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Hydrochemical Evaluation of Groundwater Quality in Parts of District Patiala, Punjab, India in Relation to Agricultural Suitability

Nibedita Ghosh, Madhuri S.Rishi, Renu Lata and Kamaldeep
Department of Environment and Vocational Studies, Panjab University, Chandigarh
E-mail : manighsh@yahoo.com

INTRODUCTION

The study of groundwater chemistry involves a description of the occurrence of the various constituents in groundwater and the relation of these constituents to water use. It is apparent from the water quality scenario in the study area that man has altered the natural soil-water system in many cases to his detriment, while he has improved his living conditions by controlling, developing and using groundwater supplies. The chemistry of groundwater is affected by several processes and factors which may have inter-dependent effect in controlling the overall chemical quality of the groundwater of an area. (Water Resource and Environment Directorate, 2004). In this context, the hydrochemical investigation of groundwater quality Patiala district was carried out. Groundwater as it flows in its course acquires the properties of its surrounding ambient conditions and accrues variety of elements, present in the areas through which it flow up to an optimum level. Some of these may have beneficial effects but when the concentration reaches beyond the recommended level it becomes hazardous for health. With respect to each essential element, all organisms depend on a specific range of tolerance or adequate range of exposure that is safe. Deficient or excess levels of concentrations for the elements can lead to adverse health effects, and in certain cases, death. Thus, for sustainable development of groundwater resources precise appraisal of hydrogeology and geochemistry and other varied quantitative assessment of groundwater are required.

SITE DESCRIPTION

Patiala district is located in the south-eastern part of Punjab. (Fig 1). The area lies between 29° 47' and 30° 41' N latitudes and 75° 55' and 76° 56' E longitudes with an aerial spread of 3708 km^2. Ghanaur with 338 km^2 area is the smallest block amongst nine bocks of Patiala district.

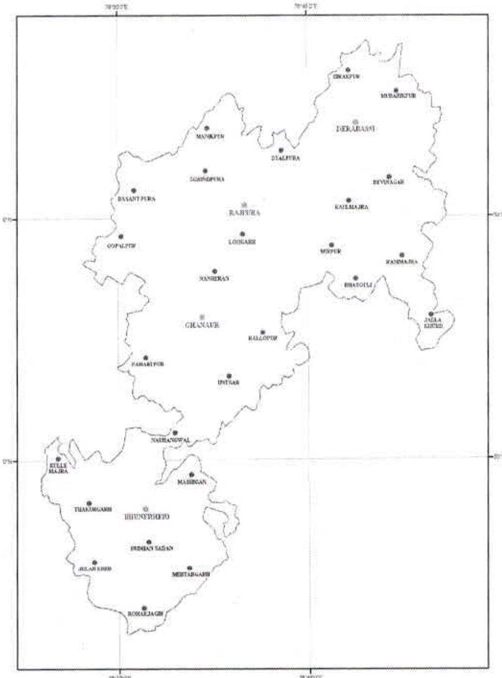

Fig 1. Location and sampling sites in the study area (Source:PunjabRemoteSensingcentre,Ludhiana)

MATERIALS AND METHODS

Water samples from 25 hand pumps and tube wells were collected during Oct 2009 and were analyzed in the laboratory. The water sampling has been carried out following the standard procedures. Good qualities, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratory for analysis. Analysis were done for pH and EC and the major ions(Na^+,K^+,Ca^{2+},Mg^{2+},SO_4^{2-},Cl^-, HCO_3^{2-},CO_3^{2-} and NO_3) using APHA method.The basic purpose of multivariate analysis was to generate groups of correlated elements from the initial data set. These groups are included into principal factors which describes processes occurring in the investigate environment.

RESULTS AND DISCUSSIONS

In the study area, 25 groundwater samples were collected for physico-chemical analysis and their results have been presented in Table1. The brief details of quality parameters are as under:

Turbidity

Turbidity concentrations ranged between 0 and 3.0 NTU. Turbidity in all the 25 samples was found to be in acceptable limits.

pH

In general waters having pH between 6.5 and 8.5 are categorized as suitable, whereas waters with pH 7.0 to 8.0 are highly suitable (ideal) for all purposes. The pH values of all the 25 groundwater samples in Patiala District ranges between 7.6 to 9.2 with a mean value of 8.08 indicating alkaline nature. pH beyond permissible limit was observed in tube well waters from 11 samples.

