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Characterization of groundwater quality of Kalayat block of Kaithal district, Haryana

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Abstract
The present survey was carried out to assess and categorize the quality of groundwater of Kalayat block of Kaithal district by focusing on spatial variability of pH, electrical conductivity (EC), cationic and anionic composition of the groundwater. It was found that pH of water samples was neutral to alkaline in nature in Kalayat block ranging between 7.04 to 9.59 with a mean of 7.99. The lowest value of pH in the water sample was observed in Kheri Lamba village and highest value was observed in Shimla village. Nearly 88% of the water samples showed EC below 6 dSm^{-1} and it ranged from 0.74 dSm^{-1} to 7.72 dSm^{-1} with maximum value at Mator village. Residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) varied from nil to 6.68 me L^{-1} and 5.08-18.05 (m mol $L^{-1})^{½}$, respectively. Concentration of Na^+, Mg^{2+}, Ca^{2+}, Cl^- and SO_4^{2-} increased with increase in the EC of the water samples and the magnitude of increase in Na^+, Mg^{2+}, Cl^- and SO_4^{2-}concentration was much higher than Ca^{2+}. Concentration of HCO_3^- and CO_3^{2-} were also found to be in appreciable quantities whereas NO_3^- was recorded in low quantity and their concentration did not show any relation with EC of groundwater. 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 13.73% water samples were of good quality, 60.79% were saline and 25.49% were sodic in nature. In saline water group, 21.57% samples were marginally saline and 39.22% were high SAR saline and in alkali group, 13.73% samples were marginally alkali and 11.76% were high alkali.

Keywords: groundwater quality, survey, electrical conductivity, geographical information system, RSC, SAR

Introduction
Water is a major natural resource and a basic human need. It provides a logical link between the physical and social environment (Bartram and Balance, 2001) [4]. Fresh water is getting scarce day by day due to its blind use by mankind for community, domestic services and industries etc. One of the major qualities of water is that it can dissolve all the natural compounds. But this advantage makes it more vulnerable to local pollutants. These pollutants contribute in adversely affecting the ground water quality (Yadav *et al*., 2009) [15]. Its quality is likely to change from source to source and day by day. Any change in the natural quality may disturb the equilibrium system and would make it unfit for designated uses. The availability of water either through surface or ground water resources is becoming critical every day.

Most of the population in India depends upon groundwater for the drinking water as it is believed to be cleaner than surface water. But the prolonged discharge of industrial effluents, domestic sewage and solid waste pollute the ground water and thus cause health problems (Raja *et al*., 2002) [10]. India accounts for 2.2% of the global land and 4% of the world water resources and accommodates 16% of the world's population (Ramesh and Elango, 2011) [11]. 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) [9]. 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) [5].

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) [3]. In the past, attempts have been made to establish water quality zones of Haryana state (Manchanda, 1976) [8] but a sea change has occurred over

the years due to exhaustive water use and a shift in the cropping pattern of the state. This variable withdrawal of groundwater along with scanty rainfall has led to the change in water quality (Kumar *et al.*, 2009) [7]. Therefore, the present study was planned to categorize the groundwater of Kalayat block of Kaithal district and to illustrate the spatial variability of various parameters of groundwater quality *i.e.* pH, EC (electrical conductivity), RSC (residual sodium carbonate), SAR (sodium adsorption ratio) and quality categorization according to All India Coordinated Research Project i.e. AICRP (1989).

Materials and Methods

Kalayat block lies in the south-western part of Kaithal district between 26.67º to 26.77º N latitude and 76.25º to 76.27º E longitudes. The block consists of 28 villages acquiring a total area of 319 Km^2. The survey and characterization of underground irrigation water of Kalayat block was undertaken during October to December, 2015-16. Water samples were collected randomly at a distance of 1-2 km by thorough covering the whole block (Fig.1).

