Analysis Of The Major Ion Constituents In Groundwater Of Jaipur City

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Abstract: The present study focused on the hydrochemistry of groundwater in Jaipur city to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. Groundwater samples were collected from eleven stations of Jaipur city during monsoon season and were analyzed for physico-chemical parameters such as pH, EC, TDS, sodium, potassium, calcium, magnesium, chloride, sulphate, carbonate, bicarbonate, nitrate and fluoride. Comparison of the concentration of the chemical constituents with WHO (world health organization) drinking water standards of 1983, the status of groundwater is better for drinking purposes. Results indicate that nitrate concentrations are in an alarming state with respect to the use of groundwater for drinking purposes. The calculated values of SAR, RSC and percentage sodium indicate that the water for irrigation uses is excellent to good quality. US Salinity diagram was used for evaluating the water quality for irrigation which suggests that the majority of the groundwater samples were good for irrigation. [Report and Opinion 2010;2(5):1-7]. (ISSN:1553-9873).

Key words: Physico-Chemical Parameters, Groundwater, US Salinity Diagram and Piper diagram.

Introduction:

Groundwater is the main source for drinking, irrigation and industrial purposes. During last two decades the indiscriminate disposal of industrial waste on mother earth slowly makes the groundwater susceptible to pollution. Jaipur city (longitude 95°24 E; latitude: 27°18), the capital of Rajasthan is becoming fragile and has been concern due to increasing industrialization, urbanization and population growth. Due to rapid urbanization and industrialization the environmental pollution is increasing day by day so it is essential to assess the quality of groundwater for its safer use. Therefore, the present study of the physico-chemical characteristics of Jaipur city has been taken up.

Various workers in our country have carried out an extensive work on water quality for various purposes. Subramani *et al.,* (2005) have studied groundwater quality and its suitability for drinking and agricultural use in Chithar River Basin. Charu *et al* (2008) have studied the drinking water quality status in Bhopal and concluded that the water quality is good and are within the range of standard values prescribed by various agencies. Raju (2007) has evaluated the groundwater quality in the upper Gunjanaeru River basin, Cuddapah District, Andhra Pradesh, South India. Kumaresan *et al.,* (2006) have studied major ion chemistry of environmental samples around sub-urban of Chennai city. Jagdap *et al.,* (2002) and Sunitha *et al.,* (2005) classify the water in order to assess the water quality for various purposes. Laluraj *et al.,* (2005) have studied ground water chemistry of shallow aquifers in the coastal zones of Cochin and concluded that groundwater present in the shallow aquifers of some of the stations were poor in quality and beyond potable limit as per the standard set by WHO and ISI. Jha *et al.,* (2000) have reported the degradation of water quality in Bihar. Study of industrial wastewater, ground water and pollution problems in ground water have also been studied in our laboratory (Sharma & Chandel, 2004; Singh & Chandel, 2003, 2006) recently. The objectives of the present work is to analyze the major ion constituents of the groundwater of Jaipur city and classify the water in order to appraise the water quality and its suitability for drinking and irrigation purposes using piper and US salinity diagram.

Materials and Methods:

Groundwater samples from different hand-pumps and tube-wells of eleven sampling points from the Jaipur city were analyzed during monsoon season (2007). Samples were collected in good quality screw-capped polyethylene bottles of one litre capacity. Sampling was carried out without adding any preservatives in rinsed bottles directly for avoiding any contamination and brought to the laboratory. Only high pure (Anal R grade) chemicals and double distilled water was used for preparing solutions for analysis. Physical parameters like pH, TDS and EC were determined at the site with the help of digital portable water analyzer kit (Model No.: CENTURY–CK–710). For rest of the analysis, water samples were preserved and bought to the laboratory in minimum period of time and were determined as per standard methods (APHA-1995). The chemical analysis was carried out for calcium, magnesium, chloride, sulphate, carbonate and bicarbonate by volumetric titration methods; while fluoride, nitrate and sulphate were estimated by spectrophotometer methods and sodium and potassium by flame photometry methods (ELICO-CL-220). All the results are compared with standard limits recommended by WHO (1983).

