International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(1): 986-990

Received: 22-11-2017
Accepted: 26-12-2017

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Characterization and mapping of groundwater quality in Siwan block of Kaithal district in Haryana

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Abstract
Present study has been carried out to assess and categorize the quality of groundwater in Siwan block of Kaithal district by focusing on electrical conductivity (EC), pH, cationic and anionic composition of groundwater. 76 groundwater samples were collected from the running tube wells across whole of the block at a distance of 1-2 km and analyzed for various chemical parameters i.e. pH, anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+). According to AICRP (1989) classification, among the 76 samples collected from Siwan block, maximum samples were in good category (64.5%) followed by alkali (34.2%) and saline (1.3%). In saline group, 1.32% samples were in marginally saline category, while in alkali group, 14.47, 15.79 and 3.95% samples were present in marginally alkali, alkali and highly alkali category, respectively. Study revealed that 98.68% of the total samples had an EC value upto 2 dSm^{-1}. Spatial maps of EC, SAR, RSC and water quality of groundwater used for irrigation in the block were prepared through GIS to study spatial variability.

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

1. Introduction
Groundwater is a precious source of fresh water being the most distributed form on the earth, excluding the polar ice caps and glaciers. Groundwater studies are gaining more importance in the present day as it is used for almost all purposes such as domestic, industrial and agricultural activities in most parts of the world. Improper management of this replenishable resource may lead to groundwater contamination and scarcity. Due to natural and anthropogenic causes, quantity of some ions and minerals increased beyond their permissible limit which make groundwater unsuitable for drinking and irrigation purposes. Groundwater quality has been given lot of importance and studied worldwide (Lahermo and Backman, 1999; Omo-Irabor *et al*., 2008; Baalousha, 2010) [4, 6, 1]. Long retention and residence time of groundwater and natural filtration capacity of aquifers facilitate less contamination of groundwater as compared to surface water. Over-dependence on it for many purposes and the indiscriminate disposal of domestic, industrial or agricultural waste slowly makes groundwater susceptible to pollution (Amos and Igboekwe, 2012) [13].
The lowering of groundwater levels has resulted in reduction in individual well yield, growth in well population, failure of bore wells, drying up of dug wells and increase in power consumption (Imtiyaz & Rao, 2008) [2]. In the past, attempts have been made to establish water quality zones of Haryana state (Manchanda, 1976) [5] but due to exhaustive water use, shift in the cropping pattern of the state and the variable withdrawal of groundwater along with scanty rainfall has led to the deterioration of water table as well as quality in many areas of Haryana state (Kumar *et al.*, 2009) [3]. Therefore, the present study was planned to categorize the groundwater of Siwan 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 (AICRP, 1989).

2. Materials and Methods
The survey and categorization of groundwater of Siwan Block was carried out during 2015-2016. Siwan block is located in Kaithal district with the total geographical area of 4176 hectares. For chemical analysis of ground water of Siwan block, total 76 water samples were

taken randomly to cover all the villages of the block. Samples were taken after every 2-3 km from running tubewells which are extensively used for irrigation purposes. 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) [9]. 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).

3. Results and Discussion

In the present study, pH of water samples was found to vary in between 7.03-9.35 with a mean value of 8.03 (Table 1). The lowest observation was recorded in Nagal village and maximum found in Siwan. The spatial variability of pH of groundwater in Siwan block is given in Fig. 1. pH in most of the part of the block was varying from 7.6-8.4. Electrical conductivity of water samples was found to vary between 0.56-3.40 dSm^{-1} with mean value of 1.1 dSm^{-1} (Table 1). Sotha village was recorded with minimum EC and maximum was found in Khurana. The spatial variability of EC of groundwater in Siwan block is given in Fig. 2. In most of the part of the block EC was found in between 0-2 dSm^{-1}, only three spots were found with EC more than 2 dSm^{-1}.

