Table 1: Anions and cations concentration in groundwater samples. All values in the table are expressed in equivalent per million (epm) except EC in μScm^{-1}, TDS in ppm and pH.

Sample No.	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	pH	EC*	TDS	Kelley Ratio	RSC*	SAR*	Na%	Mg-Ratio
1	5.85	6.8	2.3	3.2	1.5	0.9	9.4	8.3	600	384	0.18	-7.95	0.91	15.38	53.75
2	4.99	3.56	4.24	3.86	0.03	1.54	2.76	7.9	1241	734	0.50	-4.66	2.05	33.15	41.64
3	2.69	4.26	7.58	5.27	0.13	1.66	4.68	7.9	1494	927	1.09	-1.55	4.07	52.17	61.29
4	4.05	3.25	3.55	2.6	2.45	0.2	5.5	8.35	3670	2284	0.49	-2.25	1.86	32.72	44.52
5	2.55	5.9	2.8	2.15	0.35	0.35	7.1	8.45	2160	1432	0.33	-5.95	1.36	24.89	69.82
6	5.74	4.09	9.44	5.97	0.03	1.52	10.56	8.1	1918	1119.2	0.96	-3.83	4.26	48.99	41.61
7	2.9	2.5	4.55	4.2	0.9	0.15	5.6	8	1883	1205	0.84	-0.30	2.77	45.73	46.30
8	1.19	3.19	3.13	1.62	0.03	0.77	0.31	7.9	720	438	0.71	-2.73	2.12	41.68	72.83
9	4.1	3.95	2.4	6.95	0.09	0.85	2.2	7.95	1604	1026	0.30	-1.01	1.20	22.97	49.07
10	5.28	9.19	3.56	4.19	0	1.7	9.5	6.9	1760	1051	0.25	-10.28	1.32	19.74	63.51
11	4.05	4.15	6.95	5.8	1.05	0.95	6.1	8.1	2980	1914	0.85	-1.35	3.43	45.87	50.61
12	5.15	6.45	6.25	3.25	2.15	0.85	12.7	8.25	3550	2272	0.54	-6.20	2.60	35.01	55.60
13	3.75	2.3	4.45	2.9	1.65	0.8	5.05	8.9	2900	1856	0.74	-1.50	2.56	42.38	38.02
14	3.05	2.55	3.85	2.95	0.2	1.05	5.15	8.9	2900	1792	0.69	-2.45	2.30	40.74	45.54
15	2.55	9.65	11.75	4.6	2.6	1.55	16.3	8.1	6860	2390	0.96	-5.00	4.76	49.06	79.10
16	3.95	2.6	6.2	2.8	0.4	0.7	7.75	7.9	1353	780	0.95	-3.35	3.43	48.63	39.69
17	3.75	5.22	5.21	3.91	0.003	1.66	7.24	8.1	2380	1530	0.58	-5.06	2.46	36.74	58.19
18	1.8	2.2	2.95	3.4	0.7	0.2	2.6	8.3	1410	4077	0.74	0.10	2.09	42.45	55.00
19	3	3.02	2.8	2.05	0.07	1.15	4.69	8	8664	502.6	0.47	-3.90	1.61	31.75	50.17
20	4.3	3.6	4.1	2.45	1.1	0.75	4.15	8	2420	1549	0.52	-4.35	2.06	34.17	45.57
21	1.15	2.95	3	1.9	0.35	0.3	3.1	8	1400	896	0.73	-1.85	2.10	42.25	71.95
22	5.6	5	5.55	1.95	0.4	0.35	10.2	8.35	3560	2274	0.52	-8.25	2.41	34.37	47.17
23	3.95	5.45	1.95	2.4	2.1	0.8	2.8	8.8	1590	1018	0.21	-4.90	0.90	17.18	57.98
24	6.13	9.19	3.56	3.79	0.34	2.03	8.14	7.8	1667	1054	0.23	-11.19	1.29	18.86	59.99
25	8.15	8.85	4.5	1.25	0.2	1.2	16.35	8.2	4490	2874	0.26	-15.55	1.54	20.93	52.06
26	1.85	2.5	1.65	2.55	0.3	0.25	1.6	8.7	1240	791	0.38	-1.50	1.12	27.50	57.47
