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Atin Kumar
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

Satendra Kumar
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

BP Dhyani
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

Ashok Kumar
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

UP Shahi
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

Vivek
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Rohit Kumar
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

DV Dubey
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Correspondence
Atin Kumar
Department of Soil Science and Agricultural Chemistry Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Utter Pradesh, India

Assessment of underground water quality for drinking and irrigation purpose on west side of the Ganga canal command area in Meerut district of Uttar Pradesh, India

Atin Kumar, Satendra Kumar, BP Dhyani, Ashok Kumar, UP Shahi, Vivek, Rohit Kumar and DV Dubey

Abstract
The present study focused on the hydrochemistry of underground water in some location of NCR region near west side of Ganga canal command area to assess the quality of underground water's suitability for drinking and irrigation purpose. A total of 25 underground water samples of hand pump and tube wells were collected from Nagla order, Nanu, Pooth Khas, Bhola Jhal and Jani locations during April 2017 and analyzed for pH, Electrical conductivity (EC), total dissolved salts (TDS), major cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+), major anions (CO_3^{2-}, HCO_3^-, Cl^-, NO_3^- and SO_4^{2-}), Collin's ratio, Kelly's ratio, SAR and RSC. pH of the analyzed samples indicates alkaline nature of the water samples. Parameters like sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and Kelly's ratio were calculated and plotted to understand the quality of underground water for irrigation uses. The calculated parameters show that the majority of the underground water samples are suitable for drinking as well as irrigation purposes. However, high salinity values at few locations restrict the suitability of the water for drinking purposes.

Keywords: Ganga canal command water drinking, irrigation purpose

1. Introduction

Water is a vital source of life which is extremely essential for survival of all living organisms. Life is not possible on this planet without water. About 97.2% of water on earth is salty and only 2.8% is present as fresh water from which about 20% constitutes groundwater Devi and Belagali (2006) [4]. Groundwater is one of the major sources of drinking water in both urban and rural India and the quality comprises the physical, chemical, and biological properties of ground water. After air, potable water is second essential need for existing of human life on this planet Earth. Life itself originates in ocean water about 3.2 billion years ago. Groundwater, which makes up about 20% of the world's fresh water supply, is about 0.61% of the entire world's water, so it is most important sources of potable water throughout the world Khanam and Singh (2014) [11]. The importance of groundwater as a valuable source of potable water cannot be overemphasized. It forms one of the most important natural resources and complement surface sources in the provision of potable water for domestic and industrial applications. Unfortunately, the quality of groundwater has been impaired by indiscriminate dumping of solid waste materials in landfill within the municipality with attended risk to the health of the people and damage to the environment. Industrial development and uncontrolled increase of rural-urban migration that lead to growth of the urban population have resulted in an increase in the production of different types of wastes ranging from industrial to municipal, which have adverse effects on human population via groundwater quality. Solid wastes are defined to be useless and unwanted materials arising from human activities that are not free floating WHO (1971) [25].

2. Study area

The study area occupies an area of about 2522 km^2 and lies between 28° 57′ to 29° 02′ N latitude and 77° 40′ to 77° 45′ E longitude. The area has a total population of over 3 million. The study area is a part of Indo-Gangetic plains.

The two important rivers of the area are Yamuna and Hindon, which flow from north to south. The river Ganga and the river Yamuna form the eastern and the western boundaries of the area. The most common groundwater structures in the area are shallow and deep tube wells. Water requirement of this area is mainly met from groundwater. The maximum temperature is recorded to be 44°C and 32°C and minimum 17°C and 4°C in summer and winter seasons, respectively. The average annual rainfall of the study area is around 748.9 mm.

