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Assessment of Groundwater Quality and its Suitability for Irrigation Purpose from Velpula area of Kadapa District, Andhra Pradesh, India

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ABSTRACT

Hydrogeochemical study of groundwater was carried out from the Velpula area of Kadapa District, Andhra Pradesh to ascertain the suitability of groundwater for irrigation purpose. Total 14 groundwater samples were collected and were analyzed for various physical and chemical parameters such as pH, EC, TDS, Ca, Mg, Na, K, CO_3 and HCO_3 by standard methods. The mean concentration of cations is in the order Ca>Na> Mg> K, while for anions it is HCO_3> CO_3..To ascertain the suitability of groundwater for irrigation purposes, hydrochemical parameters of the study area have been evaluated for their chemical composition. The quality of groundwater for irrigation has been evaluated by various chemical parameters such as Sodium adsorption ratio (SAR), Sodium percentage (%Na), Residual sodium carbonate (RSC), Kelley Ratio (KR), Residual sodium bicarbonate (RSBC), and Magnesium adsorption ratio (MAR) and this study indicates that water of the study area is suitable for irrigation purposes. But ten samples restrict its utility with respect to MAR, and one sample is non suitable based on RSSBC. From US salinity diagram, it is evident that the water samples belong to category of C_2S_1 and C_3S_1 indicates the medium to high salinity, and low alkali hazard. *This groundwater source can be used to irrigate all types of soils. From Wilcox diagram, it is observed that groundwater of the study area is excellent to good and good to permissible quality for irrigation purpose. Based on Wilcox plot, out of 14 groundwater samples, seven samples fall in the zone of excellent to good category and seven samples fall in good to permissible category. Overall the groundwater quality of the study area is suitable for irrigational purpose.*

Key Words: Groundwater quality, Irrigation utility, Velpula, Andhra Pradesh

1. INTRODUCTION

Groundwater an important natural resources essential for sustenance of life. Over ninety eight percent of the fresh water on the Earth lies below its surface. It is widely used for domestic, drinking, industrial and agricultural purposes. The quality of groundwater has major on human health. Groundwater contamination commonly results from human and industrial activities. The quality of groundwater within a region is governed by both natural processes such as precipitation rate, weathering processes and soil erosion and anthropogenic activities and the human exploitation of water resource (Mahajan, 2012).Generally, the movement of groundwater along its flow paths below the ground surface increases the concentration of chemical species (Domenico and Schwartz, 1990; Kortatsi, 2007). Hence the groundwater chemistry of aquifers as well as suitability of groundwater for domestic and irrigation purposes. chemical status of groundwater provide better understanding the possible changes in its quality as development progress. Quality of groundwater is equally important as its quantity owing to the suitability if water for various purposes (Schiavo et al., 2006; Subramani et al., 2005). The groundwater is essential component of the hydrological cycle which facilitates unique behavior of the water on the continent (Mathur et al., 2010). The suitability of groundwater for drinking, irrigation and industrial purposes depends upon its quality. Groundwater chemistry depends on number of factors, such as lithology, degree of chemical weathering of various rock types, quality of recharge water and inputs from sources other than water-rock interaction. The chemical composition of groundwater is controlled by any factors that include the composition of precipitation, geological structures and mineralogy and various other factors (Andre et al., 2005). Change in groundwater quality may be caused by variations in climatic conditions, residence time of water, aquifer materials, and inputs from soil during recharge (Giridharan et al; 2008; Krishna et al., 2009).

