Journal of Soil Salinity and Water Quality 15(2), 184-193, 2023

Survey, Characterization and Mapping of Ground Water Quality and its Effect on Soil Properties in Gurugram Block of Haryana

Rishav Bhatia[1,3], Parmod Kumar Yadav[2], Sawan Kumar[3]*, Ramprakash[4], Satender Kumar[5] and Mukesh Kumar Jat[6]

[1]*Soil and Land Use Survey of India, C-4, Sec-1, Noida- 201301, Uttar Pradesh, India*
[2,6]*RRS, CCS HAU Bawal, Rewari-123501, Haryana, India*
[3,4,5]*Department of Soil Science, CCS Haryana Agricultural University, Hisar-125004, Haryana, India*
**Corresponding author E-mail: sawantamak0007@gmail.com*

Abstract

In Gurugram block of Gurugram district, a survey was conducted to evaluate the quality of the groundwater and determine how it affected the soil qualities. Using a handheld GPS, 72 groundwater samples and 40 soil samples overall were taken at two sites, four depths each, in the Gurugram block of the district. The pH, EC, SAR and RSC of ground water ranged from 7.38 - 8.03, 0.75-5.58 (dS m^{-1}), 4.44 - 21.75 (mmol $l^{-1})^{1/2}$ and nil to 4.50 (me l^{-1}), respectively. The anion contents followed the pattern Cl^{-}>SO_4^{2-}> HCO_3^{-}>NO_3^{-}>CO_3^{2-} whereas the cations were found to be in the following order: Na^{+}> Mg^{2+}> Ca^{2+}> K^{+}. The village Sehrawan had the lowest saturation rate (28.84%) and the village Kherki Majra had the highest saturation percentage (34.57%). The settlement of Gurugram Rural (1.22 dS m^{-1}) in the Gurugram block has the lowest EC of saturated extract. The Hamirpur village had the highest EC of saturated extract (6.12 dS m^{-1}) whereas Hamirpur (7.34) and Harsaru Garhi (8.43) were the villages with the lowest and highest pH values, respectively. The correlation coefficient revealed that electrical conductivity (EC) of soil saturation extract was significantly and positively correlated with EC (0.962), Cl^{-} (0.936) and Na^{+} (0.902) of groundwater used for irrigation.

Key words: Water quality, Electrical conductivity, Saturation percentage, RSC, SAR, Soil properties

Introduction

Quality of irrigation water is an important parameter and needs to be taken into consideration for crop production and soil health. In groundwater studies, appropriate and accurate laboratory analysis of water quality is very necessary for its effective utilization and suitability of water for human use such as drinking, industrial and agriculture is determined by hydro chemical studies. Water being an excellent solvent, it is imperative to have the knowledge of the geochemistry of dissolved constituents and way of reporting analytical data. Usually groundwater has base cations (Ca^{2+}, Mg^{2+}, Na^{+}), bicarbonate and pH in neutral to slightly alkaline range (Frengstad and Banks, 2000). Quality of water for irrigation is correlated to its impact on soils and crops as well as its management. The use of good quality irrigation water can help in production of crops of good quality with high yield (Islam and Shamsad, 2009). Agriculture needs to be sustainable, thus, soil and water management and monitoring the soil and water parameters are essential. In arid and semiarid locations, over-drafting and deteriorating ground water quality are seriously harming crop productivity (Boumans *et al.*, 1988).

Water quality in Haryana is degrading due to overuse of fertilizers and pesticides. Now a days due to various development activities and exploitation of water resources have increased to great extent due to which, quality as well as quantity of water available for use is affected severely. Because of pavement in urban areas, groundwater recharge is reducing and groundwater withdrawal is increasing affecting its availability (Kumar *et al.*, 2015). Limited work at block level on soil and water quality parameters has been studied so far. Therefore, an appraisal for the quality of irrigation water is essential for sound irrigation planning so as to assess any possibility of development of secondary salinization/sodification in Haryana. So, keeping in view the above facts, the present study was carried out.

Materials and Methods

Area and location

Gurugram district of Haryana located (Fig. 1) between 27°39′00″ North and 28°32′25″ North latitudes and between 76°39′30″ East and 77°20′45″ East longitudes (Maps of India, 2023). Gurugram Plain and Gurugram Undulating Plain with Aravalli Hills are the two main sub-parts of Gurugram District from a physiographic perspective.

Soil and climate

The majority of the Gurugram district's soils are classified as Ochrepts kinds, while Orthids-Fluvents and Ochrepts Ustrets-Ustalfs types are found in the district's central and south western regions, respectively. The Gurugram district has sandy to sandy-loam type of soil (DCO Haryana, 2011). The Gurugram district has sub-tropical continental monsoon climate. The highest daily mean temperature of 40.2° C occurs in month of May. The average rainfall of Gurugram district during year 2018 was 386.7 mm (IMD, 2018).

Collection of water samples

To evaluate the quality of the groundwater, 72 water samples were taken from tube wells in the Gurugram block during 2018–19. A hand-held GPS is used to record accurate sampling site (longitude and latitude).

Analysis of water samples

After collection of water samples, filtration was carried out in laboratory and one or two drops of toluene were added to prevent microbial growth. Then ground water samples were analysed for pH and EC using pH meter and conductivity meter. Among soluble cations, Calcium and Magnesium were determined using Versante titration method (Diehl *et al.*, 1950), sodium and potassium using flame photometer and the anions (CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-) by their standard analytical procedures. Residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) were worked out by using the formula given by Richards (1954) and Raghunath (1987), respectively.

