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A Correlation Modelling of Various Hydrochemical Parameters to Interpret the Groundwater Quality of Jaipur City, Rajasthan (India)

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Abstract

This study was made to assess the analysis of physico-chemical parameters of ground water of Jaipur city. The chemical composition of the water was analyzed during monsoon session (July—October 2008). The ground water samples were collected from 18 sampling stations with different depth such as hand pumps, bore wells and shallow open wells, surrounding the industrial locations. The sutiability of ground water for drinking purpose was predicted with the help of Hill-Piper trilinear diagram and similarly the suitability of ground water for irrigation purpose, was predicted with the help of USSL diagram. The pH, EC, TDS were also compared with permissible limits. The analysis of ground water samples show higher values of EC, TDS, nitrate, calcium and magnesium. While the values of pH, sodium, potassium, fluoride and sulfate are compared with WHO standards and found within permissible limits. The Hill-Piper trilinear diagram shows that the majority of ground water samples are calcium-magnesium-chloride-sulfate type. The US salinity diagram shows that most of samples fall in C3S1 quality with high salinity hazard and low sodium hazard. Chemical analysis of groundwater shows that mean concentration of cation (mg/l) is in order, $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ while that of for anion, (mg/l) $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}>F^{-}$.
Key words : Ground water, Hill-Piper trilinear diagram, US salinity diagram.

Water is one of the most indispensable resources and is the elixir of life. The resources of water under the threat of pollution either from human life style manifested by the low level of hygiene practiced in the developing nations. Many authors have made the study regarding analysis of ground water chemistry (1, 2). They concluded that it is the high rate of exploration than its recharging inappropriate dumping of solids and liquid wastes, lack of strict enforcement of law and loose governances are the cause of deterioration of ground water quality. Many studies have been carried out on water quality parameter in India. Kumar et al. (2007) have studied groundwater suitability for irrigation and drinking purposes in two intensively cultivated districts of Punjab. Kumaresan et al. (3) have studied major ion chemistry of environmental samples around sub-urban of Chennai city. Laluraj et al. (4) have studied ground water chemistry of shallow aquifers in the coastal zones of Coachin and concluded that ground water present in the shallow aquifers of some of the stations were poor in quality and beyond potable limit based on the standard set by WHO and ISI. Jagdap et al. (5) classify the water in order to assess the water quality for various purposes. Study of industrial wastewater, ground water and pollution problems in Jaipur city and its vicinities has also been studied in our laboratory (6—8). In the present communication systematic study was made to predict the suitability of ground water for both irrigation and drinking purposes.

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Methods

Jaipur (longitude $95^{0}24'$ E; latitude; 27^{0} 18′ N), which is located in the eastern part of Rajasthan state, is undergoing rapid urbanization and industrialization. Ground water samples from 19 sampling stations

Table 1. Ionic variation of ground water in Jaipur city during monsoon season (2008).

Code	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3	SO_4^{2-}	Cl^{-}	NO_3^{-}	F^{-}
G1	8.13	1749	373	92.2	61.2	178.3	17.23	0.0	195.2	117.3	296.3	35.5	0.43
G2	8.6	2940	890	73.6	45.5	120.29	51.3	0.0	158.6	17.3	343.1	41	0.61
G3	8.5	2440	1330	43.2	96.2	55.2	5.23	360.3	152.5	71.2	270.5	86	0.72
G4	7.72	1140	660	164.1	70.5	17.9	1.65	356.5	262.3	62.3	163.5	76	0.31
G5	8.12	840	490	83.2	62.2	85.9	8.23	200.4	164.7	79.2	123.5	43.5	0.26
G6	7.5	1040	550	120.2	87.5	21.1	1.9	310.2	445.3	27.3	75.2	61.2	0.32
G7	7.8	1520	635	127.5	43.9	120.2	11.85	0.0	512.4	32.5	150.5	13.5	0.42
G8	8.3	1160	620	106.3	49.2	51.7	2.2	0.0	396.5	114.1	82.5	31.6	0.07
G9	8.17	3020	1440	82.16	63.2	66.7	4.79	160.4	420.9	66.7	123.3	43.7	0.12
GA	8.59	1975	977	66.3	24.5	101.89	33.2	0.0	323.5	82.3	107.5	126	0.35
GB	7.25	2770	1350	41.48	53.5	28.29	4.68	0.0	286.7	44.2	77.2	63.1	0.09
GC	7.71	3400	1710	57.2	46.2	59.8	7.41	0.0	341.6	88.5	103.2	51.5	0.53
GD	7.5	3480	1785	101.2	37.8	36.8	5.07	0.0	317.2	86.9	144	43.5	0.45
GE	7.3	903	449	71.5	45.5	39.4	3.72	250.2	311.1	83.5	127.2	26.2	0.07
GF	7.4	1140	742	93.2	53.5	54	5.3	0.0	213.5	121.7	247.5	33.7	0.62
GG	7.2	1520	840	41.5	58.2	191.8	19.2	0.0	402.6	39.9	89.6	83.2	0.39
GI	7.8	1081	513	88.2	66.5	21.6	2.5	0.0	445.3	83.7	189.9	47.6	0.27
GH	7.7	1380	612	96.5	73.2	68.2	6.78	0.0	268.4	123.5	143.7	73.2	0.23