2. STUDY AREA

Kadapa district is one of the chronically drought affected area in Andhra Pradesh. The study area Velpula area (Lat 14° 37' N and Long 78° 32'E) is located in Kadapa District, Andhra Pradesh. The study area is about 60 Km from Kadapa, the district headquarter and 10 Km from Plivendula, the mandal headquarter. The Kadapa district receive moderate rain fall. Summer experiences temperatures ranging from 33^0 to 42^0. In winter the minimum temperatures between 22^0 to 25^0 . This study area forms part of the Lower Cuddapah super group comprising Papaghni and Chitravati Groups (Nagaraja Rao et al., 1987).This area chiefly consists of shales, dolomites, basalts and dolomitic limestones. The area is characterized by hot climate. The minimum and maximum temperatures are 22^0 C and 43^0C. This area receive rain fall during the months of July to October. The aim of present study is to investigate the groundwater quality in Velpula area of Kadapa District, Andhra Pradesh in order to evaluate its suitability for agricultural purposes. Studies of groundwater quality and hydrogeochemically in different part of Andhra Pradesh have been taken up by earlier researchers. (Subba Rao, 2002; Sujatha and Reddy, 2003; Reddy et al., 2009). Agriculture is the main occupation of this area. The main crops are groundnut, sunflower, leman, orange and vegetables.

3. MATERAILS AND METHODS

14 groundwater samples were collected from the Velpula area in the year 2015. The water samples were collected in one liter narrow mouth pre-washed high density polyethylene bottles. Prior to each sampling event polyethylene bottles were washed in the laboratory with dilute hydrochloric acid and then rinsed twice with distilled water. The samples bottles were also washed with groundwater of each site before samples were collected and carefully sealed with proper labeling. The chemical parameters were analyzed using standard hydrochemical analytical techniques (APHA 1985, 1992). The water samples were analyzed for the parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), Ca, Na, K, Mg, HCO_3, and CO_3. Electrical conductivity (EC), total dissolved solids (TDS) and pH and were determined in the field with standard equipment. Samples were analyzed standard analytical procedures.

Calcium, Magnesium, Carbonate and Bicarbonate were determined by titrimetric method. Sodium and potassium were determined by flame photometer. All concentrations are expressed in milligrams per liter (mg/L) except pH, and EC (µS/cm). The analyzed parameters of minimum, maximum and average values are presented in Table 1.To assess the irrigational water quality of the samples collected, six computed water quality parameters have been considered viz, Electrical Conductivity (EC), Sodium Adsorption ratio (SAR), Residual sodium carbonate (RSC), Kelly's ratio (KR.), Magnesium Adsorption Ratio (MR), Sodium percentage (Na%) and Residual sodium bi-carbonate (RSBC) where all the ionic concentrations are expressed in meq/L and presented in Table 2. Presentation of geochemical data in the form of graphical chart was performed by following Wilcox diagram (1955) and US Salinity diagram (1954) was used to study the classification and suitability of groundwater.

4. RESULTS AND DISCUSSION

Hydrochemical Characterization

The pH of the analyzed samples ranges from 6.3-8.0 averaging 7.25, indicating alkaline nature of the water. Electrical conductivity is the measure of capacity of solution or substance to conduct electric current. The conductivity of water increases with rise in temperature and varies with the amount of dissolved minerals in it (Ballukraya and Ravi, 1999). It is an important criterion for determining the suitability of groundwater for irrigation. EC values varied from 350 to 1115 µS/cm averaging 736 µS/cm. The TDS ranging from 240 to 850 mg/L averaging 540 mg/L.The major cations include Ca, Mg, Na and K. The cationic chemistry is dominated by calcium and sodium. The results revealed that the mean concentration of cations is in the order Ca>Na>Mg >K. The anion chemistry shows that bicarbonate is the dominant ion. The summary of hydrochemical analysis data is given in Table 1.

5. Groundwater Quality for Irrigation Purpose

The water used for irrigation is an important factor in productivity of crop, its yield and quality of irrigated crops. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. The Sodium Adsorption ratio (SAR), Residual sodium carbonate (RSC), Kelly's ratio (KR.), Magnesium Adsorption Ratio (MR), Sodium percentage (Na%) and Residual sodium bi-carbonate (RSBC) are the most important quality criteria, which influence the water quality and its suitability for irrigation.