Characterization of irrigation water

Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were calculated by using the following equations, respectively for the

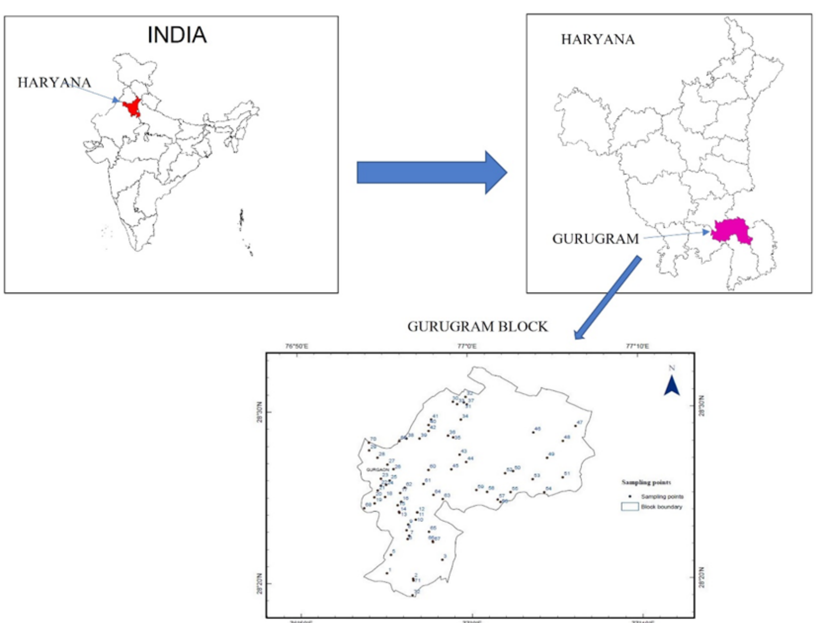

Fig. 1 Location Map of the study area

Table 1. Irrigation water quality classification criteria (AICRP on Management of Soil Affected Soils and Use of Saline Water in Agriculture, 1989*)

Sr. No.	Quality of water	Class	Quality parameters		
			EC (dS m^{-1})	SAR (mmol $l^{-1})^{1/2}$	RSC (mel^{-1})
1	Good	A	<2	<10	<2.5
2	Saline	B	-	-	-
	Marginally saline	B_1	2-4	<10	<2.5
	Saline	B_2	>4	<10	<2.5
	High SAR saline	B_3	>4	>10	<2.5
3	Alkali water	C	-	-	-
	Marginally alkali	C_1	<2	<10	2.5-4
	Alkali	C_2	<2	<10	>4
	Highly alkali	C_3	Variable	>10	>4

*Tiwari and Sharma (1989)

purpose of classification of water quality:

$$SAR\ (mmol\ l^{-1})^{1/2} = Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{0.5}$$

$$RSC\ (me/l) = [CO_3^{-2} + HCO_3^{-}] - [Ca^{+2} + Mg^{+2}]$$

Water quality has been characterized as per AICRP (1989) has been shown in table 1.

Determination of soil properties

Soil samples were collected from 0-15 cm, 15-30 cm, 30-45 cm and 45-60 cm depth of fields with the help of auger depending upon the results of ground water quality for fulfilling the purpose of determination of impact of groundwater quality on various soil properties. Soil samples were collected from same field from where groundwater samples of different categories were collected. A total of 10 sites were selected, 2 from each category of water quality for sampling of soil samples in Gurugram block on the basis of results of water quality analysis. Soil samples were analyzed for EC (1:2), pH (1:2), $CaCO_3$, saturation percentage as per standard procedures. For preparation of soil saturation paste, 2 mm sieved soil sample was taken in a beaker and distilled water added to it while stirring with spatula. This method of preparation of soil saturation paste was explained by US Salinity Laboratory Staff, 1954. Then saturation extract collected from soil saturation paste was used for analysis of various soil properties such as, EC (1:2), soluble cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}) as per standard procedures as described for water analysis (Richards, 1954).

Statistical methods

Karl Pearson method of correlation was used for computation of correlation coefficient among various parameters of groundwater and soil extracts (Panse and Sukhatme, 1954).

Results

Quality of irrigation water

The values of different water quality parameters were depicted in Table 2. The result of analysis of ground water samples of Gurugram block showed that pH, EC, SAR and RSC ranged from 7.38 - 8.03, 0.75-5.58 (dS m^{-1}), 4.44 - 21.75 (mmol l^{-1})1/2 and nil to 4.50 (me l^{-1}), respectively. The lowest value of pH (7.38), EC (0.75 dS m^{-1}) and SAR [4.44 (mmol l^{-1})1/2] found in village Hamirpur, Sehrawan and Nawada Fatehpur, respectively while the highest value of pH (8.03), EC (5.58 dS m^{-1}) and SAR [21.75 (mmol l^{-1})1/2] found in village Nawada Fatehpur, Hamirpur and Hamirpur, respectively. The cations were found to be in the order of $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$ and ranged from 5.58 to 47.40 meq l^{-1}, 1.10 to 15.75 meq l^{-1}, 0.40 to 5.75 meq l^{-1}, 0.19 to 0.66 meq l^{-1} respectively while anions followed in order of $Cl^{-} > SO_4^{2-} > HCO_3^{-} > NO_3^{-} > CO_3^{2-}$ and varied from 2.80 to 44.40 meq l^{-1}, 1.20 to 13.90 meq l^{-1}, 0.70 to 6.00 meq l^{-1}, nil to 0.80 meq l^{-1}, nil to 1.60 meq l^{-1} respectively. The spatial variability of EC, pH, RSC and SAR is represented by fig. 4, 5, 6 and 7 respectively.