Results and Discussion:

Table-1 illustrates the various physico-chemical parameters of groundwater of Jaipur city. Correlation matrix among eleven water quality parameters of groundwater of Jaipur city is shown in table-2. Classification of irrigation water on the basis of EC, Na%, SAR and RSC are shown in tables 4, 5, 6 7 and 8.

Groundwater chemistry:

Understanding the quality of groundwater is as important as its quantity because it is the main factor determining its suitability for domestic, drinking, agricultural and industrial purposes. The pH values of groundwater ranged from 7.2 to 8.35 with an average value of 7.94. This shows that the groundwater of the study area is mainly alkaline in nature and all the samples were within the permissible limit prescribed by WHO. The TDS value ranged from 187 to 1498 with a mean of 789.64. According to WHO the desirable limit of TDS is 500 and all samples were exceeding the standard permissible limit except S2, S3 and S6. The value of EC varied from 374 μs/cm to 3004 μs/cm with an average value of 1573.36 μs/cm. The maximum limit of EC in drinking water is prescribed as 1500 μs/cm. as per WHO standard. Five (S4, S5, S7, S9 and SA) samples exceed the permissible limit. The average concentration of major ion in groundwater is in the following order: Anions: - Bicarbonate> Chloride> Nitrate> Sulphate while Cations: - Sodium> Calcium> Magnesium> Potassium. Ca^{2+} value varied from 8.16 mg/L to 266.53 mg/L with an average value of 103.30 mg/L. The desirable limit of Ca^{2+} for drinking water is specified by WHO as 75 mg/L. It is observed that 5 samples were exceeding this limit. Mg^{2+} concentration varied from 17.02 mg/L to 205.5 mg/L with a mean value of 67.99 mg/L. According to WHO the desirable value of Mg^{2+} is 50 mg/L where five samples were exceeding this limit. Excess of calcium and magnesium shows the hardness in water and is not good for potable. The Chloride ion concentration varied between 19.99 mg/L to 632.25 mg/L. Only one sample (S8) exceeds the maximum allowable limit of 600 mg/L. The nitrate concentration in groundwater samples range from 11 mg/L to 228 mg/L with an average value of 126.27 mg/L. Nearly 81% samples exceed the desirable limit of 45 mg/L as per WHO norms. The high concentration of nitrate in drinking water is toxic and causes methaemoglobinamia (blue baby disease) in children and gastric carcinomas (Comly 1945). Sulphate values varied from 13 mg/L to 182 mg/L and all samples are in desirable limit as per WHO standard. Fluoride values varied from 0.12 mg/L to 0.78 mg/L. All samples examined exhibit suitable for drinking (maximum allowable limit is 1.5 mg/L according to WHO).

Correlation:

The correlation coefficients (r) among thirteen water quality parameters namely pH, EC, TDS, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{2-}, Cl^{-}, SO_4^{2-}, NO_3^{-} and F^{-} were calculated for correlation analysis. Interpretation of correlation gives an idea of quick water quality monitoring method. According to table-2 the EC and TDS shows good positive correlation with Chloride and Sulphate and also exhibit high positive correlation with Calcium, Magnesium and Nitrate ions. Ca^{++}- Cl^{-}, Mg^{++}- Cl^{-}, Mg^{++}- SO_4^{-}, Ca^{+2}- NO_3^{-}, K^{+}- Cl^{-}, CO_3^{2-}- Cl^{-}, HCO_3^{-}- F^{-}, Cl^{-}- SO_4^{2-}, Cl^{-}- NO_3^{-} and SO_4^{2-}- NO_3^{-} are also the more significant correlation pairs. Table shows that pH and F^{-} exhibit negative correlation with most of the variables.

Piper diagram:

Trilinear plotting systems were used in the study of water chemistry and quality developed by Hill (1940) and Piper (1944). The water types are designated according to the area in which they occur on the diagram segments (figure 1). These diagrams reveal the analogies, dissimilarities and different types of waters in the study areas, which are shown in table-3.