3. Sampling and analytical Methodology

Underground water samples from 5 locations of the study area were collected in a Polyethylene Terephthalate (PET) bottles (1 L capacity) in the month of April 2017. The bottles were conditioned by washing with 5 % nitric acid and then rinsed several times with distilled water. This was carried out to ensure that the sampling bottles were free from contaminants. Before collecting the water samples, the water was pumped out from bore wells for about 30 minutes to remove stagnant groundwater. The samples location was labeled on bottle. The date and time of sampling were recorded. All samples were stored at 4°C. At every location and depth one water sample was collected. Total 25 water samples from 5 locations were collected for their chemical properties. The qualitative chemical analysis was carried out at the laboratory of department of Soil Science and Agricultural Chemistry, S.V.P.U.A&T, Meerut (U.P).

The physico-chemical parameters analyzed include: pH, EC, TDS, cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, NO_3^{-} and SO_4^{2-}). The pH and EC were analyzed using pH and EC meter. Ca^{2+} and Mg^{2+} were determined by titrimetrically using standard EDTA. Na^{+} and K^{+} were determined by flame photometry using flame photometer. CO_3^{2-} and HCO_3^{-} level were measured by titration. Cl^{-} by standard $AgNO_3$ titration and Sulphate was determined by spectrophotometer. Nitrate was measured by colorimetric method. All the results obtained were compared with the Bureau of Indian Standard (BIS) and World Health Organization (WHO) for drinking water quality. The chemical data of underground water samples are subjected to compute the ionic-balance-error between the total concentration of cations (Ca^{2+}, Mg^{2+}, Na^{+} and K) and total concentration of anions (CO_3^{2-}, HCO_3^{-}, Cl^{-}, NO_3^{-} and SO_4^{2}) for testing accuracy of chemical analysis of each underground water samples, before the interpretation of the chemical data is undertaken. The value of the ionic-balance-error is observed to be within the desirable limit of ± 5% (Domenico and Schwartz, 1990).

Electro neutrality (%) = [total cations + total anions / total cations − total anions] ∗ 100

Statistical analysis was applied for water characteristics and mean was calculated using SPSS application program and detect the significant difference for chemical characteristics. In order to find the relationship between two parameters x and y, the Karl Pearson's correlation coefficient, r is used and it is determined as follows:

$$r = \frac{n\sum xy - \sum x\sum y}{\sqrt{([n\sum x^2) - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where, n = number of data points; x = value of x-variable; y = values of y-variable.

4. Results and Discussion

A comparison of physico-chemical parameters of water samples with desirable limits of BIS and WHO standards are summarized in Table 1.

Table 1: Physico-chemical parameters of water samples with desirable limits of BIS and WHO standards

S. No.	Parameters	Desirable limit		Observed values					
		BIS	WHO	Nagla Order	Nanu	Pooth Khas	Bhola Jhal	Jani	Mean
1	pH	6.5-8.5	6.5-9.2	7.47	7.64	7.58	7.73	7.71	7.63
2	EC	1	0.25	0.64	0.70	0.70	0.78	0.75	0.71
3	TDS	-	450	412.16	449.28	446.72	496.64	481.28	457.22
4	Ca^{2+}	75	75	49.85	52.71	53.91	57.28	56.55	54.06
5	Mg^{2+}	30	50	21.15	23.32	22.94	26.00	24.91	23.66
6	Na^{+}	200	200	42.92	52.61	46.74	52.61	50.98	49.17
7	K^{+}	10	-	4.94	5.56	5.24	6.04	5.70	5.50
8	CO_3^{2-}	-	-	-	3.0	9.0	9.0	15.0	9.0
9	HCO_3^{-}	200	200	171.6	201.2	190.2	207.8	204.4	195.04
10	Cl^{-}	250	250	97.61	127.79	120.38	123.77	123.94	118.70
11	NO_3^{-}	45	50	1.10	0.81	0.68	0.74	1.28	0.92
12	SO_4^{2-}	400	500	16.66	16.08	16.28	14.69	15.56	15.85

Note: All values in mg L^{-1} except pH and EC (dSm^{-1}).

