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

Assessment of Groundwater Quality for Irrigation Use and Evaluate the Feasibility Zones through Geospatial Technology in Lower Bhavani Sub Basin, Cauvery River, Tamil Nadu, India

S. Venkateswaran, S. Vediappan

Abstract- ***The present work is employed in Lower Bhavani sub-basin (study area 2424.19 sq.km), major portion of the study area fall in Erode District and small portion in Coimbatore District, Tamil Nadu and India. The 50 groundwater samples were collected from during pre monsoon (May) 2011 and were analysed for major cations and anions EC, pH and TDS. The irrigational parameters like; 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. Wilcox diagram indicates that out of 50 samples, 33 samples belong to good to permissible category and Doneen diagram revealed that 100% of the groundwater samples fall in Class I. The plotting of SAR values in USSL diagram indicates that all the samples have low SAR value. Out of 50 samples 41 samples in C_3-S_1 field. This implies that no alkali hazard is anticipated to the crops. 41 Location (82%) samples occurred within C_3–S_1 category. This category is suitable for irrigations purposes. However, the concentration of bicarbonate was in significant amount showing 54% of sites under "increasing problem" and the 44% sites under "Severe Problem" zones. Finally above said results are taken into GIS platform. To understand the spatial distribution of unsuitable zones, ArcGIS was employed. The present work reveals that groundwater in the Lower Bhavani sub-basin area is of good quality and is suitable for all uses including interbrain water transfer in the region.***

Key words: Irrigation; Sodium Absorption Ratio (SAR); Sodium Percentage; Doneen's diagram; Geographic Information System (GIS); Spatial Distribution Map; Cauvery River.

I. 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.

Manuscript published on 30 July 2013.
*****Correspondence Author(s)
S. Venkateswaran, Department of Geology, Periyar University, Salem, India.
S. Vediappan, Department of Geology, Periyar University, Salem, India.

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license http://creativecommons.org/licenses/by-nc-nd/4.0/

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. 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; Raju, 1998). This paper investigates the possible chemical processes of groundwater rock interaction in hard rock terrain. GIS has emerged as a powerful technology for instruction, for research, and for building the stature of programs (Openshaw 1991; Longley 2000; Sui and Morrill 2004; Baker and Case 2000). Saraf et al., (1994) have conducted GIS based study and interpretation of groundwater quality data. Durbude et al., (2007) mapped the ground water quality parameters in Ghataprabha command area in GIS environment.

II. STUDY AREA

Lower Bhavani sub-basin, have been selected for the present investigation. It lies between 11°14'53.91" and 11°46'39.84" N latitudes, and 77°3'55.18" and 77°41'23.35" E longitudes covering an area of 2424.19 Sq. km. Lower Bhavani sub-basin is one of the major tributaries of Cauvery river and fall in Erode and Coimbatore districts of Tamil Nadu. Erode and Coimbatore districts are characterized by a sub-tropical climate with moderate humidity and temperature. The weather is quite pleasant from November to February and becomes hot from March to June. The maximum temperature ranges from 24°C to 40°C and the minimum temperature ranges from 13°C to 28°C (Fig.1). The major source for groundwater in the study area is rainfall during monsoon season. The average annual rainfall is about 626.8 mm.

III. METHODOLOGY

The study area base map was prepared from toposheets registration in GIS environment the fallowing toposheets 58 E/2, 3, 6, 7, 9, 10 and 11 of 1:50,000 scale. The 50 groundwater samples from various locations in the study area were collected from dug and bore wells (Shallow depth) during the time of pre-monsoon season

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

(May 2011). 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. Geochemical data are taken into GIS platform and analyzed in ArcGIS software version 9.3. Spatial analysis tools were used for the preparation of interpolation map. The maps were interpolated by using inverse distance methods to generate the spatial distribution map.

IV. RESULTS AND DISCUSSION

A. Water Quality Analysis for Irrigation Purpose

The results of the geochemical analysis of groundwater in the pre-monsoon season are given in Tables 1. The pH values are in the range of 6.28 to 7.76 indicating groundwater of the study area is slightly acidic to alkaline in nature. The specific electrical conductivity (SEC) value of the samples varies from 438 to 8950 μScm^{-1} in the study area. The TDS value varies from 307 to 6265 mg/l during the pre-monsoon season (May-2011). These results indicate groundwater is of high and very high salinity water based on Durbude classification (Durbude et al., 2007).

B. Durbude Classification

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 2) as follows:

The updated attribute table in Arc GIS package with EC data was used for the zonation of various salinity zones in the study area (Fig. 2 and Table 2). The salinity representation maps were prepared and high and very high salinity zone determined. The EC based spatial distribution map indicates that high salinity zone covers an area of 1515.04 sq.km.

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 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. This can destroy the soil structure owing to dispersion of the clay particles.

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \quad \ldots\ldots\ldots \quad (1)$$ (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 very low SAR (less than 2) indicates no danger from sodium, 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 1.5 to 8.73 during pre-monsoon seasons (Table 1). Based on the table, the groundwater of the study area falls under the category of low sodium hazards zone. But there is little danger from sodium hazard in pre-monsoon season. 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;

$$Na\% = \frac{Na+K}{Ca+Mg+Na+K} \times 100 \ldots\ldots\ldots (2)$$ (Ragunath.,1987)

Where all ionic concentrations are expressed in Millieqivalent per litre.