Table 2. Chemical composition of tubewell water used for irrigation in different villages of Gurugram block

Properties	Villages of Gurugram block									
	Sehrawan	Nawada Fatehpur	Dhani Fazilpur	Kherki Majra	Badha	Naharpur Kasan	Hamirpur	Sadhrana Bamripur	Wazirpur	Garhi Harsaru
EC	0.75	1.72	2.58	2.23	5.26	4.17	5.58	1.58	2.21	2.81
pH	7.89	8.03	7.75	7.77	7.78	7.81	7.38	7.63	7.63	7.59
CO_3^{-2}	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1.60
HCO_3-	1.00	3.00	0.70	2.50	6.00	1.50	4.25	6.00	7.50	5.30
Cl^-	2.80	10.0	18.90	15.30	32.00	24.00	44.40	6.40	9.90	16.10
SO_4^{-2}	1.20	2.70	4.40	3.80	10.30	13.90	7.55	1.60	3.10	3.50
NO_3^-	0	0.80	0.22	0.40	0.72	0.39	0.58	0.05	0.52	0.45
Ca^{+2}	0.40	1.50	1.80	1.50	5.75	3.00	2.40	0.90	0.80	0.70
Mg^{+2}	1.10	5.50	5.90	4.70	15.75	9.00	7.10	2.50	2.20	2.10
Na^+	5.58	8.30	17.10	15.23	26.74	28.70	47.40	9.57	18.90	24.75
K^+	0.66	0.36	0.20	0.63	0.44	0.28	0.57	0.22	0.19	0.27
RSC	Nil	Nil	Nil	Nil	Nil	Nil	Nil	2.60	4.50	4.10
SAR	6.44	4.44	8.71	8.65	8.16	11.72	21.75	7.34	15.43	20.92
Category AICRP	A	A	B_1	B_1	B_2	B_3	B_3	C_1	C_3	C_3

AICRP (1989) classification of groundwater quality of Gurugram block

The water samples were classified based on the criteria given by All India Coordinated Research Project (AICRP) on "Management of Salt Affected Soils and Use of Saline Water in Agriculture" (1989) in which water quality has been grouped into three categories such as good, saline and alkali. This classification is based upon EC, SAR and RSC Parameters. Based on the limits of various parameters, two poor quality water classes have been further classified each into 3 subclasses. The data pertaining to classification of groundwater quality as per AICRP (1989) criteria according to which 20 groundwater samples were recorded under good (A) category, 27 under marginally saline (B_1) category, 2 under saline (B_2) category,19 under high SAR saline (B_3) category, 2 under marginally alkali (C_1) category and 2 under high alkali (C_3) category is presented in table 5. Fig. 2 and 3 represents the distribution percentage of water samples and spatial variability of groundwater quality in different water quality categories of Gurugram block. According to AICRP (1989) criteria of categorization of groundwater quality, the quality of water of village Sehrawan and Nawada Fatehpur (Good quality), Dhani Fazilpur and Kherki Majra (Marginally saline), Badha (Saline), Naharpur Kasan and

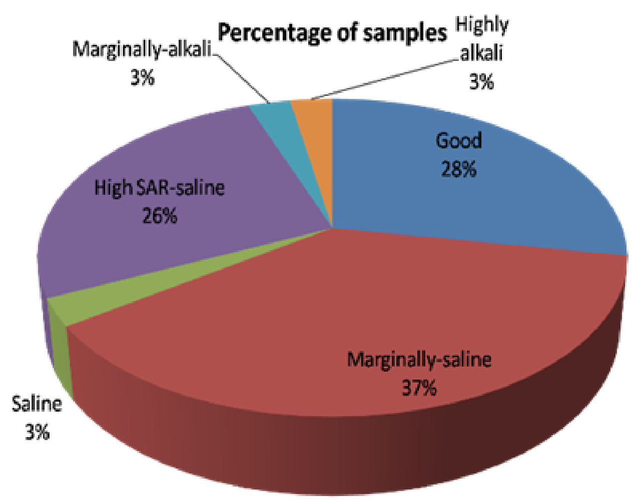

Fig. 2 Water quality distribution as per AICRP (1989)