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

S. No	Quality Parameter	Range	Mean
1	pH	7.03-9.35	8.03
2	EC (dSm^{-1})	0.56-3.40	1.10
3	RSC (me L^{-1})	0.00-5.78	1.40
4	SAR (m moL $L^{-1})^{1/2}$	3.79-13.81	5.93
5	Ca^{2+} (me L^{-1})	0.34-2.60	0.81
6	Mg^{2+} (me L^{-1})	0.95-8.10	2.31
7	Na^+ (me L^{-1})	3.50-22.40	7.34
8	K^+ (me L^{-1})	0.08-0.61	0.18
9	CO_3^{2-} (me L^{-1})	0.00-3.20	1.14
10	HCO_3^- (me L^{-1})	0.00-10.00	2.59
11	Cl^- (me L^{-1})	0.4-15.00	4.65
12	SO_4^{2-} (me L^{-1})	0.00-8.40	1.70
13	NO_3^- (me L^{-1})	0.00-1.30	0.36

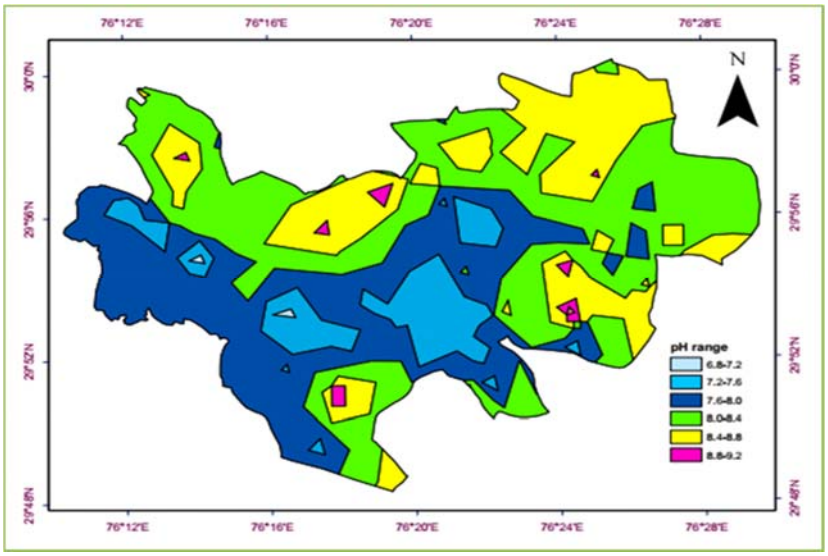

Fig 1: Spatial variability of pH of groundwater in Siwan block

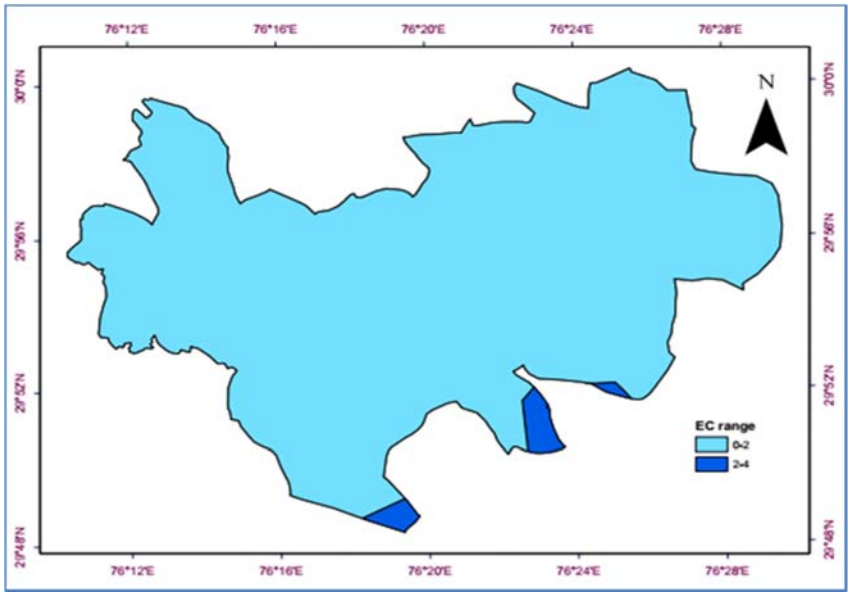

Fig 2: Spatial variability of EC of groundwater in Siwan block

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 absorption ratio (SAR) of water samples was found to varying between 3.79-13.81 $(mmoL\ L^{-1})^{1/2}$ with mean value of 5.93 $(mmol\ l^{-1})^{1/2}$ (Table 1). Dohar village was marked with maximum value and minimum value was noticed in Nawah village. The Spatial variability of SAR of groundwater in Siwan block is given in Fig. 3. Observations of residual sodium carbonate were varying from 0.00-5.78 me l^{-1} with the meanvalue of 1.40 me l^{-1} (Table 1). Nil value was noticed in many villages and highest value was found in Kangthali. Taking residual sodium carbonate as the index for assessing groundwater quality no uniformity was observed in the samples collected from different areas of block as shown in spatial variability map in figure 4.

