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Seasonal Variations in Water Quality of Mandore Region, Jodhpur District, India†

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A physico-chemical study of the ground water of Mandore region of Jodhpur district has been carried out to examine the suitability of water for drinking and irrigation purposes. Fifty-one water samples representing the ground water of the region were collected during pre- monsoon and post-monsoon seasons in the month of June and November 2011 respectively and were analyzed for physico-chemical characters. The results were used for inter elemental correlation analysis which indicates that most of the elements have good correlation. The quality of water that predominated in the study area was assessed based on hydro-chemical facies. Piper-trilinear and Stiff pattern diagrams were used to find out the hydro-chemical type of ground water, which show that most of them are Na-K-Cl type. Besides, geochemical classification the suitability of ground water for irrigation was evaluated based on sodium adsorption ratio, percent sodium (% Na) and residual sodium carbonate values. The results of study provided information needed for ground water quality management in the region.

Key Words: Water quality, Mandore region, Physico-chemical analysis, Piper and Stiff pattern diagrams, Ion correlation.

INTRODUCTION

Ground water is an important source of water supply throughout the world. In Rajasthan[1,2] arid and semi-arid tract occupy about 3/4 of the geochemical area and underground water is the main source of irrigation in this belt. Nearly 60 % of the total acreage of Rajasthan is irrigated through development of underground water resources. The ground water of this area is generally saline and scarce. Due to limited availability of water in this area, quality of water assumes greater importance. Many a times ground water carries a high mineral content than the surface water, when there is slow circulation and longer period of contact. Changes in ground water quality[3,4] with the passage of time have hydrologic significances. The objective of this study is to characterize and analyze the ground water quality in the Mandore region, Jodhpur district (Raj.) and to formulate equations[5,6] to predict the values of water quality parameters with reference to electrical conductivity measurable at site itself. Also, methods proposed by Piper[7], Stiff[8] and others[9,10] have been used to study critically the geo-chemical characteristics of the groundwater of study area.

EXPERIMENTAL

Mandore region is integral part of Jodhpur district, which is centrally situated in the desert region of western Rajasthan. It covers an area about 1281.52 Sq. km. The topograph of the area is characterized mainly by plain terrain having a thick mantis of sand, slit, clay and kanker. The area is devoid of any surface drainage system and is characterized by scanty and erratic precipitation, high evapotranspiration and extreme temperatures. Hot winds and dust storms are frequent during the summer. The average annual precipitation is about 30 cms. The main aquifer comprises of sand stone of Vindhyan age (Jodhpur group). Shale's intercalated with sand stones are also reported in few wells. Rhyolites are encountered as basement. The litho unit is main source of water in the region and covers nearly 61 % of the potential area. The depth of ground water in the area ranges from 20 to 30 m. The major ion chemistry of ground water of Mandore region has not been studied so far.

Methodology: For major ion chemistry, 51 water samples were collected from different places of Mandore region[11] during two seasons, namely pre-monsoon and post- monsoon in the year 2011. The collected water was transferred into pre cleaned polythene container for the analysis of physico-chemical characters like pH, electrical conductivity, total dissolved solids, calcium, magnesium, total hardness, total alkalinity, sulphate, chloride, fluoride, nitrate, sodium and potassium, using the standard procedures recommended by

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TABLE-I
MANDORE (PRE- MONSOON)

S. No.	Parameter	Range (mg/L)	Mean	Std. limits IS: mg/L	Peak value	Exceedence of peak value over IS std. values (%)	Percentage of samples exceeding the stds.
1	EC*	600 - 9880	2481	750	9880	1217.3	90.2
2	TDS	396 - 7200	1652	500	7200	1340.0	60.8
3	TA	70-1200	480.4	200	1200	500.0	88.2
4	TH	50 - 1250	435	300	1250	316.7	54.9
5	Calcium	12- 340	81.3	75	340	353.3	51.0
6	Magnesium	5-200	45.93	30	200	566.7	51.0
7	Sulphate	10 -1100	124	200	1100	450.0	13.7
8	Chloride	40-- 3100	407	250	3100	1140.0	39.2
9	Fluoride	0.5 -13.6	1.9	1	13.6	1260.0	35.3
10	Nitrate	5-250	58.9	45	250	455.6	49.0
11	Sodium	29-2000	182	200	2000	900	15.7

