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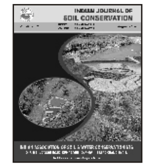

Spatial variation of groundwater quality of Meham block of Rohtak district, Haryana

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ABSTRACT

Water is most vital input in agriculture and can be optimally used only when its quality is assessed at micro level. The present study was aimed to assess and categorise the quality of groundwater of Meham block of Rohtak district by focusing on spatial variability of electrical conductivity (EC), pH, cationic and anionic composition of the groundwater. It was revealed that 75% of the samples showed EC values upto 3 dSm^{-1} and the maximum value of EC was found as 7.34 dSm^{-1}. Groundwater of south-eastern part has lower EC as compared to the other parts of the block. Residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) varied from nil to 6.30 me L^{-1} and 5.18 to 30.76 (m mol $L^{-1})^{½}$, respectively. Cl^- and HCO_3^- were found in appreciable quantities, whereas, CO_3^{-2} were in traces. Contour maps of EC, pH, SAR, RSC and quality of groundwater in the block were plotted through GIS to study spatial variability of these parameters. According to AICRP classification, it was found that 22.9% waters were of good quality, 45.8% saline and 31.3% sodic in nature. Out of the saline water, 20.8, 6.3 and 18.7% were marginally saline, saline and high SAR saline, respectively. In alkali group, 12.5, 6.3 and 12.5% were marginally alkali, alkali and high alkali, respectively. On the basis of spatial variability analysis, maximum area (25.4%) of the block was found under marginally saline category.

1. INTRODUCTION

Groundwater is the major source of water for domestic, agricultural and industrial purposes in many countries. India accounts for 2.2% of the global land and 4% of the world water resources and has 16% of the world's population (Ramesh and Elango, 2011). Inadequate supply of good quality water for irrigation is the major hurdle in boosting the agricultural production in arid and semi-arid areas of the world. The total groundwater potential in India is estimated as 43.1 M ha-m and the utilizable groundwater for irrigation is assessed as 32.47 M ha-m. It is likely to increase to 35 M ha-m by 2025 (Minhas, 2000). Groundwater will continue to be used intensively, in spite of decreasing land area of irrigated production, as a consequence of physical depletion, low quality water, economic depletion, water logging and salinization (Datta, 2005). Haryana state occupies the second place with regard to development of groundwater. Due to over exploitation of groundwater, average water table decline in 16 districts of Haryana state is 9.76 m between 1974-2011, whereas, its under exploitation in five districts has shown average rise of 2.86 m. (Anonymous, 2012). In the past, attempts have been made to establish water quality zones of Haryana state (Manchanda, 1976) but a sea change has occurred over the years due to exhaustive water use and a shift in the cropping pattern in the western part of the state. This variable withdrawal of groundwater along with scanty rainfall has led to the change in water quality (Kumar *et al.*, 2009). Therefore, the present study was envisaged to categorise the groundwater of Meham block of Rohtak district and illustrate the spatial variability of various parameters of groundwater quality *i.e.,* EC, pH, RSC, SAR and quality categorisation.

Meham block lies on the western part of Rohtak district between 28º51′22″ to 29º05′14″ N latitude and 76º12′47″ to

76º28′56″ E longitude angles. The block consists of 25 villages with relatively flat topography covering an area of 411 sq km. Groundwater was shallow (2011) in the block, having 1.3, 50.0 and 48.7% area under 0-1.5, 1.5-3.0 and 3.0-10.0 m depth (Paudyal, 2012). It may be due to a) lack of drainage system for surface runoff, b) recharge from canal irrigation and c) less draft from the existing shallow tube wells which were less in numbers. Over the years, groundwater faced rising trend from 11.62 m in year 1979 to 4.13 m in year 2009. The total replenishable groundwater resource in the block is 51.85 m m^3, while the existing groundwater draft is 27.21 m m^3 (Anonymous, 2012). The rainfall in the block is seasonal, scanty and subject to frequent variations. Average annual rainfall during twenty one years (from 1989 to 2009) in the block was 304.95 mm.

