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Suitability and assessment of groundwater for irrigation purpose: A case study of Kushaiguda area, Ranga Reddy district, Andhra Pradesh, India

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ABSTRACT

The quality assessment is made through the estimation of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, EC, TDS, TH and pH in the Kushaiguda area Ranga Reddy District, Andhra Pradesh, India. Based on these analyses, parameters like sodium adsorption ratio, sodium percentage, residual sodium carbonate and magnesium hazard were calculated. Sodium adsorption ratio is shown 69% of groundwater is belongs to S3C1, indicating high salinity and low alkali water and based on the Na% with 37.5% for groundwater falls in good to permissible category. Residual sodium carbonate values suggesting safe to marginally suitable category for irrigation purposes. The overall quality of water in the study area in Kushaiguda area Ranga Reddy District, Andhra Pradesh, is high for all constituents ruling out pollution from extraneous source.

Keywords: Groundwater quality assessment, Irrigation, Kushaiguda area, Andhra Pradesh.

INTRODUCTION

Groundwater forms one of the primary resources for development activities. In recent times, there has been tremendous demand for fresh water due to population growth and intensive agricultural activities. Groundwater quality is the physical and chemical characterization of groundwater, which measures its suitability for human and animal consumption, irrigation and other purposes. The chemical comparison of the water that enters in the groundwater reservoir and reactions with the minerals present in the rocks and soils that may modify the water composition [1]. So, groundwater is gaining more and more importance in India owing to the ever increasing demand for water supplies, especially in areas with inadequate surface water supplies. Groundwater is the primary source of water for human consumption, as well as for agriculture and industrial uses in many regions all over the world. Groundwater quality is controlled by both the natural and human activities [2]. Contamination by different pollutants, mainly due to the intense agricultural and urban development, has placed the whole environment at greater risk [3]. The quality of groundwater in agricultural area is sensitive to the contaminations originated from the agricultural chemical.

An understanding of the quality of water used for irrigation and its potential negative impacts on crop growth is essential to avoid problems and to optimize production. The geochemical investigation of groundwater allows us to obtain important information on chemical weathering of rocks. The quality of groundwater is an important criterion to decide the water for irrigation activities and various parameters such as sodium percentage (%Na^{+}), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and magnesium hazard (MH) have been used to assess the suitability of water for irrigation purposes by several researchers [4], [5], [6], [7] and [8].

MATERIALS AND METHODS

Groundwater samples were collected from the bore wells, following the standard guidelines [9] and [10] and analyzed for various chemical parameters as described by the American Public Health Association. These parameters include hydrogen ion concentration (pH), electrical conductivity (EC), total hardness (TH), total dissolved solids (TDS) and important cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}) as well as anions such as carbonates (CO_3^{2-}), bicarbonates (HCO_3^{-}), chlorides (Cl^{-}) and sulphates (SO_4^{2-}). The pH and EC values were measured in the field using a portable conductivity and pH meter. TDS were computed from EC multiplied by a factor (0.55–0.75), depending on relative concentrations of ions. Na^{+} and K^{+} were determined by flame photometer, SO_4^{2-} is analyzed by spectrophotometrically. TH as CaCO3, Ca^{2+}, CO_3^{2-}, HCO_3^{-} and Cl^{-} were analyzed by volumetric method. Mg^{2+} was calculated from TH and Ca^{2+} contents.

RESULTS AND DISCUSSION

The analytical results, computed values and the statistical parameters like minimum, maximum, mean and the standard deviation values of water samples are given in Tables 1, irrigation quality results of groundwater samples of the study results is shown in Table 2 and classification of groundwater on the basis of SAR, RSC, %Na and magnesium hazard is shown in Table 3.

Table 1. Statistical summary of the chemical composition of groundwater

Chemical parameters	Expressed	Minimum	Maximum	St. dev	Average
pH	pH Units	6.48	7.18	0.21	6.81
EC	µS/cm	1265	2881	485.86	2132.44
TDS	mg/L	809	1843	289.38	1321.25
HCO_3^-	mg/L	244	561	89.54	399.63
CO_3^{2-}	mg/L	12	66	14.36	45.38
Cl^-	mg/L	128	845	183.33	337.38
SO_4^{2-}	mg/L	23	91	21.86	44.38
Na^+	mg/L	33	127	25.07	58.28
K^+	mg/L	3	16	3.74	7.63
Ca^{2+}	mg/L	16	712	150.34	205
Mg^{2+}	mg/L	10	508	172.30	104.5
TH	mg/L	102	650	175.68	409.06