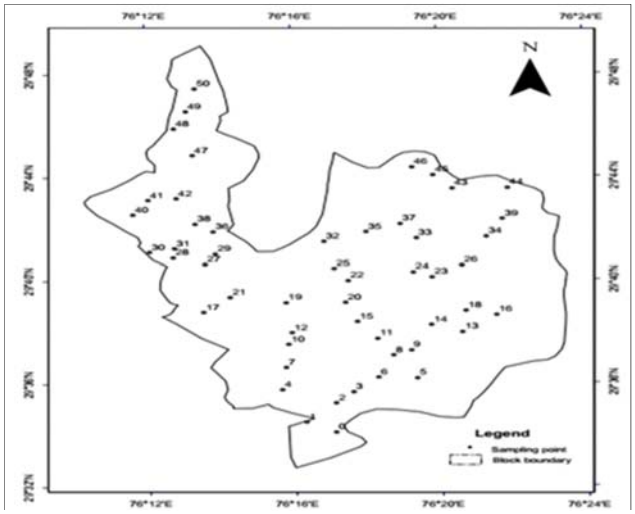

Fig 1: Sampling points of Kalayat block of Kaithal district

The longitude and latitude of location of sampling points were recorded by GPS at each location. 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) [12]. Water samples were categorized on the basis of criteria adopted by All India Coordinated Research Project on Management of salt affected soils and use of saline water, through the values of EC, SAR and RSC of the samples (Gupta *et al.*, 1994) [6]. For irrigation water quality categorization, Adhikary *et al.* (2014) [2] 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 of SAR. SAR and RSC were calculated as described by the following equations:

$$\text{SAR (mmol l}^{-1})^{1/2} = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}}$$

$$\text{RSC (me l}^{-1}) = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$$

Results and Discussion

In the present study, the range and means of different quality parameters assessed are given in Table 1. The pH of water samples ranged from 7.04 to 9.59 with a mean of 7.99. The lowest value of pH in the water sample was observed in Kheri Lamba village and highest value was observed in Shimla village. The pH was found neutral to alkaline in nature in Kalayat block. The spatial variability of pH of groundwater in Kalayat block is given in Fig. 2.

The electrical conductivity in Kalayat block ranged from 0.74-7.72 dSm^{-1} with a mean of 3.60 dSm^{-1}. The lowest and highest value of EC i.e. 0.74 and 7.72 dSm^{-1} was recorded in Kheri Serkhan and Mator village, respectively. Location specific variability of EC in the block is shown by spatial variation map (Fig. 3). No particular trend in the variation of EC is present in the block and most of the groundwater samples have EC below 6 dSm^{-1}. The highest EC range (6-8 dSm^{-1}) was found in only 6 locations in the block.

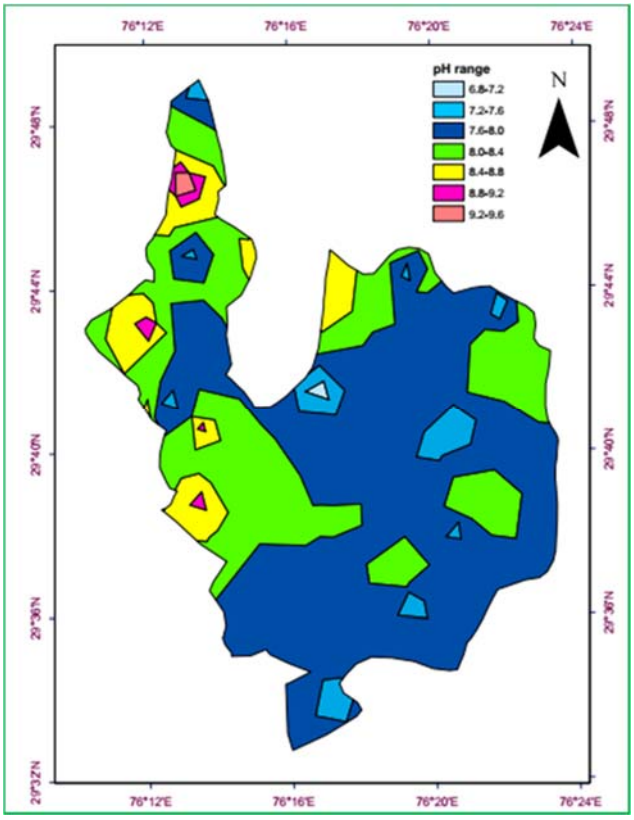

Fig 2: Spatial variability of pH of groundwater in Kalayat block

Table 1: Range and mean of different water quality parameters in Kalayat Block, Kaithal