The concept of hydrochemical facies presented by Walton (1970) to understand and identify the water composition in different classes based on the dominance of certain cations and anions in solutions (figure 2). It clearly explains the variation or domination of cation and anion concentration during monsoon season. According to table -3 alkaline earth type of water (Ca^{2+} + Mg^{2+}) exceed the alkalis (Na^{+} + K^{+}) where as in anion strong acids (Cl^{-} + SO_4^{2-}) exceed the weak acids (HCO_3^{-} + CO_3^{2-}) which show the hardness in all samples. 36% samples (S2, S3, S6 and S8) show secondary alkalinity where chemical properties are dominated by alkaline earths and strong acids. Two samples (S7 and S9) shows secondary salinity (non-carbonate hardness) where dominating ions are alkaline earth and strong acids. Only one sample (SB) shows primary salinity (dominated ions-alkali and weak acids). Not a single sample fall in primary alkalinity.

Irrigation water quality:

EC is a good measure of salinity hazard to crops. Excess salinity reduces the osmotic activity of plants and thus interferes with the absorption of water and nutrients from the soil (Saleh et al. 1999). Two (S7 and SA) out of eleven samples have very high salinity water and are not suitable for irrigation under normal conditions (Table 4).

SAR is important parameters for determining the suitability of groundwater for irrigation because it is a measure of sodium hazard to crops. SAR can be estimated by the formula (Karanth 1987):

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

where all ionic concentrations are expressed in meq/L. SAR values ranges from 0.29 to 7.13 with an average value of 2.36. All the sampling stations fall in the excellent category because none of the samples exceeded the value of SAR = 10 (table 6).

The classification system to evaluate the suitability of water for irrigation use can be determined by graphically plotting these values (EC and SAR) on the US salinity diagram (Richards, 1954). The plots of groundwater chemistry of study areas in the USSL diagram are shown in figure 3. The analytical data plotted on the US Salinity diagram illustrates that five groundwater samples (S1, S4, S5, S8 and S9) fall in the field of C3S1, indicating high salinity and low alkalinity in water, which can be used for irrigation on almost all types of soil with little danger of exchangeable Sodium. Two samples (S7 and SA) fall in the field of C4S1 indicating very high salinity and low alkalinity hazard. Three samples (S2, S3 and S6) fall in C2S1 type showed that the irrigation quality of water was fair in the study areas and one sample (SB) fall in C3S2 (figure 3).

% Na

The sodium in irrigation water is usually expressed in % Na. As per Indian standards maximum of 60% sodium is permissible for irrigation water. % Na can be determined by using the formula (Wilcox, 1955)-

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

where all the ionic concentrations are expressed in meq/L. The value of % Na varies from 10.67 to 72.83 (table-8). According to table-5 all the groundwater samples were excellent to permissible for irrigation except sample S9.

RSC

RSC has been calculated to determine the hazardous effect of carbonate and bicarbonate on the quality of water for agricultural purpose (Eaton 1950) and has been determined by the formula-

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

Where all the ionic concentration were reported in meq/L.

The classification of irrigation water according to the RSC values is presented in table-8. According to the US Department of Agriculture, water having more than 2.5 epm of RSC is not suitable for irrigation purposes while those having 1.25-2.5 epm are marginally suitable and those with less than 1.25 epm are safe for irrigation (Table 7) and the results shows that all the samples were good for irrigation except 2 samples (S6 and S9).