2. MATERIALS AND METHODS

The survey and characterization of underground irrigation water of Meham block was undertaken during October to December, 2010-11. Water samples were collected randomly at a distance of 3 to 4 kms by thorough covering the whole block (Fig.1). The elevation, longitude and latitude angles of the sampling points were recorded by GPS at each location. In shallow aquifers zones, groundwater occurs under water table conditions, whereas, in the deeper zones, confined/semi-confined conditions exist. Rainfall and canal water in the block are the sources of groundwater. The geological formations of the area contain groundwater in substantial quantity. The samples were analyzed for EC, pH, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+ and K^+ by following the procedures outlined in USDA Handbook No. 60 (Richards, 1954). Water samples were categorized on the basis of criteria adopted by All India Coordinated Research Project on Management of salt affected soil and use of saline water, through the values of EC, SAR and RSC of the samples (Gupta *et al*., 1994). For irrigation water quality categorization, Adhikary *et al.* (2014) considered five parameters such as EC, SAR, HCO_3^-, Cl^- and Mg^{2+}/Cl^- ratio in their study. The sodium or alkali hazard in groundwater for irrigation was determined by the absolute and relative concentration of cations and is expressed in terms SAR. SAR and RSC were calculated as described by the following equations:

$$SAR\,(m\,mol\,l^{-1})^{1/2} = \frac{\text{Na}}{\left\{\frac{Ca+Mg}{2}\right\}^{1/2}} \quad ...(i)$$

$$RSC\,(me\,l^{-1}) = (CO_3 + HCO_3) - (Ca + Mg) \quad ...(ii)$$

3. RESULTS AND DISCUSSION

In the present study, it has been found that EC ranged from 0.51 to 7.34 dSm^{-1} with a mean of 2.54 dSm^{-1} (Table 1) in Meham block. The lowest EC of 0.51 dSm^{-1} in water samples was observed in village Bhaini Chelawali and its highest value (7.34 dSm^{-1}) in village Sisar Khas. Location specific variability of EC in the block is shown by spatial variation map (Fig. 2). No particular trend in the variation

Table: 1
Range and average of different water quality parameters in Mehamblock

S.No.	Parameters	Range	Average
1	EC (dSm^{-1})	0.51-7.34	2.54
2	pH	6.34-8.83	7.51
3	CO_3^{-2} (me L^{-1})	0.00-4.40	0.71
4	HCO_3- (me L^{-1})	0.80-11.20	5.15
5	Cl- (me L^{-1})	3.00-58.00	18.07
6	SO_4^{-2} (me L^{-1})	0.00-23.50	2.16
7	Ca^{+2} (me L^{-1})	0.20-6.38	1.82
8	Mg^{+2} (me L^{-1})	0.30-17.62	4.97
9	Na^+ (me L^{-1})	5.77-57.56	20.61
10	K^+ (me L^{-1})	0.01-2.20	0.23
11	RSC (me L^{-1})	0.00-6.30	0.87
12	SAR (m mol L^{-1})½	5.18-30.76	12.75