27	10.4	8.25	11.7	3.55	2.45	1.6	23.8	7.85	7160	4582	0.63	-12.65	3.83	38.55	44.24
28	2.35	4.15	2.2	2.8	1.75	3	21.3	8.45	1780	1139	0.34	-1.95	1.22	25.29	63.85
29	0.5	1.75	1.65	0.8	0.25	0.55	2.45	8.6	572	366	0.73	-1.20	1.56	42.31	77.78
30	2.09	1.37	9.2	6.17	0.06	0.87	6.29	7.9	1209	721	2.66	2.77	6.99	72.67	39.60
31	4.75	8.25	13.45	3.8	0.7	0.9	19.3	8.25	5380	2200	1.03	-8.50	5.28	50.85	63.46
32	2.35	3.25	7.1	2.7	1.15	1.1	8.05	8.35	2280	1459	1.27	-1.75	4.24	55.91	58.04
33	8.3	7.1	4.5	2.95	0.45	0.35	15.45	8	4040	2586	0.29	-12.00	1.62	22.61	46.10
34	3.05	1.75	1.85	2.65	0.25	0.25	3.45	8.95	1200	768	0.39	-1.90	1.19	27.82	36.46
35	9.89	11.53	2.9	2.45	0.05	0.52	18.04	7.9	2365	1342	0.14	-18.92	0.89	11.92	53.83
36	3.95	4.25	4.95	3.85	0.8	0.75	7.8	7.9	2820	1805	0.60	-3.55	2.44	37.64	51.83
37	2.85	1.9	1.85	1.55	0.8	0.45	3.7	8.4	1300	832.2	0.39	-2.40	1.20	28.03	40.00
38	3.2	2.15	4.1	2.45	0.6	0.2	6.25	8.3	2280	1459	0.77	-2.30	2.51	43.39	40.19
39	4.05	3.01	9.2	3.91	0.03	0.72	13.03	7.8	840	486	1.30	-3.12	4.90	56.58	42.63
40	4.85	5.3	7.7	3.75	2.5	0.65	9.5	8.1	3380	2016	0.76	-3.90	3.42	43.14	52.22
41	6.1	6	2.7	2.9	3.8	1.4	7.2	8.4	2950	1960	0.22	-5.40	1.10	18.24	49.59
42	5.45	7.25	4.5	1.3	0.6	0.75	12.6	8.35	3430	2195	0.35	-10.80	1.79	26.16	57.09
43	0.85	8.6	5.6	4.4	1.65	0.8	7.55	8.2	3030	937	0.59	-3.40	2.58	37.21	91.01
44	3.45	4.09	6.45	3.88	0.02	1.3	6.8	7.8	1385	802.3	0.86	-3.64	3.32	46.10	54.24
45	6.95	7.6	5.1	6	0.35	1.35	11.9	8.65	3190	2135	0.35	-8.20	1.89	25.95	52.23
46	2.89	10.32	13.74	8.36	0.12	3.32	11.6	8.1	2330	1556.8	1.04	-4.73	5.35	50.98	78.12
47	2.45	1.05	2	2.55	0.7	0.8	1.35	8.8	1150	736	0.57	-0.25	1.51	36.36	30.00
48	3.2	3.05	4.95	2.6	0.8	0.3	5.5	8.25	2220	1421	0.79	-2.85	2.80	44.20	48.80
49	1.35	1.3	2.05	1.1	0.8	0.05	1.95	7.85	1420	902	0.77	-0.75	1.78	43.62	49.06
50	2.65	2.5	3.8	1.2	2.35	0.45	4.95	8.45	9340	5998	0.74	-1.60	2.37	42.46	48.54
51	0.39	0.29	0.06	0.24	0	0.06	4.96	8	70	39	0.09	-0.44	0.10	8.11	42.65
52	1.2	1.4	2.2	1	1.5	0.4	1.9	8.95	1620	1037	0.85	-0.10	1.93	45.83	53.85
53	2.2	1.25	2.8	3.1	0.45	0.25	2.5	8.5	1800	1152	0.81	0.10	2.13	44.80	36.23
54	2.15	4.35	3.85	3.25	0.6	0.2	5.75	8.45	1500	1322	0.59	-2.65	2.14	37.20	66.92
55	3.4	3.55	6.45	6.65	1.35	0.5	5.05	8	2660	1702	0.93	1.05	3.46	48.13	51.08

