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RESEARCH ARTICLE

EVALUATION OF GROUNDWATER QUALITY FOR IRRIGATED AGRICULTURE IN MARUDAIYAR SUB-BASIN, TAMIL NADU

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ABSTRACT

In this paper an attempt has been made to understand the groundwater suitability for irrigated agriculture in Marudaiyar sub-basin. The chemical aspects of groundwater in the study area, 32 control wells considered which are almost equally distributed throughout the study area. Geo-chemical data were analysed to understand the pH, Electrical Conductivity, Total Hardness, TDS and SAR in the study area. The plotted geochemical data in the USSL diagram indicates 34.37 per cent (in pre-monsoon) and 46.87 per cent (in post-monsoon) of water samples are of good category and most of these samples are of C3S1 type. The poor water quality category is 3.12 per cent in pre-monsoon and 6.25 per cent in post-monsoon. The assessment of groundwater quality for irrigated agriculture using Modified Piper's trilinear diagram shows result similar to that from the USSL diagram.

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INTRODUCTION

The problem of water quality becomes more important than the quantity as the environmental problems are getting more serious in different parts of the world. The quality of the water is determined by the number of the factors like geology, soil, weathering, growth of industries, emission of pollutants, sewage disposal and other environmental conditions in which the water happens to stay or move and interact with the ground, especially in the surface and consequently the presence of the different chemical, physical and biological characteristics which changes the water quality. Groundwater chemistry is important and plays a significant role in determining the water quality for various uses of man. The quality of required of a groundwater supply depends on its purpose; thus, needs for drinking water, industrial water and irrigation water vary widely. One should be very keen in understanding the water chemistry before applying it for agriculture for achieving maximum benefit. Generally, the concentrations of dissolved ions in groundwater are governed by lithology, groundwater flow, nature of geochemical reactions, residence time, solubility of salts, and human activities (Bhatt and Sakalani 1996; Kumaraswamy, *et al*., 1996; Karanth 1987; Nisi *et al.,* 2008; Schot and Van der Wal 1992). According to Doneen (1966), no water is unfit for irrigation if it is properly utilized. The Importance of hydrochemistry of groundwater has led to a number of detailed studies on geochemical evolution of groundwater (Garrels, 1967; Paces, 1973; Sarin *et al*., 1989; Patil *et al*., 2010; Susheel kumar sindhu *et al*., 2007; Masood alam *et al*., 2009; Acharya *et al*., 2008; Fetouani *et al.,* 2008; Ali *et al.,* 2009; Carmelita Nishanthiny *et al.,* 2010). In the present study have been evaluated to understand the groundwater quality and its suitability for agriculture purposes.

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Study Area

Marudaiyar basin, the study area is located in the central part of Tamil Nadu State covering an areal extent of 623 sq.km. It is geographically located between the latitudes 11°02| - 11°15| N and the longitudes 78°48| - 79°15| E (Fig.1). The area is composed of series of plains, valley bottoms, undulating uplands and broken chains of eastern - ghats viz., Pachamalai. The average height of Pachamalai hill is 100 m. The elevation of the basin ranges from 250-400 meters.