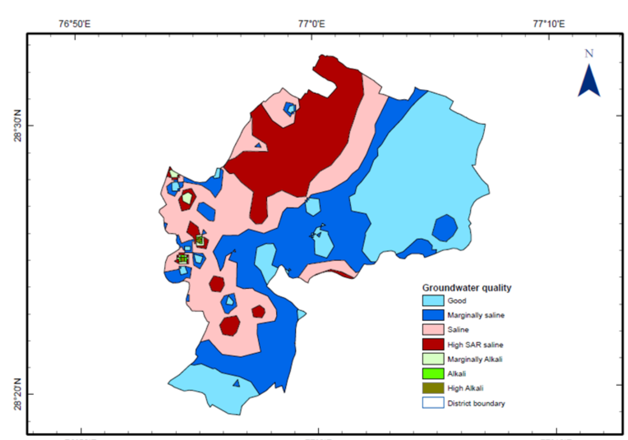

Fig. 3 Spatial variability of groundwater quality of Gurugram block

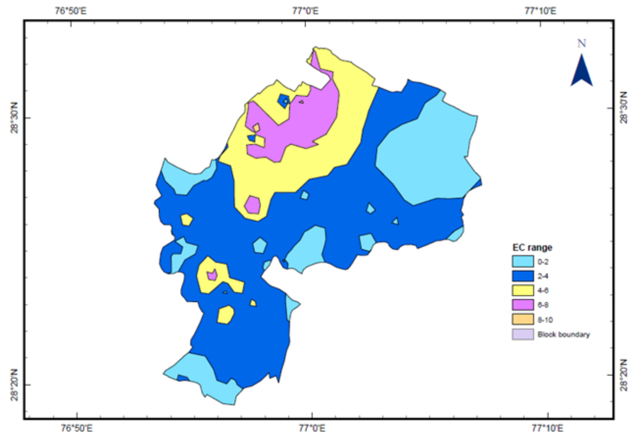

Fig. 4 Spatial variability in EC of groundwater of Gurugram block

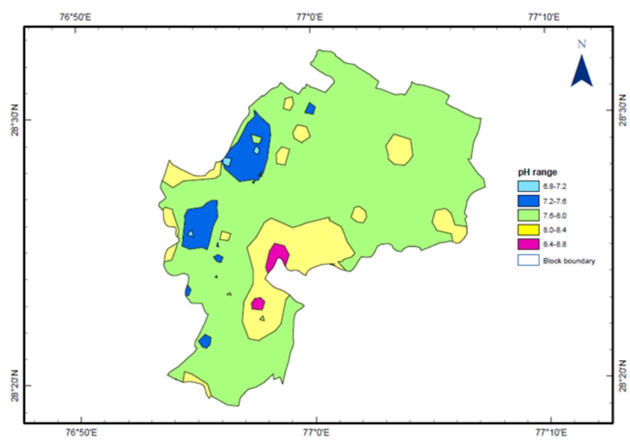

Fig. 5 Spatial variability in pH of groundwater of Gurugram block

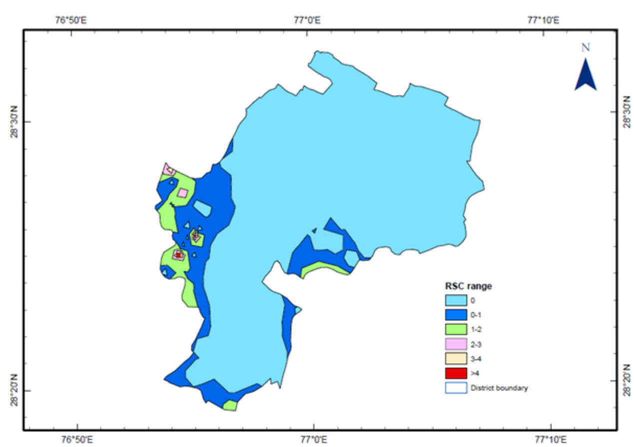

Fig. 6 Spatial variability in RSC of groundwater of Gurugram block

Hamirpur (High SAR value water), Sadhrana Bamripur (Marginally alkali), Wazirpur and Garhi Harsaru (High alkali water) were found.

Chemical properties of soil

The data related to chemical properties of soil were illustrated in Table 3. In the Gurugram block village of Sehrawan (0.93 dS m^{-1}), where water of good quality (A) category was used for irrigation, the mean lowest EC of saturation extract was found. The village of Hamirpur (6.12 dS m^{-1}) in Gurugram block, where high SAR saline (B3) category water was used for irrigation, had the mean highest EC of saturation extract. Village Hamirpur and GarhiHarsaru had the mean lowest and mean highest pH readings, respectively, of 7.34 and 8.43. The village of Sehrawan had the lowest saturation rate (28.84%) and the settlement of Kherki Majra had the highest saturation percentage (34.57%). With the exception of the villages of Nawada Fatehpur and Dhani Fazilpur, none of the Gurugram soil sampling locations contained any calcium carbonate. Average accumulation of cations and anions was found to be in the following order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$ and $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-}$ respectively.

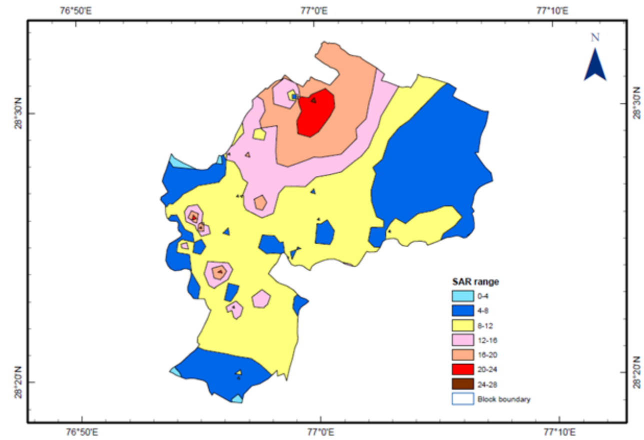

Fig. 7 Spatial variability in SAR of groundwater of Gurugram block

Statistical analysis of different water quality parameters and soil saturation extract of Gurugram block

