Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

J P P Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(1): 1056-1059
Received: 13-11-2017
Accepted: 17-12-2017

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Mapping of variability in quality of groundwater in Rajaund block of Kaithal district (Haryana)

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Abstract
Groundwater, the main source of irrigation, drinking or domestic purposes, is affected due to exponential growth of population, urbanization, industrialization and agricultural revolution. Groundwater qualityis also affected due to discharge of poor quality water from various industries and urban waste water to the natural water courses. An intensive survey was conducted to assess the quality of groundwater for irrigation purpose in Rajaund block of Kaithal district by focusing on physico-chemical parameters. In total, fifty nine samples of groundwater were collected randomly from running tubewells. Analysis of water samples revealed that 37.20 %, 32.30% and 30.50% samples were good, alkali and saline in nature, respectively. The average pH of water samples was 7.97 with a range of 7.04-8.89. Electrical conductivity of water varied from 0.66 to 8.25 dSm^{-1} with mean value of 2.40 dSm^{-1}. The analysis further revealed that order of abundance of cations in water samples was $Na^+ > Mg^{2+} > Ca^{2+} > K^+$, while that of anions was $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-} > NO_3^-$.

Keywords: EC, GIS, groundwater, salinity, sodicity, survey

Introduction
Groundwater is an important source of water supply throughout the world. The quantity and the suitability of groundwater for human consumption and for irrigation are determined by its physical, chemical and bacteriological properties. Rain water, which is pure in nature, which falls on the ground, dissolves the soluble minerals and the quality of water deteriorates depending upon the nature of the formation and the time duration (Mondal and Singh, 2004; Antony, 2012; Caleb and Gabriel, 2012) [7, 1, 3]. In India 51 per cent of irrigation is done by wells out of the total irrigation potential. Government of India encourages for use of ground water through well and bore well but approximately 32.84 per cent of total groundwater used for irrigation in India is of poor quality. This poor quality is available mainly in canal region or in command of big irrigation projects (Bhakare and Nikam, 2012) [2].
The quality of water is of vital concern for mankind since it is directly linked with human health, protection of the environment and sustainable development. The domestic sewage and industrial waste are also the leading causes of ground water pollution (Garg *et al*., 1999, Gupta *et al*., 2009) [4, 5]. Increasing population and its necessities have led to the deterioration of surface and sub-surface water. Moreover, overexploitation, excessive agriculture, untreated effluents and wastes have caused deterioration in groundwater quality. The use of poor quality water in irrigation can degrade the soils due to contamination (Palaniswami and Ramulu, 1994; Patel *et al*., 2004) [8, 9]. Thus, a reappraisal on nature, properties and extent of groundwater quality is essential for irrigation planning in Haryana state. Therefore, the present survey was planned for mapping of the groundwater in Rajaund block of Kaithal district based on 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
Rajaund block is located in Kaithal district of Haryana state and consists of 51 villages. An intensive survey of groundwater of Rajaund block was carried out during 2015-2016. For chemical analysis of ground water sample of Rajaund block, total 59 water samples were taken randomly by maintaining an average distance of 2-3 km in each location. The water samples were collected from running tubewells in such a way that all the villages of block got covered in survey. 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) [15]. 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 ofEC, SAR and RSC of the samples (Gupta *et al.,* 1994) [6].

Results and Discussion

For assessing the chemical composition of groundwater of Rajaund block, 59 water samples were collected and analyzed for various chemical parameters, viz., pH, EC, anions (CO_3^{2-}, HCO^{3-}, Cl^-, SO_4^{2-} and NO_3^-) and cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+). Thereafter, SAR and RSC were also calculated for each sample. The range and mean of different water quality parameters are given in Table 1. The pH of water samples was used to determine the acidity, neutrality or alkalinity of water. Water samples were found to have a pH range from 7.04-8.89 with a mean pH of 7.97. The lowest value of pH was found in village Jakhauli and maximum in Rajaund. The spatial variability of pH of groundwater in Rajaund block is given in Fig. 1. Range of electrical conductivity of water was 0.66-8.25 dSm^{-1} with mean EC of 2.40 dSm^{-1}. Nearly 70 per cent water samples had EC less than 2 dSm^{-1}. Minimum EC was found in Sarhada village around Sarhada to Fariabad road and maximum was observed in Kachana village. The spatial variability of EC of groundwater in Rajaund block is given in Fig. 2.

