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Survey and Characterization of Groundwater Quality for Irrigation in Faridabad District of Haryana, India

Ram Prakash[1]*, Dhram Prakash[1], Sanjay Kumar[2], Satyavan[1] and Gourav[3]

[1]Department of Soil Science, CCS Haryana Agricultural University, Hisar-125004, Haryana, India
[2]Department of Soil and Water Engineering, CCS Haryana Agricultural University, Hisar-125004, Haryana, India
[3]College of Agriculture, CCS Haryana Agricultural University, Hisar-125004, Haryana, India
**Corresponding author E-mail: ramsansanwal@gmail.com*

Abstract

A survey was conducted during 2017-18 to evaluate the quality of groundwater of Faridabad, district in, Haryana. Two hundred seventeen water samples were collected and analyzed for various physico-chemical parameters. The pH, EC, SAR and RSC in groundwater ranged from 6.81-9.88, 0.50-9.91(dS m^{-1}), 2.54-20.05 (mmol $L^{-1})^{1/2}$ and 0.00-5.60 (me l^{-1}), respectively. The cations and anions were in the order of $Na^+ > Mg^{2+} > Ca^{2+} > K^+$ and $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-}$, respectively. Of the total samples , 30.9, 34.6, 1.4, 12.4, 12.4, 3.7 and 4.6% were of good, marginally saline, saline, high SAR saline, marginally alkali, alkali and highly alkali category, respectively. Spatial variability maps of EC, SAR and RSC of groundwater used for irrigation in the district were also prepared.

Key words: Cations and anions, Electrical conductivity, Groundwater quality, Highly alkali

Introduction

Assessment of groundwater quality for irrigation is very important in the regions where rain fall is less than 500 mm and cannot meet the requirement for cropping. In modern times, water has critical importance in the economic growth of all contemporary societies (Yadagiri *et al*., 2015). The contamination with various chemical and biological sources and over exploitation had created pressure on groundwater resources (Ramprakash *et al.,* 2018; Singh *et al*., 2017). Underground water is the most important source for irrigation in India, thus deserving significant awareness about its use in agriculture and other sectors. Therefore, survey and characterization of groundwater quality for irrigation is an importance tool in arid and semi-arid regions of the world because poor knowledge about quality of water, farmers used it and ultimately it led to the primary salinization and alkalization of soil. The quality of water can be classified according to its physical, chemical and biological properties have effects on agricultural, industrial and anthropogenic activities. The chemical properties of water is governed by different factor like geological structure, amount and types of salts in soil, the mineralogy of watersheds and the geological processes involved and the chemical reactions which take place in soil (Hamzaoui-Azaza *et al.,* 2011; Etteieb *et al.,* 2017; Pal *et al.,* 2018). In Haryana state, out of total cultivated area of 3.62 mha, 1.24 mha is canal irrigated and 1.65 mha is irrigated by tube wells which often contain water of dubious quality. In the state, 37% of water is of good quality, 8% normal and 55% is of poor quality. The data on quality of water is important for planning and remediating contamination for the agriculture and humans purpose. The continuous monitoring of ground-water resources, thus, plays a major role in sustainable management of water resources. The irrigation quality of water is expressed by the type and amount of dissolved salt (Etteieb *et al.,* 2017). So, for sustainable development of society, groundwater is indispensable, hence the, survey and characterization of groundwater quality in every nook and corner of the country is prerequisite for its better supervision (Rao, 1982). The district is mainly drained by the river Yamuna, which is a perennial. Besides this, a number of

small streams originate from the hill ranges of the central parts of the district, which do not meet any major stream or river but disappear in the permeable deposits of alluvial plains after traversing some distances. The discharge of successful exploratory wells varies between 200 and 6629 lpm (litres per minute) with draw down of 2.39-9.12m. To assess the aquifer parameters, aquifer performance tests were conducted. The transmissivity values in the area vary between 125 and 1645 m^2 day^{-1}. The depth to water level lies between 1.51 to 50.74 m.bgl during pre-monsoon and 0.67 to 49.56 meter below ground level (mbgl) during post-monsoon period. Deeper water level, in the depth range of 10 m to 15 m occurs in the southeastern parts of Ballabgarh and Faridabad blocks. Water level elevation range from 220 to 180 m amsl and the general groundwater flow is towards southeast and east. Isolated groundwater mounds and troughs in different parts of the district have been created because of heavy pumping in city area. In general. water table has declined all over the district over the past decade. So, keeping in view, the present studies on survey and characterization of groundwater quality for irrigation in Faridabad district, were undertaken.

