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Study of Ground Water Quality for Irrigation in Near Industrial Area of Bhilwara, Rajasthan (India)

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47 Ground water samples of 40 villages close to industrial area of Bhilwara town were analyzed for their suitability for irrigation purpose. Ground water of the study area was classified according to Sodium Adsorption Ratio (SAR), Percentage Sodium (PS), Residual Sodium Carbonate (RSC), Kelley's Ratio and Electrical Conductivity. The higher value of electrical conductivity, percentage sodium and Kelley's ratio in some villages indicates the contamination of ground water by industrial effluent resulting in the unsuitability of ground water for irrigation purposes. The value of sodium adsorption ratio indicates that majority of samples falls in low sodium hazard category. As per classification made by Wilcox (1948), on the basis of percentage sodium and electrical conductivity 12 samples are not suitable for irrigation purpose while only 3 samples fall in excellent to good category. The remaining 10 samples fall in good to permissible, 13 samples fall in permissible to doubtful and 9 samples fall in doubtful to unsuitable category. Ground water was also classified according to the classification of United States Salinity Laboratory based on sodium and salinity hazard.

INTRODUCTION

India is a predominantly agricultural country. Its rural economy completely depends on agriculture. The sources for irrigation are rainwater, surface water and ground water. In the southern part of India surface water of ponds is used while in northern and eastern parts surface water of dams through canal system is used for irrigation purpose. In Rajasthan due to lack of perennial river system and other surface water resources, the ground water is an important source for irrigation. Surface water contains low salinity with low concentration of various ions while ground water contains a variety of minerals in higher concentration with greater salinity. The water used for irrigation purpose should be of such quality which does not harm the soil and gives maximum crop yield. Therefore, suitability of water for irrigation purpose is evaluated by its effect on soil and crops. Various classifications based on electrical conductivity (EC), Sodium Adsorption Ratio (SAR), Percentage Sodium (PS), Residual Sodium Carbonate

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(RSC) and Kelley's Ratio has been proposed to classify the irrigation purpose. On the basis of these classifications several workers[1–10] have classified irrigation water. In Rajasthan there is a problem of availability of good quality water for both drinking and irrigation purposes. In western arid districts the ground water is saline with high value of SAR and RSC[11], whereas in central and eastern districts of semi-arid tract the ground water is associated with alkalinity hazard.[12, 13].

Bhilwara (25° 1′ to 25° 58′ North latitude and 74° 1′ to 75° 28′ East longitude), the south-eastern district of Rajasthan with semi-humid climate, is known as 'Textile City'. The effluents of most industries are outletted in small streams either without treatment or by improper treatment. The effluent of these industries shows high EC values due to high concentration of cations, anions and heavy metals. All these ions get percolated into the ground resulting in the contamination of the ground water. Such ground water when used for irrigation purpose affects the soil quality and crop yield. The present paper is an attempt to evaluate and classify the ground water quality of nearby villages of the industrial area for irrigation purpose.

EXPERIMENTAL

40 Villages, close to the industrial area, were marked for the study of ground water quality for irrigation purpose. From these villages 47 ground water samples were collected in pre-cleaned poly-propylene bottles with necessary precautions[14]. Electrical conductivity and pH of all samples were determined at sampling site. Carbonate (CO_3), bicarbonate (HCO_3), sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) were analyzed in the laboratory using standard methods[15].

TABLE-1
RESULT OF GROUND WATER ANALYSIS

S.No.	Parameters	Minimum	Maximum	Mean	Standard deviation
1.	pH	7.2	9.1	8.04	0.4
2.	Electrical conductivity	490	7160	2361	1669.29
3.	Sodium	2.22	55.68	13.94	9.93
4.	Potassium	0.03	6.7	0.68	1.34
5.	Calcium	1.0	28.74	4.05	4.56
6.	Magnesium	0.58	34.22	6.23	6.11
7.	Carbonate	Nil	3.6	0.62	1.15
8.	Bicarbonate	2.16	16	7.32	2.81
9.	Sodium Adsorption Ratio	0.37	22.63	7.1	5.19
10.	Percentage Sodium	21.81	90.26	59.34	16.29
11.	Residual Sodium Carbonate	Nil	33.17	4.61	7.68
12.	Kelley Ratio	0.33	9.26	1.98	1.87

All values except pH and EC are in meq./L.