4.1 pH of water

pH is one of the important parameter of water whose determination facilitates a quick evaluation of acidic and alkaline nature of water. The pH of the underground water in the study area has been presented in Table 2. Minimum of 7.19 and maximum of 8.13 with a mean of 7.63 pH values of water sample were found in study area. The maximum pH was observed in Bhola Jhal location at 1000 m away from canal and minimum in Nanu location at 3000 m away from canal. The standard value of pH for drinking water as per BIS is between 6.5 to 8.5 and accordingly 100% analyzed samples fall within the maximum permissible limit of BIS and WHO and could be classified as suitable for drinking purpose. The similar findings were also made by Krishan *et al.* (2016) [12] and Dev and Bali (2018) [3].

Table 2: pH of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	7.64	7.38	7.62	7.30	7.41
2	Nanu	8.10	7.52	7.19	8.06	7.32
3	Pooth Khas	7.57	7.56	7.47	7.82	7.49
4	Bhola Jhal	8.13	7.59	7.61	7.76	7.55
5	Jani	7.69	8.10	7.70	7.58	7.48

4.2 EC of water

The electrical conductivity of the underground water in the study areas has been presented in Table 3. The EC value of water samples in the study area ranged from a minimum value of 0.53 to maximum 1.00 dSm^{-1} with a mean of 0.71 dSm^{-1}. The maximum salinity was recorded in Bhola Jhal location (1.00 dSm^{-1}) at 1000 m away from canal and minimum in Nanu location at 3000 m away from canal. Based on the classification of EC, all samples falls under normal water (0.2 to 1.5 dSm^{-1}). The high level of EC in water is mainly due to the high level of Na^+ and Cl^-. EC in water is known to cause gastrointestinal infection in human beings after long term use Ramesh and Elango (2012) [18]. The similar findings were also made by Dev and Bali (2018) [3].

Table 3: EC (dSm^{-1}) of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	0.73	0.59	0.73	0.55	0.62
2	Nanu	0.89	0.66	0.53	0.87	0.56
3	Pooth Khas	0.69	0.68	0.65	0.82	0.65
4	Bhola Jhal	1.00	0.71	0.72	0.78	0.67
5	Jani	0.76	0.89	0.76	0.70	0.65

4.3 Total Dissolved Salts (TDS) in underground water

The total dissolved salts of water samples in the study area ranged from a minimum value of 339.2 mg L^{-1} to maximum 640 mg L^{-1} with a mean of 457.22 mg L^{-1} (Table 4). The maximum TDS was observed in Bhola Jhal location (640 mg L^{-1}) at 1000 m away from canal while minimum in Nanu location at 3000 m away from canal. According to classification of water based on TDS 52% of water sample falls under the desirable limit of < 450 mg L^{-1} and 48% samples are within the maximum permissible limit 1000 mg L^{-1} of total dissolved salts. The high level of TDS in water is mainly due to use of various chemicals, such as lime, sodium carbonate, common salt or sodium chloride, sodium sulphate, chromium sulphate etc. The similar findings were also made by Gaur *et al.* (2012) [8] and Kumar *et al.* (2017).

Table 4: TDS (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	467.2	377.6	467.2	352.0	396.8
2	Nanu	569.6	422.4	339.2	556.8	358.4
3	Pooth Khas	441.6	435.2	416.0	524.8	416.0
4	Bhola Jhal	640.0	454.4	460.8	499.2	428.8
5	Jani	486.4	569.6	486.4	448.0	416.0

4.4 Concentration of calcium in underground water

The concentration of calcium in water sample varied from 39.28 to 66.58 mg L^{-1} with a mean value of 54.06 mg L^{-1} (Table 5). The maximum calcium was observed in Bhola Jhal location (66.58 mg L^{-1}) at 1000 m away from canal and minimum in Nanu location (39.28 mg L^{-1}) at 3000 m away from canal. According to classification of water based on calcium all water samples fall within the desirable limit of 75 mg L^{-1} as suggested by BIS. The similar findings were also made by Singh *et al.* (2014) [11] and Kumar *et al.* (2015).

