International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-2 Issue-3, February 2013

Evaluation of Groundwater for Irrigational Purposes in Cumbum Valley Theni District Tamilnadu India

R. Ayyandurai, M. Suresh, S. Venkateswaran

ABSTRACT- To evaluate the groundwater quality for irrigational purposes in Cumbum Valley, Theni District, Tamil Nadu covering a total area of about 1485.62 km^2 55 groundwater samples was collected from dug and bore wells in the various locations of study area. The samples were analyzed for physico-chemical and calculated parameters viz., Ca^{+2}, Mg^{+2}, Na^+, K^+, CO_3^-, HCO_3^-, Cl^-, SO_4^- and Kelley's ratio, SAR values, Mg-hazards, RSC have been worked out to know the suitability of the groundwater quality for irrigational purpose. Majority of the hydrochemical facies were identified using Piper trilinear diagram. It reveals that the subsurface water is alkaline earth (Ca+Mg) then alkalies (Na+K) type. The groundwater samples fall under class-I based on Doneen's classification and good to permissible category in the Wilcox classification. According to the SAR values plotted in the USSL diagram, most of the groundwater samples belong to C_3-S_1 (41.82%) class indicating high salinity and low sodium water, which can be used for almost all types of soil with little danger of exchangeable sodium that the groundwater could be used for all types of crops on soils of medium to high permeability.

Keywords: Cumbum Valley, Doneen's diagram, Irrigational, , Wilcox diagram USSL (U.S. Salinity Laboratory diagram).

I. INTRODUCTION

The Indian government and scientists have carried out a number of studies on groundwater resources in Tamil Nadu, focusing mainly on utilization surveys and prediction of evolving trends, reserve estimation, and system assessment. Hydro-chemical studies of water resources have been few, particularly with respect to interactions among surface water, groundwater, and aquifers, because Tamil Nadu is one of the leading agricultural states. The study area (Cumbum Valley watershed), Theni district, Tamil Nadu, India. 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 and Christ, 1965; Stumm and Morgan, 1970; Swaine and 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.

Manuscript published on 28 February 2013.
***Correspondence Author(s)
R. Ayyandurai, Department of Geology, Periyar University, Salem-11, India.
M. Suresh, Department of Geology, Periyar University, Salem-11, India.
S. Venkateswaran Department of Geology, Periyar University, Salem-11, India.

II. 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.

III. METHODOLOGY

Fifty five water samples were collected during the year 2012 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, but if polythene bottles are used they may be completely filled. Groundwater samples analyzed in the laboratory for major cations and anions EC, 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 were determined by Elico flame photometer (APHA, 1996). Sodium Absorption Ratio (SAR) was calculated by dividing sodium with the root of half calcium and magnesium as described by Richard (1954).

IV. RESULTS AND DISCUSSION

The main objectives of groundwater characteristics in the study area results 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).

A. Sodium Absorption 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 Absorption Ratio (SAR).

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

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 Sodium Absorption Ratio. (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 (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 post-monsoon (Table 2). All samples fall under the category of No Problem except one sample is fall under the increasing Problem category.

B. 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. 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. The formula used in the estimation of this ratio is expressed as,

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

C. 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 unfavorably (Eaton 1950 and Richards 1954). Table - 3 shows that 96% of samples are safe for irrigation purpose. The rest are unfit for irrigation use in the post monsoon season. The range of residual sodium carbonate in groundwater in the investigated area varies from -18.92 to 2.77 epm.

D. Magnesium Ratio

It is expressed as $MagnesiumRatio = \frac{Mg \times 100}{Ca+Mg}$,

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 post monsoon groundwater varies from 30 to 91.01 epm (Table - 1). Magnesium ratios were found to be more than the permissible limit in all 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).

E. Chemical Relationship

The Piper (1944) Trilinear Diagram is most useful to understand the chemical relationships among groundwater. The chemical quality data of the investigated area are used in Pipers Trilinear Diagram for graphical analysis (Fig. 2). It reveals that water is mostly of alkaline earth exceeds alkalies in the post monsoon season.

F. 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):

$$PI = \frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100 \quad \text{......................(1)}$$

Na, Ca etc. values in epm

The majority of the samples fall under class-I (Fig.3) under sampling programs as per Doneen's classification (Table 4), which indicates that groundwater is good for irrigation.

