Evaluation of Groundwater Quality for Irrigation Purpose in Bhiwani District, Haryana

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Abstract – Groundwater is major source of irrigation in Bhiwani district because of low rainfall and poor canal system. The quality of groundwater is deteriorating continuously throughout India. So, for the sustenance of agriculture in the region, groundwater was assessed for its suitability for irrigation purpose. The groundwater samples collected from various sites of district were analyzed for various physico-chemical parameters viz hydrogen ions concentration, electrical conductivity, carbonates, bi-carbonates, chlorides, fluorides, nitrates, sulphates, phosphates, sodium, potassium, calcium, magnesium ions etc. Concentration of sodium has been found above exceeding limits in 50% of samples followed by concentrations of magnesium (28), calcium and chlorides (6%). On the bases of electrical conductivity, sodium adsorption ratio and residual sodium carbonate estimation; 22, 11 and 28 percent samples were found under high or very high categories unsuitable for irrigation in the district. Results of present study indicate that quality of groundwater is deteriorating in the district and recommend immediate measures to prevent its further deterioration.

Keywords: Groundwater, Irrigation, Physico-Chemical Analysis, Suitability

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INTRODUCTION

Groundwater is an economic natural resource constituting approx. 30% of world's fresh water reservoirs and playing critical role for survival of human beings. It has been estimated that groundwater is used for drinking purpose by approx. one third population of the world. In addition to the rural households and public water supplies, farmers too use groundwater for irrigation purpose and their animals. It has played important role in success of green revolution for achieving food security in India. Presently, more than 50% of irrigated area in the country is dependent on groundwater. This overexploitation of groundwater resource for the increasing demands of irrigation, domestic consumption and industrial water supply has led to the permanent lowering of groundwater levels. Further, extensive use of pesticides and chemical fertilizers to increase the per acre yield from agriculture, intrusion of brackish water into the fresh water, seepage of domestic and industrial effluents, mixing of un-treated effluents, lack of strict regulations and improper management strategies have resulted in contamination of this precious resource in different parts of the country (Gautam et al., 2013; Vasanthavigar et al., 2012). The deterioration in quality of groundwater due to human activities (exponential population growth, industrialization, urbanization etc) has become a major issue during recent period (Brindha and Elango, 2010). The situation has become more critical in arid and semi-arid regions of world due to problem of water scarcity.

The quality of groundwater is determined by analyzing various physico-chemical parameters as hydrogen ion concentration (pH), electrical conductivity (EC), carbonates, bi-carbonates, chlorides, fluorides, nitrates, sulphates, phosphates, sodium, potassium, calcium, magnesium ions etc. and estimating different ratios as % sodium, sodium adsorption ratio (SAR), residual sodium carbonate (RSC), Wilcox diagram and Kelly index (Elangovan and Rani, 2017). Various studies on qualitative analysis of groundwater for irrigation as well as drinking purposes have been conducted in different parts of India and abroad indicating alarming situations of groundwater (Elangovan and Rani, 2017; Li et al., 2011; Rout and Attree, 2016; Saleem et al., 2016). The excessive irrigation due to intensive agriculture practices has led to salinization and alkalinisation of groundwater. This problem of groundwater alkalinity and salinity is increasing in many districts of Haryana. The extent of alkalinity is maximum in Jind, Bhiwani, Sonipat and Karnal districts. About two third of Haryana (major parts of Rohtak, Jhajjar, Bhiwani and Sonipat districts) is underlain by saline and alkali (high residual sodium carbonate) groundwater. Moreover, lack of canal network and complete dependence on groundwater in Bhiwani district has further exaggerated the problem. From the perspective of twin problems of high salinity and high alkalinity, Bhiwani is among the worst affected districts of state. So, the present study is aimed to analyze the physico-chemical parameters for qualitative assessment of groundwater for irrigation purpose in Bhiwani district.

STUDY AREA

Bhiwani is south-western district of Haryana situated between 28.19° & 29.05° N latitude and 75.26° & 76.28° E longitude. It was the largest district of state by area before the creation of Charkhi Dadri as 22nd district (on 4 December 2016; however study was conducted before the creation of new district). The district has 5140 km^2 geographical area with 4 divisions, 5 tehsils and 444 villages. It is a landlocked district surrounded by Hisar in North, Rohtak in North-east, Jhajjar in East, Mahendragarh & Rewari in South and Rajasthan state in Southwest. Geologically, Bhiwani district has flat plains with clusters of sand dunes in western parts and rocky ridges. The district has very less natural flowing water and Dohan river is the only stream in this region which ultimately dies in sands. Climate of the district is classified as tropical steppe, semi arid and hot. Annual rainfall in the district is 420 mm with uneven distribution throughout the area and occurs mainly in monsoon season (July-September). Location map of the study area is shown in figure 1.