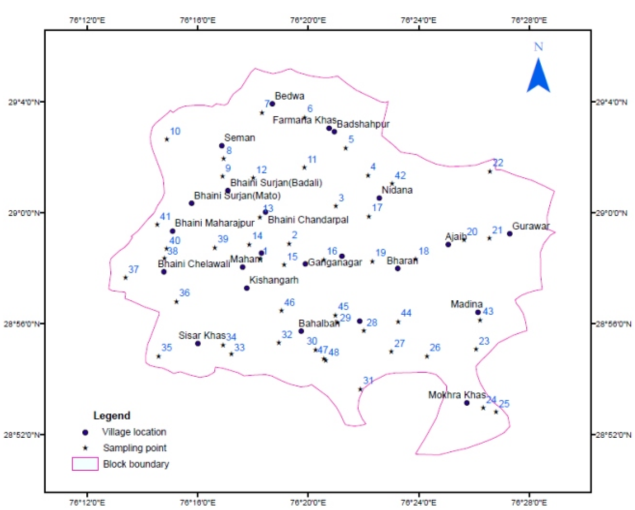

Fig. 1. Location map of the sampling points in Meham block of Rohtak district

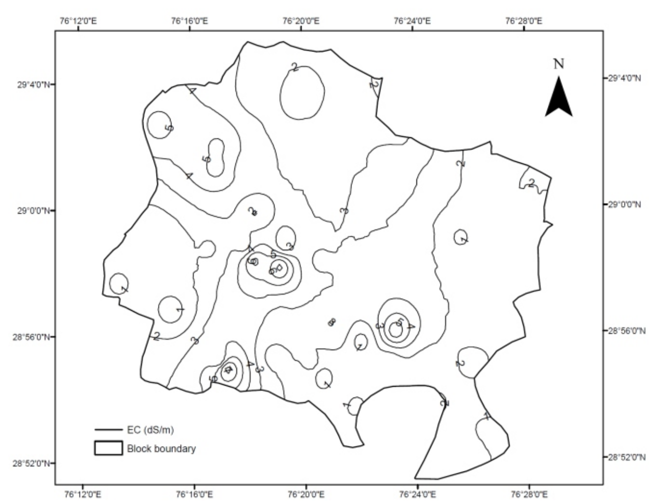

Fig. 2. Spatial variation of groundwater EC in Meham block of Rohtak district

of EC is present in the block but most parts of the block are having EC less than 4 dSm^{-1}. In the eastern part of the block, EC is ranging from 1-2 dSm^{-1}. The highest EC range (5-7 dSm^{-1}) was observed at three spots in the block. The pH ranged from 6.34 to 8.83 with an average of 7.51 and the highest pH of 8.83 in water samples was observed in village Meham. The pH in most parts of the block was ranging from 7.6 to 8.0 (Fig. 3).

SAR value of groundwater provides a useful index of the sodium hazard of that water for soils and crops. The high sodium water may produce harmful levels of exchangeable sodium in most soils and requires special soil management like good drainage, high leaching and organic matter addition. The SAR in the block ranged from 5.18 to 30.76 (m mol L^{-1})^{½} with a mean value of 12.75 (m mol L^{-1})^{½}. The lowest SAR value was observed in village Kheri Meham and its highest value in village Bahalbah. The spatial variations in the values of SAR are also shown in Fig. 4. In most parts of the block, SAR ranged from 9-15 (m mol L^{-1})^{½}. Higher SAR values reflect sodic nature of groundwater. The highest SAR of 24 to 27 (m mol L^{-1})^{½} was observed at two locations in southern part of the block. The RSC of groundwater varied from nil to 6.3 me L^{-1} with an average value of 0.87 me L^{-1}. Maximum value of the RSC (6.3 me L^{-1}) was found in the village Bharan. The variations in the values of RSC are shown in Fig. 5. There were three patches of higher RSC, ranging from 4-6 me L^{-1} in the block. In more than 50% area in the western part of the block, RSC was almost absent/nil (0-1 me L^{-1}).

In case of cations, sodium was dominant ion which ranged from 5.77 to 57.56 me L^{-1} followed by magnesium (0.30 to 17.62 me L^{-1}), calcium (0.2 to 6.38 me L^{-1}) and potassium (0.01 to 2.20 me L^{-1}). Mean value for Na^{+}, Mg^{2+}, Ca^{2+} and K^{+} were 20.61, 4.97, 1.82 and 0.23 me L^{-1}, respectively (Table 1). In case of anions, chloride was the dominant ion with maximum value of 58.00 me L^{-1} observed in village Sisar Khas and minimum value 3.00 me L^{-1} recorded in villages Bhaini Chelawali. Bicarbonate (HCO_3^-) varied from 0.80 to 11.20 me L^{-1} and its highest value was found in the water samples of village Bahalbah. Mean value for CO_3^{2-}, SO_4^{2-}, HCO_3^- and Cl^- were found to be 0.71, 2.16, 5.15 and 18.07 me L^{-1}, respectively. Shahid *et al*. (2008) also reported the similar results in Julana block of Jind district. Analytical results of groundwater quality indicated that the order of abundance of cation concentration were $Na^{+} > Mg^{+2} > Ca^{+2} > K^{+}$ while those of the anions were $Cl > HCO_3^- > SO_4^{-2} > CO_3^{-2}$. In arid and semi-arid regions, various workers have reported the dominance of sodium and chloride ions in irrigation waters (Sharma, 1998; Shahid *et al*., 2008).