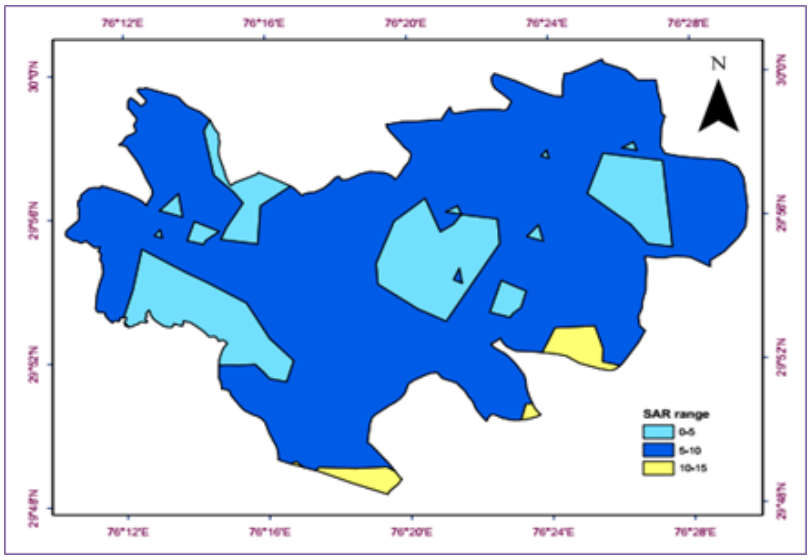

Fig 3: Spatial variability of SAR of groundwater in Siwan block

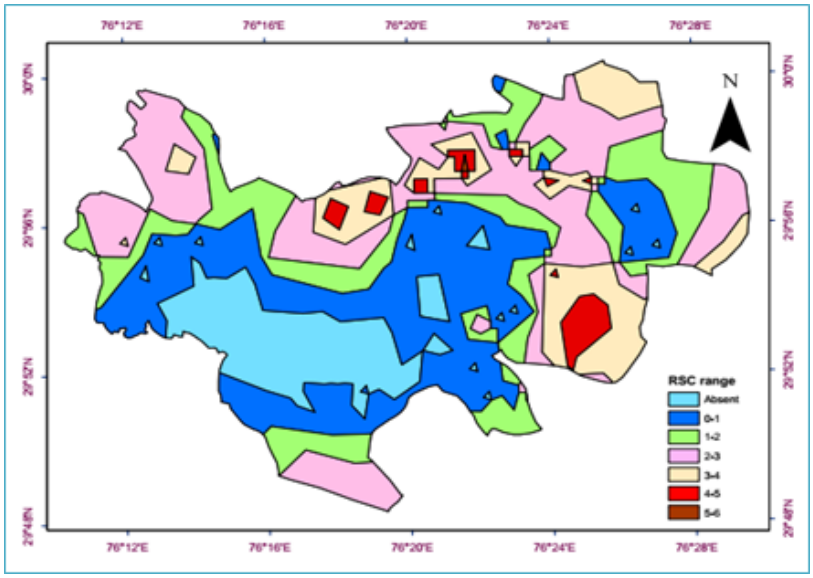

Fig 4: Spatial variability of RSC of groundwater in Siwan block

In case of cations sodium was the dominant cation and its concentration varied from 3.50-22.40 me L^{-1}, minimum value observed in Sontha village and maximum was recorded in Khurana village followed by magnesium (0.95-8.10 me L^{-1}), Calcium (0.34-2.60 me L^{-1}) and Potassium (0.08-0.61 me L^{-1}). Average value for Na^+, Mg^{2+}, $Ca^{2+}$and K^+ were 7.34, 2.31, 0.81 and 0.18 me L^{-1}, respectively (Table 1) and 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 15.00 me l^{-1} in village Khurana and minimum (0.40 me l^{-1}) was recorded in Sair village followed by sulphate (0.00-8.40 me l^{-1}), bicarbonate (0.00-10.00 me l^{-1}), carbonate (0.00-3.20 me l^{-1}) and nitrate (0.00-1.30 me l^{-1}). Average value for CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-} and NO_3^- 1.14, 2.59, 4.65, 1.70 and 0.36 me l^{-1}, respectively (Table 1) and anions were found in order of $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-} > NO_3^-$. 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, Raj paul *et al.*, 2014, Sanjay *et al.*,

2016) [12, 11, 7, 10]. Average of chemical composition and related quality parameters in different EC ranges for Siwan block are given in Table 2. The distribution of ground water samples with increasing EC reveals that the percent samples in increasing EC classes decreases continuously. Maximum percent (55.30%) of samples were found in the EC range of 0-1dSm^{-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.