5.1 Sodium Adsorption Ratio (SAR)

Sodium concentration plays an important role in evaluating the groundwater quality for irrigation. Sodium hazard of irrigation water can be well understood by knowing SAR which determines its utility for agricultural purposes. SAR is a ratio of the concentration of sodium ions to the concentration of calcium plus magnesium ions. The formula for calculating sodium adsorption ratio is: $SAR = Na^{+}/ (\sqrt{Ca^{2+}+Mg^{2+})/2})$. The groundwater with SAR < 10 is considered as excellent quality, SAR values of the water samples from 10 to 18 is good, 18 to 26 is fair and above 26 is unsuitable for the purpose of irrigation (U.S. Salinity Laboratory Staff, 1954).The SAR values in groundwater of the study area ranges from 0.52 to 3.15 (Avg 1.57) which indicates that the water is of excellent quality for irrigation (Table 2 and 3).

5.2 Kelley's Ratio (KR)

It is the ratio of sodium ions to calcium and magnesium ions and expressed as: KR = Na^+/ (Ca^{2+}+Mg^{2+}).The Kelley's ratio has been calculated for groundwater samples of the study area (Table 2).The groundwater having KR <1 is considered to be good quality for irrigation, whereas KR >1 is considered to be unsuitable for irrigation and causes alkali hazard to the soil (Kelly, 1951). The Kelley's ratio varies from was found 0.08-0.55 averaging 0.29 indicating all the samples are of good quality for irrigation (Table 2 and 3).

5.3 Magnesium Adsorption Ratio (MAR):

Magnesium adsorption ratio is calculated as MAR= Mg^{2+}x 100/ (Ca^{2+}+Mg^{2+}). Excess amount of magnesium can affect the quality of soil and reduces the yield of crops. The magnesium ratio value in the groundwater samples varies between 36.53 to 74.28 with the average value 57.14 (Table 2). The value of MAR < 50 is suitable and > 50 are unsuitable for irrigational purpose (Lloyd and Heathcote, 1985). On the basis of magnesium ratio, 4 groundwater samples in the study area are suitable for irrigation and 10 samples are unsuitable for irrigation (Table 3). In the analyzed waters, 71.43% of the groundwater samples having MAR >50%.Excess amount of magnesium reduces the yield of crop. High magnesium contents in water can affect the quality of soil.

5.4 Residual sodium bicarbonate (RSBC)

Gupta and Gupta (1987) have proposed the equation for analyzing the residual sodium bicarbonate (RSBC). The RSBC values of groundwater samples varies from -14.45 to 6.75 (Avg-3.87) and according to the norm except one water sample the rest of thirteen groundwater samples are found to be suitable (<5) for irrigation use (Table 3).

5.5 Percent Sodium (%Na)

The percent sodium is widely used for evaluating the suitability of water quality for irrigation (Wilcox, 1955).The sodium percentage can be determined using the following equation: (%Na) = Na^{++}+ $^+K^+$ / (Ca^{2+}+Mg^{2+}+ Na^++ K^+) X100. High percent sodium in irrigation water causes exchange of sodium in water, and exchange of calcium and magnesium contents in soil having poor drainage. The % Na in the study area ranges from 1.37 to 9.19 (Avg 4.53).The % Na, <60 represents safe water while it is unsafe if >60 (Eaton, 1950). As per this criterion the water from the study area is safe for irrigation purpose (Table 3).

5.6 Residual sodium carbonate (RSC)

High RSC value in water leads to an increase in the adsorption of sodium on soil (Eaton, 1950) which damages the soil structure. In water having high concentration of bicarbonate there is tendency for calcium and magnesium to precipitate as carbonates. To qualify this effect an experimental parameter termed as RSC (Eaton, 1950) was used. RSC is mainly due to increasing bicarbonate which precipitates calcium and magnesium as a result increases sodium in the form of sodium carbonate. The excess of bicarbonate and carbonate of water is expressed as residual sodium carbonate. RSC is calculated using the following equation: (RSC) = (CO_3^- + HCO_3^-) – (Ca^{2+} + Mg^{2+}).RSC values of water <1.25 are to be considered as safe, from 1.25 to 2.5 are marginally suitable, while more than 2.5 are unsuitable for the irrigation purpose (Eaton, 1950; Richards, 1954). The RSC values in waters of the study area range from -21.26 to -3.34(Avg -13.16). All samples are safe for irrigation (Table 3).