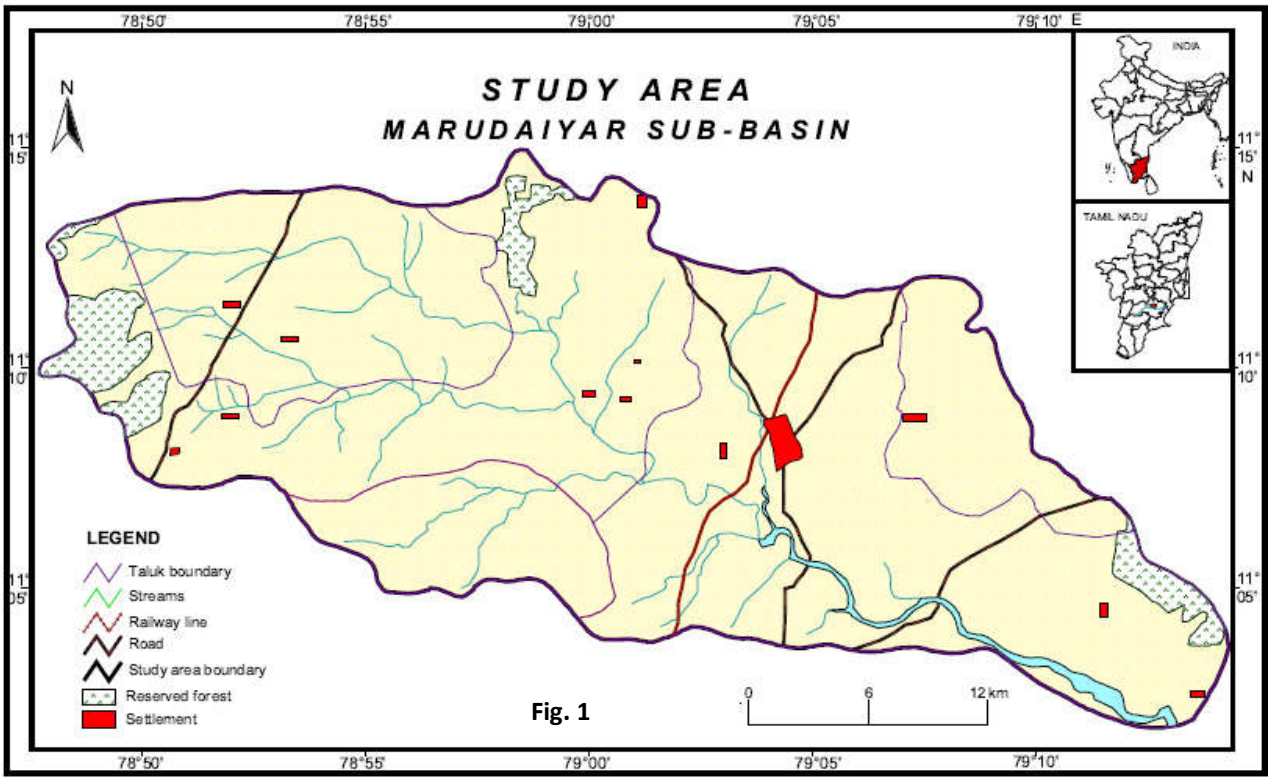

Fig. 1

The Marudaiyar basin has its origin from the Pachamalai hills, and its flows in the southeastern direction, passing through the Perambalur, Kunnam, Ariyalur Udaiyarpalayam and Lalgudi taluks of Perambalur and Tiruchirappalli District before joining the Coleroon river. On the northern side the study area is bounded by Chinnar basin and on the eastern side, it is bounded by Udiayarpalayam minor basin. On the southern and western side it is bounded by Nambiyar and Swedhanadhi minor basin respectively. Geologically, the river basin is mainly occupied by Archaean group of rocks composed of gneisses and charnockites. The Marudaiyar river basin, especially in its eastern part is composed almost entirely of sedimentary rocks especially calcareous rocks (limestone, gypsecous sandstone, calcareous sandstone etc.,). Alluvium and black soils are the predominant soils in the sub-basin.

MATERIALS AND METHODS

For analyzing the chemical aspects of groundwater in the study area, 32 control wells, which are almost equally distributed throughout the study area, have been selected for investigation. These 32 control wells are regularly monitored by Water Resources Organization (WRO) of Public Works Department, Government of Tamil Nadu for evaluating the quality of groundwater. For the present study, the geochemical data for the period 1997 - 99 (for based on average of three successive years), have been collected. Water quality data used in the analysis include pH, EC, Total Dissolved Solids (TDS), Total Hardness (TH) and Sodium Adsorption Ratio (SAR).

RESULTS AND DISCUSSION

The ground water quality standard for irrigation has been compared with standard guidelines. They are as given below.

Hydrogen Ion Concentration (pH)

The negative logarithm to the base 10 of hydrogen ion concentration is called as pH. i.e., $pH = -\log_{10} (H+)$. In other words, pH refers to the effective concentration of hydrogen ions in the water expressed as the negative logarithm (base 10) of the hydrogen ion activity in moles per litter. The pH value of natural water is measure of its net alkalinity or acidity. More accurately stated, the pH value is a measure of the hydrogen ion concentration of the water. In most natural waters, the pH value is dependent on the Carbon-di-oxide – carbonate- bicarbonate equilibrium. As the equilibrium is markedly affected by temperature and pressure, it is obvious that changes in pH of groundwater commonly ranges from 6.0 to 8.5. In surface water, it ranges from 6 to 8. Below 7 indicates acidic water. The optimum pH for irrigation water depends upon the type of crops to be grown and on the physical and chemical properties of the soil. In the study area, pH is ranging from 7.7 (in Ambapur) to 8.8 (in Irur) during pre-monsoon period (Table 1) and the post-monsoon period, its ranges from 7.4 (in Periathirukkonam) to 8.7 (in Kavulpalayam) (Table 2). Hence, all pH values well within 7.4 to 8.8 indicate to the presence of carbonates of calcium and magnesium in the study area. (pH above generally indicates to appreciable, exchangeable sodium). The study area, in general contains moderate to strong alkaline content in both the periods.

