Vol. 11, pp. 63-70 (2011)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Characterization of Groundwater Quality for Irrigation in 'Gohana' Block of Sonepat District, Haryana

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ABSTRACT

Ground water is the primary source of irrigation in most arid and semi-arid regions of India. The characterization of ground water in both space and time becomes a prerequisite for sustainable crop production in these regions. Keeping this in view, study was undertaken to assess the ground water quality as affected by monsoon rain in 'Gohana' Block of Haryana state, which is located in a semiarid region of the country. Sixty groundwater samples were collected from different places of the study area in June (pre-monsoon) and November (post-monsoon) of 2006. The water samples were analyzed for pH, EC, major cations (sodium, potassium, calcium, and magnesium), and major anions (bicarbonate, chloride, sulphate and nitrate) and specific irrigation water quality indices (sodium adsorption ratio, residual sodium carbonate, Mg / Ca ratio) have been determined. The pH of groundwater varied from 8.67 during pre-monsoon to 8.48 during post-monsoon periods, and EC value varied from 5.4 during pre-monsoon to 4.5 dSm^{-1} post-monsoon. Among different cations, sodium was found as the most dominant cation, followed by magnesium, calcium and potassium during both pre-monsoon, and post-monsoon periods. SAR values of the groundwater collected from the area varied from 3.23 to as high as 36.10 for pre-monsoon period, with a mean value of 13.61. Co-relation matrix indicated that EC is highly correlated with Cl, Na, Mg and Ca. Overall, a marginal improvement of all most all the parameters of groundwater took place due to rainfall. The groundwater is suitable for irrigation and may help the farmers to grow more crops.

Key words: Groundwater quality, EC, SAR, RSC, Irrigation

Introduction

Judicious management and monitoring of soil and water are essential for sustainable agriculture. Over drafting of ground water and its quality deterioration are the major threats to crop production in arid and semiarid regions (Boumans *et al*., 1988). Minimizing ground water use, while maintaining its quality, has become a critical issue in these areas due to depletion of groundwater resources over the past decades.

The characterization of irrigation water quality plays a vital role in deciding its management strategies for profitable farming. Ground water aquifer, a main source of water supply in arid and semiarid regions of India is most vulnerable to salinity and sodicity problem resulting in considerable reduction in crop productivity (Kamra *et al*., 2002). Moreover, the nonscientific water management practices have

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led to rise in water table in most of the canal command areas, aggravating the salinity and sodicity problems. Ground water in the canal command areas is used by farmers to supplement irrigation in various crops, without considering its impact on soil phyisco-chemical properties as well as on crop production in lean period when there is no canal water supply. Hence, an apprehension exists that the use of marginal or poor quality ground water in farmlands may pose serious threat to the soil health causing low land productivity. The periodic monitoring of ground water quality becomes a need to minimize the risk of soil health deterioration and its detrimental effects on crop production.

The chemistry of ground waters is dictated by supply of various elements from both natural and anthropogenic sources (Bishnoi *et al.,* 1984). Rainfall plays an active role for changing the water quality of underground aquifers (CGWB, 1997; Kaushik, 2002). Different studies reported that the ground water characterization in various places in arid and semi-arid parts of the country is utmost essential for sustained crop production (Bishnoi *et al.,* 1984; Kaushik, 2002, Khaiwal and Garg, 2007; CGWB, 2000). The study conducted by Kamra *et al.* (2002) in 'Gohana' block of Haryana reveals that during 72-hours of continuous pumping, there was a significant variation of ground water quality in temporal scale. He suggested for analyzing ground water not only for conventional quality parameters but also for heavy metal contamination for their safe use in agriculture. In this context, the present study was undertaken to assess the impact of rainfall recharge on changes of seasonal ground water quality in 'Gohana' block of Sonepat district, Haryana located in a semiarid region of India.