6. WILCOX DIAGRAM

Electrical conductivity (EC) and sodium concentration are very important parameters in the classification of the irrigation water. Irrigation with high sodium water causes exchange of Na in water for Ca and Mg in soil and reduces the permeability and eventually results in soil with poor internal drainage (Collins and Jenkins, 1996). Sodium percent value in analyzed samples range between 1.37 and 9.19 (Avg. 4.53). Wilcox (1955) classified groundwater for irrigation purpose by correlating percent sodium and Electrical conductivity (EC). The groundwater samples of the study area with respect to Na% and EC are plotted in Fig.1. Plot of analytical data on the Wilcox (1955) diagram reveals that 7 samples fall in the zone of excellent to good category, 7 samples fall in good to permissible (Fig.1).

7. USSL DIAGRAM

The plot of data US salinity diagram is given in Fig 2, in which EC is taken a salinity hazard and SAR as alkalinity hazard. It shows that the groundwater sample falls in the S1 category indicating excellent quality for irrigation purpose. High salt concentration (high EC) in water leads to formation of saline soil, and a high sodium concentration leads to development of an alkaline soil. Stalinization is one of the most prolific adverse environmental impacts associated with irrigation. The sodium or alkali hazard in the irrigation water are expressed in terms of sodium adsorption ratio (SAR).The correlation between sodium adsorption ratio (SAR) and electrical conductivity (EC) was plotted on the US salinity diagram (Fig. 2) (USSL, 1954) in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that the water samples belongs to categories of C_2S_1 and C_3S_1 indicates the medium to high salinity, and low alkali hazard for irritation. This water is of good quality and useful for irrigation. Salt tolerant crops should be selected for the high saline regions and irrigation water must be applied in excess to provide considerable leaching (Karanth, 1989).The adequate drainage and exchangeable sodium may be helpful in high salinity localities.

8. CONCLUSIONS

The groundwater sources in the Velpula area of Kadapa district have been evaluated for their chemical composition and suitability for irrigation use. Water analysis obtained from the present study area was utilized to analyze the suitability of water for agricultural uses. The major cations include Ca, Mg, Na and K. The cationic chemistry is dominated by calcium and magnesium. Results revealed that the mean concentration of cations is in the order Ca> Na>Mg> K. The anionic chemistry is dominated by bicarbonates.

The suitability of groundwater for irrigation has been evaluated based on various chemical parameters such as sodium adsorption ratio (SAR), sodium percent (Na %), residual sodium carbonate (RSC), Magnesium Adsorption Ratio (MAR), Residual sodium bicarbonate (RSBC), and Kelley's Ratio (KR). This study indicates that most of the water is suitable for irrigation purposes. On the basis of SAR, RSC, KR and Na% all the groundwater samples in the study area are good for irrigation. RSBC values indicate that 13 water samples are suitable and one water sample is unsuitable for irrigation. On the basis of Magnesium Adsorption ratio 4 water samples are suitable, while 10 water samples are not suitable for irrigation. The correlation of the analytical data has been attempted by plotting various graphical representations such as Wilcox and US salinity Laboratory for the classification of water. The values of EC and SAR of groundwater samples have been plotted in U S salinity diagram reveals that the water samples belongs to category of C_2 S_1 and C_3 S_1. Based on US salinity hazard diagram groundwater is good quality for agriculture purpose. The plotting of data in the diagrams of USSL suggests that the suitability of groundwater for irrigation. High values of MAR at some sites restrict the suitability of groundwater for agricultural purposes and demands special management plan for the area. Over all the calculated parameters revealed that groundwater of the study area, in general was good for agriculture uses.