Electrical Conductivity

The conductivity measurements provide an indication of ionic concentrations. It depends upon temperature, concentration and types of ions present (Hem, 1985). Most of the salts in water are present in their ionic forms and capable of conducting current and conductivity is a good indicator to assess groundwater quality (Table 3).

During the pre-monsoon, period the EC was observed to be maximum in Sirukanpur (4514), minimum in Naranamangalam (373) and in postmonsoon period higher concentration was observed in Chittali (7669) and lower in Kadugur (131) (Table 1 & 2).

But Davis and De Wiest (1996) classified the water with a TDS content of 1,000 to 10,000 mg/L as brackish, 10,000 to 100,000 mg/L as salty and more than 100,000 mg/L as brine (Table 4).

Table 1. Groundwater Quality of Marudaiyar Sub-Basin for Pre-monsoon

Well No.	Name of the Well	pH	EC micromhos/cm	TH as CaCO3 mg/L	TDS sum mg/L	SAR (epm)	USSL Classification	Modified Piper's Classification
1	Pudunaduvalur	8.4	390	145	250	1.125	C2S1	C2S1
2	Aranarai	8.5	2045	220	1309	4.585	C3S2	C3S2
3	Alambadi	8.5	448	160	287	0.063	C2S1	C2S1
4	Thuraimangalam	8.4	389	180	249	0.097	C2S1	C2S1
5	Kavulpalayam	8.2	1290	565	825	0.067	C3S1	C3S1
6	Perali	8.4	628	265	402	0.061	C2S2	C2S2
7	Chittali	8.7	1924	300	1232	3.002	C4S4	C4S4
8	Kunnam	8.1	2146	790	1374	0.149	C3S1	C3S1
9	Aiylur	8.2	633	295	405	0.932	C2S1	C2S1
10	Kalpadi	8.0	1036	390	663	0.030	C3S1	C3S1
11	Sirukanpur	8.6	4514	840	2889	0.932	C4S4	C4S4
12	Kottari	7.8	648	175	415	2.117	C2S1	C2S1
13	Kuttur	8.1	2348	490	1503	1.084	C4S2	C4S2
14	Killamathur	8.7	1421	305	909	0.447	C3S2	C3S2
15	Ottakovil	8.1	1239	335	793	0.055	C3S1	C3S1
16	Kadugur	8.0	703	265	450	1.229	C2S1	C2S1
17	Irur	8.8	2412	230	1544	3.165	C4S3	C4S3
18	Naranamangalam	8.4	373	105	239	0.146	C4S2	C4S2
19	Garudamangalam	8.6	1912	610	1224	3.684	C4S2	C4S2
20	Kulattur	8.0	2007	500	1285	0.635	C3S2	C3S2
21	Nochechikulam	8.5	1018	235	651	0.098	C3S1	C3S1
22	Pappancheri	8.3	476	150	304	0.041	C2S1	C2S1
23	Valajanagaram	8.6	1747	370	1118	0.156	C3S2	C3S2
24	V. Krishanpuram	8.2	2067	740	1323	0.235	C3S1	C3S1
25	Pudupalayam	8.9	915	60	585	0.336	C3S3	C3S3
26	Hasthinapuram	8.3	1118	425	716	0.136	C3S1	C3S1
27	Reddipalayam	7.8	1451	410	929	1.087	C3S1	C3S1
28	Periathirukkonam	8.5	1482	370	949	0.156	C3S1	C3S1
29	Vilangudi	8.3	609	175	390	0.242	C2S1	C2S1
30	Sundakkudi	8.1	1361	385	871	0.296	C3S1	C3S1
31	Ambapur	7.7	459	185	294	0.059	C2S1	C2S1
32	Ulliyakkudi	8.0	764	220	489	0.182	C3S1	C3S1

The analysis of data pertaining to pre-monsoon season for EC shows 34.37 per cent of samples are of good category; 56.25 per cent of samples are of permissible category and the remaining 9.37 per cent of samples are of doubtful category. As far as the post-monsoon samples are consumed 3.12 per cent of samples fall under the excellent category, 34.37 per cent of samples under good category, 53.12 per cent of samples fall under the permissible category and the remaining 9.37 per cent of samples are of doubtful category. The concentration of EC value depends up on the basic rock type, soil and the amount of rainfall received. The highest EC values which are classified as doubtful category are found in the areas nearer to limestone and carbonate minerals.

Total Dissolved Solids (TDS)

The Total Dissolved Solids (TDS) refers to, the total concentration of dissolved minerals or salts in water. An approximate method of calculating the TDS in water can be obtained by multiplying the specific conductance (EC) at 25° by a factor of 0.64 (Hem, 1985). The Total Dissolved Solids (TDS) or Total Salt concentration of groundwater varies from less than 100 to more than 100,000 mg/L. For irrigation of water and most other natural waters, a millimhos is customarily taken as equal to 640 mg. per liter.