Materials and Methods

The study was conducted in 'Gohana' Block (293 sq. km area; 28º57'12''-29º11'24'' N latitude and 76º48'39''-76º50'44'' E longitude) of Haryana state (Figure 1). The block has an elevation ranging from 213m to 227m above mean sea level. The slope is generally from North-West to South-East corner. The topographic situation of the block influences leaching pattern. The climate of the area is subtropical, semi-arid with hot dry summer, and cold winter with mean annual rainfall of 567 mm. Around 80 per cent of total rainfall occurs during the monsoon period (July-September). The average annual evapotranspiration is 1650 mm. The temperature varies from 1ºC in winter to 45ºC in extreme summer. Soils of 'Gohana' block represent a typical alluvial profile of Yamuna origin. As per USDA classification, the soils of the study area belong to sandy loam to silty-loam textural classes.

The ground water level in the study area varies in the range of 4-8 m. Rice-wheat is the dominating cropping system in the region under surface irrigation (flooding and basin). The crops are irrigated by both canal water (40%) and ground water supply (60%).

For hydrochemical investigation, water samples were collected twice from 60 tube-wells of 'Gohana' block in pre-cleaned 500 ml plastic bottles covering almost all villages of the study area. The first sampling was done in June, 2006 (pre-monsoon) and the second one in November, 2006 (post-monsoon). The sampling locations are shown in Figure 1. The collected water samples were analysed for pH, EC, Na, K, Ca, Mg, Cl, HCO_3, CO_3 SO_4 and NO_3 in the laboratory using the standard procedures. The water quality indices: SAR (Sodium Adsorption Ratio), RSC (Residual Sodium Carbonate) and Mg^{+2}/Ca^{+2} were then calculated using the formula:

$$\text{SAR (meq / lit)} = Na^{+} / \{(Ca^{+2} + Mg^{+2}) / 2\}^{0.5}$$

$$\text{RSC (meq / lit)} = (CO_3^{-2} + HCO_3^{-}) - (Ca^{+2} + Mg^{+2})$$

After hydro-chemical analysis, the waters were categorized as per the classification suggested by AICRP, 1989 (Table 1), and presented in Figure 2. The relationships between various quality parameters were analyzed by the correlation matrix.