Electrical conductivity (EC)

Electrical conductivity of water sample is the measure of its total dissolved contents and gives

Table 1: Descriptive statistics of groundwater samples during Oct 2009

Oct 2009					
S.No	**Parameters**	**Mean**	**Std Dev**	**Max**	**Min**
1	**Temperature**	22.8	1.09	23	21.5
2	**pH**	8.12	0.36	9.2	7.6
3	**EC**	1245	610.0	1840	650
4	**TDS**	893	424	1600	415
5	**Ca^{2+}**	24.7	20.74	83.3	4
6	**Mg^{2+}**	20.5	14.03	53	4.8
7	**TH**	89.7	35.06	154	35
8	**Cl^-**	103	61.8	230	34.39
9	**Na^+**	241	150.09	599	65.06
10	**K^+**	3.14	1.985	8.8	0.8
11	**CO_3^-**	0.13	0.342	1.18	0
12	**HCO_3^-**	312	86.41	494	166.7
13	**NO_3^-**	1.01	1.425	5.46	0.12
14	**SO_4^-**	178	185.0	635	44.05

an idea about the extent of mineralization of ground water. The groundwater having EC less than 2000 micro Siemens/cm (μS/cm at 25° C) is generally considered as fresh water. EC of groundwater ranged between 650 μS/cm and 1840 μS/cm at 25°C. The average mean value of EC was 1245 μS/cm.

Total Dissolved Solids (TDS)

Total dissolved salt concentrations is the primary indicator of the total mineral content in water and are related to problems such as excessive hardness. TDS concentrations in the study area ranged between 415mg/l to 1600 mg/l among various locations and depths which are in acceptable limit. The average mean value of TDS is 893 mg/l indicating presence of moderate concentration of salts.

Total Hardness (TH)

It results from the presence of divalent metallic cations of which calcium and magnesium are the most abundant. As per drinking water specifications (BIS 1991), the desirable limit in the absence of alternative source of water is 600 mg/l. In the study area it ranged between 35.0 mg/l and 154 mg/l.

Total Alkalinity

Alkalinity usually is due to the presence of carbonates, bicarbonates and hydroxide ions. Its permissible limit in drinking waters is between 200 and 600 mg/l and beyond this limit taste becomes unpleasant. The total alkalinity in water samples varied between 41.2 and 765.2 mg/l which were within the permissible limit.

Chloride (Cl)

Chloride in drinking water is not generally harmful to human beings until high concentration is present. The Chloride concentration ranged between 34.39 and 230 mg/l. No water sample in this block had chloride content exceeding BIS acceptable limit. Thus, groundwater in the area is fit as far as chloride content is concerned.

Sulphate (SO_4)

The desirable limit of sulphate is 200mg/l and maximum permissible limit is 400 mg/l. In the study area, Sulphate concentration in the ground waters ranged from 44 to 635 mg/l. Out of 25 samples 7 samples have shown SO_4 concentrations more than the acceptable limit of 400 mg/l.

Fluoride (F)

Fluoride content in drinking water supplies in the study area ranges between 0 and 7.8 mg/l with an average value of 0.85 mg/l. Values higher than permissible limit have been found in 6 water sources and constituting of 43.91 % of total water samples.At village Kassiana, the fluoride concentration was 2.30 mg/l. It falls in the third category and causes the water to be rejected.

Calcium (Ca)

In drinking water the desirable limit of calcium is 75 mg/l and permissible limit in the absence of alternative source of water is 200 mg/l as per BIS standards (1991). The calcium concentration of water samples was well within the acceptable limit (0-75 mg/l).

Magnesium (Mg)

The levels of magnesium in groundwater is generally less than calcium due to the slow dissolution of magnesium bearing minerals and greater abundance of calcium in earth crust. The magnesium content ranged between 4.8 and 53 mg/l. The BIS desirable limit (30 mg/l) was not met in 26 per cent groundwater samples, while in remaining samples; it was well within the acceptable limit.

Nitrate (NO_3)

Groundwater with excess nitrate consumed by human being particularly infants is likely to be a health hazard and may cause Methaemoglobinemia. Nitrate values in the groundwater varies between 0.12 mg/l to 5.46 mg/l. The average mean value of NO_3 is 1.01 mg/l which is within the BIS limit. The nitrate concentration in groundwater of all the samples in the block is within the desirable limit.