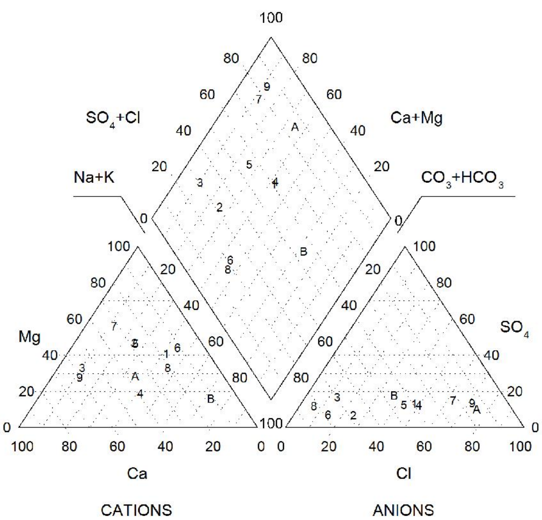

Figure 1. Trilinear Piper Diagram for monsoon season

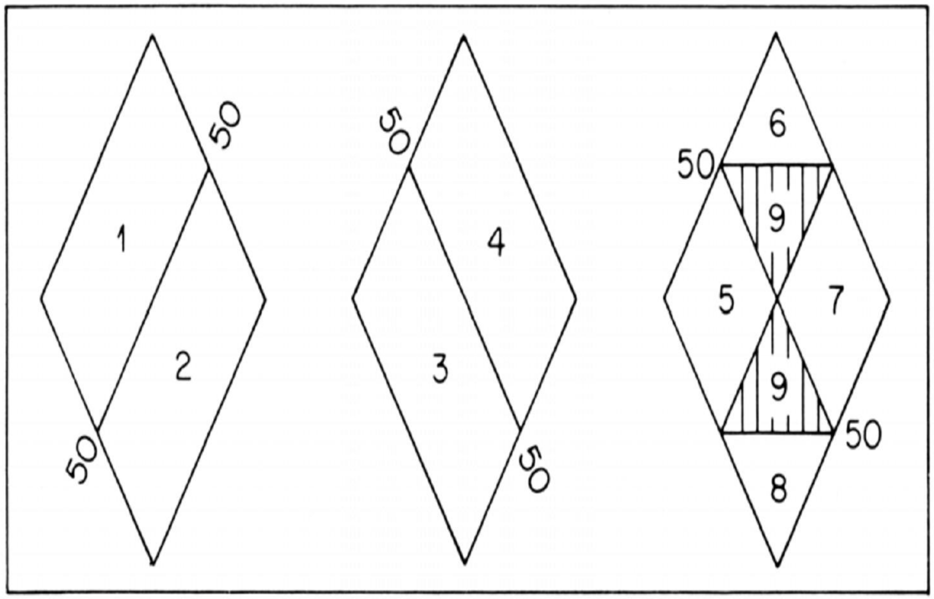

Figure 2. Subdivisions of the diamond-shaped field of the Piper diagram (9 facies)