EC* – Electrical conductivity, RSC* – Residual Sodium Carbonate, SAR* – Sodium Adsorption Ratio investigated area are used in Piper's trilinear diagram for graphical analysis (Fig. 2). It reveals that water is mostly of alkaline earth exceeds alkalies in the pre monsoon season.

Doneen's Permeability Index: 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) as given below.

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

Where, Na, Ca, etc. values are in epm. The majority of the samples fall under Class-I (Fig. 3) as per Doneen's classification (Table 4), which indicates that groundwater is good for irrigation.

Wilcox Diagram: Wilcox (1955) used sodium % and specific conductance in evaluating the suitability of groundwater to irrigation. Sodium percentage determines the ratio of sodium to total cations viz., sodium, potassium, calcium and magnesium. All the concentration values are expressed in equivalents per million (epm). The results (Table 5) show that the groundwater near the upstream is good for irrigation and the contamination is found to be high near the downstream (Fig. 4). This may be due to effluents from the industries as well as the domestic sewage directed into the river.

USSL Diagram: U.S. Salinity Laboratory diagram (1954) interpretation is given in Fig. 5. The two most significant parameters of sodium and salinity hazards indicate usability

Table 2: Classification of sodium adsorption ratio in groundwater.

S.No.	Limiting Values	Water quality	Total No. of Samples	Percentage %
1	0 - 6	No Problem	54	98.18
2	6 - 9	Increasing Problem	1 (30)	1.82
3	> 9	Severe Problem	-	-

Table 3: Classification of residual sodium carbonate in groundwater.

S.No.	Limiting Values	Category	Total No. of Samples	Percentage %
1	< 1.25	Safe	53	96.36
2	1.25 - 2.5	Marginal	2	3.64

Table 4: Classification of irrigation groundwater based on Doneen (1964).

Sl. No.	Category of irrigation water	Sample Numbers (Locations samples)	Total No. of Locations	Percentage (%)
1	Class - I	1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17, 18,19,20,22,23,24,25, 27,28,31,32,33,34, 35,36,37,38,39,40,41,42,43,44,45,46,48, 50,54,55.	45	81.82
2	Class - II	2,21,26,29,30,47,49,51,52,53.	10	18.18
3	Class - III	Nil	Nil	-

Table 5: Classification of groundwater for irrigation based on Wilcox Diagram Interpretation (1955).

Sl. No.	Category of irrigation Water	Pre Monsoon (Locations samples)	Total No. of Locations	Percentage (%)
1	Excellent to Good	1,8,29,51	4	7.27
2	Good to Permissible	2,3,6,7,9,10,17,19,21,23,24,26,28,34,37,39,44,47,49,52,53,54	22	40.00
3	Permissible to Doubtful	30	1	1.81
4	Doubtful to Unsuitable	5,11,13,14,18,20,32,35,36,38,41,43,46,48,55	15	27.27
5	Unsuitable	4,12,15,16,22,25,27,31,33,40,42,45,50	13	23.64

Table 6: Groundwater classification based on USSL Diagram Interpretation (1954).