Table 1: Range and mean of different water quality parameters of Rajaund block

Sr. No.	Quality Parameter	Range	Mean
1	pH	7.04-8.89	7.97
2	EC (dSm^{-1})	0.66-8.25	2.40
3	RSC (me L^{-1})	0.00-5.80	1.20
4	SAR (m mol $L^{-1})^{1/2}$	4.14-19.25	9.21
5	Ca^{2+}(me L^{-1})	0.30-5.30	1.64
6	Mg^{2+}(me L^{-1})	0.84-14.84	4.63
7	Na^+(me L^{-1})	4.60-61.10	17.01
8	K^+(me L^{-1})	0.04-0.95	0.16
9	CO_3^{2-}(me L^{-1})	0.00-3.70	1.53
10	HCO_3^-(me L^{-1})	0.80-6.20	2.68
11	Cl^-(me L^{-1})	0.60-48.00	12.72
12	SO_4^{2-}(me L^{-1})	0.30-41.10	5.80
13	NO_3^-(me L^{-1})	0.00-1.96	0.58

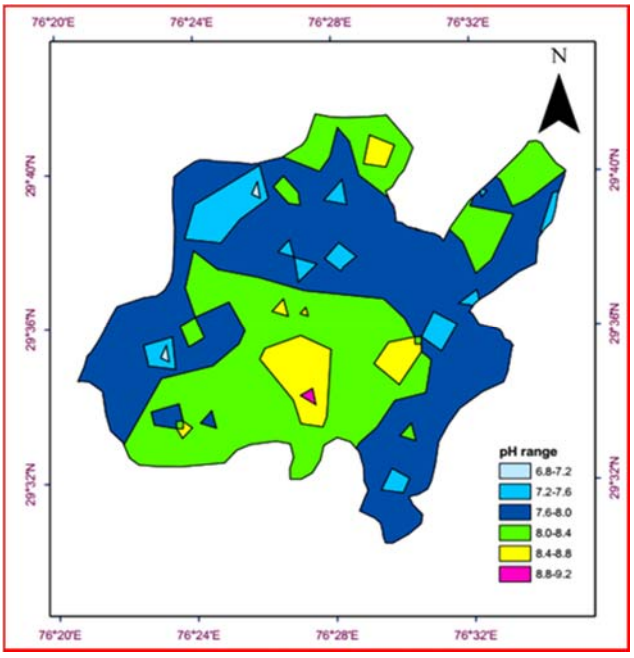

Fig 1: Spatial variability of pH of groundwater in Rajaund block

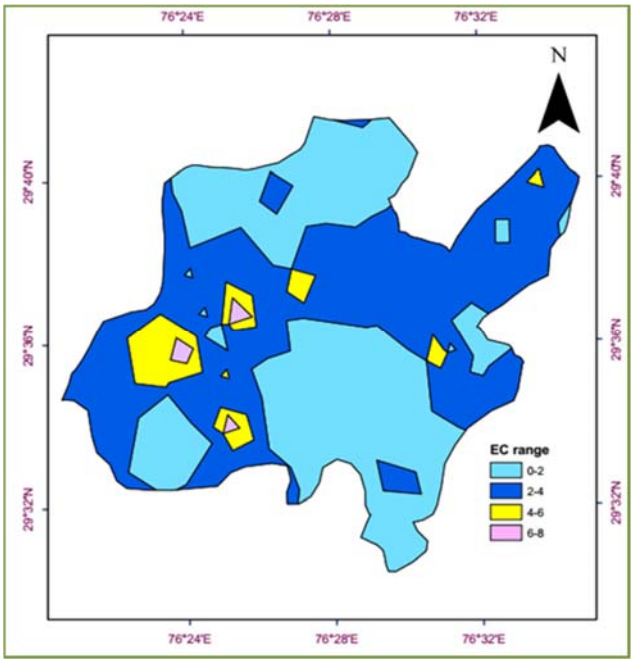

Fig 2: Spatial variability of EC of groundwater in Rajaund block

Sodium adsorption ratio value of groundwater provides a useful index of the sodium hazard of the water for soils and crops. 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. Range of sodium adsorption ratio (SAR) of water samples as shown in Table 1 was found from 4.14-19.25 (m mol $L^{-1})^{1/2}$ with a mean value of 9.21 (m mol $L^{-1})^{1/2}$. Minimum SAR was observed in Majra village and maximum was found in Kachna village. Spatial variability of SAR of groundwater in Rajaund block is given in Fig. 3. Observation of residual sodium carbonate varying from nil-5.80 me L^{-1} with the mean value of 1.20 me L^{-1} (Table 1). Minimum value of RSC (0.00) was recorded in many villages and Fariabad village having region around Fariabad to Rajaund road was marked with maximum RSC. The Spatial variability of RSC of groundwater in Rajaund block is given in Fig. 4.