Table 2. Irrigational quality results of groundwater samples of the study area

S. No	SAR	RSC	Na%	MH	EC
KW-1	0.99	-4.57	19.55	23.93	1730
KW-2	1.43	-3.96	22.48	16.16	2530
KW-3	0.96	-58.73	8.10	46.27	1556
KW-4	1.09	-5.97	19.25	7.61	2858
KW-5	0.58	-33.79	6.29	87.18	1960
KW-6	0.75	-46.16	7.28	77.44	1265
KW-7	1.25	0.17	22.95	46.12	2380
KW-8	0.87	-3.22	16.47	11.20	2120
KW-9	0.57	-5.61	11.35	20.87	2130
KW-10	0.57	-5.62	10.88	20.55	2240
KW-11	0.70	-6.59	12.33	15.43	2525
KW-12	0.81	-3.54	14.76	24.39	1364
KW-13	1.10	0.40	25.86	31.19	2250
KW-14	1.19	-2.78	22.22	14.59	2881
KW-15	0.86	-0.60	17.32	8.39	2470
KW-16	1.64	8.36	45.98	60.71	1860

The hydrogen-ion-concentration (pH) samples varies from 6.48 to 7.18 (Table 1) with an average of 6.81indicating their alkaline nature. In the study area the TDS value varies between a minimum of 809 mg/l and a maximum of 1,843 mg/l. Hence, high concentration of TDS in the groundwater sample is due to leaching of salts from soil and also domestic sewage may percolate into the groundwater, which may lead to increase in TDS values [17].

Table 3. Classification of groundwater on the basis of SAR, RSC and Magnesium hazard

Classification scheme	Categories	Ranges	Percent of samples
RSC	Good	<1.25	94
	Medium	1.25 – 2.5	0
	Bad	>2.5	6
SAR	Excellent	0-10	100
	Good	10-18	0
	Fair	18-26	0
	Poor	>26	0
Magnesium Hazard	Suitable	<50	81
	Unsuitable	>50	19

Suitability for irrigation uses

EC and sodium concentration are very important in classifying irrigation water. 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 as low (EC = <250 µS/cm), medium (250–750 µS/cm), high (750–2,250 µS/cm) and very high (2,250– 5,000 µS/cm) salinity classes [11]. While a high salt concentration (high EC) in water leads to formation of saline soil, a high sodium concentration leads to development of an alkaline soil. The sodium or alkali hazard in the use of water for irrigation is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR) and it can be estimated by the formula:

$$SAR = Na^{+}/\sqrt{(Ca^{2+} + Mg^{2+})/2} \qquad \text{Eq. 1}$$

Where the concentrations are reported in meq/L.

There is a significant relationship between SAR values of irrigation water and the extent to which sodium is adsorbed by the soils. If water 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. The calculated value of SAR in the study area ranges from 0.57 to 1.64 (Table 2) in the groundwater. The plot of data on the US salinity diagram (Fig 1), in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that majority of the water samples fall in the category C3S1, indicating high salinity and low alkali water, which cannot be used on soils with restricted drainage and requires special management for salinity control. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and salt-tolerant crops/plants should be selected for such region. About 31% samples fall in the zone of C4S1 indicating very high salinity and low alkali water (Fig 1) and graphical representation for sodium adsorption ratio is shown in Fig 2.

Sodium percentage (Na %)

Na^{+} is an important cation which in excess deteriorates the soil structure and reduces crop yield [8], [13] and [14]. When the concentration of Na^{+} is high in irrigation water, Na^{+} tends to be absorbed by clay particles displacing Mg^{2+} and Ca^{2+} ions. This exchange process of Na^{+} in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage. The Na% is calculated using the formula given below:

$$Na\% = Na^{+} + K^{+}/Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \text{ X } 100 \qquad \text{Eq. 2}$$

where the concentrations are reported in meq/L.

According to Wilcox classification [15], the water is classified based on the Na% with respect to the other cations present in water. 37.5% for groundwater falls in good to permissible category and 62.5% groundwater falls in doubtful to unsuitable category (Fig 3).