The correlation coefficient revealed that electrical conductivity (EC) of soil saturation extract was significantly and positively correlated with EC (0.962), Cl^- (0.936) and Na^+ (0.902) of groundwater used for irrigation. Similarly, Cl^- and Na^+ of soil saturation extract were significantly and positively correlated with EC (0.926), Cl^- (0.895) and EC (0.888), Na^+ (0.966) of groundwater used for irrigation, respectively. The

Table 3. Effect of ground water quality on soil properties of different villages of Gurugram block

Properties	Villages of Gurugram block									
	Sehrawan	Nawada Fatehpur	Dhani Fazilpur	Kherki Majra	Badha	Naharpur Kasan	Hamirpur	Sadhrana Bamripur	Wazirpur	Garhi Harsaru
EC	0.93	2.27	3.59	3.79	5.57	5.42	6.12	2.00	3.13	3.59
pH	7.81	7.93	8.21	7.94	7.94	8.11	7.34	7.73	8.17	8.43
CO_3^{-2}	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	1.78
HCO_3-	0.89	7.40	9.91	11.13	12.39	15.66	21.61	7.93	13.89	16.36
Cl^-	5.80	11.61	20.58	21.88	36.46	26.70	30.06	9.91	14.60	15.03
SO_4^{-2}	2.05	2.94	4.43	4.31	6.16	11.14	8.81	1.04	2.65	2.10
Ca^{+2}	3.66	4.24	8.63	11.29	15.30	12.24	12.20	5.18	2.30	2.61
Mg^{+2}	1.03	6.00	7.26	7.24	13.88	9.09	7.30	1.69	4.93	5.16
Na^+	4.21	11.65	18.96	17.38	24.72	30.94	39.03	11.69	22.83	26.24
K^+	0.20	0.76	0.75	1.05	1.31	1.56	2.13	0.72	0.95	1.26
Saturation (%)	28.84	29.70	30.97	34.57	30.80	29.97	31.43	32.43	30.61	30.81
$CaCO_3$ (%)	Nil	0.52	0.70	Nil	Nil	Nil	Nil	Nil	Nil	Nil

data pertaining to correlation coefficient between groundwater and soil parameters of Gurugram block is presented in Table 4.

Discussion

Quality of ground water

The electrical conductivity (EC) of groundwater samples collected from Gurugram block varied between 0.69 to 8.95 dS m^{-1} with average EC of 3.32 dS m^{-1} and the pH value of groundwater samples varied between 6.88 to 8.85 with average value of 7.83. According to the pH value, water of Gurugram block can be classified as slightly acidic to alkaline in nature. Higher value of pH could be due to high concentration of ions such as Sodium and bicarbonates. Bicarbonates produce hydroxyl ion which is reason for increase or decrease in pH value. Mukesh (2003), Deshmukh (2012), Kumar (2015), Mandal *et al*. (2016), Pal (2017) obtained similar results. Sodium was recorded as governing cation among all the cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) examined. High concentration of sodium resulted due to sodium compounds' water solubility and nature to be present in aqueous solution and cation exchange of groundwater mineral. Surface soil's salt leaching due to irrigation water or rain water could also be reason behind the dominance of Na^+ and Cl^- in the groundwater. It was found that concentration of all cations analyzed increased with increase in value of EC in the block except potassium which followed a steady trend. It was also observed that degree of increase in sodium and magnesium concentration was much higher than other anions. Results of the study were in

Table 4. Correlation coefficient between ground water and soil parameters of Gurugram block

	EC_{iw}	EC (soil)	pH (water)	pH (soil)	Cl^- (water)	Cl^- (soil)	Na^+ (water)	Na^+ (soil)
EC_{iW}	1	-	-	-	-	-	-	-
EC (soil)	.962**	1	-	-	-	-	-	-
pH (water)	-.498	-.462	1	-	-	-	-	-
pH (soil)	-.286	-.139	.280	1	-	-	-	-
Cl^- (water)	.974**	.936**	-.528	-.377	1	-	-	-
Cl^- (soil)	.926**	.949**	-.298	-.161	.895**	1	-	-
Na^+(water)	.926**	.902**	-.708*	-.285	.933**	.766**	1	-
Na^+ (Soil)	.888**	.918**	-.668*	-.087	.868**	.757*	.966**	1

**Correlation is significant at p= 0.01 level of significance

*Correlation is significant at p= 0.05 level of significance

Table 5. AICRP (1989) classification of groundwater quality of Gurugram block

Water quality	Class	Number of samples	Percentage
Good	A	20	27.78
Saline waters	B	-	-
Marginally-saline	B_1	27	37.50
Saline	B_2	2	2.78
High SAR-saline	B_3	19	26.38
Alkali waters	C	-	-
Marginally-alkali	C_1	2	2.78
Alkali	C_2	0	0.00
Highly alkali	C_3	2	2.78
		72	100.00

line with Shahid *et al.* (2008), and Rathi *et al.* (2018). Ion exchange of minerals with soils and rocks surrounding the groundwater might be the reason behind the presence of magnesium in groundwater whereas concentration of potassium and carbonates was very low and negligible, respectively