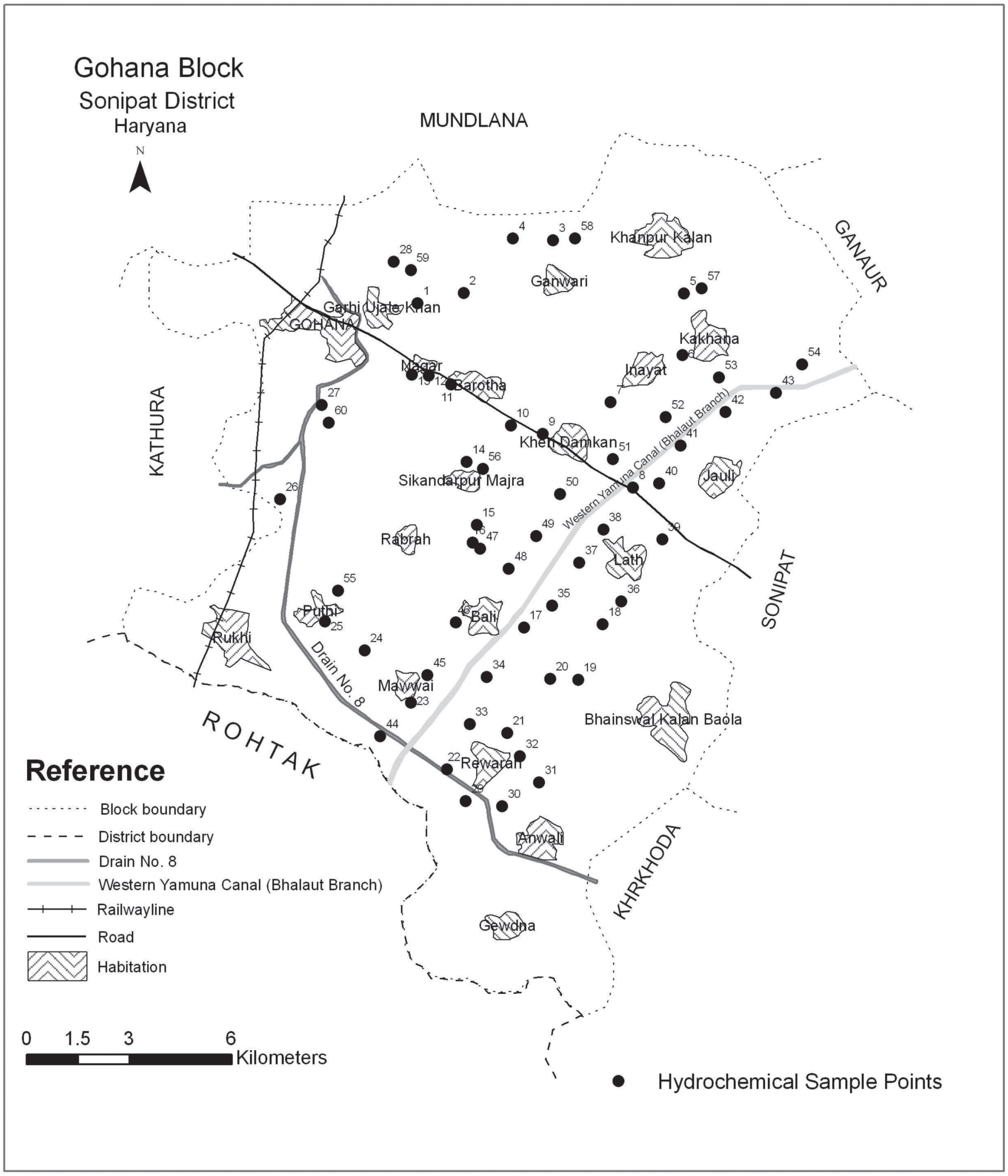


Fig. 1. Map of the study area indicating all hydro-chemical sample points/locations

Results and Discussion

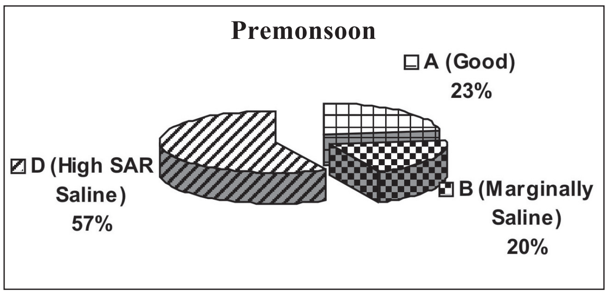
Variation in pH and EC of Ground Water

The descriptive statistics of hydro-chemical parameters indicates that the pH of groundwater of ‘Gohana’ block varied from 7.70 to 9.50 with a mean of 8.67 during pre-monsoon and 7.60 to 9.50 with a mean of 8.48 during post-monsoon periods (Table 2). Overall, the groundwater of ‘Gohana’ was alkaline (pH, 7.6 – 9.5) in both the seasons. The minimum pH value during pre-monsoon varied from 7.7 to 9.5, whereas the maximum value varied in the range 7.6–9.5, indicating no significant impact of monsoon rainfall on maximum pH value of ground water. Moreover, the mean and stand deviation of pH values did not vary significantly between pre-monsoon and post-monsoon seasons.

EC value of the ground water samples varied from 0.8 to 12.4 dSm^{-1} with a mean value of 5.10

Table 1. Irrigation water quality classifications (AICRP, 1989-91)

S. No.	Quality	Class	Quality Parameter		
			EC (dSm^{-1})	SAR ($(mmol^{-1})^{1/2}$)	RSC (meL^{-1})
1	Good	A	<2	<10	<2.5
2	Marginally saline	B	2-4	<10	<2.5
3	Saline	C	>4	<10	<2.0
4	High SAR saline	D	>4	>10	<2.5
5	Marginally alkali	E	<4	<10	2.5-4.0
6	Alkali	F	<4	<10	>4.0
7	Highly alkali	G	Variable	>10	>4.0