Sl. No.	Category of	Pre Monsoon (Locations samples)	Total No. of Locations	Percentage (%)
1	C1-S1	51	1	1.82
2	C2-S1	1,8,29	3	5.45
3	C3-S1	2,3,5,6,7,9,10,16,18,21,23,24,26,28,34,37,39,44,47,49,52,53,54	23	41.82
4	C3-S2	30	1	1.82
5	C4-S1	4,11,12,13,14,15,17,19,20,22,25,33,35,36,38,40,41,42,43,45,48,50,55	23	41.82
6	C4-S2	27,31,32,46	4	7.27

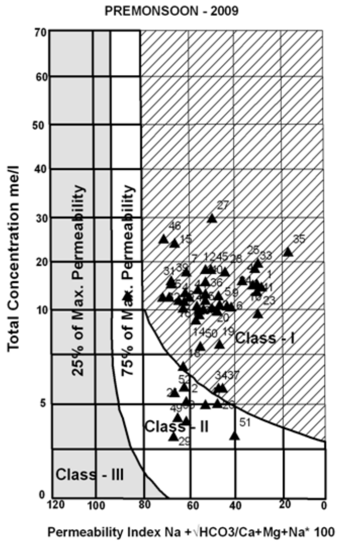

Fig. 3: Classification of groundwater for irrigation for soils of medium permeability (Doneen).

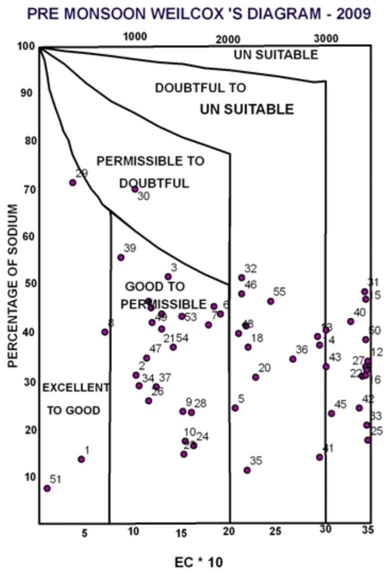

Fig.4. Wilcox diagram.

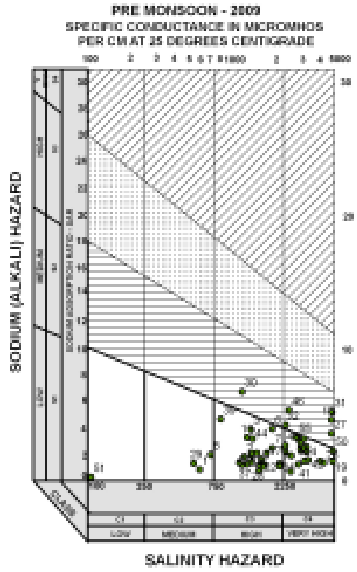

Fig. 5. USSL diagram.

for agricultural purposes. USSL classification of groundwater in the study area is given in Table 6. Twenty three locations (41.82 %) samples occur within C_3-S_1 category. These categories are predominant in the study area and accordingly it is inferred that the groundwater in those areas is suitable for irrigation purpose.

CONCLUSION

In this study, the assessment of groundwater for irrigation has been evaluated on the basis of various guidelines. Piper trilinear diagram interpretations were made to know the chemical type of the groundwater. It reveals that the subsurface water is alkaline earth (Ca+Mg) exceeds alkalies (Na+K) type. The groundwater fall under Class-I for 81.82% as per the classification of Doneen's Permeability Index, and could be treated as good for irrigation. The Wilcox classification has shown 23.64% of groundwater under "unsuitable" zone. According to U.S. Salinity diagram, 41.82 % of groundwater samples belong to C_3-S_1 (high salinity-low SAR) under the present investigations, and this type of groundwater should be used for soils of medium to high permeability. It is evident that high salinity of groundwater persists at majority of sites. Hence, it is suggested that suitable measures in terms of enhancement of drainage have to be made in areas where high salinity is observed, for satisfactory crop growth.

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