Sr. No.	Quality Parameter	Range	Mean
1	Ph	7.04-9.59	7.99
2	EC (dSm^{-1})	0.74-7.72	3.60
3	RSC(me L^{-1})	0.00-6.68	1.03
4	SAR(m mol $L^{-1})^{1/2}$	5.08-18.05	11.31
5	Ca^{2+}(me L^{-1})	0.40-5.10	2.52
6	Mg^{2+}(me L^{-1})	1.12-14.28	7.20
7	Na^+(me L^{-1})	5.40-56.20	25.30
8	K^+(me L^{-1})	0.08-3.20	0.36
9	CO_3^{2-}(me L^{-1})	0.00-5.30	1.25
10	HCO_3^-(me L^{-1})	0.00-10.50	3.05
11	Cl^-(me L^{-1})	3.00-47.90	23.08
12	SO_4^{2-}(me L^{-1})	0.20-20.80	7.77
13	NO_3^-(me L^{-1})	0.00-1.40	0.45

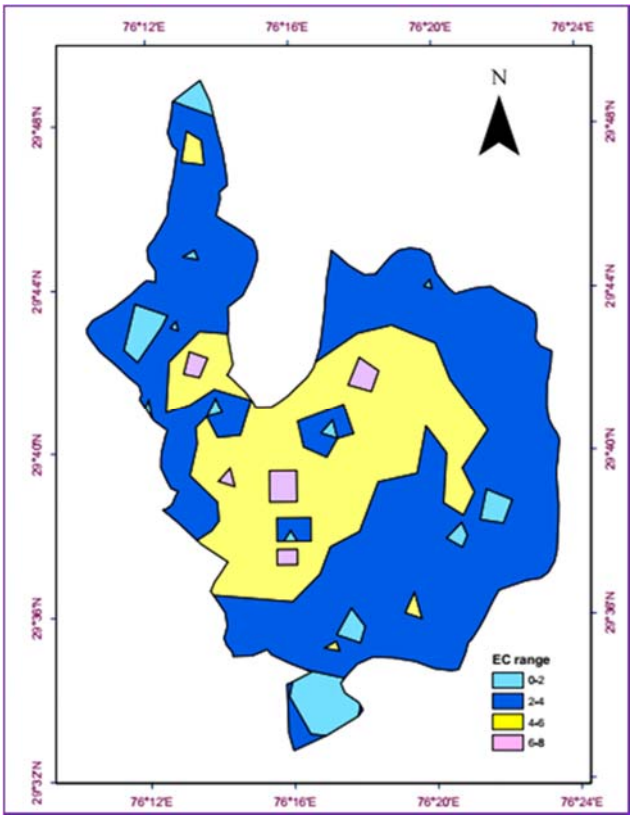

Fig 3: Spatial variability of electrical conductivity (EC) of groundwater in Kalayat block

In case of cations, sodium was the dominant ion with minimum value observed in Kheri Serkhan village and maximum was recorded in Mator village and its concentration varied from 5.40-56.20 me L^{-1}, followed by magnesium (1.12-14.28 me L^{-1}), calcium (0.40-5.10 me L^{-1}) and potassium (0.08-3.20 me L^{-1}). Average value for Na^{+}, $Mg^{2+,}$ Ca^{2+} and K^{+} were 25.30, 7.20, 2.52 and 0.36 me L^{-1}, respectively. Maximum value of magnesium and calcium was found in Mator village and lowest in village Kheri Serkhan. Potassium was minimum in Mator village and maximum in village Dubal. The cations in groundwater were found in order of $Na^{+}>Mg^{2+}>Ca^{2+}>K^{+}$. In case of anions, chloride was the dominant anion with maximum value of 47.90 me L^{-1} in village Bata and minimum (3 me L^{-1}) in Ballu village followed by sulphate (0.20-20.80 me L^{-1}), bicarbonate (0.00-10.50 me L^{-1}), carbonate (0.00-5.30 me L^{-1}) and nitrate (0.00-1.40 me L^{-1}). Average value for CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and NO_3^{-} were 1.25, 3.05, 23.08, 7.77 and 0.45 me L^{-1}, respectively (Table 1). Analytical results of groundwater quality indicated that the order of abundance of anion concentration were $Cl^{-}> SO_4^{2-}>HCO_3^{-}>CO_3^{2-}>NO_3^{-}$. Shahid *et al.* (2008) [13] also reported the similar results in Julana block of Jind district. 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) [13, 14].