RESULTS AND DISCUSSION

The minimum, maximum and mean values of electrical conductivity, pH, sodium, potassium, calcium, magnesium, carbonate, bicarbonate, sodium absorption ratio, residual sodium carbonate and Kelley ratio are presented in Table-1 with standard deviation.

On the basis of EC, SAR, RSC, PS and Kelley's Ratio the ground water quality of the study area is described below.

Electrical conductance: The most important criterion regarding salinity and therefore of water availability to the plant is the total salt concentration. The electrical conductance of the water is the sum of ionic conductance of all ionic constituents; therefore there exists a straight-line correlation between electrical conductance and total salt concentration of water. The most expedient procedure to evaluate salinity of water is to measure its electrical conductance. It influences the quality of water for irrigation purpose due to its relation with the ionic constituents of water. The high electrical conductance value is harmful for the plant growth physically by reducing the uptake of water through modification of osmotic pressure or chemically by metabolic reaction caused by toxic constituents. Beside these effects water with high EC changes the soil structure, permeability and aeration, which ultimately affects plant growth and crop yield considerably. Such adverse effects are called salinity hazard. Electrical conductance of our study area ranges from 490 to 7160 μmho/cm with a mean value of 2361 μmho/cm. According to the classification made by United States Salinity Laboratory[16] ground water of the study area is classified into four classes as presented in Table-2.

Sodium adsorption ratio (SAR): Sodium is the most important element, which influences the soil quality and plant growth either by affecting the permeability of soil by clogging or replacing other cations. The extent of replacement of other cation by sodium is denoted by SAR and calculated by the following equation as described by Richards[16].

$$SAR = \frac{Na}{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)^{0.5}}$$

where Na^+, Ca^{2+}, Mg^{2+} are in Meq/L.

SAR in our study area ranges from 0.37 to 22.63 with a mean value of 7.10. Salinity Laboratory of Agriculture recommended the water classification according to the value of SAR as presented in Table-3.

Residual Sodium Carbonate: The concentrations of bicarbonate and carbonate also influence the suitability of water for irrigation purpose[16, 17]. One of these empirical approaches is based on the assumption that all Ca^{2+} and Mg^{2+} precipitate as carbonate. Considering this hypothesis, Ealton[17] proposed the concept of residual sodium carbonate (RSC) for the assessment of high carbonate waters.

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

TABLE-2
CLASSIFICATION OF GROUND WATER ACCORDING TO ELECTRICAL CONDUCTANCE (SALINITY HAZARD)

S.No.	Electrical conductance (μmho/cm)		Category of Water	Number of Samples	Percentage of sample (%)	Suitability
	Grade	Range				
1.	Low salinity	< 250	Excellent	0	0	It can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices expect in soil of extremely low permeability.
2.	Medium salinity	250 to 750	Good	3	6	It can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control
3.	High salinity	750 to 2250	Fair	25	54	It cannot be used on soil with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.
4.	Very high salinity	> 2250	Poor	19	40	It is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soil must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt-tolerant crops should be selected.

Source Richard (1954)

TABLE-3
CLASSIFICATION OF GROUND WATER ACCORDING TO SODIUM ADSORPTION RATIO (SODIUM HAZARD)

S.No.	Sodium Adsorption Ratio		Category of water	Number of samples	Percentage of sample (%)	Suitability
	Grade	Range				
1.	Low sodium	< 10	Excellent	40	85	It can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocado may accumulate injurious concentrations of sodium.
2.	Medium sodium	10 to 18	Good	5	10	It will present an appreciable sodium hazard in fine-textured soils having high CES, especially under low leaching conditions, unless gypsum is present in soil. This water may be used on coarse-textured or organic soils with good permeability.
3.	High sodium	18 to 26	Fair	2	5	It may produce harmful levels of exchangeable sodium in most soils and will require special soil management: good drainage, high leaching and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that use of amendments may not be feasible with waters of very high salinity.
4.	Very high sodium	> 26	Poor	0	0	It is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Source: Richard (1954).