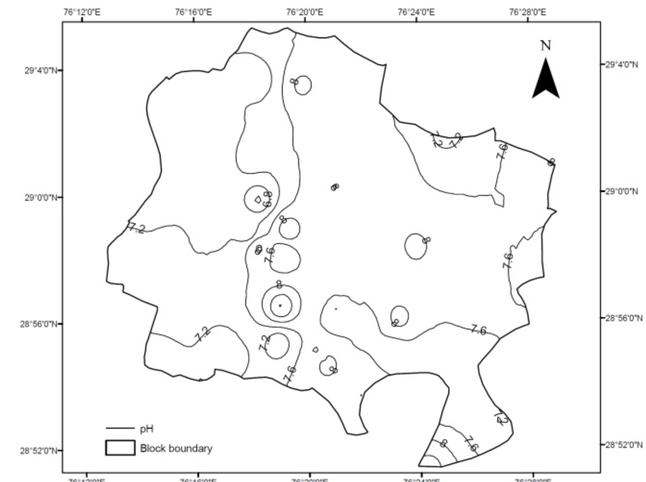

Fig. 3. Spatial variation of groundwater pH in Meham block of Rohtak district

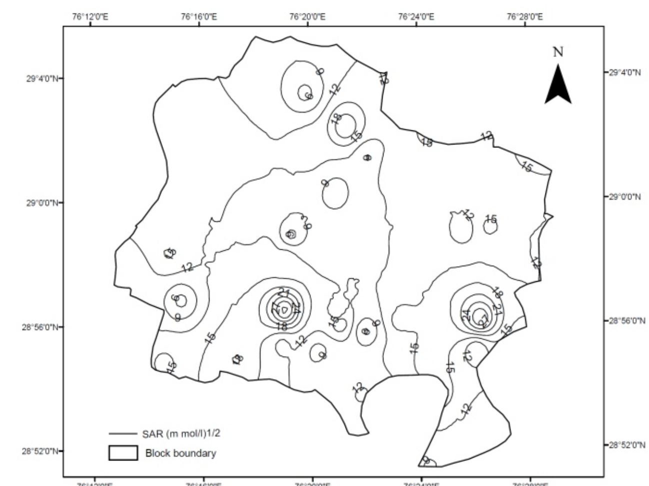

Fig. 4. Spatial variation of groundwater SAR in Meham block of Rohtak district

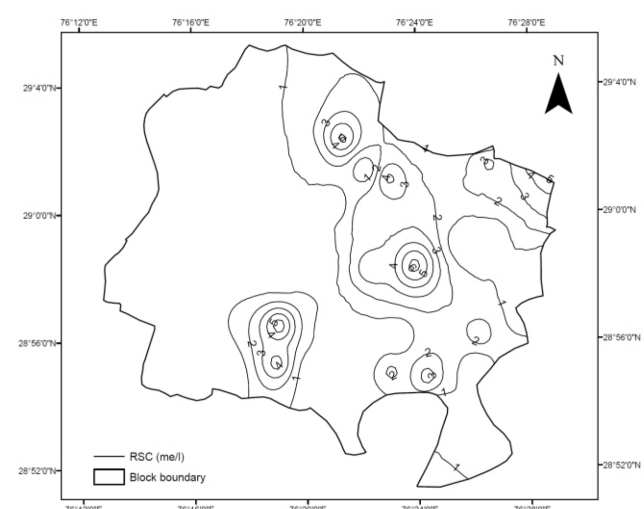

Fig. 5. Spatial variation of groundwater RSC in Meham block of Rohtak district

The mean chemical composition and related quality parameters in different EC ranges for Meham block are given in Table 2. Maximum per cent (31.3) of samples were in the EC range of 2-3 dSm^{-1}. The study revealed that 75% of the samples showed EC upto 3 dSm^{-1}. Number of samples upto EC of 3 dSm^{-1} was increased but with further increase in EC, the number of samples deceased and its number was reduced significantly after an EC of 4 dSm^{-1}. No samples was found having EC greater than 8 dSm^{-1}. Concentration of Na^+, Mg^{2+} and Ca^{2+} increased with increase in the EC of the water samples and the magnitude of increase in Na^+ and Mg^{2+} concentration was much higher than Ca^{2+}. Similarly, concentration of Cl^- anions increased with the increase in the EC of the water samples. SO_4^{2-} and HCO_3^- was also found to be in appreciable quantities, whereas, K^+ and CO_3^{2-} was in low quantities and their concentration did not show any relation with EC of irrigation water.

According to AICRP classification, it was found that 22.9% groundwater samples were of good quality, 45.8% saline and 31.3% alkali in nature (Fig. 6). Out of the saline water, 20.8, 6.3 and 18.7% were marginally saline, saline and high SAR saline, respectively. In alkali group, 12.5, 6.3 and 12.5% were marginally alkali, alkali and high alkali, respectively. No particular trend in the variation of groundwater quality is present in the block (Fig. 7) but the groundwater quality in the western part of the block is better than eastern part. By analysing the area under different groundwater quality in the block through GIS, it was found that out of seven categories, the maximum area (104.4 sq km) of the block was estimated under marginally saline category, followed by good category with an area of 82.61 sq km and minimum area (24.3 sq km) was observed under alkali category. Number of samples was maximum in good quality category, whereas, area under marginally saline category was worked to be maximum. While calculating the per cent samples in different categories, locations of the samples were not considered, only simple statistics was used. But in calculation of the area under different categories, spatial technique was used through GIS. Thus on the basis of spatial variability analysis, 25.4% area of the block was found under marginally saline category. At every location, it is not feasible to work out the quality of groundwater in view of the time and cost involved in data collection and its analysis. So the spatial distribution maps generated for various parameters and groundwater quality by using GIS techniques could be useful for planners and decision makers to start with developmental activities (Adhikary *et al.,* 2011).