Sodium adsorption ratio value of groundwater provides a useful index of the sodium hazard of the water for soils and crops. Higher SAR values reflect sodic nature of groundwater. 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. SAR of water samples were observed in range of 5.08-18.05 (m mol $L^{-1})^{1/2}$ having mean value of 11.31 (m mol $L^{-1})^{1/2}$. Village Mator was marked with maximum SAR value and village Ballu was noticed with minimum SAR. Most of the water samples were found to have SAR between 10-15 (m mol $L^{-1})^{1/2}$. Residual sodium carbonate values of water samples were highly variable and ranged from 0.00-6.68 me L^{-1} with mean value of 1.03 me L^{-1}. In most of the regions of Kalayat block, RSC was absent and maximum RSC was recorded in Dubal village. The Spatial variability of SAR and RSC of groundwater in Kalayat block is given in Fig. 4 and 5, respectively.

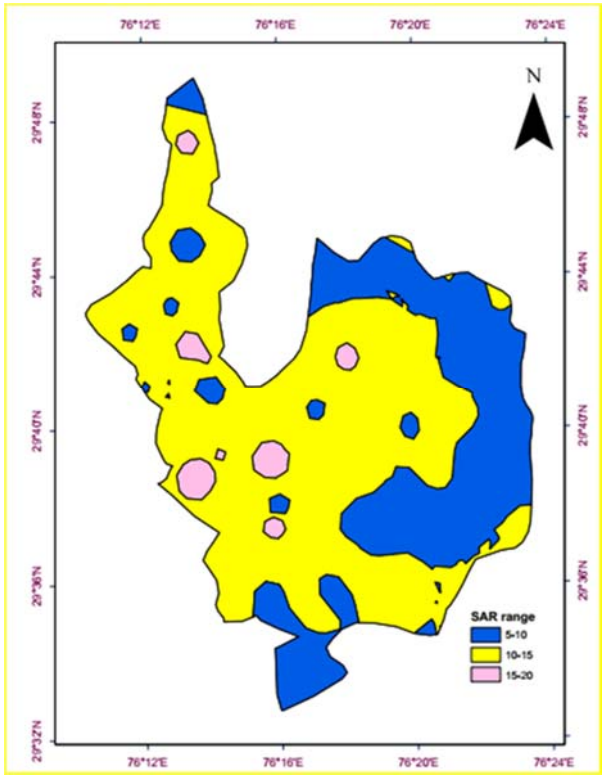

Fig. 4: Spatial variability of SAR of groundwater in Kalayat block

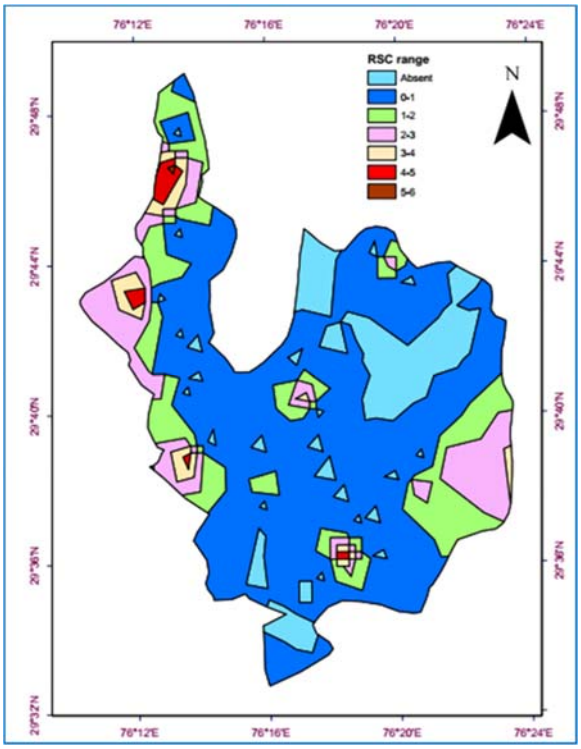

Fig 5: Spatial variability of RSC of groundwater in Kalayat block

Average chemical composition of water samples of Kalayat block in different EC classes

Average of chemical composition and related quality parameters in different EC ranges for Kalayat block are given in Table 2. Minimum per cent (11.76) of samples were in the EC range of 6-8 dSm^{-1}. The study revealed that 88.23% of the samples showed EC less than 6 dSm^{-1}. No samples was found having EC greater than 8 dSm^{-1}. Concentration of Na^+, Mg^{2+}, Ca^{2+} and K^+ 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^- and SO_4^{2-} increased with the increase in the EC of the water samples. HCO_3^- and CO_3^{2-} were also found to be in appreciable quantities whereas NO_3^- was recorded in low quantity and their concentration did not show any relation with EC of groundwater. The distribution of groundwater samples with increasing EC reveals that the percent samples in EC classes remains steady upto EC 4-6 dSm^{-1} and thereafter decreased.