The sodium percentage in the study area varies from 47.92 to 58.28 (Table 1). As per the world health organization, 2011 standards, the sodium percentage of 60 is the maximum recommended limit for irrigation water. The high sodium saturation in the water samples directly causes calcium deficiency in human beings.

C. 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 0.62 to 0.98 epm (Table 1). The formula used in the estimation of this ratio is expressed as,

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

D. Magnesium Hazards

(It is expressed as)

$$MagnesiumHazards = \frac{Mg \times 100}{Ca+Mg}$$

Where all the ions are expressed in epm.

Excess of magnesium in ground water samples affects the quality of soils, which causes poor in yield of crops. The magnesium ratio in some groundwater samples varies from 28.98 to 39.06 epm (Table 1). From the above table, the Magnesium ratios were found to be more than the permissible limit in all water sample locations, except in few locations. High Mg ratio in the ground water samples leads to surface and subsurface water interact with country rock (Pandian et. al., 2007). The study area occupies mostly charnockite and fissile hornblende biotite gneiss as country rock which highly my rich minerals such as pyroxene, mica, garnet etc. of some Mg bearing minerals.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

E.Residual Sodium Carbonate

Residual Sodium Carbonate is given by the formula:

$RSC = (CO_3 + HCO_3) - (Ca + Mg)$ All values in epm

In general the high concentration of CO_3 and HCO_3 represents alkaline nature, for this area is unfavorable for agriculture uses (Eaton 1950 and Richards 1954). Table 3 shows that hundred percent of samples are safe for agriculture purposes. The range of residual sodium carbonate in groundwater of the investigated area varies from -9.85 to 2.15 epm.

F.Bicarbonates

The bicarbonate concentration under "Increasing Problem" zone was found in 82% of the total samples in the study area (Table 4). The samples under "Severe Problem" zone were observed at only four sites. However, larger numbers of samples were observed under "increasing problem zone". In general, the higher value of bicarbonate (> 15 epm) observed during pre monsoon ground water sampling periods was essentially due to biochemical reactions. Mandel and Shiftan (1981) reported bicarbonate content more than 1 meq/l (epm) or 60 mg/1 (ppm) in the water is necessarily attributed from the biological activities of plant roots, from the oxidation of organic matter included in the soils and in the rock, and from various chemical reactions.

G. USSL Diagram

The plotting of SAR values in USSL diagram indicates that all the samples have low SAR value. Out of 50 samples, one sample lies in C_2-S_1 field, 41 samples in C_3-S_1 and one samples in C_4-S1, field (Fig. 3) The C_3-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. 41 Location (82%) 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). Above said results were taken in to GIS environment for spatial distribution map preparation. The spatial distribution results are given in Table 5. The spatial distribution map is shown in Fig. 4. Spatially 1432.64 km^2 area in C_3S_1 category, this class are could be used for all types of crops.

H. 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 good to permissible category for irrigation use, except three samples which are under Unsuitable category (Tab 6).

Percentage of sodium plotted on Wilcox diagram indicates that out of 50 samples, 33 samples belong to good to permissible category, 7 samples belong to Permissible to doubtful category and 3 samples belong to unsuitable category (Fig.5). The spatial distribution map results are given in the Table 6. In the present investigation, the spatial distribution map (Fig.6) indicates that the "Good to permissible" covers an aerial extent of 420.56 km^2.

I. 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

PI values of groundwater samples range from 52.38 to 65.63 with an average value of 59.37 (Table 7). Analytical data of PI values plotted on Doneen diagram revealed that 100% of the groundwater samples fall in Class I (Fig. 7). The water sample fall under, Classes I in the Doneen diagram are generally good for irrigation purposes.

V. CONCLUSION

In this study, the assessment of groundwater for irrigational uses has been evaluated on the basis of various guidelines. The salinity based on Durbude Classification of the study area spatial distribution map indicates that high and very high salinity zone covers an area of 1515.04 km^2 and 313.10 km^2. Another one classification with respect to SAR and sodium percentage, more than 75% of the samples are within the permissible limit and the groundwater is suitable for irrigation purpose. The Mg ratios were found to be more than the permissible limit in all water sample locations, except in few locations. The residual sodium carbonate values of groundwater samples showed 38 (76%) samples under "Safe" category. U.S. Salinity diagram, the 41 Location (82%) samples occurred within C_3–S_1 category under the present investigations. Spatially 1432.64 km^2 area in C_3S_1 category, this class are could be used for all types of crops. The groundwater fall under class-I for all sites as per classification of Donnen's Permeability Index, and could be treated as good for irrigation. The Wilcox classification has shown 66% of groundwater under "Good to Permissible" zone. Thus, the overall groundwater quality in the basin is fresh and suitable for irrigation use. According to in the present study, it is evident that high salinity of groundwater persists at majority of sites. The ground water samples leads to surface and subsurface water interact with country rock. The study area occupies mostly charnockite and fissile hornblende biotite gneiss as country rock which highly my rich minerals such as pyroxene, mica, garnet etc. Hence, for high to very high salinity of waters, soil must be permeable with adequate drainage facilities for satisfactory crop growth.