Table 5: Calcium (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	55.16	46.88	54.75	43.32	49.12
2	Nanu	64.25	52.36	39.28	62.39	45.26
3	Pooth Khas	53.36	53.18	50.78	60.78	51.43
4	Bhola Jhal	66.58	53.58	54.19	59.66	52.38
5	Jani	56.88	63.83	57.54	53.64	50.84

4.5 Concentration of magnesium in underground water

The concentration of magnesium in water varied from 17.29 to 33.81 mg L^{-1} with a mean value of 23.67 mg L^{-1} (Table 6). The maximum magnesium was recorded in Bhola Jhal location (33.81 mg L^{-1}) at 1000 m away from canal and the minimum in Nanu location (17.29 mg L^{-1}) at 3000 m away from canal. According to classification of water based on magnesium, 92% of water samples falling within the desirable limit of 30 mg L^{-1} and 8% samples were having higher level of magnesium concentration but within maximum permissible limit of 100 mg L^{-1} as suggested by BIS. The similar findings were also made by Dutta *et al.* (2010) and Kumar *et al.* (2017).

Table 6: Magnesium (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	24.16	19.46	23.59	18.17	20.39
2	Nanu	29.66	22.28	17.29	28.92	18.44
3	Pooth Khas	23.17	22.75	20.63	27.42	20.75
4	Bhola Jhal	33.81	23.39	23.43	26.61	22.76
5	Jani	24.67	30.37	25.46	23.41	20.65

4.6 Concentration of sodium in underground water

The concentration of sodium in water varied from 36.77 to 76.88 mg L^{-1} with a mean value of 49.17 mg L^{-1} (Table 7). The maximum sodium was recorded in Bhola Jhal location (76.88 mg L^{-1}) at 1000 m away from canal while minimum in Nanu (36.77 mg L^{-1}) at 3000 m away from canal. According to classification of water based on sodium, all the water samples fall within the desirable limit of 200 mg L^{-1} as suggested by BIS and WHO. The possible source of sodium concentration in the groundwater is due to the dissolution of rocks salts and weathering of sodium-bearing minerals. A higher sodium intake may cause hypertension, congenial heart diseases and kidney problems Singh *et al.* (2008) [11]. The similar findings were also made by Kumar *et al.* (2017).

Table 7: Sodium (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	46.19	39.73	47.32	38.93	42.42
2	Nanu	74.49	44.54	36.77	63.32	43.95
3	Pooth Khas	46.16	44.64	42.41	56.10	44.38
4	Bhola Jhal	76.88	46.02	46.46	48.89	44.81
5	Jani	48.79	68.25	49.52	45.40	42.93

4.7 Concentration of potassium in underground water

The concentration of potassium in water varied from 4.10 to 8.80 mg L^{-1} with a mean value of 5.50 mg L^{-1} (Table 8). The maximum potassium was recorded in Bhola Jhal location (8.80 mg L^{-1}) at 1000 m away from canal and minimum in Nanu location (4.10 mg L^{-1}) at 3000 m away from canal. According to classification of water based on potassium, 100% of water samples fall within the desirable limit of 10 mg L^{-1} as suggested by BIS. The excess amount of potassium present in the water sample may lead nervous and digestive disorder Tiwari *et al.* (2013) [23]. The high concentration of potassium in water is most likely due to silicate weathering and cation exchange processes. The similar findings were also made by Kumar *et al.* (2017) [5].

Table 8: Potassium (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	5.5	4.6	5.5	4.3	4.8
2	Nanu	7.5	4.9	4.1	6.8	4.5
3	Pooth Khas	5.1	5.2	4.8	6.2	4.9
4	Bhola Jhal	8.8	5.3	5.4	5.8	4.9
5	Jani	5.7	7.1	5.7	5.2	4.8

4.8 Concentration of carbonate in underground water

The concentration of carbonate in different locations varied from Nil to 15 mg L^{-1} with a mean value of 1.8 mg L^{-1} (Table 9). The maximum concentration of carbonate was recorded in Jani location (15 mg L^{-1}) at 2000 m away from canal. Carbonate was absent in most of the locations. The BIS and WHO does not mention any permissible limit with respect to carbonates in water.