G. 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 concentration values are expressed in equivalents per million. The results (Table 5) show that the groundwater near the upstream is good for irrigation and the contamination are found to be high near the downstream (Fig.4). This may be due to the effluents from the industries as well as the domestic sewages directed into the river.

H. Ussl Diagram

U.S. Salinity Laboratory diagram (1954) interpretation is given in the Fig.5. The two most significant parameters of sodium and salinity hazards indicate usability 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 interred that the groundwater in those areas suitable for irrigation purpose.

V. 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 Donnen'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, the 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.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-2 Issue-3, February 2013

In the present study, it is evident that high salinity of groundwater persists at majority of sites. Hence, it is suggested that suitable measures interms of enhancement of drainage has to be made in areas were high salinity is observed for satisfactory crop growth.

REFERENCES

1. Apha (american public health association) (1996) standard methods for the examination of water and wastewater, 19th eds. Public health association, washington, dc.
2. Ayers, r.s., (1977) quality of water for irrigation, j. Irrigation and drainage div., asce, vol. 103, no. Ir2, pp. 135-154.
3. Christiansen, j.e., e.c. Olsen and l.s. Willardson, (1977) irrigation water quality evaluation, j. Irrigation and drainage div., asce, vol.103, no. Ir2, pp. 155-169.
4. Doneen, l.d., (1964) notes on water quality in agriculture, water science and engineering.
5. EATON, E.M. (1950) significance of carbonate in irrigation water. Soil. Sci., v.69, pp.123-133.
6. KELLEY, W.P. (1951) alkali soils – their formation properties and reclamation, reinold publ. Corp., new york.
7. Michael, a.m., (1990) irrigation: theory and practice, vikas publishing house pvt. Ltd., new delhi, 801p.
8. PANDIAN, K., and SANKAR, K. (2007) Hydrogeochemistry and groundwater quality in the vaippar river basin, tamil nadu jour Of gsi, v.69, pp.970-982.
9. PIPER, A.M. (1944) a graphical procedure in the chemical interpretation of groundwater analysis, trans. Amer. Geophy. Union, v.25, pp.914-923.
10. RICHARDS, L.A., (1954) diagnosis and improvement of saline and alkali soils, u.s.d.a handbook, vol.60, 160p.
11. U.s. SALINITY LABORATORY STAFF, (1954) diagnosis and improvement of saline and alkali soils, u.s. Dept. Agriculture hand book – 60p.
12. Vogel, a.i. (1968) a text book of quantitative inorganic analysis including elementary instrumental analysis. 3rd edn, elbs/longman, 121p.
13. Wilcox l.v (1955) classification and use of irrigation waters. Us department of agriculture, arc 969, washington dc.
14. Garrels, r.m and christ, c.l (1965) solutions, minerals and equilibria. Harper and row, new york, n.y., 450p.
15. Stumm, w. And morgan, j.j. (1970) aquatic chemistry. Wiley, new york, n.y. 1022p.
16. Swaine, s. And schneider, p.j. (1971) the chemistry of surface water in prairie ponds. Am. Chem. Soc. Adv. Chem. Ser.., v.106, pp.99-104
17. Kimblin, r.t. (1995) the chemistry and origin of groundwater in triassic sandstone and quaternary deposits, northeast england and some u.k. Coparisons. Jour. Hydrology, v.172. Pp.293-311.
18. Raju, k.c.b. (1998) importance of recharging depleted aquifers, state of the art of artificial resharge in india. Jour. Geol. Soc. India, v.51, pp.429-454.

Table 1. Anions & Cations Concentration in Groundwater Samples (All values in the table are expressed in epm except EC in µScm^{-1} and pH / TDS in ppm)

Sample.No.	Ca	Mg	Na+K	HCO_3	CO_3	SO_4	Cl	pH	EC*	TDS	K.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 Absorption Ratio.