In the study area, TDS leaves of pre-monsoon samples goes upto 1544 mg/L (in Irur) and drops down even 239 mg/L (in Naranamangalam). As far as post-monsoon season samples, it goes upto 4908 mg/L (in Chittali) and slides down to 84 mg/L (in Kadugur). Generally, the TDS value below 1000 mg/L is considered as fresh water.

In the study area, the concentration of TDS ranges below (<1000 mg/L) during the pre-monsoon in Pudunaduvalur, Alambadi, Thuraimangalam, Perali, Kottarai, Kadugur, Naranamangalam, Pappancheri, Vilangudi and Ambapur; during the post-monsoon Aranarai, Kavulpalayam, Aiylur, Kalpadai, Killamathur, Ottakovil, Garudamangalam, Kulattur, Nochechikulam, Valajanagaram, V.Krishnapuram, Pudupalayam, Hasthinapuram, Reddipalayam, Periathirukkonam and Sundakkudi.

The concentration of TDS is >1000 mg/L (slightly saline) found during the both the season in Chittali, Kunnam, Siruganpur, and Irur. In the post-monsoon period, the TDS values are lesser in almost all the area (within the permissible limit of TDS less than 2000 mg/L). The concentration of TDS is found to be saline water in Chittali (4908 mg/L) in post monsoon and Valajanagaram, (2889 mg/L) in pre-monsoon.

Table 2. Groundwater Quality of Marudaiyar Sub-Basin for Post-monsoon

Well No.	Name of the Well	pH	EC micromhos/cm	TH as CaCO3 mg/L	TDS sum mg/L	SAR (epm)	USSL Classification	Modified Piper's Classification
1	Pudunaduvalur	8.2	606	210	388	1.725	C2S1	C2S1
2	Aranarai	8.7	1426	145	912	4.069	C3S1	C3S1
3	Alambadi	8.6	421	190	269	1.088	C2S1	C2S1
4	Thuraimangalam	8.2	430	185	275	1.691	C3S2	C3S2
5	Kavulpalayam	8.7	651	200	417	2.828	C2S1	C2S1
6	Perali	8.5	1167	460	746	1.585	C3S1	C3S1
7	Chittali	8.3	7669	1600	4908	12.500	C4S4	C4S4
8	Kunnam	8.1	2003	800	1282	1.945	C4S1	C4S1
9	Aiylur	7.7	746	285	477	1.481	C3S1	C3S1
10	Kalpadi	8.1	1215	355	777	3.184	C3S1	C3S1
11	Sirukanpur	8.0	1662	580	1063	3.034	C3S1	C3S1
12	Kottari	8.3	797	265	510	2.150	C3S1	C3S1
13	Kuttur	8.6	2623	250	1678	13.598	C4S4	C4S4
14	Killamathur	8.4	733	225	469	2.600	C3S1	C3S1
15	Ottakovil	8.5	999	210	639	2.277	C3S1	C3S1
16	Kadugur	8.2	131	65	84	0.248	C1S1	C1S1
17	Irur	7.9	1621	510	1037	3.631	C3S1	C3S1
18	Naranamangalam	8.1	2502	430	1601	5.064	C4S2	C4S2
19	Garudamangalam	8.4	1496	330	958	5.230	C4S2	C4S2
20	Kulattur	8.1	328	110	210	0.858	C2S1	C2S1
21	Nochechikulam	8.1	1268	260	812	5.271	C3S2	C3S2
22	Pappancheri	8.4	468	135	300	2.668	C2S1	C2S1
23	Valajanagaram	8.3	944	185	604	5.073	C3S1	C3S1
24	V. Krishanpuram	8.4	884	170	565	6.903	C3S2	C3S2
25	Pudupalayam	8.7	754	115	482	5.968	C3S1	C3S1
26	Hasthinapuram	8.3	849	265	543	2.703	C3S1	C3S1
27	Reddipalayam	8.4	1265	335	809	4.644	C3S1	C3S1
28	Periathirukkonam	7.4	401	137	256	1.721	C2S1	C2S1
29	Vilangudi	7.9	494	175	316	1.890	C2S1	C2S1
30	Sundakkudi	8.1	1075	347	687	2.961	C3S1	C3S1
31	Ambapur	8.2	497	195	318	1.432	C2S1	C2S1
32	Ulliyakkudi	8.3	895	210	572	4.140	C3S1	C3S1