Hydrochemical Facies

The geochemical evolution of groundwater can be understood by plotting the concentrations of major cations and anions in the Piper (1944) tri-linear diagram. Aquachem software was used for plotting the Piper diagram (fig 2). The piper plot of groundwater of Patiala district showed that almost all the groundwater samples of Oct 2009 fall in the category of (Cl^- and SO_4^{2-}). It is clearly evident from the plot that alkalis (Na^+ and K^+) significantly exceeded the alkaline earth metals (Ca^{2+} and Mg^{2+}) and strong acids (Cl^- and SO_4^{2-}) dominated weak acids (HCO_3^- and CO_3^{2-}). The groundwater had secondary salinity, as indicated by the presence of sodium. In the study area, the alkalies had a higher concentration than bicarbonate which indicated exchange of Na^+ ion from the alkaline earths and the water as base exchanged hardened water.

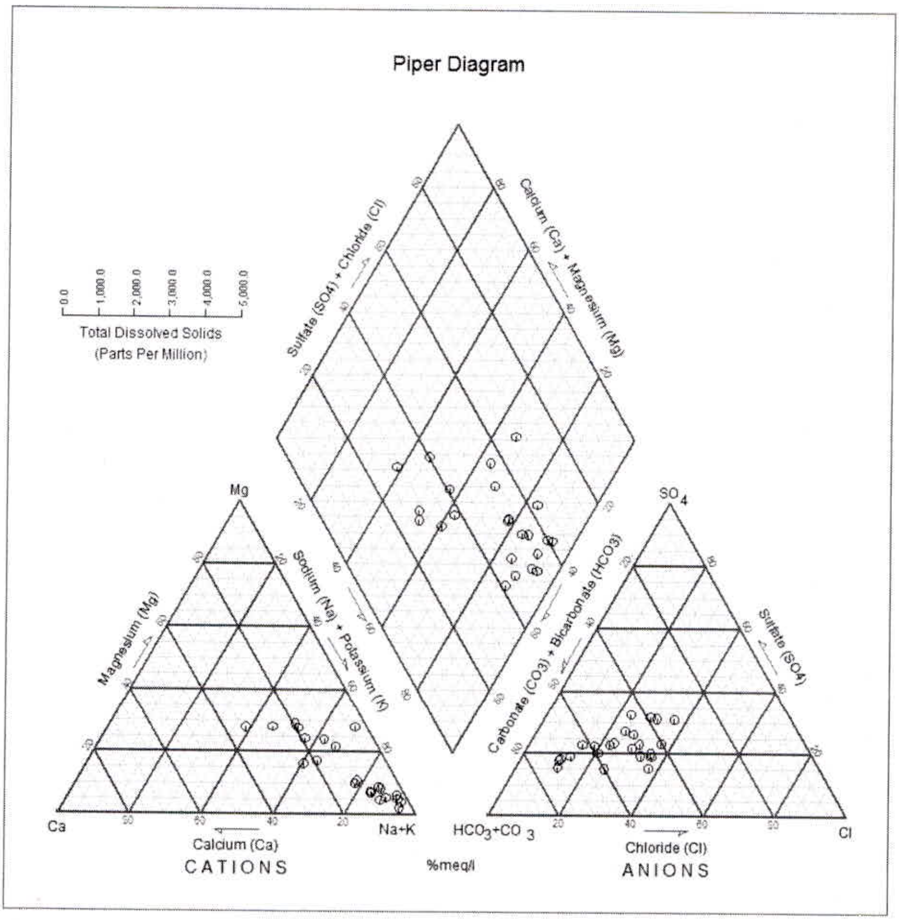

Fig. 2 : Hill Piper plot diagram for groundwater of Patiala District for Oct 2009

Inter Relationship between Chemical Parameter

Investigating on the origin of various ions present in natural water in the study area and the type of minerals present in strata through which water passes is one of the most challenging and important problem in hydrochemistry. An idea about the types of minerals with which water has been in contact, in some cases can be obtained from statistical relationship (fig 3-4). Some of these relationships generally used are factor analysis, principal component analysis study of correlation coefficients and regression equations. For the present study, various inter-ionic relationships have been studied to determine whether their sources of origin have been similar or divergent. Statistical relations for various ions are shown in Table2.