were analyzed during post monsoon session. Samples were collected in good quality polyethylene bottles of 1-liter capacity. Sampling was carried out without adding any preservatives in rinsed bottles directly for avoiding any contamination and brought to be laboratory. Monitoring was done during post monsoon session (June-September 2008). Only high pure (AR grade) chemicals and double distilled water was used for preparing solutions for analysis. Physical

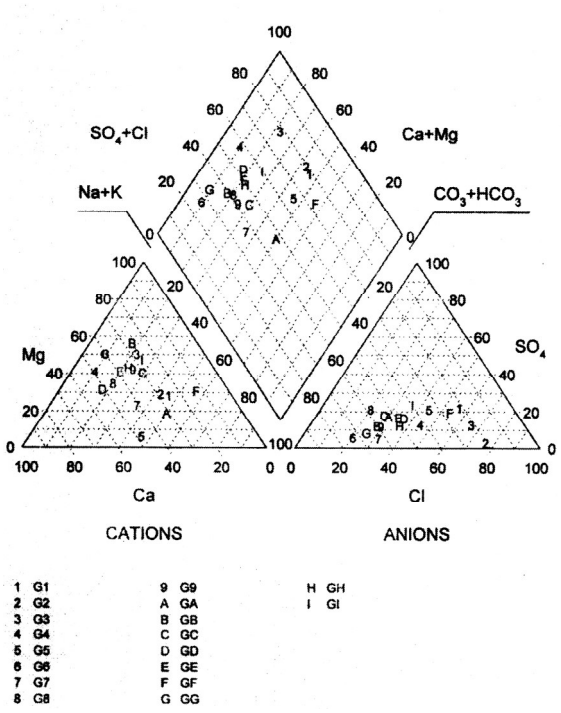

Figure 1. Piper Trilinear diagram.

Table 2. Water qualities on the basis of EC, RSC and sodium percent.

Parameters	Range %	Water class	Samples
	<20	Excellent	6(GB, GD, GE, GG, G4 and G6)
	20—40	Good	7(GC, GH, GI, G3, G7, G8 and G9)
Na percent	40—60	Permissible	4(GA, GF, G1and G5)
	60—80	Doubtful	1(G2)
	>80	Unsuitable	Nil
	<1.25	Good	All samples except (GD, GH and G6)
RSC	1.25—2.5	Doubtful	2 (GD and GH)
	>2.5	Unsuitable	1 (G6)
	0—250	Good	Nil
	251—750	Permissible	Nil
EC (μS/cm)	751—2,250	Doubtful	12(G1, G4, G5, G6, G7, G8, GA, GE, GF, GG, GH and GI)
	>2.250	Unsuitable	6(G3, G2, G9, GB, GC and GD)