Table 3. Classification of Irrigation Water Based on Electrical Conductivity

Sl. No.	EC Values in micromhos/cm	Quality of Water	Salinity Condition
1	Less than 250	Excellent quality	Water of low salinity is generally composed of higher proportions of calcium, magnesium and bicarbonate ions.
2	250 – 750	Good quality	Moderately saline water, having varying ionic concentrations
3	750 - 2250	Permissible	High saline waters consist mostly of sodium and chloride ions
4	More than 2250	Doubtful	Water containing high concentration of sodium, bicarbonate and carbonate ions have high pH

Total Hardness as $CaCO_3$ (TH)

Hardness of water relates to its reaction with soap and to the scale of encrustations accumulating in containers or conduits of transportation. Since soap is precipitated primarily as calcium and magnesium ions, hardness defined as the sum of the concentrations of these two ions expressed in milligrams per liter of calcium carbonate. Water can be classified into four class based on its hardness (Table 4).

Table 4. Water Condition Based on Total Dissolved Solids

Sl. No.	Water Condition	Range of Concentration
1	Fresh Water	Less than 1,000 mg/l
2	Slightly Saline	1,000 to 3,000 mg/l
3	Moderately Saline	3,000 to 10,000mg/l
4	Very Saline	10,000 to 35,000 mg/l
5	Brine	More than 35,000 mg/l

Source: Davis and De Wiest (1996)

In the study area, total hardness is ranging between 105 mg/L (in Naranamangalam) and 840 mg/L (in Siruganpur) during pre-monsoon (Table 1) and in the post-monsoon period (Table 2), it ranges between 65 mg/L (in Kadugur) and 1600 mg/L (in Chittali). The concentration of total hardness is more than the maximum permissible limit in Chittali (1600mg/L). The rest of the sample wells having less than 1000 mg/L (within permissible limit) during pre and post-monsoon period of the study area. The concentration of total hardness ion during the both the season was found to be moderate (<200 mg/L) in Pudunaduvalur, Alambadi, Thuraimangalam, Kottari, Kadugur, Kulattur, Naranamangalam, Pappancheri, Pudupalayam, Vilangudi and moderately hard (200-600 mg/L) in Aranarai, Kunnam, Killamtur, Nochechikulam, Hasthinapuram, Reddipalayam and Sundakkudi; hard (>600 mg/L) in Chittali, Kuttur, Pudupalayam, Kulattur, V.Krishnapuram Periathirukkonam; Irur Valajanagaram and Siruganpur. The hardness below 500 mg/L is generally recommended for drinking purpose.

But for agriculture purpose, even more than 1000 mg/L of hardness is accepted (Rao, 1975).

Sodium Adsorption Ratio SAR

The Sodium Adsorption Ratio (SAR) value was estimated based on Na/ √ *(Ca+Mg)/2* the formula for each sample location of the study area and based on their values to understand the spatial pattern of SAR ratio in the study area. The Sodium hazards of water classification proposed by Richards 1954 are given Table 5. The SAR is found to range from 0.030 (in Kalpadi) to 4.585 (in Aranarai) during the pre-monsoon season of the study area.

Table 5. Irrigation Water Classification based on Sodium Adsorption Ratio

Sodium Adsorption Ratio (SAR)in epm	Water class
Less than 10	Excellent
10 to 18	Good
18 to 26	Permissible
More than 26	Unsuitable

Source: Richards (1954)

During the pre-monsoon period, the concentration of SAR falls in the excellent water class (<10). In the central part of the study area is range between 1.0 and 2.0. For the remaining parts of the study area having the value is above 2.0. The concentration of SAR ranges from 0.248 (in Kadugur) to 13.598 (in Kuttur) of the study area during postmonsoon period. Almost all the samples fall in excellent water type (<10).

Table 6. The plotting of the chemical data in the said diagram give an idea about the suitability of groundwater for irrigation and it would be possible to group the areas with good, moderate and bad waters. From the figures, it is observed that about 68.74 per cent (twenty samples out of thirty two) of the groundwater samples are falling under good quality water zone. Seven samples out of thirty-two (21.87 per cent) fall under moderate quality whereas the poor quality water is found in about 6.24 per cent (two samples) and very poor water quality in about 3.12 per cent (one sample) locations. Post-monsoon shows appreciable changes in groundwater quality. Groundwater is found to be of good quality in 81.23 per cent of the locations (26 samples out of 32) while moderate quality of water zone has decreased to 12.49 per cent of basin area. Poor quality water zone are absent during the post-monsoon season. However, the very poor water quality has increased from 3.12 per cent during pre-monsoon season to 6.25 per cent (2 samples) in the post-monsoon period. The overall changes between the pre-monsoon and post-monsoon periods show that the good quality water zone areas has increased by 12 per cent but moderate quality of waters have decreased by 9.38 per cent from pre-monsoon to post-monsoon period. Poor water quality is not observed in any of the samples in post-monsoon period. On the contrary, very poor quality water has got an increment of 3.12 per cent during the post-monsoon period. Now, looking into the increment of good water from pre-monsoon.