Materials and Methods

Study area

A survey was conducted in Faridabad district in Haryana during 2017-2018 to evaluate the quality of groundwater for irrigation for different crops. Faridabad district is located on south eastern part of Haryana state and lies between 27°39′ and 28°31′ north latitude and 76°40′ and 77°32′ east longitudes. In the north, it is bordered by the Union Territory of Delhi, in the east by Uttar Pradesh, in the North-West by Mewat, and in the west by Gurgaon districts. Total geo-graphical area of the district is 2151 sq. km. Faridabad district is divided into two Blocks, namely, Faridabad and Ballabgarh. The climate of Faridabad district can be classified as tropical steppe, semiarid and hot which is mainly characterized by the extreme dryness of the air except during monsoon months. During three months of south-west monsoon from last week of June to September, the moist air of oceanic penetrates into the district and causes high humidity, cloudiness and monsoon rainfall. The period from October to December constitutes post-monsoon season. The cold weather season prevails from January to the beginning of March and followed by the hot weather or summer season which prevails up to the last week of June. The normal annual rainfall in Faridabad district is about 542 mm spread over 27 days. The south west monsoon sets in the last week of June and withdraws towards the end of September and contributes about 85% of the annual rainfall. Soils of Faridabad district are classified as tropical and brown soils, existing in major parts of the district. The organic content is 0.2 to 0.4 percent and falls in low category.

In order to assess water quality of the study area a total 217 water samples were collected from two blocks of Faridabad district from crop growing areas from running tube wells and their locations were recorded and the map is presented in (Fig. 1).

The samples were collected in thoroughly cleaned, properly labeled and carefully corked plastic bottles. Before collection of water in a particular bottle, the bottle was rinsed thoroughly with the respective samples of groundwater and immediately after collection the samples were transferred to laboratory for chemical analysis. The chemical analysis was accomplished at CCS Haryana Agricultural University, Hisar, India as per the standard methods relevant to analysis of groundwater as described by Richards (1954). Electrical conductivity (EC) was measured by conductivity meter and pH by digital pH meter. Sodium (Na^+) and potassium were measured by flame photometer. Calcium and magnesium were determined with standard EDTA solution titrimetrically. Carbonate and bicarbonate were estimated by titration with H_2SO_4, Chloride by titrating against standard silver nitrate ($AgNO_3$) solution. The colorimetric analysis of sulphate was done by spectrophotometer. Measurements were done in triplicate to ensure reliability and good quality control. Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC) are calculated as:

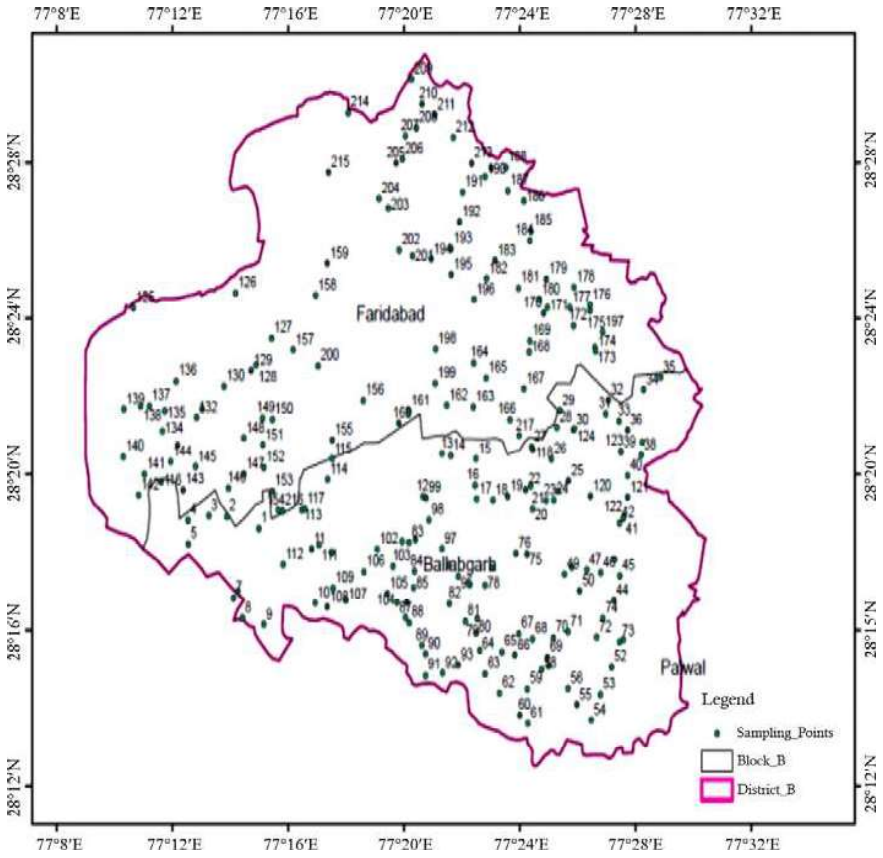

Fig. 1 Location map of the sampling points in Faridabad district

a) Sodium adsorption ratio (SAR) {Richards, 1954}

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

b) Residual sodium carbonate (RSC) (Eaton, 1950):

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

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.

Results and Discussion

The pH is important parameter for determining acidity, neutrality or alkalinity of water. The pH of collected groundwater samples was in the range of 6.81- 9.88 with the mean value of 7.82. Variation in electrical conductivity reflects the variation of total soluble salt concentration and ultimately the salinity of the groundwater samples. The electrical conductivity ranged from 0.50 to 9.91dS m^{-1} with a mean of 2.57 dS m^{-1} (Table 1). To study the spatial distribution of EC in the whole district, a spatial variable map was prepared by using ArcGIS through the interpolation of the

Table 1 Range and mean of different water quality parameters for Faridabad district

Sr. No.	Quality parameters	Range	Mean
1	pH	6.81-9.88	7.82
2	EC (dS m^{-1})	0.50-9.91	2.57
3	RSC (me l^{-1})	0.00-5.60	0.95
4	SAR (mmol $L^{-1})^{1/2}$	2.54-20.05	7.76
5	Ca^{2+} (me l^{-1})	5.50-8.10	2.09
6	Mg^{2+} (me l^{-1})	1.50-26.10	6.16
7	Na^{+} (me l^{-1})	2.60-63.20	16.35
8	K^{+} (me l^{-1})	0.06-3.14	0.27
9	CO_3^{2-} (me l^{-1})	0.00-6.40	1.47
10	HCO_3^{-} (me l^{-1})	0.20-15.20	5.03
11	Cl^{-} (me l^{-1})	1.90-68.00	12.95
12	SO_4^{2-} (me l^{-1})	0.20-31.40	4.47

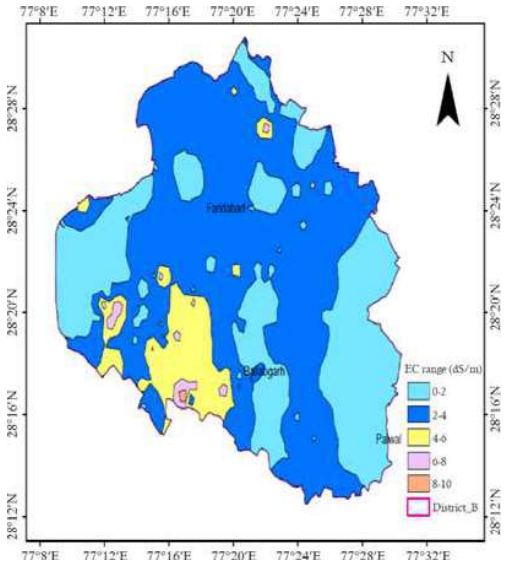

Fig. 2 Spatial variability of EC

available data at 217 sampling points (Fig.2). The EC classes were grouped into five different classes with an interval of two units. The percent distribution of samples in different EC classes is shown in Table 2. The number of samples in different EC classes is different, and the highest samples (103) were found in EC class of 0-2 dS m^{-1} and its lowest number of sample (1) was found in EC class 8-10 dS m^{-1}. In EC range of 0-4 dS m^{-1}, there were 188 water samples which is nearly an indication of good quality groundwater according to AICRP criteria on the basis EC only. Pal *et al*. (2018) reported that the mean chemical composition and related quality parameters in different EC classes of Firozpur–Jhirka block in Mewat district and percent distribution of sample in different EC classes.

In case of anions, chloride was the dominant anion with maximum the concentration of chlorides in groundwater samples varied from 1.90 to 68.0 me l^{-1} with the mean value of 12.95 me l^{-1}. The concentration of bicarbonates in groundwater samples varied from 0.20 to 15.20 me l^{-1} with a mean value of 5.03 me l^{-1}. The mean values for CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} were found to be 1.47, 5.03, 12.95 and 4.47 me l^{-1}, respectively (Table 1). Table 2 illustrate the mean of anions according to the EC classes in district, the Cl^- was the highest and its value increased with the increase in EC.