Table 1. Physico-chemical characteristics of groundwater of study Area
The values are in mg/l except pH and EC (µS/cm)

Physico-chemical parameters	Range of Concentration	Average Concentration
pH	6.3 to 8.0	7.25
TDS	240 to 850	540
EC	350 to 1115	736
Ca	52 to 245	150
Mg	26 to195	97
Na	40 to 230	105
K	0.4 to 14	5
CO_3	10 to 142	47
HCO_3	90-550	210

Table 2: Irrigational water quality parameters from the study area

S.No	EC	EC*10	SAR	% Na	RSC	KR	RSBC	MAR
1	730	7.3	0.71	2.15	-11.02	0.23	-2.39	54.30
2	790	7.9	3.15	9.19	-12.94	0.52	-3.14	58.77
3	1115	11.15	2.18	7.12	-21.26	0.46	-14.45	46.70
4	425	4.25	3.03	8.38	-14.42	0.55	-2.48	69.49

5	575	5.75	0.77	2.83	-3.34	0.21	0.45	72.45
6	940	9.4	0.55	1.37	-7.61	0.18	-1.41	56.14
7	1075	10.75	1.16	3.61	-18.86	0.15	-10.18	48.62
8	829	8.29	1.69	3.78	-16.81	0.27	-8.65	36.53
9	535	5.35	2.75	7.33	-13.51	0.46	-2.88	63.05
10	827	8.27	3.03	7.80	-14.42	0.55	-2.35	70.49
11	350	3.5	0.52	2.35	-12.19	0.10	-1.81	53.20
12	435	4.35	0.67	2.36	-13.29	0.19	-1.51	59.22
13	590	5.9	0.68	1.94	-6.10	0.17	6.75	74.28
14	1095	10.95	0.65	1.80	-20.26	0.08	-10.25	40.24
Min	350	3.5	0.52	1.37	-21.26	0.08	-14.45	36.53
Max	1115	11.15	3.15	9.19	-3.34	0.55	6.75	74.28
Avg	736	7.36	1.57	4.53	-13.16	0.29	-3.87	57.14

Table 3: classification of groundwater based on irrigation suitability

Quality parameters for irrigation	Range	Number of samples	Percentage of samples
Sodium adsorption ratio (SAR)			
Excellent	0-10	14	100%
Good	10-18	-	-
Fair	18-26	-	-
Unsuitable	>26	-	-
Residual sodium bi-carbonate (RSBC)			
Suitable	<5	13	92.86%
Unsuitable	>5	01	7.14%
Residual Sodium Carbonate (RSC)			
Good	<1.25	14	100%
Moderate	1.25-2.5	-	-
Unsuitable	>2.5	-	-
Kelly's Ratio (KR)			
Good	<1	14	100%
Not good	>1	-	-
Sodium percentage (%Na)			
Safe	<60	14	100%
Unsafe	>60	-	-
Magnesium adsorption ratio (MAR)			
Suitable	<50	04	28.57%
Unsuitable	>50	10	71.43%