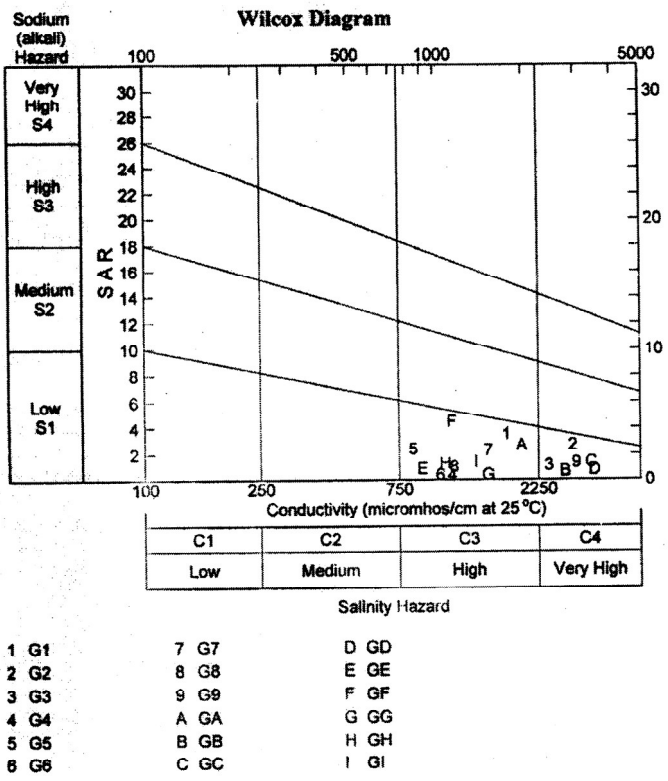

Figure 2. USSL diagram

parameters like pH, TDS and EC were determined at the with the help of digital portable water analyzer kit (Model No. CENTURY–CK–710). For rest of the analysis, water samples were preserved and brought to the laboratory in minimum period of time and were determined following standard methods (9). The suitability of the groundwater for irrigation was evaluated by using the irrigation water quality indices like percent Na, SAR and RSC.

Results and Discussion

Table 1 gives the various physico-chemical parameters of ground waters of Jaipur city. Classification of irrigation water on the basis of EC, Na%, SAR and RSC are shown in Tables 2—4.

Groundwater Chemistry

Ground water parameters were compared with permissible limit as prescribed by WHO standard and permissible limits also mentioned along with practical values. The pH values of ground water varied from 7.2 to 8.6 with an average value of 7.85, which indicates that water is slightly alkaline in nature and pH in all the ground waters within permissible limit (9.5). The EC values range from 840 μs/cm to 3,480 μs/cm (permissible limit 1500 μs/cm). Ten samples (GA, GB, GC, GD, GG, G1, G2, G3, G7 and G9) exceed the desirable limit. TDS values ranged from 373 to 1,785 with an average value of 887 (permissible limit 500) and all the samples exceed desirable limit except (GE, G1 and G5). The mean concentration of cation (in mg/liter) is in order, $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ while that of for anion, (in mg/l) $HCO_3^{-}>Cl^{-}>SO_4^{2-}>NO_3^{-}>F^{-}$. The Mg^{2+} concentration varied from 24.5 to 96.2 mg/liter with an average value of 57.68 (permissible limit 50 mg/liter) all the samples exceed the desirable limit except (GA, GC, GD, GE, G2, G7 and G8). The Ca^{2+} values varied from 41.48 to 164.13 mg/liter with an average value of

Table 3. Characterization of groundwater on the basis of Hill Piper diagram.

Subdivision of the diamond	Characteristics of corresponding subdivision of diamond shaped field	Samples	Percentage of samples in this category
1	Alkaline earths ($Ca^{2+} + Mg^{2+}$) exceed alkalies ($Na^{+} + K^{+}$)	All (except GF)	94.4
2	Alkalies exceeds alkaline earths	I (GF)	5.6
3	Weak acids ($CO_3^{2-} + HCO_3^{-}$) exceed strong acids ($SO_4^{2-} + Cl^{-}$)	8 (G6, G7, G8, G9, GA, GB GC and GG)	44.4
4	Strong acids exceed weak acids	10 (G1, G2, G3, G4, G5, GD, GE, GF, GH and GI)	56
5	Magnesium bicarbonate type	8 (G6, G7, G8, G9, GA, GB, GC and GG)	44.4
6	Calcium chloride type	2 (G3 and G4)	11.1
7	Sodium chloride type	I (GF)	5.56
8	Sodium bicarbonate type	Nil	0
9	Mixed type (No cation-anion pair exceeds 50%)	10 (G1, G2, G3, G4, G5, GD, GE, GF, GH and GI)	56

82.90 mg/liter, all the samples exceed the desirable limit except (GA, GB, GC, GE, GG, G3 and G2). Na^{+} and K^{+} values ranging from 21.1 to 178.3 and 1.65 to 51.3 mg/liter respectively. (within permissible limit). The CO_3^{2-} content ranged between 0.00 to 360.3 mg/liter, whereas HCO_3^{-} content range 152.5 to 445.3. Cl^{-} values varied from 75.2 to 343.1 mg/liter (permissible limit 200 mg/liter), four samples (GF, G1, G2 and G3) exceed the desirable limit. The concentration of SO_4^{2-} ranged from 17.3 to 123.5 mg/liter and all the samples below the permissible limit. F^{-} values varied from 0.07 to 0.72 mg/liter (permissible limit 1.5 mg/liter). NO_3^{-} values varied from 13.5 to 126 mg/liter; 50% samples exceed permissible limit (45 mg/liter).