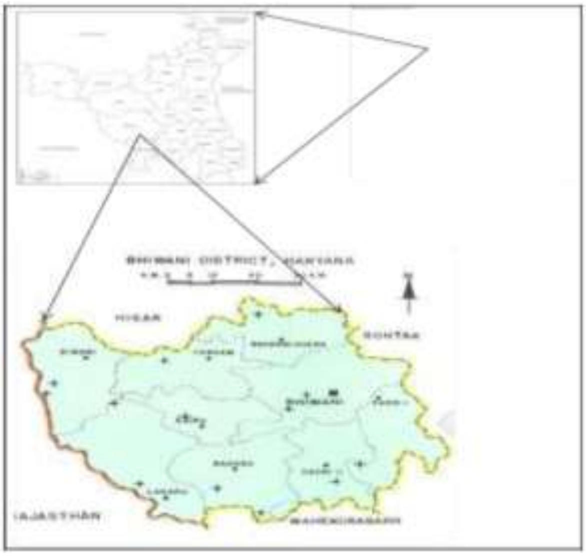

Figure 1 Location map of study area

MATERIALS AND METHODOLOGY

Sample collection: Water samples were collected from eighteen hydrological stations of Bhiwani district developed by Central groundwater board during the period of March-June 2017 (table 1). The samples were collected in the polyethylene bottles having capacity of 1 litre.

Table 1 Site of hydrological stations

S.N.	Block	Site Name	Well No.	S.N.	Block	Site name	Well No.
1	Badhra	Gopi	1	5	Dadri-II	Chiriya	10
2	Bawani khera	Sui	2			Naya Atela	11
3	Bhiwani	Badala	3	6	Kairu	Jui kalan	12
		Bohal	4			Lohani	13
		Dhanana	5	7	Loharu	Jhumpa	14
		Haluwas	6	8	Siwani	Gurera	15
4	Dadri-I	Baund kalan	7			Siwani	16
		Imlota	8	9	Tosham	Miran	17
		Sanwar	9			Tosham	18

Methodology: The water samples collected from various hydrological stations were analysed using field water testing kit. The physico-chemical analysis included pH, electrical conductivity (EC), carbonates (CO_3^{2-}), bi-carbonates (HCO_3^-), chlorides (Cl^-), fluorides (F^-), nitrates (NO_3^-), sulphates (SO_4^{2-}), phosphates (PO_4^{3+}), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^+), ions (ions are measured in concentration of mg/l) following standard procedures (APHA, 1998). Sodium adsorption ratio (SAR) and Residual sodium carbonate (RSC) have been calculated using following formulas:

i) $SAR = Na^+/ (Ca^{2+} + Mg^{2+}/2)^{1/2}$ (Eaton, 1950; All conc. used in meq/l)

ii) $RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$ (Richards, 1954; All conc. used in meq/l)

RESULTS AND DISCUSSION

Chemical analysis

Groundwater quality analysis is essential to estimate its suitability for various purposes viz drinking, irrigation, and industrial. For the production of crops efficiently, good quality water must be used for irrigation. Irrigation by poor quality groundwater can adversely affect the crop production as well as soil features. pH was measured in units, EC in µS/cm and all ions were estimated in mg/l. Comprehensive values of various parameters analyzed for water quality are pH: 7-9.1, EC 578-5815 µS/cm, CO_3^{2-}: 0-88 mg/l, HCO_3^-: 86-620 mg/l, Cl^-: 28-1283 mg/l, F^-: 0.56-13 mg/l, NO_3^-: 0.66-212 mg/l, SO_4^{2-}: 8-1072 mg/l, PO_4^{3-}: 0.01-0.5 mg/l, Na^+: 58-1263 mg/l, K^+: 1.8-89 mg/l, Ca^{2+}: 10-244 mg/l and Mg^{2+}: 18-409 mg/l. The detailed values of all parameters are shown in table 2. Major anions have been found in order as $Cl^- > SO_4^{2-} > HCO_3^- > NO_3^-$ and cations in order $Na^+ > Mg^{2+} > Ca^{2+} > K^+$.