Based on USSL methods of classification, the irrigation water samples of the basin area classified as follows (Table 7).

Table 6. Quality of Irrigation Water Based on U. S. Salinity Diagram for Pre and Post- monsoon Seasons

Water Class	Category	Pre-monsoon Period		Post-monsoon Period	
		No. of Samples	Percentage (%)	No. of Samples	Percentage (%)
GOOD	C1S1			1	3.12
	C2S1	10	31.25	9	28.12
	C3S1	11	34.37	15	46.87
	C4S1	1	3.12	1	3.12
MODERATE	C3S2	5	15.62	3	9.37
	C4S2	2	6.25	1	3.12
POOR	C3S3	1	3.12	0	0
	C4S3	1	3.12	0	0
VERY POOR	C4S4	1	3.12	2	6.25
	Total	32	100%	32	100%

Table 7. Water Quality Classification for Irrigation

Salinity Class	Electrical Conductivity mmhos / cm	Sodium Class	Alkalinity Hazard (SAR)
C-1	Upto 250	S-1	Less than 10
C-2	250 to 750	S-2	10 to 18
C-3	750 to 2250	S-3	18 to 26
C-4	2250 to 4000	S-4	More than 26
C-5	More than 4000	-	-

U. S. Salinity Laboratory Water Classification

The U.S. Salinity Laboratory (1954) has prepared a diagram for classification of irrigation waters, with reference to SAR as an index of sodium (alkali) hazard and EC as an index of salinity hazard. Electrical Conductivity in mmhos per centimetre at 25° C is plotted on X axis against SAR on Y-axis and are shown in Fig. 2 and Fig. 3 for pre-monsoon and post-monsoon respectively. The estimated values are tabulated in

In the USSL diagram of both pre and post-monsoon seasons, the level of electrical conductivity is generally good upto 2250 mmhos/cm and it is tolerable upto 4000 mmhos/cm and more than 4000 mmhos/cm and SAR less than 18 is generally good, 18 to 26 tolerable and more than 26 is beyond tolerable level for irrigated agriculture. In the USSL diagram, the categories namely C2-S1, C3-S1, C4-S1, C3-S2, C4-S2, C3-S3, C4-S3 and C4-S4 are falling under three different classes shown in table 6. Considering the category of good water, it includes

C2-S1, C3-S1 and C4-S1 classes. The C2-S1 class in generally harmless for all crops, whereas all other types need remedial measures (application of gypsum and good drainage). In the study area, ten samples (31.25 per cent) viz., Pudunaduvalur, Alambadi, Thuraimangalam, Aiylur, Kottarai, Kadugur, Naranamangalam, Pappancheri, Vilangudi and Ambapur show this types of water quality, during the pre-monsoon period which 28.12 per cent or nine samples of C2-S1 type are observed in Pudunaduvalur, Alambadi, Kavulpalayam, Killamathur, Kulattur, Pappancheri, Periathirukkonam, Vilangudi and Ambapur of the study area. The class C1-S1 is found only in the Ariyalur block (in Kadugur) it has 3.12 per cent during the post-monsoon periods.

The class C3-S1 spreads in 34.37 per cent of the area in Kavulpalayam, Kunnam, Kalpadi, Ottakovil, Nochechikulam, V. Krishnapuram, Hasthinapuram, Reddipalayam, Periathirukkonam, Sundakkudi and Ulliyakkudi samples during pre-monsoon period and during the post-monsoon period it has 46.87 per cent of sample wells viz Siruganpur, Kottari, Killamathur, Irur, Ottakovil, Valajanagaram, Pudupalayam, Hasthinapuram, Reddipalayam Sundakkudi and Ulliyakkudi. The cultivators in this area should practice adequate drainage, special management for salinity control and selection of high salt tolerant plants. The danger of exchangeable sodium is also observed here. The C4-S1 class water is observed in only one a location is pre and post-monsoon periods in Kuttur and Kunnam which is 3.12 per cent.