Table. 2 Classification of Sodium Absorption Ratio in Groundwater

Sl.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

Sl.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
3	> 2.50	Unsuitable	-	-

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 (%)

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

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	-	-	-

Table 5. Classification of Groundwater for Irrigation Based on Wilcox Diagram Interpretation (1955)

Sl. No.	Category of Irrigation Water	Post 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
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	Post Monsoon (Locations samples)	Total No. of Locations	Percentage %
1	C1S1	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	C3S2	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

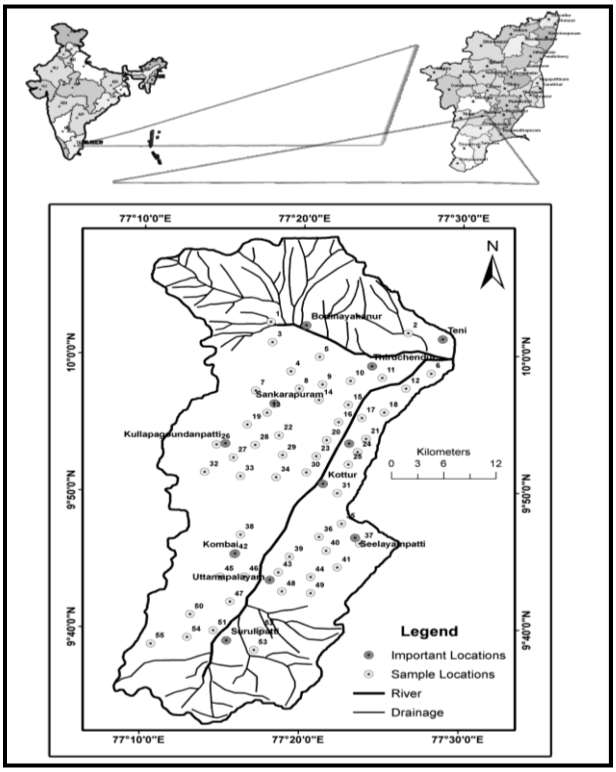

Fig.1. Study Area and Groundwater Sample Locations

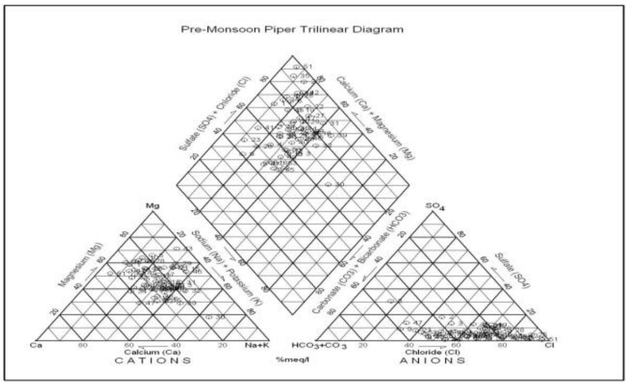

Fig.2 Piper Trilinear Diagram

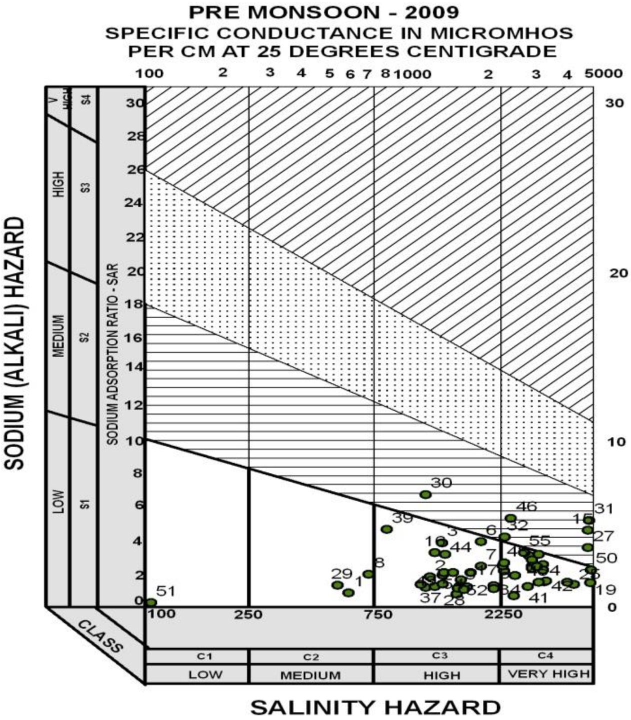

Fig. 5. USSL Diagram

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)