*EC is expresd in µS/cm

TABLE-2
MANDORE (POST- MONSOON)

S. No.	Parameter	Range (mg/L)	Mean	Std. limits IS: mg/L	Peak value	% Exceedence of peak value over IS std. values	Percentage of samples exceeding the stds.
1	EC*	350-9600	2294.9	750	9600	1180.0	62.7
2	TDS	231-6336	1495.8	500	6336	1167.2	64.7
3	TA	50-1883	319	200	1883	841.5	62.7
4	TH	40-1120	435	300	1120	273.3	54.9
5	Calcium	4-324	87.5	75	324	332.0	41.2
6	Magnesium	2 -180	39	30	146	386.7	37.3
7	Sulphate	8-960	102	200	960	380.0	15.7
8	Chloride	30-2800	353	250	2800	1020.0	33.3
9	Fluoride	1-11.3	1.87	1	11.3	1030.0	31.4
10	Nitrate	5-150	48	45	150	233.3	49.0
11	Sodium	25-1950	170.3	200	1950	875	13.5

*EC is expresd in µS/cm

TABLE 3
CORRELATION MATRIX AMONG DIFFERENT WATER QUALITY VARIABLES OF MANDORE
(Pre-monsoon)

	pH	EC	TDS	TA	TH	Ca	Mg	SO_4	Cl	F	NO_3	Na	K
pH	1												
EC	-0.2033	1											
TDS	-0.2020	0.9935	1										
TA	-0.3943	0.5569	0.5594	1									
TH	-0.3959	0.6848	0.6493	0.4715	1								
Ca	-0.3571	0.5629	0.5485	0.4195	0.7826	1							
Mg	-0.2191	0.5937	0.5525	0.3221	0.7877	0.2975	1						
SO_4	-0.2962	0.3422	0.3329	0.6136	0.5693	0.3651	0.5171	1					
Cl	-0.0780	0.8054	0.8096	0.3964	0.4488	0.1601	0.5992	0.1377	1				
F	0.3346	0.3119	0.3207	0.1291	-0.1360	-0.2325	0.0650	-0.1140	0.4133	1			
NO_3	-0.0532	0.4909	0.4795	0.5600	0.5978	0.4338	0.4308	0.3503	0.3217	0.0144	1		
Na	0.2221	0.6168	0.6270	-0.0442	0.1470	-0.0434	0.3622	0.0717	0.7912	0.6551	0.0910	1	
K	0.1968	0.5145	0.560	-0.0375	0.0441	0.0031	0.1947	-0.0417	0.6857	0.5065	0.1098	0.829	1

APHA[12]. The chemical characteristics sodium adsorption ratio (SAR), % sodium and residual sodium carbonate (RSC) of ground water in the study areas are also listed along with other physico-chemical parameters.

RESULTS AND DISCUSSION

The results are summarized in Tables 1 and 2. It is clear from the tables that salinity (in terms of EC) of ground water varies from less than 9800 µS/cm to more than 350 µS/cm. It has been observed that nearly 70 % of the area is occupied by saline water. Hardness is not a serious problem in this block but occurrence of high fluoride in ground water is a serious health hazard. Ground water at village Daikara in Mandore block has been found to contain highest fluoride concentration of more than 13 mg/L.

To find out correlation among the numerous water quality parameters correlation coefficient (r) values were calculated and recorded in Tables 3 and 4. The r^2 values were also recorded because they represent the proportion of variation in the dependent variable accounted for linear regression equation[13]. The higher r^2 values indicate better performance of the relationship and suitability in computing the dependent variables. The linear regression approach was made to develop a relation between EC (easily measurable at site itself) and