MARUDAIYAR SUB-BASIN

U S S L DIAGRAM FOR CLASSIFICATION OF GROUNDWATER

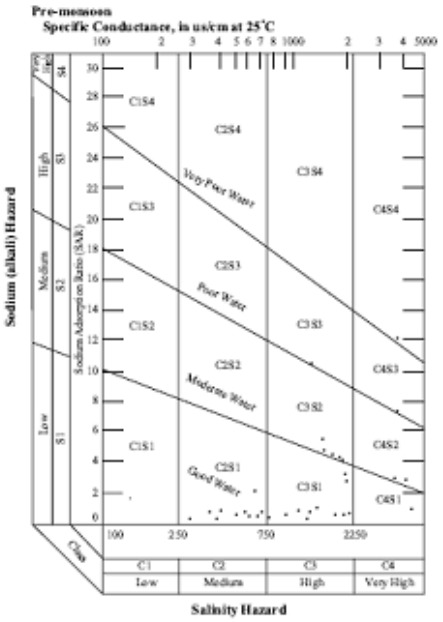

Fig.2.

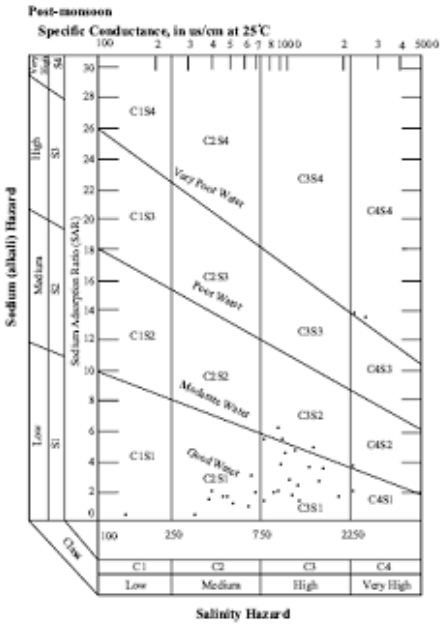

Fig.3.

MARUDAIYAR SUB-BASIN

GROUNDWATER CLASSIFICATION FOR AGRICULTURE

(MODIFIED PIPER'S TRILINEAR METHOD)

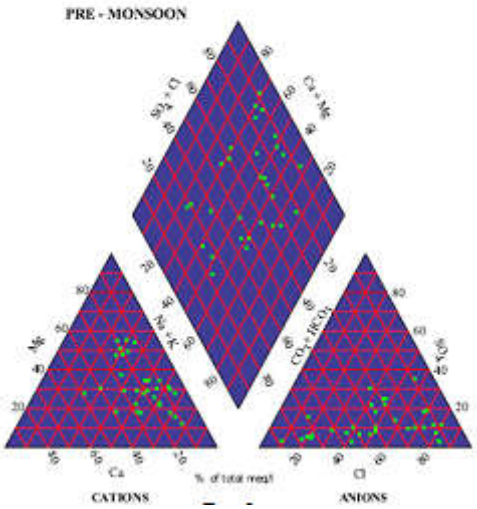

Fig.4.

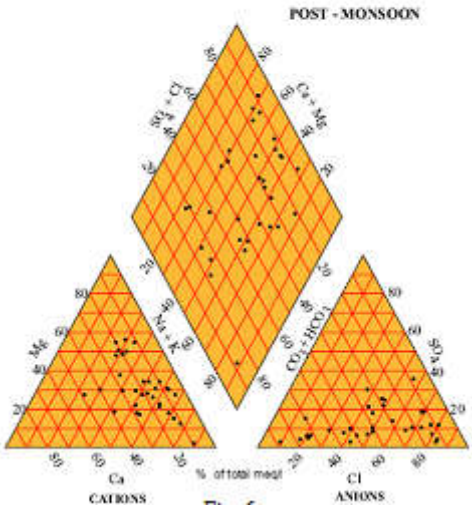

Fig.5.

The waters in this class are not suitable for irrigation because of the high salinity. The soil in this area must have been leached considerably and highly salt tolerant crops should be selected. Moderate class includes C3-S2 and C4-S2. The C3-S2 classes of water, which is suitable only in coarse textured or organic soils with good permeability. Fifteen per cent of C4-S2 water samples are found in Killamathur, Kulattur and Valajanaragram during the pre-monsoon period. In the post-monsoon period 9.37 per cent of C3-S2 class of water is observed in Garudamangalam, Nochechikulam, V. Krishnapuram of the study area.

In the study area, the C4-S2 water type occupies 6.25 percent (Kuttur and Naranamanaglama) during the pre-monsoon period. In post-monsoon period it occupies only in Garudamangalam, which is 3.12 per cent. These types of waters needs special management practices on salinity control and only salt tolerant crops should be selected for irrigated agriculture. Poor quality water is generally less in the study area, which is as low as 6.24 per cent during pre-monsoon period and in post-monsoon period, there is no observation well found. It includes C3-S3 and C4-S3 classes. The C3-S3 class is observed only in Pudupalayam. The C4-S3 class constitutes also only one sample in Irur in pre-monsoon period. This class needs special management plans and selection of salt tolerant crops and chemical amendments are warranted for replacement of exchangeable sodium in the soil. Moreover these amendments may not feasible with waters of very high salinity.