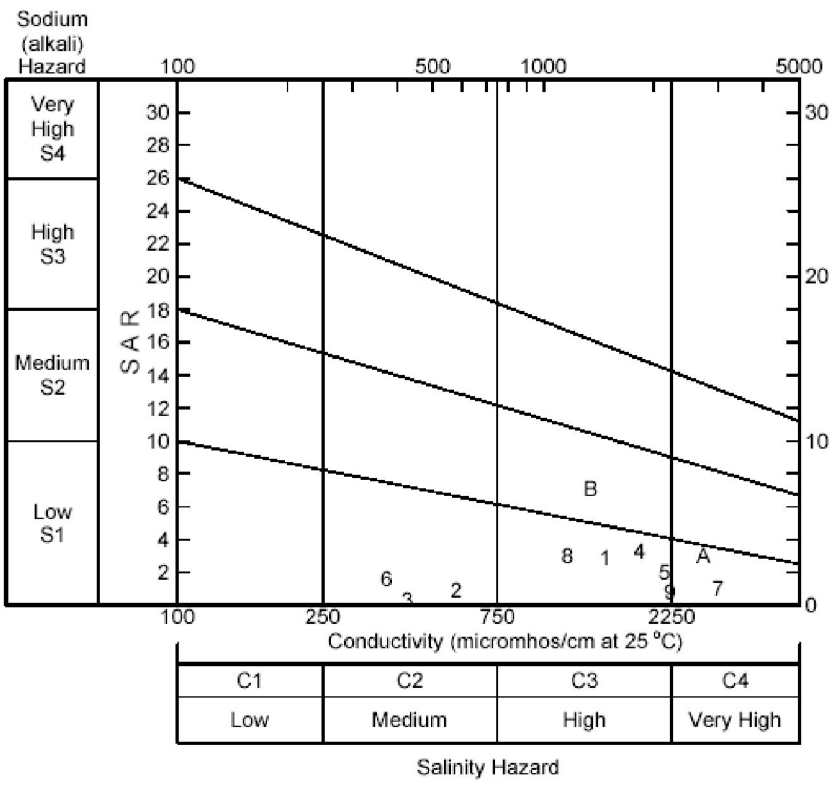

Figure 3. Classification of irrigation waters using U.S. Salinity diagram.

Table 1: Ionic Variation of groundwater in Jaipur City during monsoon season:

CODE	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3^{-}	F^{-}
S1	8.20	1482	738	52.1	72.96	140	3.8	18	256.2	207.92	78	158	0.18
S2	8.25	580	290	32.06	32.83	31.5	4.3	12	183	44.98	16	52	0.2
S3	8.32	426	213	48.1	17.02	9.2	2.1	12	146.4	19.99	32	39	0.26
S4	7.18	1831	918	142.28	41.34	116.7	3.4	0	337.7	259.9	86	226	0.21
S5	7.40	2148	1076	118.24	120.38	126.2	3.7	0	549	317.37	122	79	0.59
S6	8.31	374	187	8.16	19.46	36	2.2	36	109.8	19.99	13	11	0.32
S7	7.60	3004	1498	192.38	205.5	84	2.9	0	335.5	562.27	182	228	0.56
S8	8.20	1166	583	48.1	46.21	121.4	1.8	0	549	24.99	63	54	0.78
S9	7.79	2213	1106	266.53	74.28	60	3.8	0	140.3	392.34	98	216	0.14
SA	7.75	2737	1401	198.39	92.42	204	24	0	207.4	632.25	112	200	0.2
SB	8.35	1346	676	30.06	25.54	220	3.2	36	250.1	153	100	126	0.12

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

Table 2: Correlation of physico-chemical parameters of groundwater:

	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	NO_3^{-}
EC	-0.7238											
TDS	-0.7218	0.9998										
Ca^{2+}	-0.6907	0.8423	0.8422									
Mg^{2+}	-0.5642	0.8320	0.8256	0.6095								
Na^{+}	-0.1682	0.4865	0.4941	0.1181	0.1508							
K^{+}	-0.1926	0.4598	0.4773	0.4020	0.1659	0.4955						
CO_3^{2-}	0.6942	-0.6120	-0.6114	-0.6970	-0.5288	0.0325	-0.2576					
HCO_3^{-}	-0.4187	0.3099	0.3047	0.0041	0.3650	0.3450	-0.1667	-0.4710				
Cl^{-}	-0.6508	0.9546	0.9582	0.8523	0.7780	0.4213	0.6302	-0.5331	0.0640			
SO_4^{2-}	-0.6274	0.9317	0.9271	0.6770	0.8688	0.4974	0.2202	-0.4633	0.4102	0.8347		
NO_3^{-}	-0.6381	0.8356	0.8340	0.8070	0.5509	0.4045	0.3428	-0.4690	-0.0072	0.8139	0.7418	
F^{-}	-0.1742	0.1387	0.1328	-0.0607	0.4160	-0.0677	-0.2471	-0.3952	0.7964	-0.0394	0.2466	-0.2637

Table 3.Characterization of groundwater of Jaipur on the basis of Piper tri-linear diagram:

Subdivision of the diamond	Characteristics of corresponding subdivision of diamond shaped field	Samples
1.	Alkaline earths (Ca^{2+} + Mg^{2+}) exceed alkalies (Na^{+} + K^{+})	10(All samples except SB)
2.	Alkalies exceeds alkaline earths	1 (SB)
3.	Weak acids (CO_3^{2-} + HCO_3^{-}) exceed strong acids) (SO_4^{2-} + Cl^{-} + F^{-})	4 (S2, S3, S6 and S8)
4.	Strong acids exceed weak acids	7 (all samples except S2, S3, S6 and S8)
5.	Carbonate hardness (secondary alkalinity) exceeds 50% (chemical properties are dominated by alkaline earths and weak acids)	4 (S2, S3, S6 and S8))
6.	Non-carbonate hardness (secondary salinity) exceeds 50% (chemical properties are dominated by alkaline earths and strong acids)	2 (S7 and S9)

7.	Carbonate alkali (primary salinity) exceeds 50% (chemical properties are dominated by alkalies and weak acids)	1 (SB)
8.	Carbonate alkali (primary alkalinity) exceeds 50% (chemical properties are dominated by alkalies and weak acids)	0
9.	No cation–anion pair exceeds 50%	4 (S1, S4, S5 and SA)

Table 4 Quality of irrigation water based on Electrical Conductivity:

Salinity-hazard class	Specific conductance (µS/cm)[1]	Characteristics	Samples
Low	0-250	Low-salinity water can be used for irrigation on most soil with minimal likelihood that soil salinity will develop.	Nil
Medium	251-750	Medium-salinity water can be used for irrigation if a moderate amount of drainage occurs.	3 (S2, S3 and S6)
High	751-2,250	High-salinity water is not suitable for use on soil with restricted drainage. Even with adequate drainage, special management for salinity control may be required.	6 (S1, S4, S5, S8, S9 and SB)
Very high	More than 2,250	Very high-salinity water is not suitable for irrigation under normal conditions.	2 (S7 and SA)

[1]µS/cm, microsiemens per centimeter at 25 degrees Celsius.

Table 5: Quality of groundwater based on % Sodium:

% Na	Quality of water	Samples
<20%	Excellent	3(S5, S7 and SB)
20-40%	Good	3(S3, S8 and SA)
40-60%	Permissible	4(S1, S2, S4 and S6)
60-80%	Doubtful	1(S9)
>80%	Unsuitable	Nil

Table 6: SAR values can then be compared to characteristics of the four sodium-hazard classes as follows:

SAR	Water-suitability for irrigation
0-10	Suitable for all types of soils except for those crops which are highly sensitive to Sodium.
10-18	Suitable for coarce textured or organic soil with good permeability. Relatively unsuitable in fine textured soil.
18-26	Harmful for almost all types of soils. Requires good drainage, high leaching and gypsum addition.
>26	Unsuitable for irrigation

Table 7: Quality of groundwater based on residual Sodium Carbonate:

RSC	Remark the quality	Samples
< 1.25	Good	All samples except S6 and S9
1.25-2.5	Doubtful	1 (S9)
>2.5	Unsuitable	1(S6)

Table 8: The Value of RSC, SAR and Na %:

CODE	RSC	SAR	Na%
S1	Nil	2.94	41.84
S2	Nil	0.93	25.61
S3	Nil	0.29	10.67
S4	Nil	3.27	41.89
S5	Nil	1.95	26.11
S6	0.99	1.56	44.69
S7	Nil	1	12.33
S8	2.8	3	46.21
S9	Nil	0.84	12.24
SA	Nil	3	35.15
SB	1.7	7.13	72.83

Conclusion:

From the observation, it may concluded that almost all the parameters like pH, sodium, potassium, carbonate, bicarbonate, chloride are within the permissible limits prescribed by WHO but calcium, magnesium and nitrate values were exceeding the limits. The piper diagram shows that alkaline earth (Ca^{2+}+ Mg^{2+}) exceed over alkaline (Na^{+}+ K^{+}) where in anion strong acids (SO_4^{2-}+ Cl^{-}) were predominated. On the other hand most of the sampling station considered suitable for irrigation uses according to EC, SAR, %Na and RSC values.

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