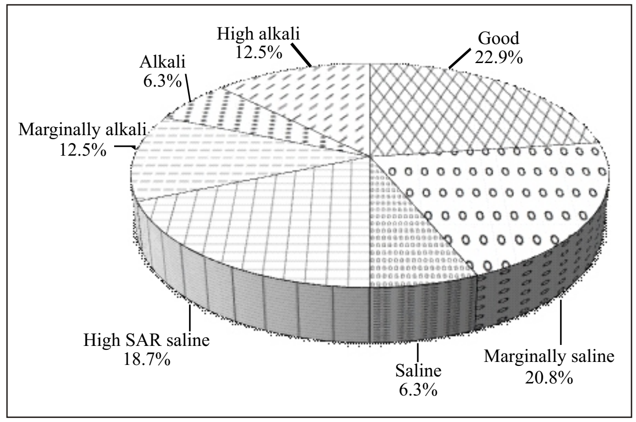

Fig. 6. Percent samples under different categories of ground water qualityin Meham block of Rohtak district

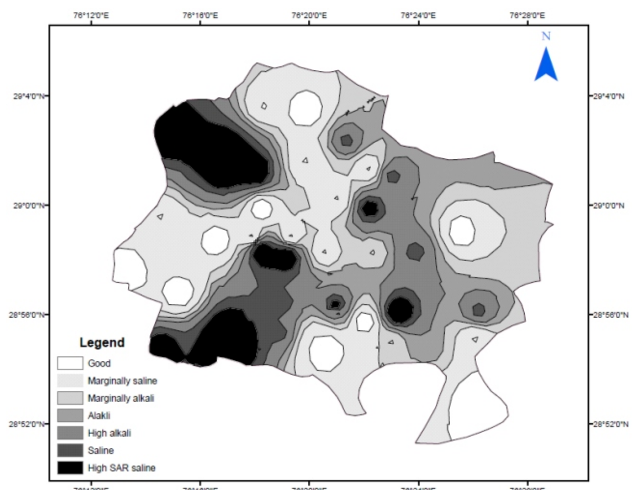

Fig. 7. Spatial variation of groundwater quality in Meham block of Rohtak district

Table: 2
Chemical composition of groundwater samples in different EC classes of Meham block

EC classes ($dS\ m^{-1}$)	% of samples	CO_3	HCO_3	Cl	SO_4	Ca	Mg	Na	K	RSC	SAR
		($me\ L^{-1}$)									($m\ mol\ L^{-1})^{½}$
0-1	20.8	0.00	2.86	4.75	0.11	0.47	1.12	7.99	0.07	0.09	9.75
1-2	22.9	0.45	4.64	9.64	0.61	0.75	1.96	13.63	0.30	1.61	13.93
2-3	31.3	1.43	5.47	18.31	1.79	1.91	5.23	20.79	0.16	1.52	12.89
3-4	8.3	1.23	8.05	23.05	1.10	2.67	7.78	27.80	0.30	0.30	12.39
4-5	2.1	3.00	11.20	30.00	0.00	2.50	7.50	30.24	0.40	4.20	13.52
5-6	8.3	0.00	6.05	40.30	7.53	4.09	10.34	38.98	0.66	0.00	14.57
6-7	2.1	0.00	6.40	51.60	4.40	4.80	15.20	46.20	0.14	0.00	14.61
7-8	4.2	0.00	5.80	52.20	15.00	5.68	16.12	52.04	0.20	0.00	15.91

4. CONCLUSIONS

The maximum samples were found in good quality (22.9%) category followed by marginally saline (20.8%). But on the basis of spatial variability analysis, 30.7% area of the block was found under high SAR saline category. Good quality and marginally saline waters can be successfully used for crop production without any hazardous effect on soil and plant. Alkali waters can be used with special management practices depending upon the rainfall, crop to be grown and soil type. The waters rated as saline and high SAR saline are, in general, unfit for irrigation but can be used in conjunction with canal water by cyclic mode or mixing and by adding gypsum to neutralize the RSC of water used for irrigation.

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