Table 2: Average chemical composition of water samples in different EC classes of Siwan 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})$^{1/2}$
0-1	42	55.26	0.82	1.80	3.66	1.25	0.29	0.65	1.85	5.55	0.18	0.94	5.05
1-2	33	43.42	1.53	3.57	5.87	2.27	0.44	1.02	2.92	9.63	0.18	1.83	7.00
2-3	1	1.32	1.00	8	15	8.4	0.45	2.6	8.1	22.40	0.17	0.0	9.68

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 76 samples collected from Siwan block maximum sample were in good category (64.5%) followed by alkali (34.2%) and saline (1.3%) as represented in Table 3. In saline group 1.32% was in marginally saline category, while in alkali group, 14.47, 15.79 and 3.95% were present in marginally alkali, alkali and highly alkali group respectively. Distribution percentage of different categories of water samples is shown quality is shown in pie chart Fig. 5. The Spatial variability of water quality of groundwater in Siwan block is presented in and Fig. 6. Out of seven categories of water maximum (64.47%) were found in good category and minimum (1.32%) in marginally saline.

Table 3: Ground water quality classification in Siwan Block

Water quality	Class	Number of samples	Percentage
Good	A	49	64.47
Saline	B		
Marginally Saline	B1	1	1.32
Saline	B2	0	0.00
High SAR Saline	B3	0	0.00
Alkali Water	C		
Marginally Alkali	C1	11	14.47
Alkali	C2	12	15.79
Highly alkali	C3	3	3.95
Total		76	

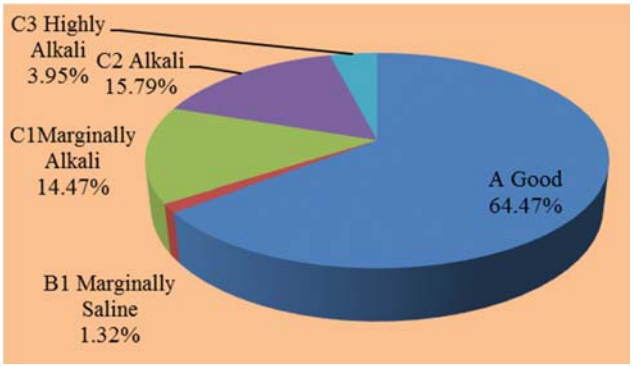

Fig 5: Quality of groundwater (percent) in Siwan block

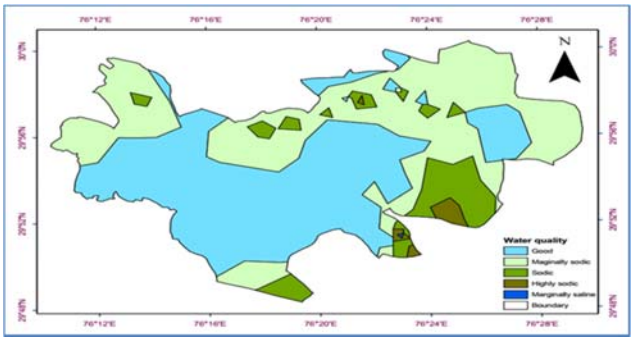

Fig 6: Spatial variability of water quality of groundwater in Siwan block

4. Conclusions

Spatial maps of various chemical parameters can be used for improving the groundwater quality in the area. Among the76 samples collected from Siwan block maximum sample were in good category (64.5%) followed by alkali (34.2%) and saline (1.3%) Graphical maps prepared by using GPS can be used for monitoring the degraded land and soil affected by salinity problem. To minimize the adverse effect of saline and alkali water on soil health, it should be used in combination with good water for irrigating the crops. In addition to this, good soil water management strategies will help in maintaining adequate salt-water balance for appropriate crop growth.

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