Based on AICRP classification, 13.70%, 60.79% and 25.49% samples of groundwater were of good quality, saline and alkali in nature, respectively (Fig. 6). In saline group, 21.57% and 39.22% were marginally saline and high SAR saline, respectively. Among the alkali group, 13.73% samples were marginally alkali and 11.76% were highly alkali in nature. No particular trend in the spatial variation of groundwater quality was found but maximum numbers of samples were found in 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 the data collection and its analysis. So the spatial distribution maps generated for various parameters and groundwater quality by using GIS technique could be useful for planners and decision makers to start with development activities.

Table 2: Average chemical composition of water samples in different EC classes of Kalayat block

EC Classes (dSm^{-1})	Number of samples	Percent of Samples	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	RSC	SAR
			($me\ L^{-1}$)										($m\ mol\ L^{-1})^{1/2}$
0-2	15	29.41	1.41	3.57	7.29	2.05	0.42	1.08	2.60	10.71	0.22	1.82	8.01
2-4	15	29.41	1.37	3.17	19.94	5.40	0.47	2.38	6.78	20.49	0.41	1.22	10.05
4-6	15	29.41	0.88	2.12	33.78	11.22	0.42	3.34	9.64	34.74	0.43	0.45	13.72
6-8	6	11.76	1.52	3.73	43.68	19.40	0.58	4.73	13.39	50.25	0.43	0.00	16.67

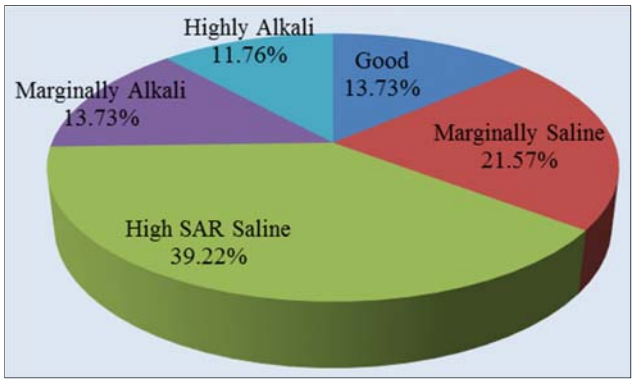

Fig 6: Quality of groundwater (percent) in Kalayat block

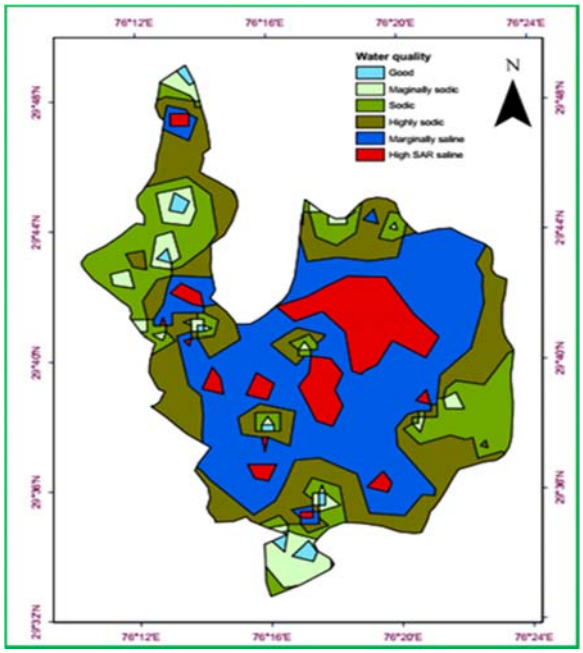

Fig 7: Spatial variability of water quality of groundwater in Kalayat block

Conclusion

The maximum number of samples were found in saline category (60.79%) followed by alkali (25.49%). Good quality and marginally saline waters can be used with management practices depending upon the rainfall, crop to be grown and soil type. The waters rated high SAR saline and highly alkali in general are not suitable for irrigation but can be used in conjunction with canal water by cyclic mode and by adding gypsum to neutralize the RSC of water for irrigation.

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