TABLE-4
CORRELATION MATRIX AMONG DIFFERENT WATER QUALITY VARIABLES OF MANDORE
(Post-monsoon)

	pH	EC	TDS	TA	TH	Ca	Mg	SO_4	Cl	F	NO_3	Na	K
pH	1												
EC	-0.1930	1											
TDS	-0.1896	0.9945	1										
TA	-0.1488	0.7439	0.7440	1									
TH	-0.3863	0.7003	0.7000	0.2759	1								
Ca	-0.3390	0.5928	0.5927	0.2884	0.8102	1							
Mg	-0.1768	0.6737	0.6731	0.3864	0.7572	0.3426	1						
SO_4	-0.2710	0.3207	0.3204	0.1178	0.5794	0.3769	0.4155	1					
Cl	-0.1022	0.8022	0.8023	0.7130	0.4308	0.1679	0.6679	0.1129	1				
F	0.3140	0.3048	0.3044	0.4736	-0.1377	-0.2126	0.1031	-0.1329	0.4063	1			
NO_3	-0.0098	0.4676	0.4684	0.2027	0.5957	0.4474	0.5407	0.3191	0.3216	0.0412	1		
Na	0.2040	0.6197	0.6202	0.6088	0.1307	-0.0391	0.3805	0.0487	0.7895	0.6558	0.1060	1	
K	0.1441	0.5211	0.522	0.6521	0.0489	0.0171	0.2997	-0.0425	0.6672	0.5194	0.1353	0.829	1

diffe-rent water quality variables. Regression equations were computed for parameters having correlation coefficient (r) values greater than 0.5, are recorded in Tables 5 and 6.

TABLE-5
REGRESSION EQUATIONS FOR DIFFERENT WATER QUALITY PARAMETERS OF MANDORE
(Pre-monsoon)

Regression equations	r^2	t-value	F-value
TDS = 0.6795 EC - 49.741	0.9949	97.77	9558.84
Cl = 0.2156 EC -125.38	0.6489	9.52	90.56
TH = 0.0947 EC + 202.57	0.4689	6.58	43.26
Level of significance 5 %			

TABLE-6
REGRESSION EQUATIONS FOR DIFFERENT WATER QUALITY PARAMETERS OF MANDORE
(Post-monsoon)

Regression equations	r^2	t-value	F-value
TDS = 0.6568 EC - 1.809	0.9942	91.65	8399.28
Cl = 0.2026 EC- 115.52	0.6435	7.87	61.88
TH = .0908 EC + 162.04	0.4904	7.34	53.82
Level of significance 5 %			

On the basis of student's distribution (*t*-test) at 0.05 significance level (5 %), it can be inferred that regression coefficients obtained are significant, as all *t*-values are greater than $t_{0.95}$ = 1.99 for 51-2 = 49° of freedom (df). The significance of relationship is also supported by F-test.

To verify the validity of regression approach these equations were used to compute the concentration of selected water quality constituents. A good agreement was found between observed and computed values. The closeness of estimated and observed values showed that the pattern arrived could be used to predict concentrations of different water quality variables at any location in the region.

The Piper trilinear diagram and Stiff diagrams were used to infer hydro- geochemical facies. Piper plots include two triangles, one for plotting cations and other for plotting anions. The cation and anion fields are combined to show a single point in a diamond shaped field, from which inference can be drawn on the basis of hydro-geochemical concept. These trilinear diagrams are useful in bringing out chemical relationships among groundwater samples in more definite terms rather than other possible plotting methods.

Chemical data of the study areas are presented by plotting them on the Piper trilinear diagrams for pre and post-monsoon period (Figs. 1 and 2). The cation plot in the diagram in the both pre and post -monsoon season reveals that the majority of samples fall in Na + K type. For anion concentration Cl-type of water predominated during both pre and post-monsoon. The grouping of samples according to their hydro-chemical facies clearly indicates predominance of Na-K-Cl type water in the study area. This fact is also supported by Stiff pattern diagrams. There is no significant change in the hydro chemical facies noticed during the study period (pre and post-monsoon), which indicates that most of the major ions are anthropogenic in origin.

The suitability of ground water for irrigation purposes[14-16] depends upon its mineral constituents. The general criteria for judging the quality largely depends on sodium concentration because sodium reacts with soil and reduces its permeability. Excessive sodium in irrigation water may create specific problems as source of toxicity to certain sensitive crops, in addition to its contribution to total salinity. Wilcox[17,18] related the sodium and potassium concentrations to calcium and magnesium concentrations expressed as percent sodium in irrigation water.