Table 2 Physico-chemical parameters of groundwater samples in Bhiwani district

Sr. No.	Chemical analysis of groundwater samples												
	pH	EC	CO_3	HCO_3	Cl	F	NO_3	SO_4	PO_4	Na	K	Ca	Mg
1	9.1	2362	52	620	472	12.4	188	398	0.01	464	7	16	18
2	8.3	5310	12	114	880	1.67	12.6	215	0.05	444	85	40	409
3	7.8	2480	38	256	116	8.9	66	67	0.02	255	3	38	46
4	8.8	578	17	271	46	4.0	0.66	288	0.14	68	6	114	102
5	7.5	3700	0	112	224	0.32	25	8	0.07	634	7	182	149
6	7.0	2342	62	827	278	0.68	0.92	199	0.33	688	4	10	96
7	7.9	1702	0	86	390	3.2	18	1072	0.01	126	49	134	70
8	8.0	775	8.5	223	82	6.0	33	786	0.5	166	16	76	23
9	8.2	885	0	252	344	1.58	212	441	0.03	78	4.6	28	29
10	7.8	1330	40	534	48	4.34	118	66	0.03	58	9	18	156
11	7.5	1710	34	442	164	2.0	0.69	935	0.09	244	33	42	23
12	8.9	5815	16	486	1283	0.06	17	562	0.05	1263	6.8	118	178
13	8.2	1778	14	370	540	0.08	2.8	476	0.13	72	89	86	49
14	7.7	1424	58	516	28	2.9	48	23	0.11	300	1.8	54	30
15	7.0	4200	80	546	320	4.8	167	92	0.07	868	5.6	60	58
16	7.6	724	0	160	81	13.0	37	614	0.06	170	9	40	33
17	8.8	1665	14	265	134	9.4	4	12	0.02	133	2.5	82	90
18	9.0	1942	88	196	99	0.56	0.83	18	0.3	84	16	244	76
Min.	7.0	578	0	86	28	0.56	0.66	8	0.01	58	1.8	10	18
Max.	9.1	5815	88	620	1283	13.0	212	1072	0.5	1263	89	244	409

As per the guidelines of BIS (1998), 50% samples on basis of sodium, 28% samples on basis of pH & magnesium and 6% samples on basis of chlorides & calcium have higher concentrations than permissible values for irrigation (table 3).

Table 3 Percent wells exceeding permissible values for irrigation purpose

S.N.	Parameter	BIS limit (1998)	% Samples exceeding permissible values
1	pH	6.5-8.5	28
2	Chloride	1000 (mg/l)	6
3	Sodium	200 (mg/l)	50
4	Magnesium	100 (mg/l)	28
5	Calcium	200 (mg/l)	6

Suitability of groundwater for irrigation purposes

Groundwater used for irrigation must be suitable otherwise it may be hazardous for crops and soil. For the assessment of quality of groundwater suitability for irrigation purpose, among various parameters EC, SAR and RSC are most commonly used. SAR and RSC were calculated using formulas where ionic concentrations were used in meq/l. The values of SAR in groundwater samples ranged from 1.0 to 19.2 and RSC values ranged from -33.8 to 9.6 (table 4).

Table 4 Calculated values of SAR and RSC

Sample No.	SAR	RSC
1	18.9	9.6
2	4.6	-33.8
3	6.6	-0.27
4	1.1	-9.19
5	8.4	-19.68
6	14.6	7.12
7	1.7	-5.12
8	4.3	-1.78
9	2.5	0.31
10	1.0	-3.81
11	7.5	4.36
12	17.1	-12.23
13	1.5	-1.85
14	8.1	5.19
15	19.2	3.78
16	4.8	-2.13
17	2.4	-6.29
18	1.2	-12.39

Electrical conductivity: EC is good indicator of total salinity as it is the measure of quantity of dissolved solids. It is used to assess the ability of water to conduct electric current. EC depends on various cations (sodium, calcium, magnesium etc) and anions (chlorides, nitrates, sulphates etc) dissolved in water. Higher EC in water decrease the productivity of crop as less water available to plants. The standards of EC water suitability for irrigation purposes and samples falling in categories are shown in table 5. Among the total samples, 22 % (four) samples fall in high EC category which are not suitable for irrigation, while 78% samples were in low and medium category and suitable for irrigation of crops.

Table 5 Groundwater quality classification on the basis of EC

Parameter	Reference	Range (µS/cm)	Category	Samples
EC	IS 11624 (BIS, 1986)	< 1500	Low	6 (33)*
		1500-3000	Medium	8 (45)
		3000-6000	High	4 (22)
		> 6000	Very high	0 (0)

* Values in parentheses are percent values

Sodium adsorption ratio: SAR is considered as primary indicator for assessing the quality of groundwater for irrigation purpose. It evaluates the concentration of sodium along with calcium and magnesium in water. Irrigation with groundwater having high SAR leads to increased %Na^+ in soil causing decreased infiltration and percolation rates. It can also lead to poor aeration in soil causing adverse effects on seedlings (Lesch and Suarez, 2009). SAR can also be calculated by using SAR Calculator developed by Oklahoma State University Turfgrass Science. On the basis of SAR, 89% water samples were suitable for irrigation purpose and fall under low and medium categories; however, 11% samples have high SAR (table 6).