REFERENCES

1. BAKER THOMAS R., and CASE STEVEN B. (2000). Let GIS be your guide. The Science Teacher 67, no. 7: 24-26. http://kangis.org/learning/publications/science_teacher/print/tst0010_24. pdf.
2. BIS. (1991) Indian standards specifications for drinking water. Bureau of Indian Standards, New Delhi. IS: 10500.
3. DONEEN, L.D., (1961) Notes on water quality in Agriculture. Published as a water science and Engineering Paper 4001, Department of Water Sciences and Engineering. University of California.
4. DONEEN, L.D., (1964) Notes on Water Quality in Agriculture, Water Science and Engineering.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

5. DURBUDE D. G., and VARARRAJAN, N. (2007) Monitoring and mapping of groundwater quality. Journal of Applied Hydrology, v.xx, No. 1&2, pp.22–30.
6. EATON, E.M., (1950) Significance of carbonate in irrigation water. Soil. Sci., Vol.69, pp.123-133.
7. FRAPE, S.K., FRITZ, P., and MCNUTT, R.H. (1984) Water rock interaction and chemistry of groundwaters from the Canadian Shield. Geochem. Cosmochim. Acta, v.48, pp.1617–1627.
8. GARRELS, R.M., and CHRIST, C.L. (1965) Solutions, Minerals and Equilibria. Harper and Row, New York, N.Y., 450p.
9. HEM, J.D. (1985) Study and interpretation of the chemical characteristics of natural water. US Geol. Surv. Water Supply pp.254, 263, USGS, Washington.
10. HERCZEG, A.L., TORGERSEN, T., CHIVAS, A.R., and HABERMEHL, M.A. (1991) Geochemistry of groundwater from the Great Artesian Basin, Australia. Jour. Hydrology, v.126, pp.225–245.
11. KELLEY, W.P., BROWN, S.M. and LEIBIG, G.I. Jr. (1940) Chemical effects of Saline Irrigation water on soils. Soil Science, Vol.49, pp. 95-107.
12. KIMBLIN, R.T., (1995) The chemistry and origin of groundwater in Triassic sandstone and Quaternary deposits, Northwest England and some U.K. comparisons. Jour. Hydrology, v.172. pp.293–311.
13. LONGLEY PAUL, A., (2000) The academic success of GIS in geography: Problems and prospects. Journal of Geographical Systems, 2 no. 1: pp.37 – 42.
14. MANDEL, S. and Z.L. SHIFTAN, (1981). Ground Water Resources Investigation and Development, Academic Press Inc., New York.
15. MICHAEL, A.M., (1990) Irrigation: Theory and Practice, Vikas Publishing House Pvt. Ltd., New Delhi, 801p.
16. OPENSHAW, S.A., (1991) view on the crisis in geography, or using GIS to put humpty-dumpty back together again. Environment and Planning, A 23, no. 5: pp.621-628.
17. PANDIAN, K., and SANKAR, K. (2007) Hydrogeochemistry and groundwater quality in the Vaippar river basin, Tamil Nadu Jour. of GSI, Vol.69, pp.970-982.
18. PAWAR, N. J. (1993) Geochemistry of carbonate precipitation from the grounwaters in basaltic aquifers, An equilibrium thermodynamic approach, Jour. Geol. Soc. India, v.41, pp.119–131.
19. RAJU, K.C.B. (1998) Importance of recharging depleted aquifers, State of the art of artificial recharge in India. Jour. Geol. Soc. India, v.51, pp.429–454.
20. RICHARDS, L.A., (1954) Diagnosis and improvement of saline and alkali soils, U.S.D.A handbook, Vol.60, 160p.
21. SALEH, A., AL-RUwaih, F. and SHEHATA, M. (1999) Hydrogeochemical processes operating within the main aquifers of Kuwait. J. Arid Env. V.42, pp.195-209.
22. SARAF, A.K., GUPTA, R.P., JAIN, R.K., and SRIVASTAVA, N.K. (1994) GIS based processing and interpretation of ground water quality data, Proceedings of Regional workshop on Environmental Aspects of Ground water Development, Oct. 17-19, Kurukshetra, India.
23. SOM. S.K., and BHATTACHARYA, A.K. (1992) Groundwater geochemistry of recent weathering at Panchpatmali bauxite bearing plateau, Koraput district, Orissa. Jour. Geol. Soc. India, v.40, pp.453–461.
24. STUMM, W., and MORGAN, J.J. (1970) Aquatic Chemistry, Wiley, New York, N.Y. 1022p.
25. SUI DANIEL, and RICHARD MORRILL. (2004) Computers and geography: From automated geography to digital earth. In Geography and Technology, edited by STANLEY, D., BRUNN SUSAN, L., CUTTER, and J.W. HARRINGTON, JR. DORDRECHT, NL: KLUWER.
26. 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.
27. TODD, D.K. (1980) Groundwater Hydrology. 2nd Edn. John Wiley & sons, Inc, New York.
28. WICKS, C.M., and HERMAN, J.S. (1994) The effect of a confining unit on the geochemical evolution of groundwater in the Upper Floridan aquifer system. Jour. Hydrology, v.153, pp.139–155.
29. WILCOX L.V (1955) Classification and use of irrigation waters. US Department of Agriculture, Arc 969, Washington DC.