The water with high RSC will have high pH and makes soil infertile by depositing black alkali on the surface. The concentrations of calcium and magnesium neutralize the excess concentration of carbonate and bicarbonate. In our study area RSC ranges from nil to 33.17 with a mean value of 4.61. According to a classification made by the United States Salinity Laboratory 23 (49%) samples are safe for irrigation purpose with RSC value below 1.25 meq/L while 23 (49%) samples are unsuitable for irrigation purpose with RSC value above 2.5 meq/L. Only one sample, which is between these two limits, is considered as of marginal category[16].

Percentage Sodium: Percentage sodium (PS) is another important factor to study sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentrations. It is also used for adjudging the quality of ground water for the use of agricultural purpose. The use of high PS waters for irrigation purpose stunts the plant growth[5]. It is calculated by the following formula

$$PS = \frac{Na^+ + K^+}{(Ca^{2+} + Mg^{2+} + Na^+ + K^-)} \times 100$$

Excess sodium concentration (high PS) when present with carbonate and bicarbonate as predominant anion, the water is called alkaline while when it is present with chloride and sulphate as predominant anions, water is called saline. Therefore, Wilcox[18] used PS and specific conductivity in evaluation of irrigation water classification by plotting PS and sp. cond. on *X* and *Y*-axis respectively as shown in Fig. 1.

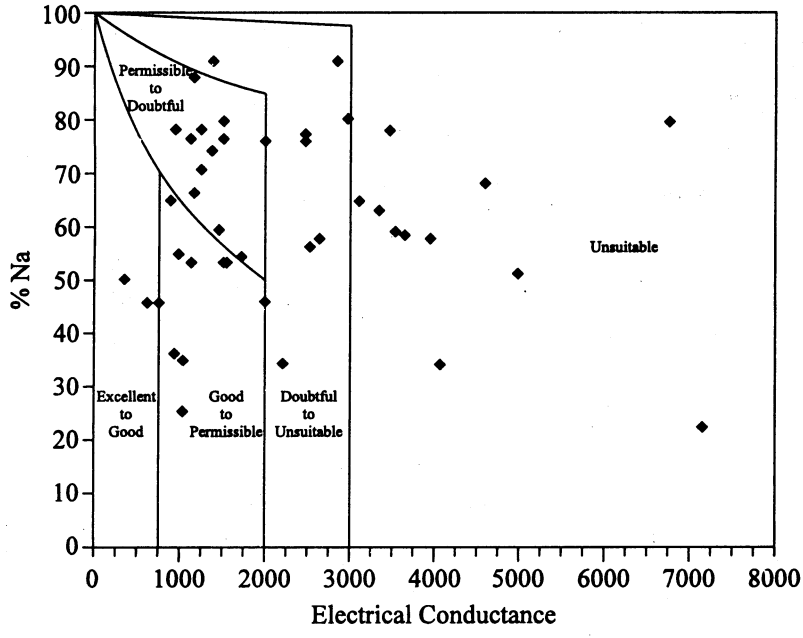

Fig. 1: Water classification in relation to % sodium and electrical conductivity (after US Salinty Lab, 1954).

From the figure it is clear that only 3 samples fall in excellent to good category while 10 samples fall in good to permissible category. On the other hand, 12 samples are unsuitable while 9 samples are doubtful to unsuitable. Remaining 13 samples fall in permissible to doubtful category. From above discussion we can conclude that 13 samples of 12 villages are suitable and 17 samples of 15 villages are unsuitable for irrigation purposes while the remaining 13 samples are doubtful for its use for irrigation purposes.

Kelley's Ratio: Ground water of study area is also classified according to Kelley's ratio. Kelley's ratio is calculated by using the following formula as calculated by Kelley[19], Paliwal[20] and Gowd *et al.*[5].

$$\text{Kelley's ratio} = Na^{+}/(Ca^{2+} + Mg^{2+})$$

The value of Kelley's ratio more than one indicates the excess of sodium concentration. According to this classification the samples having Kelley ratio below one are suitable while above one are unsuitable for irrigation purpose. In our study Kelley ratio ranges from 0.26 to 9.23 with a mean value of 1.98. Only 34 (72%) samples of the study area were found to have more than one Kelley ratio indicating unsuitability of ground water for irrigation purpose.