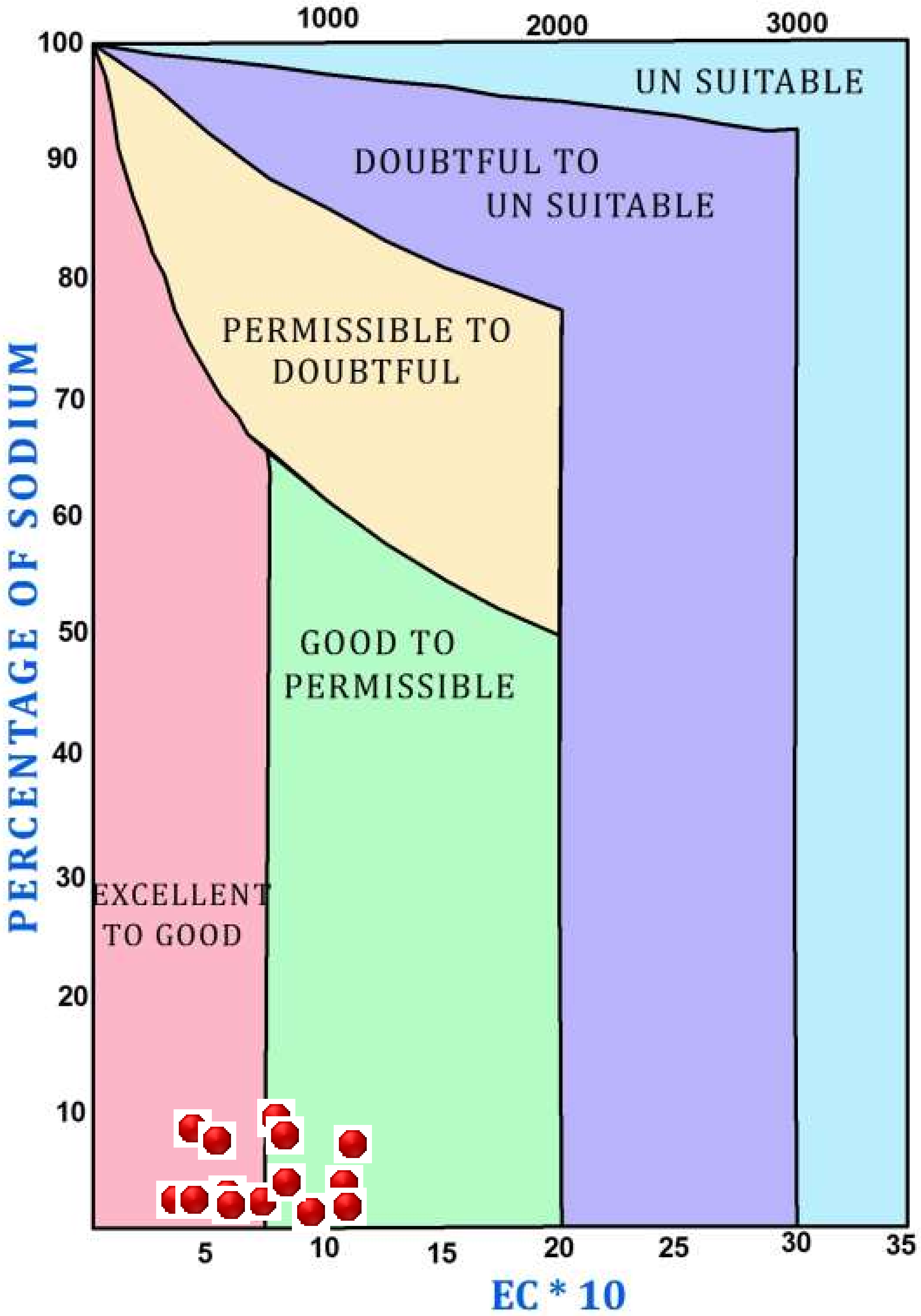

Fig. 1 Wilcox diagram for classification of groundwater

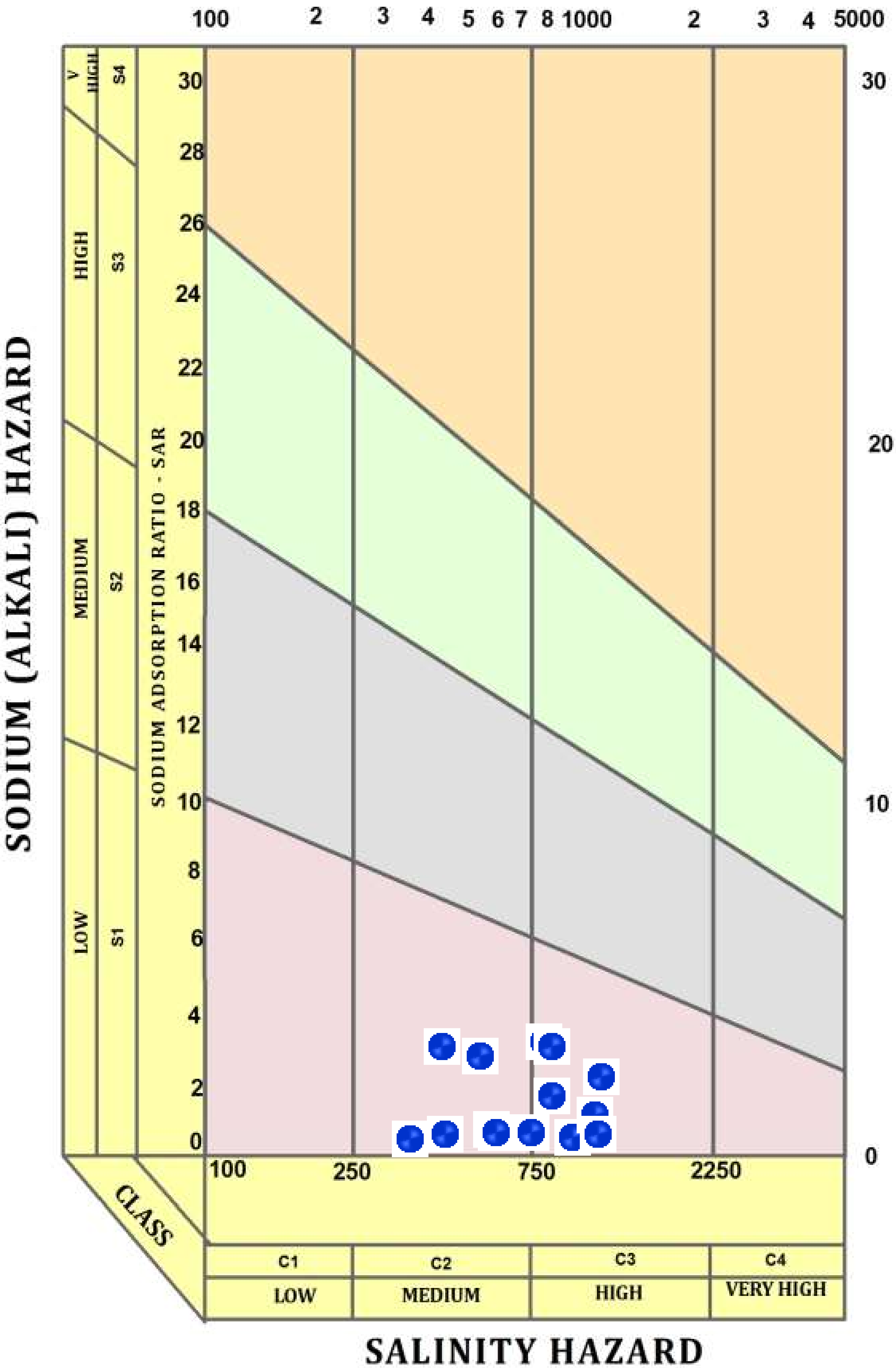

Fig. 2 USSL Diagram for classification of groundwater

REFERENCES

Andre, L., Franceschi, M., Pouchan, P. and Atteia, O. (2005). Using geochemical data and modeling to enhance the understanding of groundwater flow in a regional deep aquifer, Aquitaine Basin, south-west of France. Jour. Hydrol., V. 305, pp.40-62.

APHA (1985). Standard method for the examination of water and waste water. American Public Health Association, USA.

APHA (1992). Standard method for the examination of water and waste water. American Public Health Association. 18th ed.

Ballukaraya, P.N. and Ravi, R. (1999). Characterization of groundwater in the unconfined aquifers of Chennai Cit, India. Part I-Hydrochemistry. Jour. Geol. Soc. India, V.54, pp.1-11.

Collins, R. and Jenkins, A. (1966). The impact of agricultural land use on stream in the middle hills of the Himalayas, Nepal. Jour. Hydrol., V.185, pp.71-86.

Domenico, P.A. and Schwarta, F.W. (1990). Physical and chemical hydrogeology. John Wiley and Sons, New York, 824p.