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 - Hazards
1	5.59	2.88	6.70	0.38	7.54	0.00	2.71	5.30	7.09	1521	1065	0.79	-0.93	3.25	53.48	33.99
2	6.29	3.13	7.26	0.43	10.72	0.00	1.08	5.30	7.53	1645	1152	0.77	1.31	3.35	52.87	33.20
3	6.04	3.04	8.00	0.46	9.81	0.00	1.42	6.32	6.89	1823	1276	0.88	0.73	3.75	56.11	33.51
4	5.39	2.80	5.78	0.33	9.68	0.00	0.90	3.72	7.41	1312	918	0.71	1.50	2.86	50.69	34.16
5	16.17	7.07	19.74	1.15	13.39	0.00	1.98	28.76	6.28	2520	1764	0.85	-9.85	5.79	54.90	30.43
6	20.96	8.55	26.57	1.56	22.72	0.00	3.33	31.58	6.72	6090	4263	0.90	-6.79	6.92	56.19	28.98
7	6.09	3.04	6.30	0.38	10.08	0.00	2.91	2.82	7.01	1432	1002	0.69	0.95	2.95	50.16	33.32
8	28.14	11.76	39.00	2.30	36.24	0.00	5.21	39.76	6.98	8950	6265	0.98	-3.67	8.73	58.26	29.47
9	3.69	2.14	4.74	0.28	6.56	0.00	0.79	3.50	7.13	1065	746	0.81	0.73	2.78	54.55	36.67
10	4.34	2.38	6.09	0.36	8.25	0.00	1.08	3.84	7.76	1375	963	0.90	1.53	3.32	57.04	35.46
11	5.29	2.63	5.83	0.33	8.82	0.00	1.08	4.17	7.36	1320	924	0.74	0.90	2.93	51.58	33.22
12	6.69	3.29	8.43	0.49	5.14	0.00	2.71	11.05	7.29	1922	1345	0.85	-4.84	3.78	55.04	32.97
13	3.29	1.97	4.78	0.28	7.41	0.00	1.00	1.92	7.19	1080	756	0.91	2.15	2.95	57.35	37.47
14	3.89	2.22	5.48	0.33	5.90	0.00	0.50	5.53	7.47	1241	869	0.90	-0.22	3.13	56.97	36.32
15	4.14	2.30	4.61	0.28	8.18	0.00	0.56	2.59	7.33	1035	725	0.72	1.73	2.57	51.32	35.73
16	4.59	2.47	4.91	0.28	7.94	0.00	0.81	3.50	7.38	1109	776	0.70	0.89	2.62	50.41	34.96
17	5.34	2.80	7.70	0.46	8.84	0.00	1.58	5.87	7.10	1750	1225	0.95	0.71	3.82	58.04	34.37
18	6.14	3.13	8.43	0.49	10.24	0.00	1.62	6.32	7.53	1920	1344	0.91	0.98	3.92	56.95	33.74
19	5.14	2.71	7.52	0.43	9.30	0.00	1.77	4.74	7.67	1710	1197	0.96	1.45	3.80	58.28	34.56
20	4.74	2.55	5.09	0.31	8.30	0.00	1.17	3.21	7.44	1145	802	0.70	1.01	2.66	50.59	34.97
21	4.89	2.63	5.48	0.33	8.40	0.00	0.87	4.06	7.48	1241	869	0.73	0.88	2.82	51.67	34.99
22	6.59	3.29	7.43	0.43	9.79	0.00	1.98	5.98	7.22	1689	1182	0.75	-0.09	3.35	52.22	33.31
23	3.49	2.06	4.00	0.23	7.26	0.00	0.60	1.92	7.31	895	627	0.72	1.71	2.40	51.53	37.05
24	5.89	2.96	7.09	0.41	9.76	0.00	1.62	4.96	7.71	1605	1124	0.80	0.91	3.37	53.75	33.46
25	3.44	2.06	4.00	0.23	5.46	0.00	0.77	3.50	7.66	896	627	0.73	-0.04	2.41	51.79	37.39
26	5.59	2.88	6.17	0.36	8.51	0.00	0.96	5.53	7.26	1396	977	0.73	0.05	3.00	51.49	33.99
27	3.94	2.22	4.43	0.26	8.23	0.00	1.04	1.58	7.40	996	697	0.72	2.07	2.53	51.38	36.03
28	2.69	1.73	3.43	0.20	5.36	0.00	0.56	2.14	7.75	769	538	0.78	0.93	2.31	53.70	39.06
29	4.49	2.47	6.04	0.36	7.23	0.00	2.29	3.84	7.19	1369	958	0.87	0.28	3.24	56.04	35.46
30	4.59	2.47	4.87	0.28	8.15	0.00	1.35	2.71	6.98	1099	769	0.69	1.09	2.59	50.20	34.96
31	3.34	1.97	4.09	0.23	6.18	0.00	0.75	2.71	7.76	916	641	0.77	0.86	2.51	53.09	37.12
32	9.43	4.36	12.70	0.74	13.77	0.00	2.29	11.17	6.98	2900	2030	0.92	-0.02	4.83	57.02	31.61
33	9.88	4.61	13.43	0.79	9.01	0.00	3.12	16.58	6.88	3070	2149	0.93	-5.48	4.99	57.24	31.79
34	6.49	3.21	8.78	0.51	9.93	0.00	2.29	6.77	7.57	1995	1397	0.91	0.24	3.99	56.78	33.08
35	5.89	2.96	6.57	0.38	1.26	0.00	9.58	4.96	7.27	1488	1042	0.74	-7.59	3.12	51.88	33.46
36	9.78	4.52	11.43	0.66	13.69	0.00	3.12	9.59	7.01	2610	1827	0.80	-0.61	4.28	53.52	31.62
37	18.26	7.89	19.70	1.15	22.51	0.00	2.50	22.00	6.80	4510	3157	0.75	-3.65	5.45	51.88	30.18