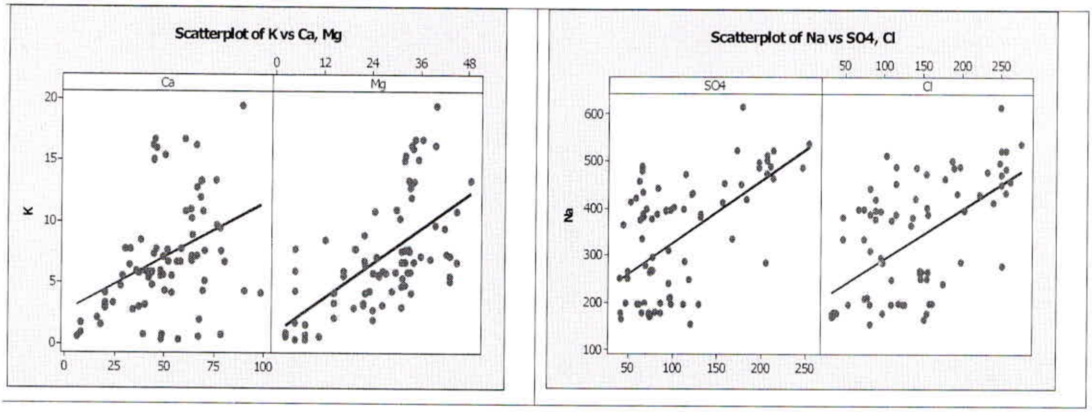

Fig. 3-4 : showing Inter Ionic relationship

1. **HCO_3-Ca:** - It is clear from the statistical relationship between HCO_3-Ca that there is negative correlation between the two and there is generally predominance of bicarbonate ions over calcium in groundwater at most of the places in the study area .It implies that bicarbonate is also being contributed by the sources other than the common source of HCO_3-Ca.

2. **HCO_3-Mg:** Statistical relationship between the HCO_3-Mg shows that there is weak negative correlation and correlation coefficient is (-) 0.14.It indicates that apart from common source of HCO_3-Mg, bicarbonate is also likely to be derived from additional sources which may be associated with calcium.

3. **Na-Cl:** Study of the statistical relationship between Na-Cl depicts that there is a strong positive correlation (+90.0) between the two. It indicates the same source of origin of these ions. There is marked predominance of sodium over chloride ions in the groundwater. It indicated that apart from the common source of Na-Cl, there are addition sources of sodium ions, such sources are likely to be clays which occur extensively in this area.

4. **Mg-Ca**: Study of statistical relationship between Mg-Ca show positive(+0.29) and Mg-Ca ions predominant over Ca ions in the analyzed water samples. Excess of Mg over Ca indicates presence of additional sources of Mg apart from common sources.

Irrigation Water Quality

SAR : High concentration of sodium is undesirable in water because sodium adsorbs on the soil cation exchange sites, causing soil

Table 2: Correlations: pH, EC, TDS, Ca, Mg, TH, Na, K, Cl, CO_3, HCO_3, NO_3, SO_4

	pH	EC	TDS	Ca^{2+}	Mg^{2+}	TH	Na^{+}	K	Cl^{-}	CO_3^{-}	HCO_3^{-}	NO_3^{-}	SO_4^{-}
pH	**1.00**												
EC	**0.51**	**1.00**											
TDS	**0.99**	**0.42**	**1.00**										
Ca^{2+}	**0.96**	0.16	**0.92**	**1.00**									
Mg^{2+}	-0.15	0.33	0.04	-0.29	**1.00**								
TH	0.10	0.28	0.30	0.33	**0.64**	**1.00**							
Na^{+}	0.19	0.01	0.23	0.10	0.24	0.16	**1.00**						
K^{+}	0.10	0.35	0.21	**0.90**	**0.42**	0.30	0.10	**1.00**					
Cl^{-}	0.17	**0.68**	0.01	0.07	- 0.11	0.10	**0.90**	0.06	**1.00**				
CO_3^{-}	0.30	0.05	0.18	0.19	0.17	0.15	0.26	0.27	0.33	**1.00**			
HCO_3^{-}	0.15	**0.52**	**0.46**	**0.49**	-0.14	0.27	0.24	**0.42**	-0.08	**0.53**	**1.00**		
NO_3^{-}	0.06	-0.06	0.26	**0.46**	0.19	**0.62**	0.23	**0.46**	0.25	0.18	0.32	**1.00**	
SO_4^{-}	0.13	**0.61**	0.19	0.28	0.11	-0.09	0.37	-0.07	**0.89**	0.23	**0.49**	**0.52**	**1.00**

aggregates to break down (deflocculating) sealing pores of the soil and making it impermeable to water flow. The tendency for sodium to increase its proportion on the cation exchange site at the expense of other type of cations is estimated by the ratio of sodium content to the content of calcium plus magnesium in the irrigation water; this is referred as sodium absorption ratio or SAR

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

In the study area, the SAR values ranges between 1.63 meq/l to 21.48 meq/l (fig 7-8). The study area falls in the category or water class of low to medium hazard where as only few samples come in the class of appreciable and high Na^{+} hazard (fig 5).