Eaton, F.M. (1950). Significance of carbonates in irrigation waters. Soil Sci., Vol.39, pp.123-133.

Giridharan, L., Venugopal, T. and Jayaprakash, M. (2008). Evaluation of the seasonal variation on the geochemical parameters and quality assessment of the groundwater in the proximity of Rve Cooum, Chennai, India. Environ. Monit. Assess., V. 143, pp.161-178.

Gupta S.K and Gupta I.C. (1987). Management of saline soils and water. Oxford and IBM Publ. Co., New Delhi, 399.

Karanth, K.R. (1989). Groundwater assessment development and management. Tata McGraw-Hill Publ. Com. Ltd., New Delhi, India.

Kelley, W.P. (1951). Alkali sols- their formation properties and reclamation. Reinhold Publ. Corp., New York.

Kortatsi, B.K. (2007). Hydrochemical framework of groundwater in the Ankobra Basin, Ghana. Aquatic Geochem., V.13 (1), pp.41-74.

Krishna, K.S., Rammohan, V., Rajkumar, S.J. and Jeevanandam, M. (2009). Assessment of groundwater quality and hydrogeochemistry of Manimuktha River basin, Tamilnadu, India. Environ. Monit. Assess., V.159, pp.341-351.

Llyod, J.W. and Heathcoat, J.A. (1985). Natural inorganic hydrochemistry in relation to groundwater: An introduction. Oxford Uni. Press, New York, 296p.

Mahajan, G.D. (2012). Hydrochemical characteristics and quality assessment of groundwater in parts of Kannad, District Aurangabad, MS), India. Int. Jour. Recent. Trends. Sc. Tech., V. 3 (3), pp.71-76.

Mathur, R., Suthar, A.K., Sharma, R., Sharma, A. and Shara, S. (2010). Assessment of groundwater quality of Rajasthan with special reference to

Jodhpur and Barmer region. Internat. Jour. Chem. Sci., V. 8 (3), pp.1992-1998.

Nagarajarao, B.K., Rajurkar, S.T., Ramalingaswami, G. Ravindra Babu. (1987). Stratigraphy structure and evolution of Cuddapah Basin. In: Radhakrishna, B.P (ed), Purana Basins of peninsular India. Geol. Soc. India. V.6, pp.33-86.

Reddy L. Chnadrasekhar., Deshpande, S.M., Reddy K.V.Ramana. and Aher, K.R., (2012).Characterization and quality assessment of groundwater with special emphasis on irrigation utility: A case study of Vemula area, Kadapa district, Andhra Pradesh, India. Int.Jour.Env. and Earth Sciences, Vol. 2(1), pp.36-49.

Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soils. Agri. Handbook 60, U.S. Dept of Agriculture, Washington D.C., 160p.

Schiavo, M.A., Havser, S., Gusimano, G. and Gatto, L. (2006). Geochemical Characterization of groundwater and sub-marine discharge in this southeastern Sicily. Continental Shelf Res., V. 26, pp.826-834.

Subba Rao, N. (2002). Geochemistry of groundwater in parts of Guntur district, Andhra Pradesh, India. Environ. Geol., Vol.41, pp.552-562.

Subramani, T., Elango, L. and Dhamodarasamy, SR. (2005). Groundwater quality and suitability for drinking and agricultural uses in Chithar River Basin, Tamilnadu, India. Env. Geo., V. 47, pp.1099-1110.

Sujatha, D. and Reddy, R.B. (2003). Quality characterization of groundwater in the south-eastern part of Ranga Reddy district, Andhra Pradesh, India. Environ, Geol., Vol. 44 (5). Pp.579-586.

USSL (US Salinity Laboratory) (1954). Diagnosis and improvement of saline and alkali soils. U.S. Department of Agriculture Hand Book, No. 60, p.160,

Wilcox, L.V., (1955).Classification and use of irrigation waters, US Dept of Agriculture Circular 969, Washington DC.