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

38	3.44	2.06	4.00	0.23	6.94	0.00	1.77	1.02	7.39	896	627	0.73	1.45	2.41	51.79	37.39
39	3.04	1.89	3.57	0.20	5.25	0.00	0.75	2.71	7.54	796	557	0.72	0.31	2.27	51.72	38.32
40	4.84	2.55	5.48	0.33	8.03	0.00	1.33	3.84	7.28	1241	869	0.74	0.64	2.85	52.06	34.50
41	3.49	2.06	4.13	0.26	6.23	0.00	1.00	2.71	7.43	931	652	0.74	0.68	2.48	52.50	37.05
42	3.84	2.14	5.17	0.31	4.83	0.00	0.31	6.32	7.50	1169	818	0.87	-1.15	2.99	55.98	35.75
43	6.69	3.29	7.43	0.43	6.63	0.00	2.08	9.14	7.17	1688	1182	0.75	-3.35	3.33	51.93	32.97
44	6.69	3.29	9.00	0.54	8.16	0.00	1.87	9.48	7.05	2050	1435	0.90	-1.81	4.03	56.72	32.97
45	3.64	2.06	4.13	0.23	7.65	0.00	1.17	1.24	7.42	926	648	0.72	1.95	2.45	51.49	36.08
46	4.29	2.38	5.35	0.31	7.98	0.00	1.87	2.48	7.48	1214	850	0.80	1.30	2.93	54.00	35.72
47	5.29	2.71	5.83	0.33	8.91	0.00	1.08	4.17	7.36	1320	924	0.73	0.90	2.91	51.40	33.91
48	1.80	1.15	1.83	0.10	3.41	0.00	0.23	1.24	7.74	438	307	0.62	0.46	1.50	47.92	39.06
49	4.99	2.63	6.26	0.36	9.35	0.00	1.17	3.72	7.12	1420	994	0.82	1.73	3.21	54.48	34.53
50	8.78	4.19	11.91	0.69	12.87	0.00	3.12	9.59	6.94	2720	1904	0.92	-0.11	4.68	57.01	32.32

EC* – Electrical conductivity, RSC* – Residual Sodium Carbonate, SAR* – Sodium Adsorption Ratio.

Table 2. Spatial Distribution Result of specific Electrical Conductivity Classification for Irrigational Purpose

Sl.No.	Conductivity (μScm^{-1})	Zone	Spatially Area in km^2
1	< 250	Low Salinity Zone	Nil
2	250-750	Medium Salinity Zone	7.96 sq.km
3	750-2250	High Salinity Zone	1515.04 sq.km
4	2250-5000	Very High Salinity Zone	313.10 sq.km

(Durbude et al., 2007)

Table 3. Residual Sodium Carbonate in Groundwater (Christiansen et al., 1977)

S. No	RSC (epm)	Category	Pre monsoon (No. of samples)	Pre monsoon (Total No. of samples)	Percentage (%)
1	<1.25	Safe	1,3,5,6,7,8,9,11,12,14,16,17, 18,20,21,22,24,25,26,28,29, 30,31,32,33,34,35,36,37,39, 40,41,42,43,44,47,48,50	38	76
2	1.25 – 2.5	Marginal	2,4,10,13,15,19,23,27,38, 45,46,49	12	24
3	>2.50	Unsuitable	Nil	Nil	Nil

Table 4. Bicarbonate Concentration of Ground Water Samples (Mandel and Shiftan 1981)

Sl. No.	Bicarbonate (epm) or (meq/l)	Effects	Sample Numbers (No. of samples)	Total No. Samples	Percentage
1	0 – 1.5	No Problem	35	1	2
2	1.5 – 8.5	Increasing Problem	1,9,10,12,13,14,15,16 20,21,23,25,27,28,29, 30,31,38,39,40,41,42, 43,44,45,46,48	27	54
3	>8.5	Severe Problem	2,3,4,5,6,7,8,11,17,18, 19,22,24,26,32,33,34, 36,37,47,49,50	22	44

Table 5. Classifications of groundwater samples based on USSL in the Lower Bhavani Sub-basin

Type of Water	Sample location number as shown in Fig. 3	Total No. of Samples	Percentage of Samples	Spatial Distribution Area in km^2
C1-S1 (Good)	-Nil-	-Nil-	-Nil-	-
C2-S1 (Good)	48	1	2 %	12.17 sq.km
C3-S1 (Good)	1,2,3,4,7,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,34,35,38, 39,40,41,42,43,44,45,46,47,49	41	82 %	1432.64 sq.km
C4-S1 (Good)	5	1	2 %	359.82 sq.km
C3-S2 (Moderate)	-Nil-	-Nil-	-Nil-	-
C4-S2 (Moderate)	6,8,32,33,36,37,50	7	14 %	31.47 sq.km

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

C4-S3 (Bad)	Nil	Nil	Nil	Nil

Table 6. Classifications of Groundwater Samples Based on Wilcox's in the Lower Bhavani Sub-basin

Type of Water	Sample location number as shown in Fig. 5	Total No. of Samples	Percentage of Samples	Spatial Distribution Area in sq.km
Excellent to Good	38,48	2	4 %	878.59 sq.km
Good to Permissible	1,2,3,4,7,9,10,11,13,14,15,16,20 ,21,23,24,25,26,27,28,29, 30,31,35,39,40,41,42,43,45, 46,47,49	33	66 %	420.56 sq.km
Permissible to Doubtful	12,17,18,19,22,34,44	7	14 %	427.14 sq.km
Doubtful to Unsuitable	5,32,33,36,50	5	10 %	93.44 sq.km
Unsuitable	6,8,37	3	6 %	16.35 sq.km