The concentration of sodium in groundwater samples varied from 2.60 to 63.20 me l^{-1} with an average value of 16.35 me l^{-1} (Table 1), followed by magnesium (1.50 to 26.10 me l^{-1}) and calcium (5.50 to 8.10 me l^{-1}). Mean values for Na^+, Mg^{2+}, Ca^{2+} and K^+ were 16.35, 6.16, 2.09 and 0.27me l^{-1}, respectively. Table 2 illustrates the mean of cation according to the different EC classes in Faridabad district, Na^+ was the highest and its value increased with the increase in EC. Its lowest mean value (8.78 me l^{-1}) was found in the class 0-2, the highest mean value (63.20 me l^{-1}) was laid in the EC class of 8-10 dS m^{-1}. Likewise sodium(Na^+) Calcium (Ca^{+2}) and magnisium value also increased with the increase in EC. The values of anions CO_3^{2-}, HCO_3^-, Cl^- and SO_4^{2-} also increased with the increase in EC in Faridabad district (Table 2).

The order of abundance of cations and anions in Faridabad district was $Na^+ > Mg^{+2} > Ca^{+2} > K^+$ and anions were $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-}$ same results was observed by Singh *et al*. (2017) in Gulha Block of Kaithal district. Rathi *et al*. (2018) analyzed groundwater quality of Kalayat Block of Kaithal district and reported that the order of abundance of cations was $Na^+ > Mg^{+2} > Ca^{+2} > K^+$ and those of the anions were $Cl^- > SO_4^{2-} > HCO_3^- > CO_3^{2-}$. The high concentration of sodium may be attributed to a base –exchange reaction and leaching of sodium salt like halite during the movement of water through sediments (Etteieb *et*

Table 2. Chemical composition of groundwater samples of Faridabad district in different EC classes

EC classes (dS m^{-1})	No. of samples	Na^+	Ca^{2+}	Mg^{2+}	K^+	CO_3^{-2} (me l^{-1})	HCO_3^-	Cl^-	SO_4^{-2}	RSC	SAR (mmol $L^{-1})^{1/2}$
0-2	103	8.78	1.19	3.41	0.22	1.20	4.04	5.60	1.73	1.37	5.78
2-4	85	17.76	2.40	7.11	0.30	1.64	5.82	14.65	4.53	0.71	8.25
4-6	17	32.51	3.96	11.31	0.31	1.79	5.66	29.78	9.86	0.13	11.98
6-8	11	47.08	4.89	14.74	0.32	2.18	6.78	37.62	20.14	0.16	15.23
8-10	01	63.20	8.10	26.10	0.53	2.30	10.50	68.00	16.80	0.00	15.28

al., 2017). The magnesium is commonly found in ferro-magnisum minerals in igneous rocks and as carbonate in sedimentary rocks (Sridharan and Nathan, 2017). The lower concentration of potassium in groundwater samples may be ascribed to its tendancey to be fixed by clay minerals and to participate in the formation of secondary minerals (Jalali, 2010).

Sodium adsorption ratio (SAR)

SAR ranged from 2.54 to 20.05 (mmol $L^{-1})^{1/2}$ with a mean of 7.76 (mmol $L^{-1})^{1/2}$ (Table 1). Out of 217 water samples, maximum (203) water samples were found of good quality i.e SAR<15 (mmol $L^{-1})^{1/2}$ and only 12 samples were found in sodic range i.e SAR>15 (mmol $L^{-1})^{1/2}$. In (Table 2) SAR also showed increasing trend. Bhat *et al.* (2016) reported that according to Richards classification of SAR 50.6%, 44.4% and 4% samples belonged to the excellent, good and doubtful category, respectively in the area of their study. The spatial variability map of SAR of groundwater in Faridabad is given in (Fig. 3). Ramprakash *et al.* (2018) reported that SAR varied from 1.74-53.08 (mmol $L^{-1})^{1/2}$ in groundwater of Fatehabad district in Haryana.