Salinity and Sodium Hazard Classification: EC and sodium are two factors, which are responsible for salinity and sodium hazard respectively; therefore, US Salinity Laboratory proposed a classification based on EC and SAR. A semi-logarithm graph was plotted by taking SAR on *X*-axis and EC on *Y*-axis as shown in Fig. 2. This classification categorizes water into 16 classes but in our study area the ground water is related to only 7 classes as described below:

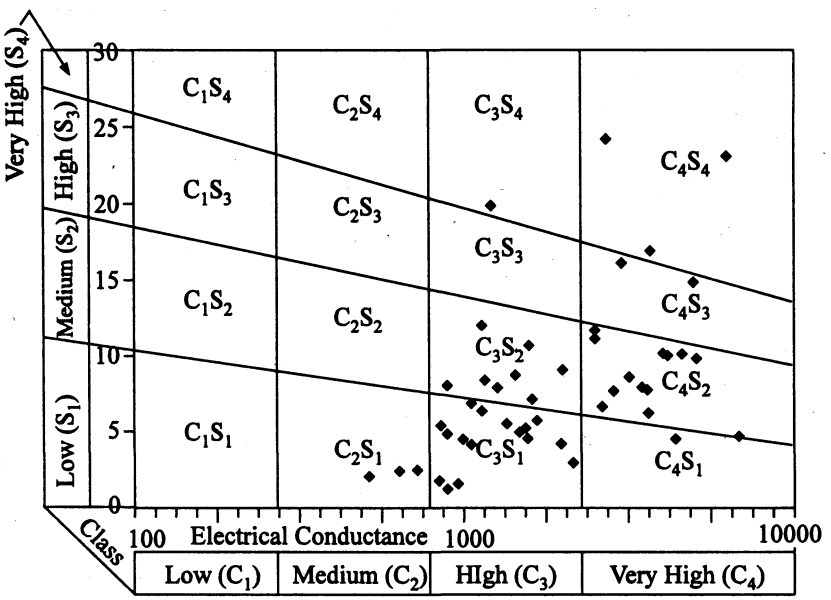

Fig. 2. Salinity and sodium hazard relation for water classification.

1. **Medium salinity and low sodium hazard water:** Only 3 villages (*viz.*, Pipali, Siyar and Biliya Kalan) have such type of ground water. In these villages the use of ground water for irrigation purpose requires proper management practices.
2. **High salinity and low sodium hazard water:** 19 Samples of 15 villages (*viz.*, Kanoli, Nya Samaliya, Mangrop, Maheshpura, Baga ka Khera, Suwana, Dariba, Kochriyas, Kiratpura, Pur, Gadarmala, Sarup Ganj, Bardod, Hammirgarh and Biliya) represent the ground water of this category. This water could be used for irrigating semi-tolerant crops without any harmful sodic effect.
3. **High salinity and medium sodium hazard water:** 8 Samples of 6 villages (*viz.*, Bhansa Kundal, Guwardi, Iras (Bhopa ka khera), Akola and Agarpura have ground water of this category. The medium SAR values, which are usually associated with high salinity, may develop moderate alkaline condition.
4. **High salinity and very high sodium hazard water:** Only one village (Rupaheli) falls in this category. The use of ground water for irrigation purpose is unsuitable.
5. **Very high salinity and medium sodium hazard water:** 12 Samples of 10 villages (*viz.*, Manfiya, Ramria Khera, Laxmipura, Atoon, Jodha ka Khera, Sidriyas, Dantajati, Mandal, Noor Bag and Kanwliyas) fall in this category. Medium SAR of these samples indicates dominance of calcium and magnesium ions. Such dominance when occurs with high carbonate concentration, the water is said to be of alkaline nature as noted in 4 villages. On the other hand when this dominance is present with chloride, the water is said to be saline as noted in 6 villages.
6. **Very high salinity and high sodium hazard water:** 2 Villages (*viz.*, Salariya and Kalyanpur) fall in this category. The ground water of both villages is unsuitable for irrigation purpose.
7. **Very high salinity and very high sodium hazard water:** 3 Samples of 2 villages (*viz.*, Gathila Khera and Haler) fall in this category. The ground water of both villages is unsuitable for irrigation purposes. The very high salinity and high SAR of both villages are due to greater pollution level as they are very close to industrial area.

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