Piper Diagram

The hydrochemical evolution of groundwater can be understood by plotting the concentration of major cations and anions in the piper tri-linear diagram (1944). This diagram consists of two lower triangles that show the percentage distribution, on milli-equivalent basis, of the major cations (Mg^{++}, Ca^{++} and Na^{+} plus K^{+}) and the major anions (Cl^{-}, SO_4^{2-} and CO_3^{2-} plus HCO_3^{-}) and a diamond-shaped part above that summarizes the dominant cations and anions to indicate the final water type. This classification system shows the anion and cation facies in terms of major-ion percentages (Fig. 1). GWW software was used for plotting the piper diagram. The analytical results summarized in (Table 3).

Irrigation Water Quality

SAR is important parameters for determining the suitability of groundwater for irrigation (10—13) because it is a measure of alkali/ sodium hazard to crops. SAR can be estimated by the formula :

$$SAR = (Na^{+}) / \sqrt{[(Ca^{2+}) + (mg^{2+}) / 2}$$

Where all the concentrations are expressed in meq/ liter.

SAR values ranged from 18 to 13.28 (Table 4). The analytical data plotted on the US salinity diagram illustrates most of the groundwater samples fall in the field of C3S1, indicating high salinity and low sodium water, which can be used for irrigation on almost all types of soil with little danger of exchangeable Sodium. SAR values ranges from 0.42 to 4.5 with an average value of 1.56 (Fig. 2). The analytical data plotted on the US salinity diagram illustrates most of the groundwater samples fall in the field of C3S1, indicating high salinity and low sodium water. Twelve samples except (G2, G3, G9, GC and GD) fall in the field of C3S1 indicating high salinity and low alkalinity hazard. Six samples in C4S1 (low alkalinity and very high salinity hazard) (Fig. 2).

Percent Na

The sodium in irrigation water is usually expressed on percent Na. Based on Indian standards

Table 4. The value of RSC, SAR and Na percent.

Code	RSC	SAR	Na percent
G1	NIL	3.5	45.98
G2	NIL	2.71	75.86
G3	NIL	1.13	21.94
G4	NIL	0.39	9.71
G5	NIL	2.4	45.87
G6	3.02	0.42	5.45
G7	NIL	2.34	35.67
G8	NIL	1.04	20.28
G9	NIL	1.34	24.51
GA	NIL	2.71	50.07
GB	NIL	0.68	17.26
GC	NIL	1.42	29.55
GD	1.98	0.79	17.49
GE	NIL	0.89	19.82
GF	NIL	4.5	56.27
GG	NIL	0.42	9.19
GH	1.66	1.27	22.46
GI	NIL	1.41	25.81

maximum of 60% sodium is permissible for irrigation water. Percent Na can be determined by using the formula

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

Where all the ionic concentrations were expressed in mili-equivalents per liter.

The value of % Na varies from 9.19 to 75.86. Six samples (GB, GD, GE, GG, G4 and G6) fall in excellent category, seven samples (GC, GH, GI, G3, G7, G8 and G9) fall in good category, four samples (GA, GF, GI and G5) fall in permissible limit and one sample (G6) falls under doubtful category, so all samples except (G6) were good for irrigation (Table 4).

RSC

RSC has been calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose and has been determined by the formula

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

Where the concentrations are reported in meq/liter

Fifteen samples except (GD, GH and G6) fall in excellent category, two samples (GD and GH) in doubtful category and remaining one sample (G6) in poor category (Table 4).

Conclusion

Interpretation of hydrochemical analysis reveals that the groundwater area is hard to very hard, fresh to slightly saline and alkaline in nature. The trilinear diagram shows that most of the samples fall in the field of $Ca^{2+} - Mg^{2+} - Cl^- - SO_4^{2-}$ type water. The US salinity diagram illustrates that most of groundwater samples fall in the field of C3S1. The classification of irrigation water according to the RSC values, most of groundwater samples fall in excellent category. Na percent values indicate one sample falls under doubtful category.

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