Table 7. Classifications of Groundwater Samples Based on Doneen in the Lower Bhavani Sub-basin

Type of Water	Sample location number as shown in Fig. 7	Total No. of Samples	Percentage of Samples	Spatial Distribution Area in sq.km
Class – I	All Samples	50	100%	1836.10 sq.km
Class - II	Nil	Nil	Nil	Nil
Class - III	Nil	Nil	Nil	Nil

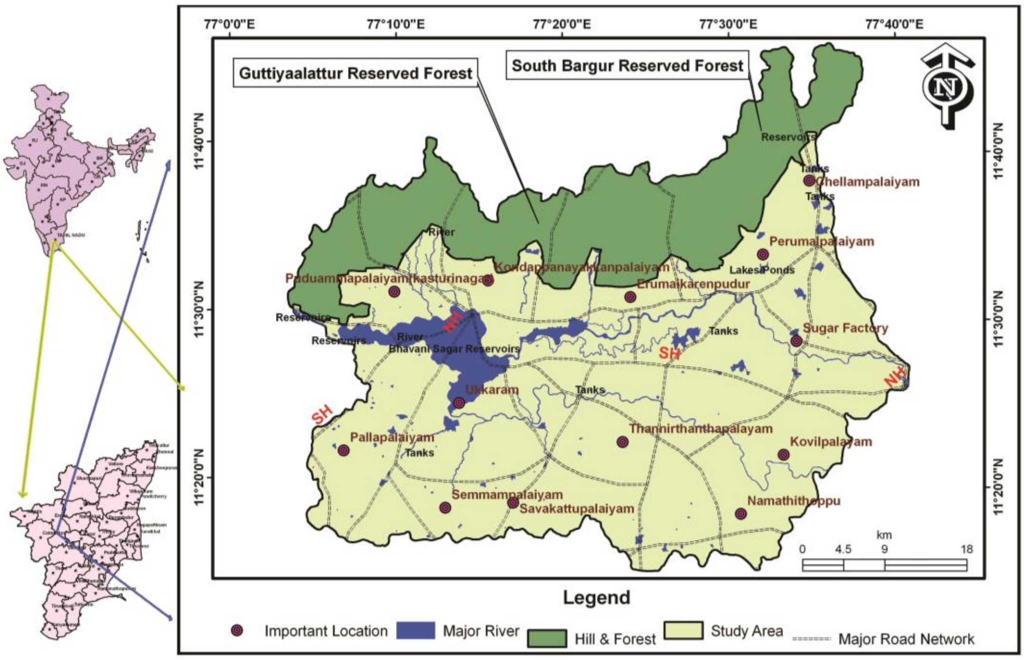

Fig.1 Study Area Map

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

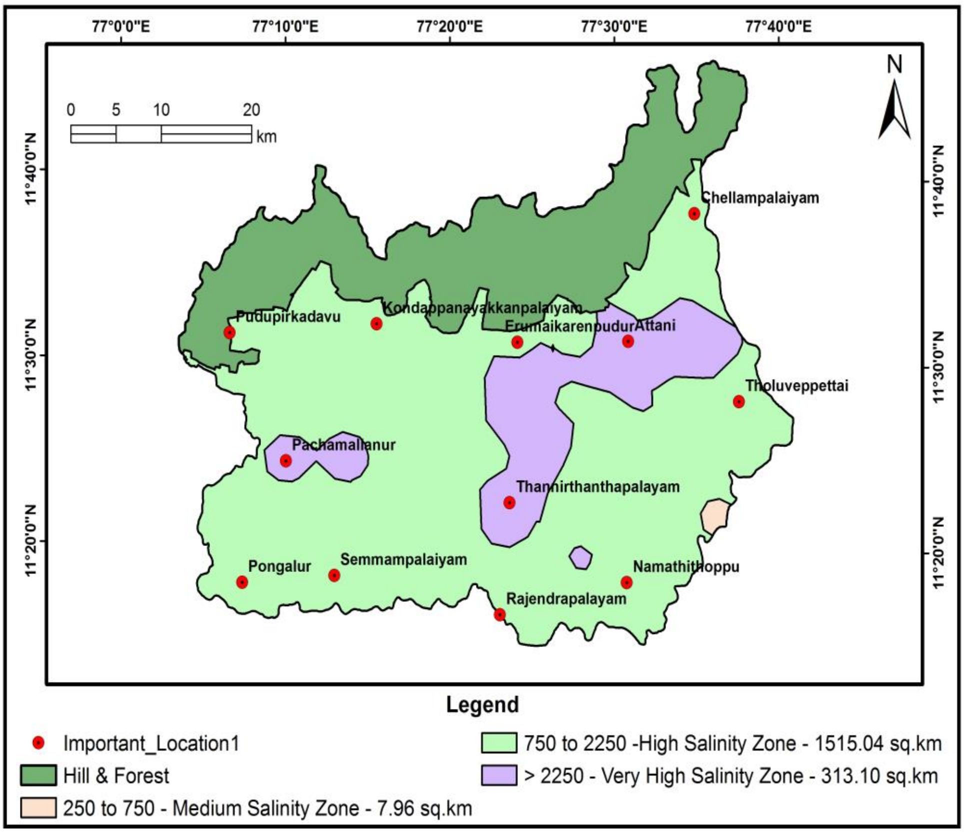

Fig. 2 Spatial Distribution Map of Specific Electrical Conductivity - Classification for Irrigational Purpose - Durbude et al., 2007