The bad or very poor quality water includes C4-S4, which is observed only in Siruganpur (3.12 per cent) during the pre-monsoon season. In post-monsoon period it increased to two samples, which is 6.25 per cent. It is noticed in Chittali and Kuttur only. The EC value is more than 750 mmhos / cm in a large number of locations. The alkalinity hazard is noticed in medium range and in one location it is high i.e. the SAR value exceeds more than 18. The prevailing criteria to evaluate water quality and their associated potential hazards to crop growth are salinity and sodium hazards. The quality of groundwater of the study area can be evaluated on the basis of these criteria (Table 3 & 8).

Modified Piper's Trilinear

Among the various trilinear methods of plotting, Piper (1954) diagram has been extensively used to understand the types of groundwater. The diagram consists of three distinct fields. Two triangular fields and a diamond shaped fields. Triangular fields plotted separately, using the percentage epm value of cation and Mg and Na and anion HCO_3, SO_4 and Cl. The overall characteristics of quality of groundwater are represented in the diamond shaped field by projecting the position of the plots in the triangular field for irrigated agriculture. In the diagram, total soluble cation (TSC) or total soluble anion (TSA) is plotted against the percent sodium for every groundwater sample, where the level of TSC or TSA below 22.5 epm is generally good, from 22.5 to 37.5 epm is tolerable and more than 37.5 epm is beyond tolerable level. While analyzing the level of sodium, it is classified as upto 30 percent is good for irrigation, between 30 and 57.5 percent is tolerable and more than 57.5 percent is beyond tolerable level. Based on Honda's modification, the quality of irrigation water in the study area is classified as in the Table 9.

Table 9. Quality Criteria for Irrigation Water

Class	Salinity	Total Soluble Anion or Total Soluble Cation (epm)
C1	Low	Less than 2.5
C2	Low – Medium	2.5 to 7.5
C3	Medium – High	7.5 to 22.5
C4	High – Very High	22.5 to 37.5
C5	Extremely	Greater than 37.5

Based on these characteristics, the groundwater samples have been classified with different combinations. It is quite interesting to note that the results of USSL diagram and Handa's classifications are more or less same. A little difference in the level of sodium between the two methods is that it is divided into (i.e. S1, S2, S3, S4 and S5) in the case of USSL diagram whereas into three (ie. S1, S2 and S3) in Handa's Classification or modified Piper's diagrams (Fig. 4 & Fig. 5).

Conclusion

Groundwater quality data obtained from the Water Resources Organizaiton (WRO) of the PWD, Government of Tamil Nadu for the period 1997-1999, were made use of to understand the quality aspects of the groundwater of the study area. Geo-chemical data were analysed to understand the pH, Electrical Conductivity, Total Hardness, TDS and SAR in the study area. Further the suitability of groundwater for irrigation purposes was assessed using a number of methods such as USSL method and plottings made in the modified Piper's Trilinear diagram.

From the analysis it is observed that in the groundwater of study area, the pH is ranging from 7.7 to 8.8 during pre-monsoon period and in the post-monsoon period, its ranges from 7.4 to 8.7. The pH values of all samples fall well within 7.4 to 8.8 which indicates the presence of carbonates of calcium and magnesium in the study area. During the pre-monsoon period the EC ranges from 4514-373 micromhos/cm and in post-monsoon period higher concentration was observed and it was found to rage from 7669-131 micromhos/cm.

The total Hardness (TH) of water ranges from 60 to 840 ppm during pre-monsoon while it is 65 to 1600 ppm during post-monsoon season. Total dissolved solids (TDS) in the study area range from 239 to 1544 ppm during pre-monsoon season while it ranges form 84 to 4908 ppm during post-monsoon season. Electrical Conductivity of pre-monsoon and post-monsoon shows 34.37 per cent of samples under good category, and nearly 55 per cent of samples under permissible category and the remaining 9.37 per cent of samples under doubtful category.

Portions of study area nearer to limestone and carbonate minerals possesses highest EC values which are classified as doubtful category. Further the analysis has shown that the study area is dominated by types I and II indicating the existence of recent waters. The plotting of geochemical data in the USSL diagram indicates that 22 out of 32 pre-monsoon season samples and 26 out of 32 post-monsoon season samples are of good category and most of these samples are of C3S1 type.

The assessment of groundwater quality for irrigated agriculture using Modified Piper's trilinear diagram shows result similar to that from the USSL diagram.

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