RSC

The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonate and carbonate, in excess of alkaline earths, has special significance in assessing the suitability of water for irrigational purposes. Therefore, the RSC concept of Eaton (1950) has a merit for judging the suitability of waters for irrigation. Residual sodium carbonate (RSC) is determined by the formula:

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

(The concentrations are expressed in meq/l.)

The groundwater having RSC< 2.5 me/l. to 5 meq/l as marginally fit and >5 meq/l is unfit for the irrigation. In the groundwater of the study area, an RSC value varies from nil to 13.8 meq/l. On persual of RSC map of study area, it is seen that in the major part of the area, the RSC values are between <2.5. However at few pockets in eastern parts higher RSC values have also been observe.

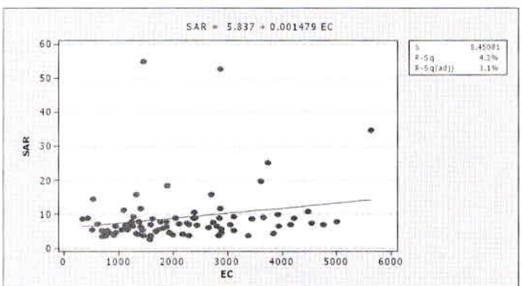

Fig. 5 : Variation of SAR with EC

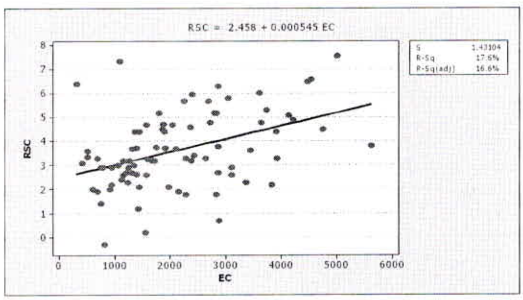

Fig. 6 : Variation of RSC with EC

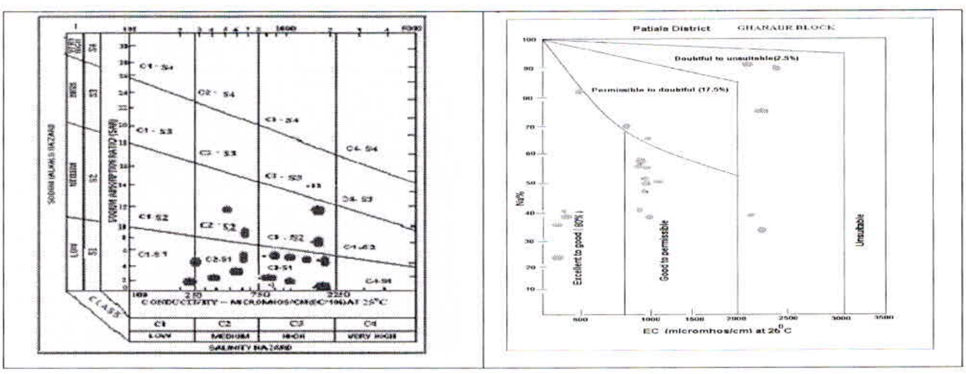

Fig.7-8 : US Salinity diagram showing classification of groundwater

CONCLUSIONS

A detailed study of groundwater quality in district Patiala revealed that the natural quality of groundwater is undoubtedly the result of number of physical, chemical and biological reactions as well as processes occurring to some degrees in the unsaturated as well as in the saturated zones. Groundwater is generally alkaline in nature with pH ranging between 7.6 and 9.2 with an average of 8.12. The EC of groundwater ranged from 650 ìS/cm to above 1840 ìS/cm with a mean of 1245 ìS/cm. Among cations, Na was the most dominant cation followed by Ca & Mg. Among the anions, SO_4 and Cl ion were found to be dominating in the water. From the above analysis, it is concluded that the groundwater in district Patiala is in general is suitable for domestic and agricultural purposes except for few locations, but care should be taken to avoid further contamination, further degradation and overexploitation of groundwater.

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