Residual Sodium Carbonate (RSC)

For agricultural purposes, residual sodium carbonate (RSC) is usually used to evaluate the deleterious effect of carbonate and bicarbonate on the quality of water. The residual sodium carbonate was recorded from 0.00 to 5.60 me l^{-1} with a mean of 0.95 me l^{-1} (Table 2). The spatial variability of RSC of groundwater in Faridabad district is given in Fig. 4. Out of 217 water samples maximum samples were found in low water class good quality and safe for irrigation (Fig. 5). Bhat *et al.* (2016) reported that 58% samples were of good quality and safe for irrigation, 4.9% were classified as permissible and 37% samples were found unsuitable for irrigation.

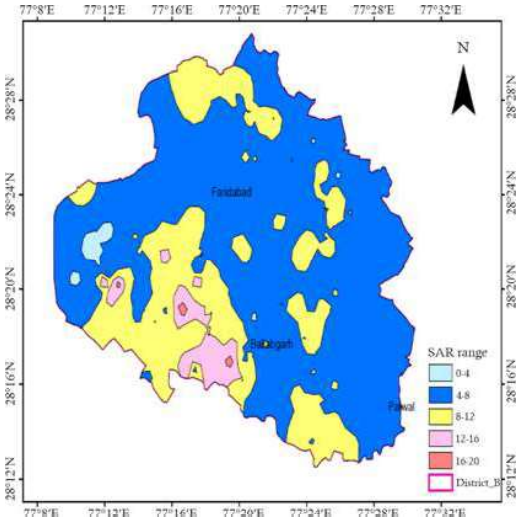

Fig. 3 Spatial variable map of SAR

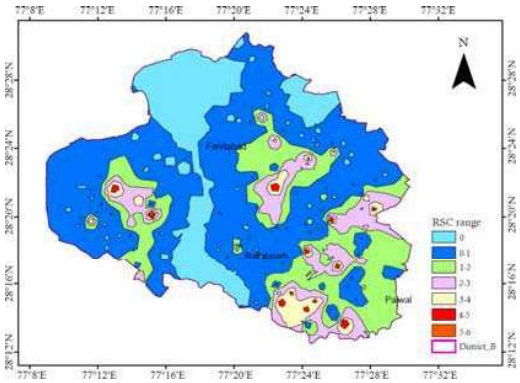

Fig. 4 Spatial variable map of RSC

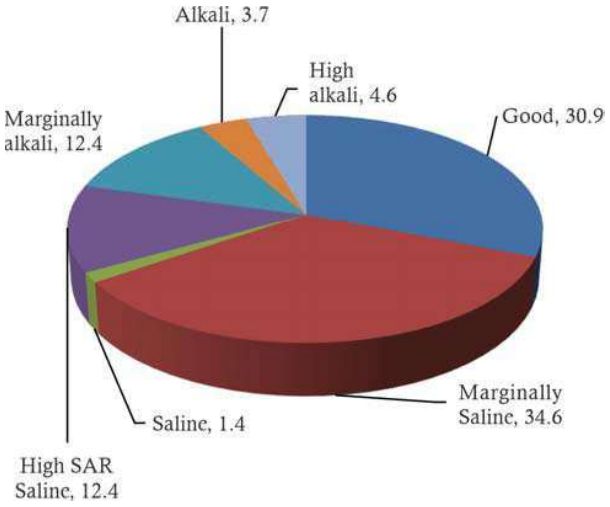

Fig. 5 Quality of groundwater (percent)

According to AICRP classification, it was found that 30.9 percent samples were of good quality, 48.4 percent saline and 20.7 percent alkali in nature (Fig. 5). Out of the saline water, 34.6, 1.4 and 12.4 percent were in marginally saline, saline and high SAR saline, respectively. In alkali group 12.4, 3.7 and 4.6 percent were in marginally alkali, alkali and high alkali, respectively. Out of seven categories of water, maximum 34.6percent

of samples were found in marginally saline followed by good quality (30.6 percent) and minimum 1.4 percent were found in saline category.

Conclusion

The dominance of major cations were in the order of $Na^{+} > Mg^{+2} > Ca^{+2} > K^{+}$ and the anions were in order of $Cl^{-} > HCO_3^{-} > SO_4^{2-} > CO_3^{2-}$. Therefore, the chemical composition of the groundwater was characterized by the Na–Cl water type. It was found that 30.9 percent samples were of good quality, 48.4 percent saline and 20.7 percent alkali in nature. Therefore, the groundwater should be blended with canal water before irrigation which implies that regular monitoring of groundwater is imperative to avoid major environmental threat. The spatial distri-bution maps generated for various physico-chemical parameters using GIS techniques could be valuable for policy makers for initiating groundwater quality monitoring in the area.

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