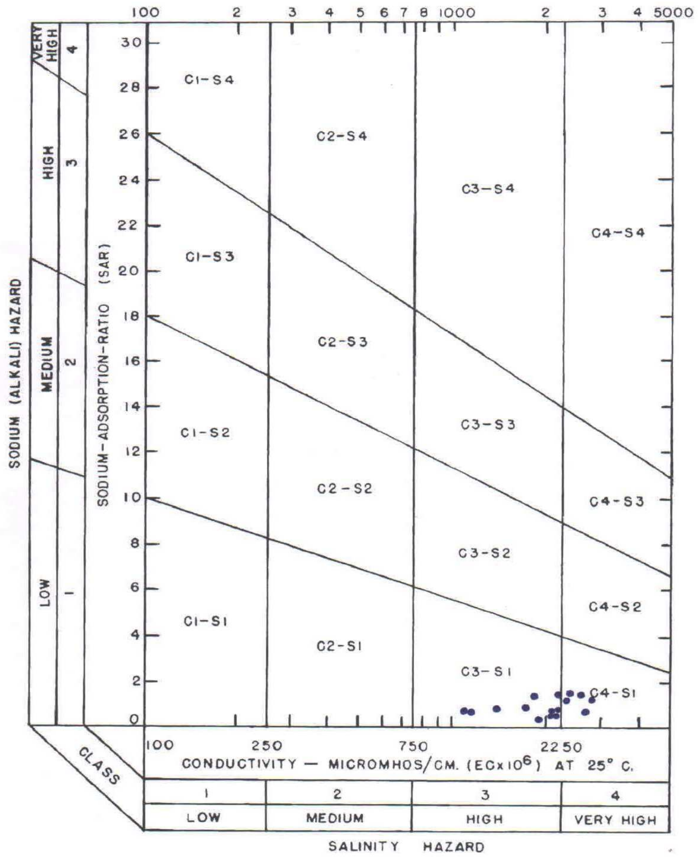

Fig. 1. Rating of groundwater samples in relation to salinity hazard and sodium hazard [12]

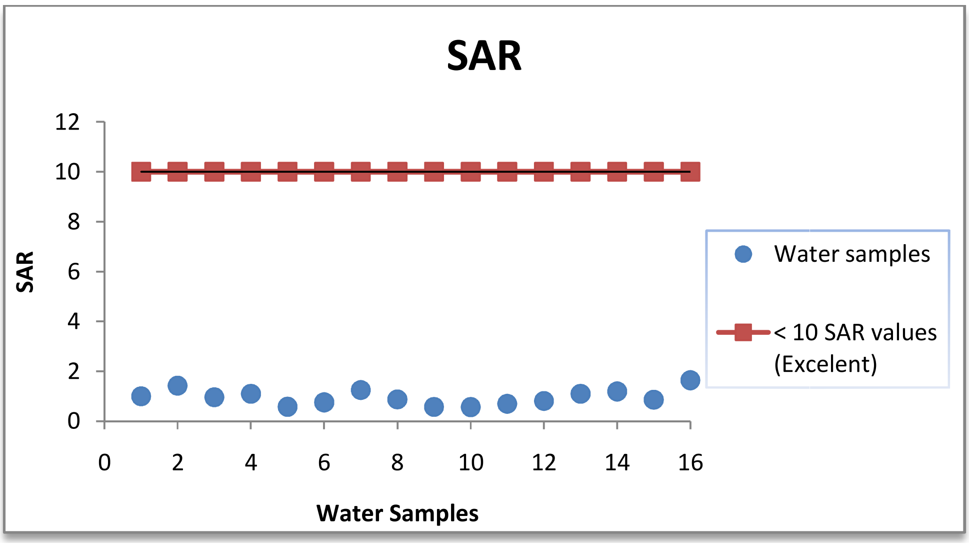

Fig 2. Graphical representation for sodium adsorption ratio

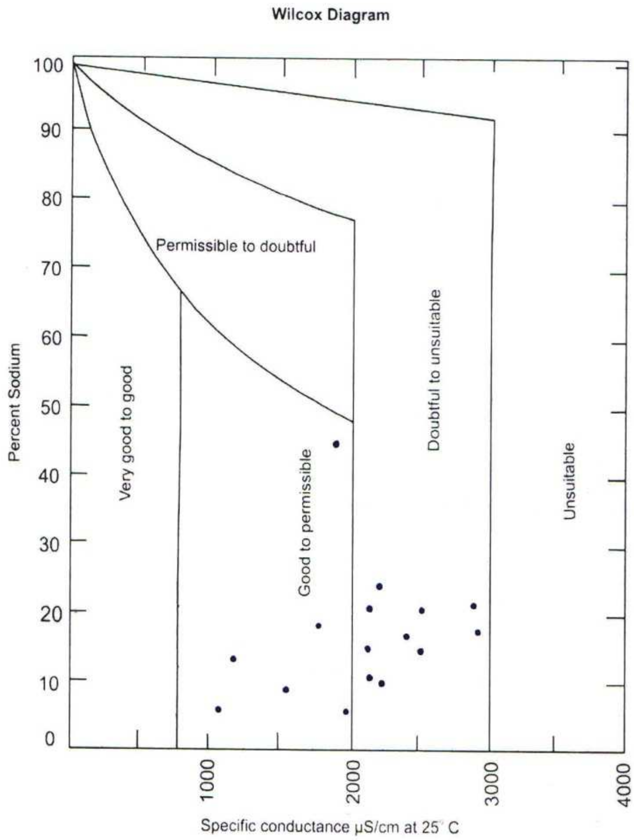

Fig.3. Rating of groundwater samples on the basis of electrical conductivity and percent sodium [15]

Residual sodium carbonate (RSC)

In addition to the SAR and Na%, the excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the unsuitability of groundwater for irrigation. This is termed as residual sodium carbonate (RSC) [11]. The RSC is calculated using the formula given below:

$$RSC = [(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})] \quad \text{Eq. 3}$$

Where the concentrations are reported in meq/L.