In case of anions, chloride was recorded as governing anion among all the anions (CO_3^{2-}, HCO_3^-, Cl, SO_4^{2-}, NO_3^-) analyzed. After that order of dominance of anions was sulphate, bicarbonate, nitrate and carbonate in groundwater of the block. It was observed that HCO_3^-, Cl^-, SO_4^{2-} and NO_3^- concentration have positive and significant correlation with EC of groundwater samples. In all the EC classes, sodium and chloride were the major cation and anion, respectively. Sharma, (1998), Rajpaul *et al.* (2014), Sanjay *et al.* (2016) and Ramprakash *et al.* (2020) obtained similar results. In contrast to bicarbonates concentration, concentration of carbonates was very low in groundwater. Dissolution of carbonic acid of aquifers and weathering of carbonates can be the reason for presence of CO_3^{2-} and HCO_3^- ions in water samples. Oxidation of pyrite, sulphur in igneous rocks, merasite, sulpharite and solution of other sulphur bearing minerals results in presence of sulphate ion concentration in groundwater. Findings are in agreement of results recorded by Pradhan *et al.* (2011) and Rahman *et al.* (2013). Industrialization, urbanization and fertilizers and chemicals application led to occurrence of nitrate concentration in groundwater of Gurugram block of Gurugram district. Shahid (2004), Jitender (2006) and Kumar and Kumar (2015) also found nitrate concentration in ground waters of Julana block of Haryana, Karnal block of Karnal, Haryana and Kisanganj district of Bihar, Rewari/Bawal block of Hrayana, Kaithal district of Haryana and Firozpur-Jhirka and Punhana block of Haryana, respectively.

The SAR value of groundwater sample taken from Gurugram block of Gurugram district varied between 1.41 to 25.26 meq $L^{-1}$with average value of 10.56 $(mmol^{-1})^{1/2}$. Combination of Sodium with carbonates and bicarbonates results in sodicity hazard due to removal of exchangeable calcium and magnesium from soil solution. Sodic condition due to decrease in exchangeable calcium and calcium precipitation results from usage of water with high SAR value. With increase in concentration of sodium ion, increase in SAR value of groundwater samples was also observed by Singh *et al.* (2011) and Kumar (2015). Residual sodium carbonate was found nil in most of the area of Gurugram block because combined concentration of carbonate and bicarbonate was less than combined concentration of calcium and magnesium. RSC varied between nil to 4.30 with average value of 0.32 meq L^{-1} in Gurugram block. With increase in bicarbonates and carbonates concentration, increase in RSC value was observed by Amin (2014) and Yadav *et al.* (2016).

Impact of ground water on soil properties

The pH of soil profiles showed irregular trend with soil profile depth. It followed decreasing trend in some of the villages whereas in some of the villages, it increased with increase in soil profile depth. Reason behind highest value of pH in 0-15 cm soil depth was precipitation of calcium and magnesium carbonates in course of evaporation process due to presence of HCO_3^- ions along with exchangeable and soluble sodium. So, an indication of sodicity and salinity development was given by high value of pH of soil saturation extract. Vijaykant (2016) and Rathi *et al.* (2018) observed similar results. Due to increase in sodium and clay content, increase in pH with depth in soil profile was observed whereas decrease in pH value with soil depth might be due to release of hydrogen ion under influence of soluble cation present in applied irrigation water. Similar results were confirmed by Gandhi *et al.* (2009) and Tikkoo *et al.* (2010) and Jayaprakash *et al.* (2012). Maximum accumulation of salts was observed in surface layer of soil (0-15 cm) and with increase in depth of soil profile, EC of soil saturation extract showed decreasing trend except in some villages like Nawada Fatehpur and Dhani Fazilpur, EC of saturation extract decreased up to 15-30 or 30-45 cm depth and then increased in 30-45 or 45-60 cm depth. High concentration of salts at lower depth due to leaching of soluble salts might be the reason for increase in EC of soil saturation extract with depth. Results in line were observed by Singh (2005). Decrease in calcium and magnesium concentration in soil saturation extract led to decrease in EC of soil saturation extract. Mediratta *et al.* (1985), Singh (2005), Qadir *et al.* (2007), Raghubanshi and Singh (2013), Vijaykant (2016) also confirmed similar results.

In the majority of the villages in the Gurugram block, the saturation percentage of the soil profile had a strange relationship to the depth of the soil profile. Similar findings were also reported by Arvind (2007). In several of the villages, such as Hamirpur in the Gurugram block, the pore size shrank as the depth of the soil increased due to increased compaction. The same outcomes were noted by Mukesh (2003). Calcium carbonate content where found was due to dissolution and leaching of carbonate and bicarbonate in coarse textured soil and CO_2 evolution due to high temperature resulted in calcium carbonate content at these sites. Tikkoo *et al.* (2010) and Yadav *et al.* (2016) confirmed similar results.

Although concentration of all the cations and anions followed decreasing trend with increase in depth of soil profile but concentration of some of ions like Cl^-, SO_4^{2-}, Ca^{2+}, Na^+, Mg^{2+} increased at lower depth of 30-45 or 45-60 cm at some of the soil sampling sites. Maximum accumulation of cations and anions in surface layer of soil and decrease in their concentration with depth might be due to capillary action of water which results in movement of these ions toward surface layer of soil. Reason behind high concentration of ions in surface layer of soil profile might be sampling before monsoon and evaporation due to high temperature during summer months. The increase in EC at lower depth at some of the sites led to increase in concentration of some of the ions at lower depth of soil profile. More *et al.* (1988), Gandhi *et al.* (2009) and Vijaykant (2016) validated similar results

Conclusions

The results revealed that most of the areas of Gurugram block were under poor-quality water with maximum area under saline water in contrast to alkali water. So special management strategies based on climatic factors, soil texture and crops to be grown, are essential for optimum utilization of poor-quality groundwater for sustainable crop productions without deteriorating the soil quality.