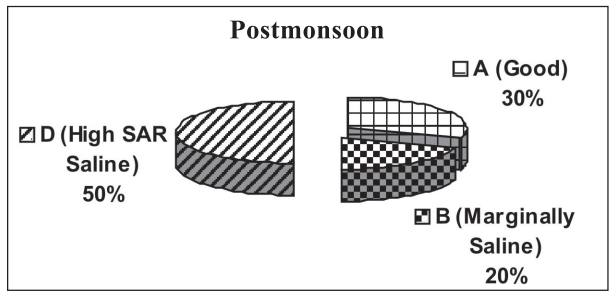


Fig. 2. Water quality classification for pre and post-monsoon of Gohana block according to AICRP, 1989

dSm^{-1} during pre-monsoon, whereas, this value varied from 0.5 dSm^{-1} to 11.2 dSm^{-1} with a mean value of 4.50 dSm^{-1} during post-monsoon period (Table 2). The mean and standard deviation values indicated that there was a high deviation in magnitude of pH in both pre-monsoon and post-monsoon periods. Out of 60 groundwater samples, 18 samples showed medium to high EC value (0.75-2.25 dSm^{-1}; Class- C_3), 12 samples showed high EC value (2.25-5.00 dSm^{-1}; Class- C_4) and 30 sample showed very high EC value (> 5.00 dSm^{-1}; Class-C_5) according to USDA water quality rating for irrigation (Table 3). During post-monsoon, the number of water samples collected come under Class-C_2 (EC: 0.25-0.75 dSm^{-1}), Class- C_3 (EC: 0.75-2.25 dSm^{-1}), Class- C_4 (EC: 2.25-5.00 dSm^{-1}) and Class- C_5 (EC: >5.00 dSm^{-1}) are 4, 16, 13 and 27 respectively. It indicates that the seasonal variation of EC value is marginal, but the spatial variation of EC value is significant. Marginal variations of EC value after monsoon may be due to dilution effect of rainwater that infiltrated to ground water. This observation corroborates the observations of Biswal *et al.* (2004), Kumaresan and Riyazuddin (2005) and Laluraj and Gopinath (2005).

Variation in Cations and Anions of Ground Water

Among different cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) analysed in ground water, sodium was found as the most dominant cation, followed by magnesium, calcium, and potassium during both pre-monsoon, and post-monsoon periods. The mean value of Na^+, K^+, Ca^{2+} and Mg^{2+} ions concentration in the groundwater samples were 39.72, 0.55, 5.98 and 9.66 $meqL^{-1}$ during pre-monsoon and 32.85, 0.57, 5.27 and 7.78 $meqL^{-1}$ during post-monsoon period, respectively. However, among anions (CO_3^{2-}, HCO_3^- , Cl^-, SO_4^{2-} , $NO3^=$), chloride has the highest mean concentration in the ground water during both pre-monsoon (35.39 $meqL^{-1}$) and post-monsoon (32.03 $meqL^{-1}$) periods. The mean value of carbonate, bicarbonate, sulphate and nitrate concentrations were 0.82, 8.55, 2.56 and 2.56

Table 2. Descriptive statistics of the hydro-chemical parameters for the pre- and post -monsoon samples

Sl.	Parameters	Minimum		Maximum		Mean		Standard deviation	
No.		PRM*	POM#	PRM	POM	PRM	POM	PRM	POM
1	pH	7.70	7.60	9.50	9.50	8.67	8.48	0.516	0.512
2	EC (dSm^{-1})	0.80	0.50	12.40	11.20	5.10	4.50	3.236	3.071
3	Na^{+} ($meqL^{-1}$)	4.60	2.80	108.7	85.70	39.72	32.85	27.122	23.176
4	K^{+} ($meqL^{-1}$)	0.01	0.01	1.60	1.92	0.55	0.57	0.459	0.439
5	Ca^{2+} ($meqL^{-1}$)	0.90	0.90	18.30	17.10	5.98	5.27	3.982	3.802
6	Mg^{2+} ($meqL^{-1}$)	2.00	1.70	23.00	20.80	9.66	7.78	5.536	4.976
7	CO_3^{2-} ($meqL^{-1}$)	0.52	0.35	5.50	5.10	0.82	0.65	1.312	1.059
8	HCO_3^{-} ($meqL^{-1}$)	3.10	2.50	15.60	14.90	8.55	6.38	3.245	2.759
9	Cl^{-} ($meqL^{-1}$)	3.20	2.40	98.30	90.60	35.39	32.03	23.999	23.112
10	SO_4^{2-} ($meqL^{-1}$)	0.10	0.10	9.90	9.50	2.56	2.40	2.698	2.588
11	NO_3^{-} ($meqL^{-1}$)	0.10	0.10	13.10	12.80	2.56	2.44	3.348	3.249
12	SAR (mmol $L^{-})^{1/2}$	3.23	2.15	36.10	35.01	13.61	12.46	7.558	7.406
13	RSC($meqL^{-1}$)	Nil	Nil	2.41	2.40	Nil	Nil	7.852	8.277