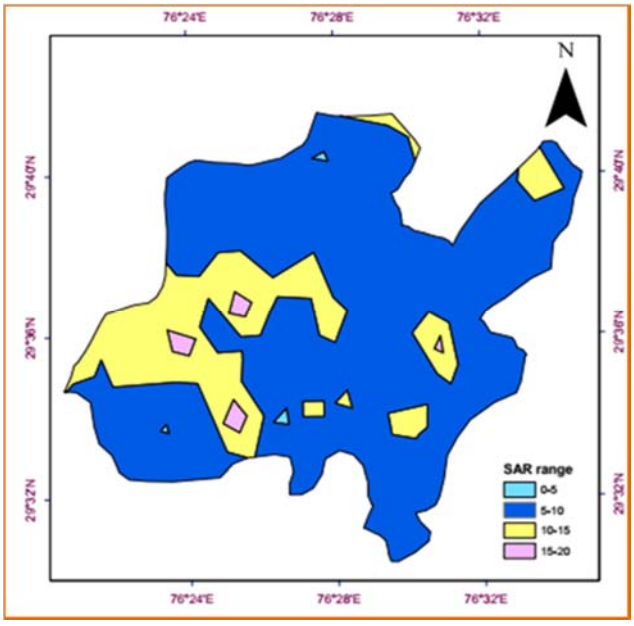

Fig 3: Spatial variability of SAR of groundwater in Rajaund block

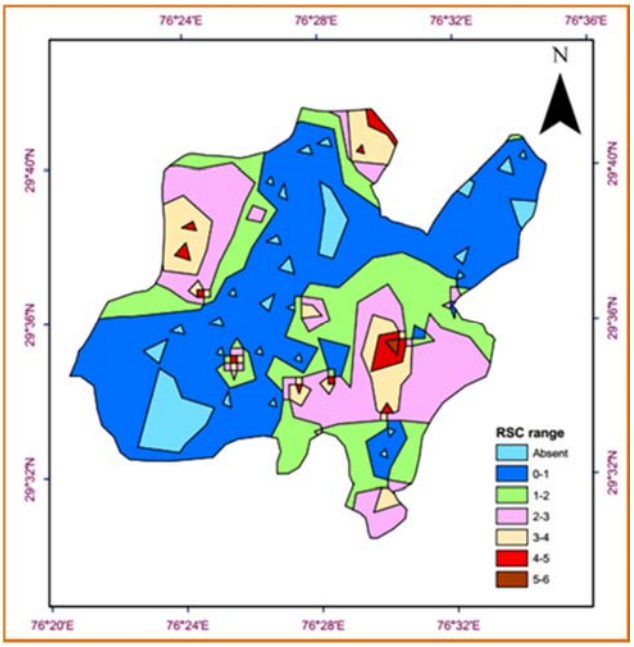

Fig 4: Spatial variability of RSC of groundwater in Rajaund block

In case of cations, sodium was the dominant cation and its concentration varied from 4.60-61.10 me L^{-1}, with minimum concentration observed in Sarhada village and maximum was recorded in Kachna village followed by magnesium (0.84-14.84 me L^{-1}), calcium (0.30-5.30 me L^{-1}) and potassium (0.04-0.95 me L^{-1}). Average concentrations of Na^+, Mg^{2+}, Ca^{2+} and K^+ in Rajaund block were 17.01, 4.63, 1.64 and 0.16 me L^{-1}, respectively (Table 1). 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 48.00 me L^{-1} in village Kachna and minimum was recorded in Rajaund village, followed by sulphate (0.30-41.10 me L^{-1}), bicarbonate (0.80-6.20 me L^{-1}), carbonate (0.00-3.70 me L^{-1}) and nitrate (0.00-1.96 me L^{-1}). Average values for CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^- was 1.53, 2.68, 12.72, 5.80 and 0.58 me L^{-1}, respectively (Table 1) and anions were found in order of $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-} > NO_3^-$. 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, Ramprakash *et al.*, 2013) [13, 12, 10]. Rajpaul *et al*. (2014) [11] and Kumar *et al*. (2016) [14] also observed the same dominant cation and anion in the surveys conducted for assessing the groundwater quality.

Average of chemical composition and related quality parameters in different EC ranges for Rajaund block are given in Table 2. The distribution of ground water samples with increasing EC reveals that the per cent samples in increasing EC classes decreases continuously. Maximum percent (69.49%) of samples were in the EC less than 2 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. In anion distribution among different EC classes, chloride ion was to dominate with maximum value of 32.92 me L^{-1} in class having EC more than or equal to 4 dSm^{-1} (Table 2) and anions were decreasing in the order of $Cl^- > SO_4^{2-} > HCO3^- > CO_3^{2-} > NO_3^-$. Among cations, sodium was found dominant with 43.82 me L^{-1} average value in class with EC ≥ 4 $dSm^{-1}$and cations were distributed in following order $Na^+ > Mg^{2+} > Ca^{2+} > K^+$.