References

Amin M (2014) Geoinformatics for Groundwater characterization - A Case Study. M.Sc. Thesis submitted to CCSHAU, Hisar.

Arvind K (2007) Characterization of groundwater quality of Bhiwani Khera and Bhiwani block of Bhiwani District of Haryana, M.Sc. Thesis submitted to CCSHAU, Hisar.

Boumans JH, Van Hoorn JW, Kruseman GP and Tanwar BS (1988) Water table control, reuse and disposal of drainage water in Haryana. *Agricultural Water Management* **14**: 537- 545.

DCO, Haryana (2011) District Census Handbook- Gurgaon. Census of India- Haryana, Series-7, Part-XII(A). Directorate of Census Operations, Haryana. Ministry of Home Affairs, Goverment of India, pp 15.

Deshmukh KK (2012) Studies on chemical characteristics and classification of soils from Sangamner area, Ahmednagar district, Maharashtra, India. *Rayasan Journal of Chemistry* **5(1)**: 74-85.

Diehl H, Goetz CA and Hach CC (1950) The versenate titration for total hardness. *Journal (American Water Works Association)* **42**(1): 40-48.

Ewusi A, Obiri-Yeboah S, Hans-Jurgen V, Asabere BS and Bempah CK (2013) Groundwater quality assessment for drinking and irrigation purposes in Obuasi Municipality of Ghana, a preliminary study. *Research Journal of Environmental and Earth Sciences* **5(1)**: 6-17.

Frengstad B and Banks D (2000) Evolution of high pH Na-HCO_3^- groundwaters in Anorthosites: silicate weathering or cation exchange? In: Sililo et al. (eds) *Groundwater: Past Achievements and Future Challenges*, Proc. XXXIInd Congress of the International Association of Hydrogeologists. Cape Town, South Africa. Balkema, Rotterdam, pp 493–498.

Gandhi AW, Wagan MR, Yosup MK, Oad FC, Inayatullah R and Siddque MH (2009) Water quality effect on fodder maize and soil characreristics. *Sarhah Journal of Agriculture* **25(2)**: 217-223.

IMD (2018) Automatic weather/rain gauge station data- Gurgaon (Haryana). Indian Meteorological Department, Ministry of Earth Sciences, Government of India. Available online at: http://aws.imd.gov.in:8091/state.php?id=HARYANA. Accessed on 04-08-2023

Islam MS and Shamsad SZKM (2009) Assessment of irrigation water quality of Bogra District in Bangladesh. *Bangladesh Journal of Agricultural Research* **34(4)**: 597-608.

Jayaprakash R, Shetty YV and Punitha BC (2012) Vertical distribution of chemical properties and macro nutrient status in non traditional areca growing soil profiles of Karnataka. *Indian Journal of Fundamental and Applied Life Sciences* **2(1)**: 72 -77.

Jitender (2006) Quality appraisal of underground waters of Karnal block of Karnal district, Haryana. M.Sc Thesis submitted to CCS HAU Hisar.

Kumar A and Kumar V (2015) Fluoride Contamination in Drinking Water and its Impact on Human Health of Kishanganj, Bihar, India. *Research Journal of Chemical Sciences* **5(2)**: 76- 84.

Kumar A, Hooda RS, Goyal A and Goel A (2015) satellite data based groundwater prospects study in Gurgaon District, Haryana, India. *Research Journal of Recent Sciences* **4**: 255-260.

Kumar V (2015) Survey and characterization of groundwater quality of Rewari and Bawal block of district Rewari. M.Sc Thesis submitted to CCS HAU Hisar.

Kumaresan M and Riyazuddin P (2005) Major ion chemistry of environmental samples around suburban of Chennai city. *Current Science* **91**: 1668- 1677.

Mandal AK, Joshi PK, Singh R and Sharma DK (2016) Characterization of some salt affected soils and poor quality waters of Kaithal District in Central Haryana for reclamation and management. *Journal of the Indian Society of Soil Science* **64(4)**: 419-426.

Maps of India (2023) District map of Gurugaon (Haryana). Available at: https://www.mapsofindia.com/maps/haryana/districts/gurgaon.htm accessed on 04/08/2023

Mediratt JC, Bansal KN and Gupta GP (1985) Characterization of some salt-affected soils of Harsi command area of Madhya Pradesh. *Journal of the Indian Society of Soil Science* **33**: 214- 217.

More SD, Shinde JS and Malewar GV (1988) Characterization of some salt-affected soils of Purna command area of Maharashtra. *Journal of the Indian Society of Soil Science* **36**: 146-150.

Mukesh K (2003) Characterization of ground water quality of Safidon block in district Jind, Haryana. M.Sc. Thesis submitted to CCS HAU, Hisar.

Oladeji OS, Adewoye AO and Adegbola AA (2012) Suitability assessment of groundwater resources for irrigation around Otte Village, Kwara State, Nigeria. *International Journal of Applied Sciences and Engineering Research* **1(3)**: 437-445.

Pal SK (2017) Characterization of ground water quality of Firozpur-Jhirka and Punhana block of Mewat district and their effect on soil properties. M.Sc Thesis. CCS HAU Hisar.