Irrigation water having RSC values greater than 5 meq/L have been considered harmful to the growth of plants, while waters with RSC values above 2.5 meq/l are unsuitable for irrigation. A RSC value between 1.25 and 2.5 meq/L is considered as the marginal quality and value <1.25 meq/L as the safe limit for irrigation. The calculated RSC values in the groundwater samples of Kushaiguda area are found various from -58.73 to 8.36 meq/L (Table 2) and the calculated values reveal that all the sampling sites are good for irrigation purpose except few (Table 3).

Magnesium hazard (MH)

Generally, alkaline earths are in equilibrium state in groundwater. If soils have more alkaline earths, they reduce a crop yield. Szaboles and Darab [16], have proposed a magnesium hazard in relation to the alkaline earths for irrigation. This hazard is expressed in terms of magnesium hazard (MH), which is computed by (Eq. 4), using the values of ions in meq/L.

$$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} X\ 100 \quad \text{Eq. 4}$$

Where the concentrations are reported in meq/L.

The computed values of magnesium hazard from the groundwater of the study area are in between 7.61 and 87.18 (Table 2). If the water contains more than 50 of magnesium hazard, such water quality is considered to be harmful for irrigation, as the MH adversely affects the crop growth. About 81% (thirteen locations, Fig 4) of the groundwater samples of the study area are safe for irrigation, as the value of magnesium hazard in them less than 50 (Table 3, Fig 4). The remaining groundwater samples 19% (only three locations, Fig 4) show the value of MH exceeds 50 and hence they are unsafe for irrigation purpose.

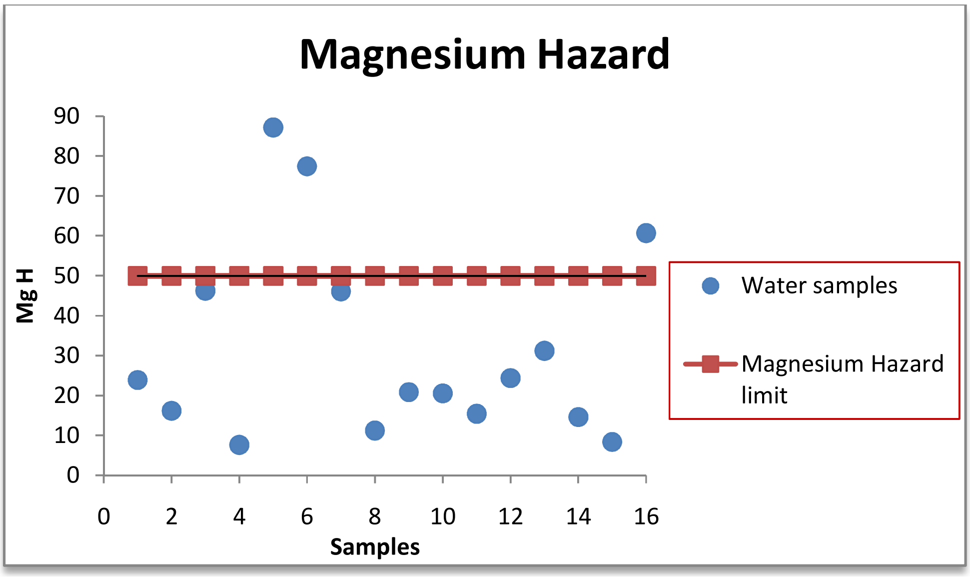

Fig 4. Graphical representation for magnesium hazard

CONCLUSION

The plot of data on the US salinity diagram, in which the EC is taken as salinity hazard and SAR as alkalinity hazard, shows that majority of the water samples fall in the category C3S1, indicating high salinity and low alkali water, which cannot be used on soils with restricted drainage and requires special management for salinity control. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and salt-tolerant crops/plants should be selected for such region. About 31% samples fall in the zone of C4S1 indicating very high salinity and low alkali water. According to Wilcox classification, the water is classified based on the Na% with respect to the other cations present in water. 37.5% for groundwater falls in good to permissible category and 62.5% groundwater falls in doubtful to unsuitable category. The calculated RSC values in the groundwater samples of Kushaiguda area are found various from -58.73 to 8.36 meq/L, suggesting safe to marginally suitable category for irrigation and About 81% (thirteen locations) of the total groundwater samples of the study area are safe for irrigation, as the value of magnesium hazard in them less than 50. The remaining groundwater samples 19% (only three locations) show the value of MH exceeds 50 and hence they are unsafe for irrigation purpose.

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