Table 6 Groundwater quality classification on the basis of SAR

Parameter	Reference	Range	Category	Samples
SAR	IS: 11624 (BIS, 1986)	<10	Low	14 (78)*
		10-18	Medium	2 (11)
		18-26	High	2 (11)
		>26	Very high	0 (0)

* Values in parentheses are percent values

Residual sodium carbonate: This parameter is an index of sodicity hazards analysis and indicates concentrations of carbonates and bi-carbonates in water. When soil solution becomes concentrated due to high Na^+; Ca^{2+} and Mg^{2+} precipitate as carbonates and bi-carbonates. It is also known as Eaton's index. On the basis of RSC, 72 % samples were of excellent quality for groundwater irrigation purposes, however, 28% samples were of bad quality falling in high and very high category of RSC unsuitable for irrigation (table 7).

Table 7 Groundwater quality classification on the basis of RSC

Parameter	Reference	Range	Category	Samples
RSC	IS: 11624 (BIS, 1986)	<1.5	Low	13 (72)*
		1.5-3.0	Medium	0 (0)
		3.0-6.0	High	3 (17)
		> 6.0	Very high	2 (11)

* Values in parentheses are percent values

The quality of groundwater varies due to types of dissolved salts and their concentrations in the water. So, qualitative analysis carried out not only on the basis of EC but combination of parameters viz EC, RSC, and SAR. 22, 11 and 28% samples from different sites of the district were found in high and very high concentration categories on the bases of EC, SAR and RSC respectively (Figure 2).

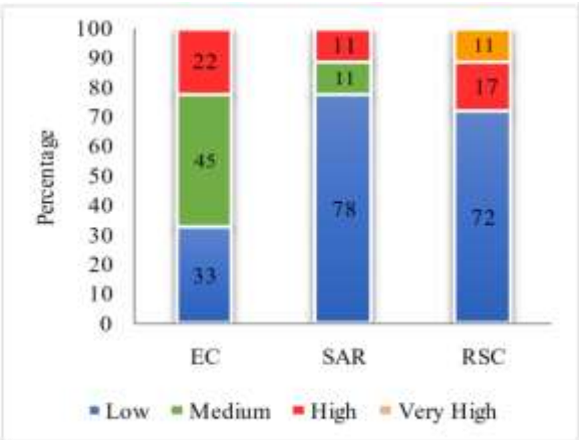

Figure 2 Groundwater quality classifications following irrigation standards

Shah and Mistry (2013) evaluated the quality of groundwater in Vadodara district of Gujarat for irrigation suitability on the basis of EC, SAR, Kelly ratio, and soluble sodium % and reported that 50% samples were unsuitable for the purpose of irrigation in the district. Similarly, Elangovan and Rani (2017) have studied the groundwater suitability for irrigation purpose in Parambikulum Aliyar project area and reported % sodium in 10%, EC in 20% and RSC in 7.5% samples exceeding the permissible levels for irrigation purpose. Various other workers have also studied groundwater quality using % sodium, EC, SAR and RSC as major parameters of qualitative assessment and reported alarming results of unsuitable water usage continuously for irrigation in the respective regions (Jalali, 2006; kumar et al., 2009; Wasim et al., 2014).

Salinity and alkalinity problems in agricultural lands are increasing worldwide mainly because of agriculture intensification for short term benefits; however the use of saline waters for irrigation may cause severe hazards to the crops as well as soil in long terms. With the implementation of strict regulations and laws of groundwater usage & monitoring, efficient treatment of industrial and municipal effluents, controlled usage of fertilizers and adopting alternative irrigation methods, this problem can be controlled and prevented.

CONCLUSION

The quality of groundwater in Bhiwani district for irrigation purpose has been studied in the present paper as groundwater is the main source of irrigation in the district due to lack of sufficient canal system. Water samples collected from different sites were analyzed for various physico-chemical parameters and assessed using standard values for irrigation purpose. Concentration of sodium has been found above exceeding limits in 50% of samples followed by concentrations of magnesium (28), calcium and chlorides (6%). On the bases of electrical conductivity, sodium adsorption ratio and residual sodium carbonate estimation; 22, 11 and 28 percent samples were found under high or very high categories unsuitable for irrigation in the district. Further, it was recommended to prevent judicious use, municipal & industrial effluents mixing and specific treatment of soil while using poor quality of groundwater for irrigation purpose.

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