Panse VG and Sukhatme PV (1954) *Statistical Methods for Agricultural Workers*. New Delhi, India. Indian Council of Agricultural Research. pp 361.

Pradhan S, Chadrasekharan H, Jain N and Yadav BR (2011) Characterization of groundwater quality for irrigation in Gohana block of Sonepat district, Haryana. *Journal of Agricultural Physics* **11**: 63-70.

Pradhan S, Chadrasekharan H, Jain N and Yadav BR (2011) Characterization of groundwater quality for irrigation in Gohana block of Sonepat district, Haryana. *Journal of Agricultural Physics* **11**: 63-70.

Qadir M, Qureshi AS and Cheraghi SAM (2007) Extent and characterisation of salt affected soils in Iran and strategies for their amelioration and management. *Land Degradation & Development* **19(2)**: 214-227.

Raghubanshi BPS and Singh RP (2013) Chemical properties of major nutrients (N, P, K and S) and micro nutrient (Zn) status in soil profile of Mandapur village, Badalapur block of district Jaunpur (U.P.), Technofame- *A Journal of Multidisciplinary Advance Research* **2(1)**: 44 -50.

Raghunath HM (1987) *Ground Water*, 2nd edn. Wiley, New Delhi, pp 563

Rahman MM, Selim RAHM, Mahfuzur MR, Ramizul-Islam and Abdur MR (2013) Geochemical characterization of groundwater in Bhangamor Union, Fulbari Upazila, Kurigram. *International Journal of Chemistry and Material Science* **1(2)**: 22-35.

Rajpaul, Ramprakash, Kumar S, Sharma SK and Satyavan (2014) Spatial variability of groundwater quality in irrigated agriculture Salhawas block of Jhajjar district (Haryana). *Annals of Biology* **30(3)**: 460-463.

Rajpaul, Ramprakash, Kumar S, Sharma SK and Satyavan (2013) Mapping of groundwater quality of Beri block of Jhajjar district in Haryana. *Journal of Soil Salinity and Water Quality* **13(2)** :134-139.

Ram Prakash, Tomar Dinesh, and Kumar Sanjay and Singh, Manjeet (2020) GIS mapping of groundwater quality in Kharkhoda Block of Sonipat District in Haryana, India. *Journal of Soil Salinity and Water Quality* **12(2)**: 163-169.

Rathi P, Ramprakash, SK and Satyavan NR (2018) Characterization and mapping of groundwater quality in Siwan block of Kaithal district in Haryana. *International Journal of Chemical Studies* **6(1)**: 986-990.

Richards LA (1954) *Diagnosis and Improvement of Saline and Alkali Soils*. U.S.D.A. Handbook No. 60. United States Department of Agriculture.

Sanjay K, Sharma SK, Ramprakash, Rajpaul and Satyavan (2016) Spatial variation of groundwater quality of Meham Block of Rohtak District, Haryana. *Indian Journal of Soil Conservation* **44(2)**: 163-167.

Shahid M (2004) Quality appraisal of underground waters of Julana and Pillu Khera block in Jind district, Haryana. M.Sc Thesis submitted to CCS HAU Hisar.

Shahid M, Singh AP, Bhandari DK and Ahmad I (2008) Groundwater quality appraisal and categorization in Julana block of Jind district, Haryana. *Journal of the Indian Society of Soil Science* **56(1)**: 123-125.

Sharma DR (1998) Assessment of the nature and extent of poor quality of underground water resources. In: National Seminar on Strategies for the Management of Poor Quality Water in Agriculture, CSSRI, Karnal. 4-5.

Singh AP, Asha S, Tiwari HL and Diwedi PK (2011) The effect of salts on the hydraulic conductivity of the saline alkali soil. *Indian Journal of Science Research* **2(4)**: 117-119.

Singh D (2005) Characterization of ground water quality of Asandh and Nissing block of district Karnal, Haryana M.Sc Thesis submitted to CCS HAU Hisar.

Singh UV, Abhishek A, Singh KP, Dhakate R and Singh NP (2013) Groundwater quality appraisal and its hydrochemical characterization in Ghaziabad (a region of indo-gangetic plain), Uttar Pradesh, India. *Applied Water Science* **4(2)**: 145-157.

Sitender and Rajeshwari (2015) Estimation of ground water resource of Gurgaon district, Haryana. *Journal of Land use and Water Management* **14(1)**: 25-36

Tikkoo A, Yadav SS, Singh S, Sharma SK, Yadav HD, Singh JP and Narwal RP (2010) Sodic water management strategies for crop production in South-west Haryana. Regional Research Station, Bawal and Department of Soil Science, CCS HAU Publication: 1-14.

Tiwari KN and Sharma DN (1989) Report for AICRP on Management of Salt Affected Soils and Poor Quality Waters, CS Azad University of Agricultural and Technology, Kanpur. Soil Salinity Research Institute Karnal

Vijaykant (2016) Assessment of ground water quality of Kaithal and Guhla block of Kaithal district, Haryana-A Case Study. M.Sc. Thesis submitted to CCSHAU, Hisar.

Yadav PK, Jat MK, koo Abha, Yadav SS and Sharma SK (2016) Three decades of using sodic water irrigation in coarse textured soils. *Journal of Applied and Natural Sciences* **8(3)**: 1456-1461.

Received: July 2, 2023; Accepted: August 14, 2023