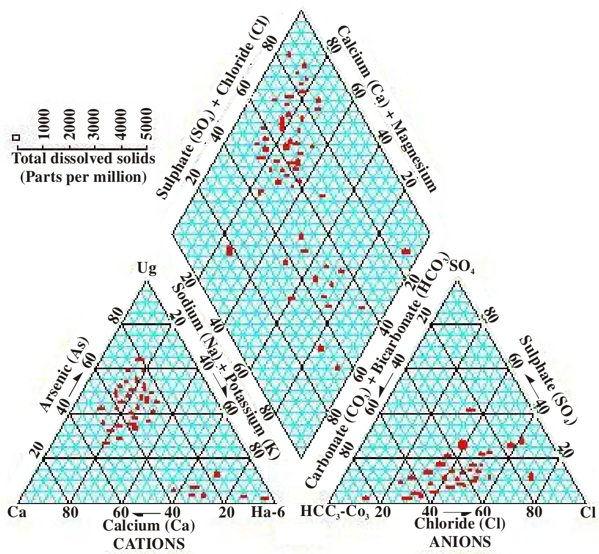

Fig. 1. Piper trilinear diagram of mandore (pre-monsoon)

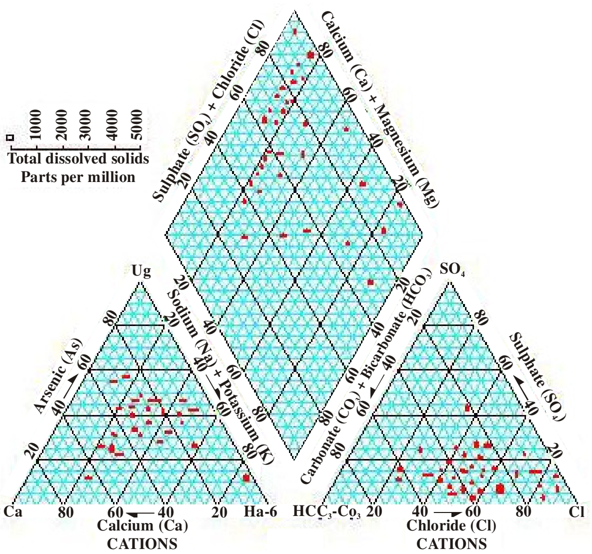

Fig. 2. Piper trilinear diagram of mandore (post-monsoon)

The classification of ground water samples with respect to percent sodium and EC is recorded in Table-7. It is observed that about 63 % of samples were excellent to good during pre and post-monsoon.

TABLE-7
CLASSIFICATION OF IRRIGATION WATER ON BASIS OF PERCENT SODIUM (Na %)*

Percent sodium (meq/L)	Water class	Pre	Post
0-20	Excellent	26, 28, 34, 40, 42,43,46	26, 28, 34, 40, 42, 43, 46
20-40	Good	3, 4, 6-11, 20, 24, 25, 27, 29, 30, 32, 33, 35-39, 44, 45, 47-51	1-4, 6-11, 20, 24, 25, 27, 29, 30, 32, 33, 35-38, 44, 45, 47-51
40-60	Permissible	1, 2, 5, 13, 16, 18, 19, 21, 41	5, 13, 16, 18, 19, 21, 39, 41
>60	Doubtful	12, 14, 15, 17, 22, 23, 31	12, 14, 15, 17, 22, 23, 31

The quality of irrigation water is also judged by its total salt concentration, relative proportion of cations or sodium adsorption ratio[19,20] (SAR), The classification of ground water samples from the study areas with respect to SAR is represented in Table-8. During pre-monsoon and post-monsoon about 94 % water was considered as excellent for irrigation.

TABLE-8
CLASSIFICATION OF IRRIGATION WATER ON THE BASIS OF SODIUM ADSORPTION RATIO (SAR)/SODICITY*

Sar value (meq/L)	Water class	Representing sample number	
		Pre	Post
<10	Excellent	1-11, 13-21, 24-51	1-11, 13-21, 24-51
10-18	Good	Nil	Nil
18-26	Fair	Nil	Nil
>26	Poor	12, 22, 23	12, 22, 23

*The quality of irrigation water is judged by its total salt concentration, relative proportion of cations or sodium adsorption ratio. Sodium hazard can be best understood by knowing SAR value. High sodium in water leads to the development of alkali soil, which has unfavourable structure and restricts aeration

In waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate. Residual sodium carbonate (RSC)[21] is calculated. According to US Department of agriculture, water having more than 2.5 epm of residual sodium carbonate is not suitable for irrigation purposes. Ground waters of the study area were classified on the basis of residual sodium carbonate and the results are presented in Table-9 for both pre and post-monsoon. Based on residual sodium carbonate values, over, 61 % samples have values less than 1.25 and were safe for irrigation, during pre-monsoon. During post-monsoon 82 % samples were safe for irrigation.