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

EC Classes (dSm^{-1})	No. 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	41	69.49	1.75	3.07	6.88	1.74	0.55	0.96	2.69	10.38	0.11	1.73	7.69
2-4	9	15.25	0.96	1.68	19.50	7.39	0.35	2.49	7.05	20.39	0.25	0.00	9.37
≥4	9	25.25	1.12	1.90	32.92	22.70	0.37	3.89	11.00	43.82	0.33	0.00	15.94

Depending on the concentration of EC, SAR and RSC water samples were classified into different categories as per the classification of All India Coordinated Research Project (AICRP, 1989) on "Management of salt affected soils and use of saline water in agriculture" According to this classification, among the 59 samples collected from Rajaund block maximum sample were in good category (37.20%) followed by alkali (32.30%) and saline (30.50%) as represented in Table 3. In saline group, 13.60% samples were in marginally saline category and 16.90% were in high SAR saline while in alkali group 11.90%, 13.60% and 6.80% were found in marginally alkali, alkali and highly alkali category, respectively. Distribution percentage of different categories of water samples is shown in Fig. 5. The spatial variability of groundwater quality in Rajaund block as per AICRP classification is presented in Fig. 6.

Table 3: Ground water quality classification of Rajaund Block

Water quality	Class	Number of samples	Percentage
Good	A	22	37.20
Saline	B		
Marginally Saline	B1	8	13.60
Saline	B2	0	0.00
High SAR Saline	B3	10	16.90
Alkali Water	C		
Marginally Alkali	C1	7	11.90
Alkali	C2	8	13.60
Highly alkali	C3	4	6.80
Total		59	

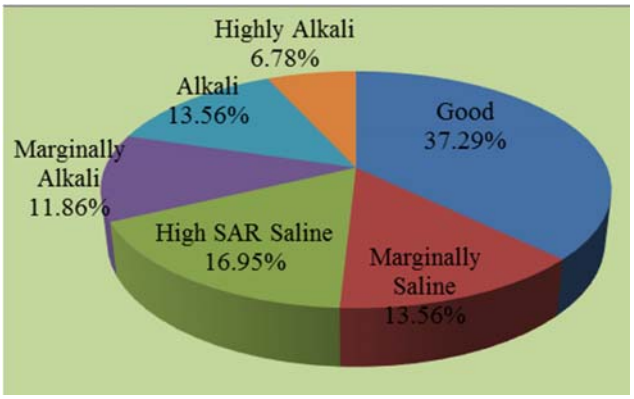

Fig 5: Per cent distribution of water quality according to AICRP classification in Rajaund block

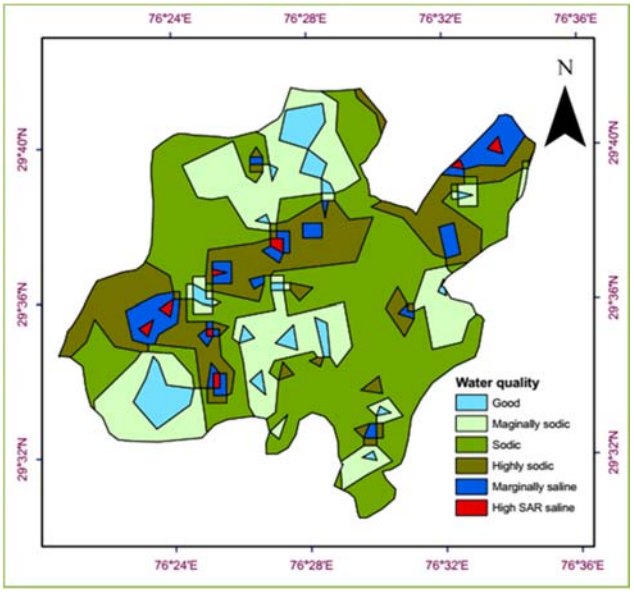

Fig 6: Quality of groundwater according to AICRP classification in Rajaund block

Conclusion

Spatial maps of various chemical parameters can be used for improving the groundwater quality in the area. About one third samples of ground water collected from Rajaund block were only of good quality hence making the remaining samples problematic for irrigating the crops. Therefore, good soil water management strategies are needed for maintaining adequate salt-water balance for appropriate crop growth. Moreover, salinity control with salt tolerant crops couldbe recommended for the areas with saline waters.

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