*PRM: Pre-monsoon, #POS: Post-monsoon

Table 3. USDA water quality criteria for irrigation purposes

Sl.	Parameter	Permissible values for				
No.		Safe	Moderate safe	Moderate unsafe	Unsafe	Very unsafe
1	EC (dsm^{-1})	<0.25	02.5-0.75	0.75-2.25	2.25-5	>5
2	SAR	<10	10-18	18-26	>26	
3	RSC (me L^{-1})	1.25	1.25-2.5		>2.5	
4	Cl^{-1} (me L^{-1})	<2	2-4	4-10	>10	
5	Mg/Ca Ratio	<1.5	1.5-3.0		>3.0	

$meqL^{-1}$ during pre-monsoon, while these were 0.65, 6.38, 2.40, 2.44 and 0.65 $meqL^{-1}$ during post-monsoon, respectively. Dominance of sodium and chloride ions in ground water even during pre-monsoon period is probably due to leaching of salts from surface soils through deep percolation of rain and irrigation water in the past. The higher accumulation of salts in surface soil was probably caused by higher evaporation from top soil in this semiarid environment. Earlier observations by Paliwal and Yadav (1976) and Shahid et al. (2008) reported similar trend of enhancement of Na^{+} and Cl^{-} in ground water in arid and semiarid areas. However, the mean concentrations of sodium and chloride ions were reduced by 6.87 $meqL^{-1}$ and 3.36 $meqL^{-1}$ during post monsoon over that at pre-monsoon, respectively, due to addition of rainwater to ground water. All the anions showed similar trend of sodium and chloride in ground water during pre-monsoon and post monsoon periods. The improvement in groundwater quality is ascribed to the dilution effect of monsoonal rainfall that was percolated through vadose zone of soil. Similar types of results have been observed by Biswal *et al.* (2004), Kumaresan and Riyazuddin (2005), and Laluraj and Gopinath (2005).

Variation in SAR and RSC of Ground Water

SAR values of the groundwater collected from the area varied from 3.23 to as high as 36.10 for pre-monsoon period, with a mean value of 13.61

(Table 2). However, the values of post-monsoon SAR varied in the range 2.15 to 35.0, with a mean value of 12.46. According to USDA water quality rating (Table 3) for SAR, number of samples coming under low (SAR : <10; Class S_1), Medium (SAR: 10-18; Class S_2), High (SAR: 18-26; Class S_3) and Very High (SAR: >26; Class S_4) classes of SAR were 20, 25, 8 and 7, respectively, for premonsoon and 27, 22, 7 and 4, respectively, for postmonsoon periods. Low sodium water (Class S_1) can be used for irrigation in almost all types of soils with little danger of development of harmful levels of exchangeable sodium. Medium sodium water (Class S_2) creates appreciable sodium hazard in fine textured soils of high cation exchange capacity, especially under low leaching conditions, unless gypsum is present in the soil, but may be used on coarse textured or organic soils which have good permeability. Moreover, very high sodium water (S_4) is generally unsatisfactory for irrigation purposes, except at low and medium soil salinity. Application of gypsum or other amendments may possibly render this water feasible for irrigation use. Though there was no significant effect of ground water recharge through monsoon rainfall on mean SAR value of ground water, the number of samples under high, medium, high, and very high SAR varied significantly, indicating some improvement of groundwater quality with respect to SAR during post-monsoon. The negative value of RSC indicates that the combined concentration of Ca^{2+} and Mg^{2+} was more than the addition of $CO_3{}^{2-}$, $HCO_3{}^{-}$. However, the water was observed to be safe (RSC < 2.5) for irrigation use in relation to sodicity during both pre-monsoon and post-monsoon periods.