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

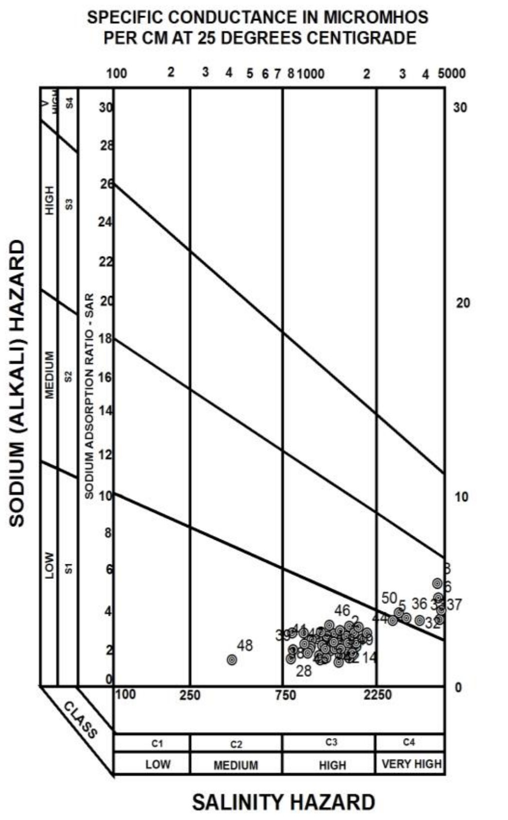

Fig.3, USSL diagram for classification of groundwater quality in the Omalur Taluk, Salem Dist. SouthIndia

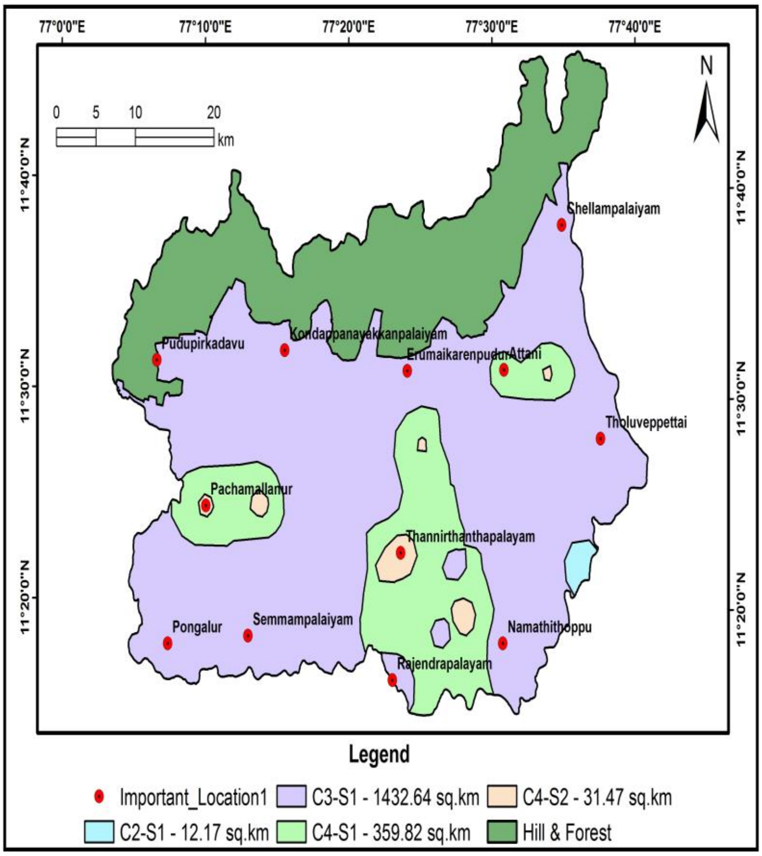

Fig.4, Spatial Distribution Map of groundwater quality Based on USSL classification in the Lower Bhavani

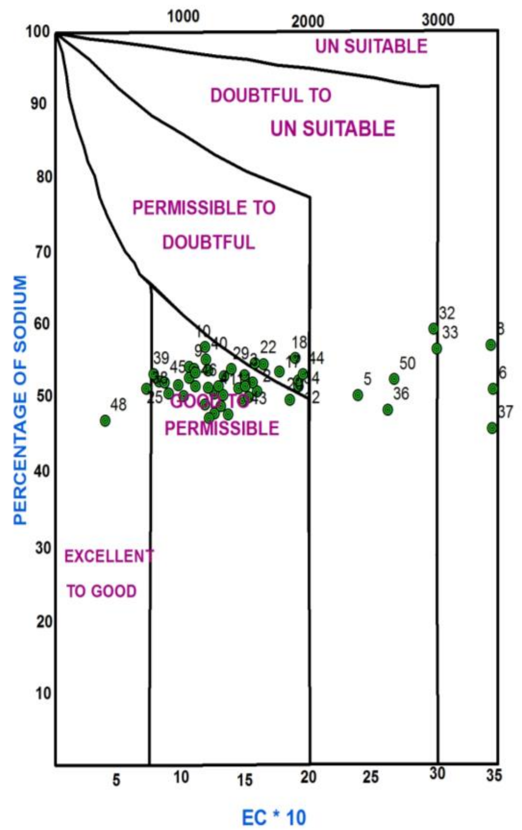

Fig.5, Wilcox's diagram for classification of groundwater quality in the Omalur Taluk, Salem Dist. SouthIndia