TABLE-9
CLASSIFICATION OF IRRIGATION WATER ON THE BASIS OF RESIDUAL SODIUM CARBONATE (RSC) ALKALINITY*

RSC value (meq/L)	Condition	Representing sample number	
		Pre	Post
< 1.25	Suitable	3,4, 6, 7, 9, 13, 15, 16, 18-21, 27, 30, 31, 34-40, 42-47, 49-51	1-11, 13, 15-17, 19-21, 24-28, 30-32, 34-40, 42-50
1.25-2.5	Marginal	1,5, 25, 26, 28	Nil
>2.50	Not suitable	2,8,10 - 14, 17, 22-24, 29, 32,33, 41,48	12, 14, 18,22, 23, 29, 33, 41, 51

*Bicarbonate is an important constituent in the evaluation of irrigation water quality In water having high concentration of bicarbonates there is tendency for calcium and magnesium to precipitate as carbonates. To quantify this effect an empirical parameter termed as Residual Sodium Carbonate is used

REFERENCES

1. K.K. Singh, S.K. Sarolia and M.S. Shekhawat, *Indian J. Environ. Hlth.*, **43**, 28 (2001).
2. D.D. Ojha and P.C. Jain, *Indian Water Works Assoc.*, **1**, 31 (1993).
3. M. Kumaresan and P. Riyazuddin, *Curr. Sci.*, **91**, 1668 (2006).
4. N.J. Raju, *Curr. Sci.*, **92**, 371 (2007).
5. H.S. Ramesh and B. Mahendran, *Indian J. Environ. Hlth.*, **42**, 121 (2000).
6. N. Rajmohan, L. Elango, S. Ramachandran and M. Natrajan, *Indian J. Environ. Hlth.*, **45**, 5 (2003).
7. A.M. Piper, A Graphic Procedure in Geochemical Interpretation of Water Analysis, USGS Ground Water Note no. 12 (1953).
8. Jr. H.A. Stiff, *J. Petrol. Technol.*, **3**, 15 (1951).
9. W. Back, Techniques for Mapping of Hydrochemical Facies, USGS Prof. Pap., **424 D**, 380 (1961).
10. D.K. Todd, Ground water Hydrology, Wiley New York, edn. 2, p. 315 (1980).
11. S. Purohit, Ph. D. Thesis, Assessment of Water Quality and Aspects of Pollution in some Rural and Urban Areas of Jodhpur District (Raj.) India, Jai Narayan Vyas University, Jodhpur, India, pp. 158-188 (2007).
12. APHA, Standards methods for the examination of water and waste water (American Public Health Association), Washington DC, 20th edn (1998).
13. C.K. Jain and M.K. Sharma, *Indian J. Environ. Health*, **42**, 159 (2001).
14. M. Ali and T.N. Tiwari, *Indian Water Works Assoc.*, pp. 319-322 (1988).
15. H.M. Hui, R.F. Stallard and J.M. Edmond, *Nature*, **298**, 550 (1982).
16. A.M.C. Edwards and P.S. Liss, *Nature*, **243**, 341 (1973).
17. L.V. Wilcox, Classification and Use of Irrigation Waters, US Department of Agriculture, Washington DC, p. 19 (1955).
18. W. Back and B.B. Hanshaw, Advance in Hydro Science, In Chemical Geohydrology, Academic Press, New York, vol. 2, p. 49 (1965).
19. US Salinity Laboratory staff, Diagnosis and Improvement of Saline and Alkali Soil, US Department of Agricultural Handbook, **60**, 160 (1954).
20. P.J. Lyerly and D.E. Longenecker, *Texas Agric. Extn. Service Bull.*, **876**, 20 (1957).
21. E.M. Eaton, *Soil Sci.*, **69**, 123 (1950).