Based on EC and derived parameters i.e. SAR and RSC, the water samples were classified as per criteria for water quality classification given by AICRP (1989-91) for both the seasons (Figure 2). According to this criteria, water samples with high SAR saline, marginal saline and good water were 57%, 20%, and 23%, respectively, during pre-monsoon period and 50%, 20%, 30%, respectively, during post-monsoon period. Maximum number of samples was recorded under high SAR saline category for both the seasons. The improvement in groundwater quality during post-monsoon period was earlier observed by Biswal *et al.* (2004), Kumaresan and Riyazuddin (2005), and Laluraj and Gopinath (2005).

Correlation and regression analysis

The degree of linear association between any two of the water quality parameters, as measured by the simple correlation coefficient (r) is presented by correlation matrix for the pre- and post- monsoon samples (Table 4 a & b). It is observed that, for pre-monsoon samples, EC is highly correlated with Na, Cl, Mg and Ca. The highest r value between EC and Cl for the pre-monsoon sample (0.992) and post-monsoon

Table 4a. Correlation matrix of water quality parameters for pre-monsoon samples

Parameters	EC	Na	K	Ca	Mg	Cl	CO_3	HCO_3	NO_3	SO_4
EC	1									
Na	0.987	1								
K	0.777	0.765	1							
Ca	0.796	0.735	0.506	1						
Mg	0.850	0.782	0.645	0.851	1					
Cl	0.992	0.987	0.760	0.797	0.830	1				
CO_3	0.672	0.710	0.595	0.382	0.461	0.661	1			
HCO_3	0.604	0.608	0.512	0.445	0.470	0.556	0.526	1		
NO_3	0.367	0.373	0.417	0.219	0.353	0.379	0.188	-0.015	1	
SO_4	0.405	0.367	0.330	0.439	0.545	0.407	-0.006	0.143	-0.047	1

Table 4b. Correlation matrix of water quality parameters for post-monsoon samples

Parameters	EC	Na	K	Ca	Mg	Cl	CO_3	HCO_3	NO_3	SO_4
EC	1									
Na	0.989	1								
K	0.721	0.733	1							
Ca	0.789	0.732	0.491	1						
Mg	0.784	0.723	0.513	0.857	1					
Cl	0.993	0.986	0.715	0.793	0.772	1				
CO_3	0.614	0.667	0.496	0.165	0.207	0.610	1			
HCO_3	0.515	0.524	0.451	0.257	0.235	0.467	0.596	1		
NO_3	0.366	0.378	0.306	0.168	0.298	0.360	0.204	-0.106	1	
SO_4	0.424	0.390	0.151	0.494	0.572	0.411	0.044	0.169	-0.037	1

sample (0.993) indicated that the EC is mostly affected due to the variation Cl concentration in water. The r value between EC and other ions indicate that Na, Mg, Ca, and K also affected the EC value of water. Hence it can be inferred that the main compound responsible for high EC value is the chloride of sodium besides small contributions from other salts. It was also observed that among all the cations Na is having highest correlation coefficient with Cl followed by Mg, and Ca for both the seasons. The relationship of Cl with K (0.76), Ca (0.79), and mg (0.83) was superior to the relationships among other ions. Carbonate and nitrate developed a negative corelationship with sulphate, whereas bicarbonate developed same trend of relationship with nitrate. The negative correlationship indicates the decreasing trend of one parameter with increasing of other one.

Conclusions

From the present investigation it can be concluded that there is a significant variation in the spatial distribution of salt content in the groundwater of 'Gohana' block. Sodium is the most dominating cation and chloride is the most dominating anion in the groundwater, which indicates sodium chloride is the main salt responsible for higher EC in it. However, a significant improvement in all most all chemical parameters except pH, and concentrations of K^+, SO_4^{2-}, and NO_3^- were observed in groundwater after monsoon, despite low rainfall in this region. This will helpful to grow the crops which are sensitive to salinity and sodicity. Moreover, the suitability of ground water for irrigation in post-monsoon period will encourage the farmers to cultivate more crops with higher productivity, offering better economic return.

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