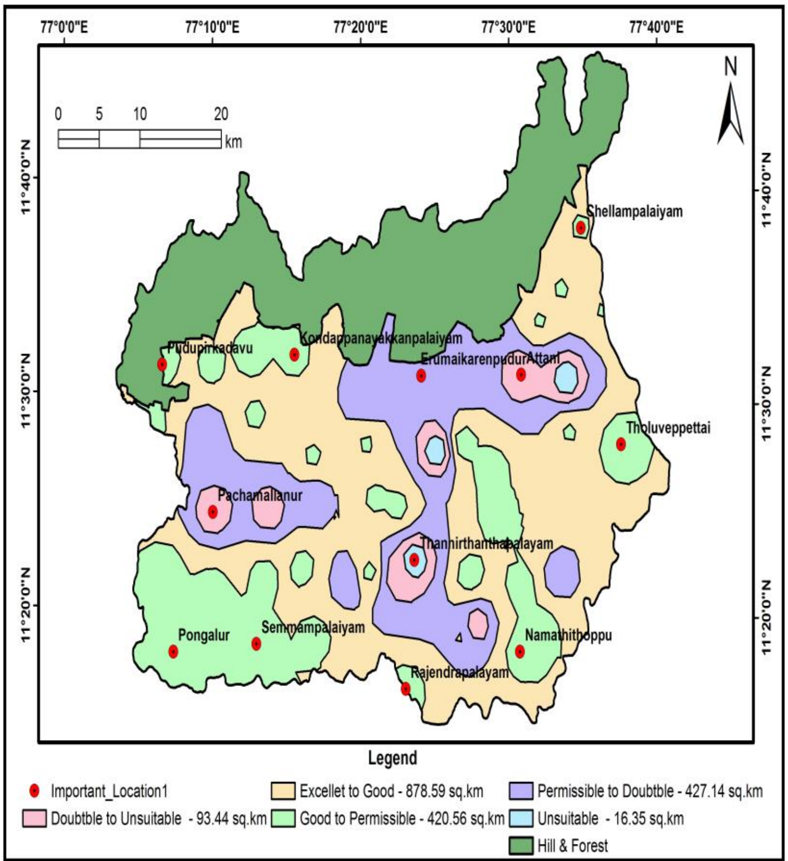

Fig.6, Spatial Distribution Map of groundwater quality Based on Wilcox's classification in the Lower Bhavani

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.

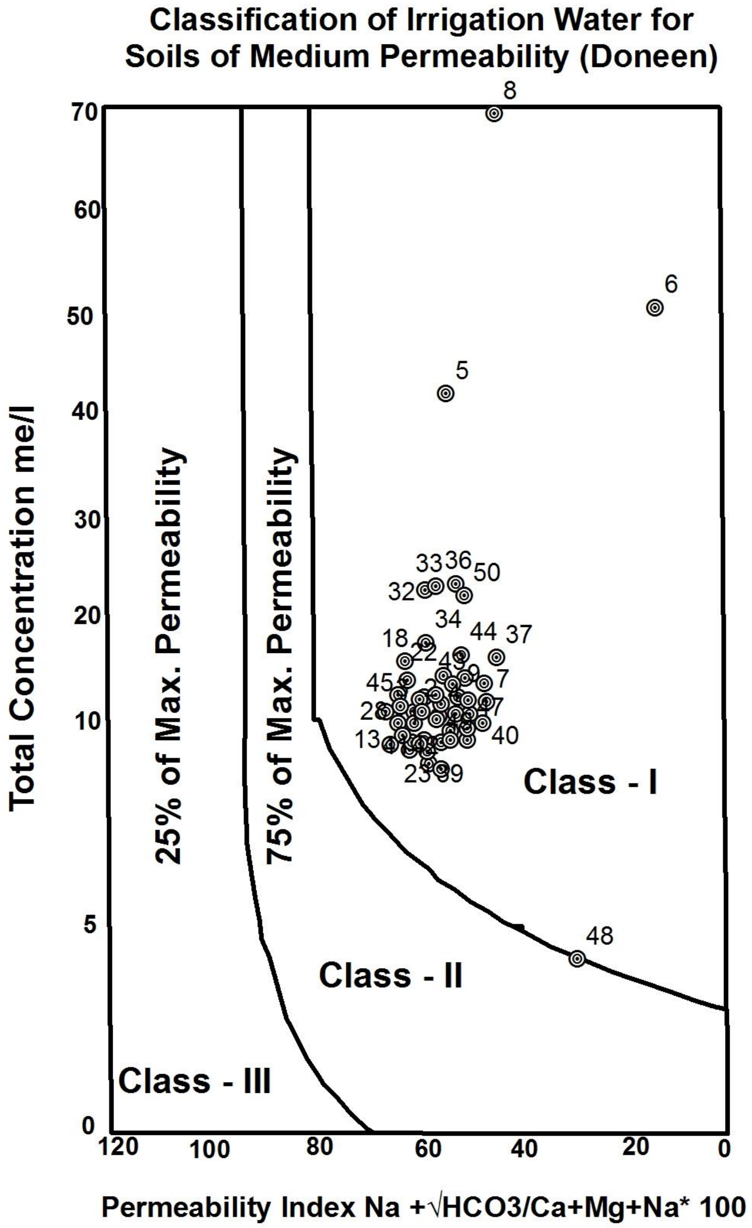

Fig.7 Doneen's diagram for classification of groundwater quality in the Lower Bhavani

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)
© Copyright: All rights reserved.