Table 9: Carbonate (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	Absent	Absent	Absent	Absent	Absent
2	Nanu	Absent	Absent	Absent	Absent	3
3	Pooth Khas	Absent	Absent	6	12	Absent
4	Bhola Jhal	Absent	9	Absent	Absent	Absent
5	Jani	Absent	15	Absent	Absent	Absent

4.9 Concentration of bicarbonate in underground water

The concentration of bicarbonate in water varied from 131 to 243 mg L^{-1} with a mean value of 195.04 mg L^{-1} (Table 10). The maximum bicarbonate was recorded in Bhola Jhal location (243 mg L^{-1}) at 1000 m away from canal and minimum in Nanu location (131 mg L^{-1}) at 3000 m away from canal. According to classification of water based on bicarbonate, 60% of water samples fall within the desirable limit of 200 mg L^{-1} and 40% of water samples have higher level of bicarbonate concentration but within the maximum permissible limit of 600 mg L^{-1} as suggested by BIS and WHO. The high alkalinity values may be due to the influx of sewage rich in alkalinity causing chemicals, such as soap and detergents. The similar findings were also made by Panaskar *et al.* (2016) [17].

Table 10: Bicarbonate (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	204	154	196	144	160
2	Nanu	239	180	131	237	219
3	Pooth Khas	192	187	172	223	177
4	Bhola Jhal	243	194	195	219	188
5	Jani	208	239	210	193	172

4.10 Concentration of chloride in underground water

The concentration of chloride in water varied from 81.49 to 147.28 mg L^{-1} with a mean value of 118.70 mg L^{-1} (Table 11). The maximum chloride was recorded in Pooth Khas location (147.28 mg L^{-1}) at 1000 m away from canal and the minimum in Nagla Order location (81.49 mg L^{-1}) at 4000 m away from canal. According to classification of water based on chloride, all water samples fall within the desirable limit of 250 mg L^{-1} as suggested by BIS and WHO. High chloride content has a deleterious effect on metallic pipes, structures and agricultural crops. Natural processes such as weathering, dissolution of salt deposits and irrigation drainage return flow are responsible for the chloride content in the groundwater, which is supported by the Cl/HCO_3 ratio of 1:3.0 Lusczynski and Swarzenski (1996) [15]. The similar findings were also made by Sirohi *et al.* (2014) [12].

Table 11: Chloride (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	117.27	88.41	110.37	81.49	90.53
2	Nanu	134.22	120.07	123.28	135.24	126.14
3	Pooth Khas	147.28	103.52	109.23	140.22	101.63
4	Bhola Jhal	140.33	120.25	110.41	123.46	124.41
5	Jani	118.29	142.62	114.32	146.25	98.20

4.11 Concentration of nitrate in underground water

The concentration of nitrate in water varied from 0.31 to 3.14 mg L^{-1} with a mean value of 0.92 mg L^{-1} (Table 12). The maximum nitrate was recorded in Jani location (3.14 mg L^{-1}) at 1000 m away from canal and the minimum in Bhola Jhal location (0.31 mg L^{-1}) at 2000 m away from canal. According to classification of water based on nitrate, all water samples fall within the desirable limit of 45 mg L^{-1} suggested by BIS and 50 mg L^{-1} as suggested by WHO. In general the possible sources of nitrate that lead to its increase in groundwater are nitrogen rich sediments, interaction of groundwater with nitrogen rich industrial waste, inputs of organic nitrogen into soil, biological dinitrogen fixation by microorganisms, inputs of human and animal waste, water in unused dug wells, stagnate water and nitrogenous inorganic fertilizers Barnes and Smith (1992) [11]. The similar findings were also made by Shinde *et al.* (2011) [2] and Tripathi *et al.* (2014) [12].

Table 12: Nitrate (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	0.80	0.43	0.39	2.21	1.69
2	Nanu	1.17	0.94	0.62	0.73	0.59
3	Pooth Khas	0.53	0.47	0.38	1.55	0.46
4	Bhola Jhal	0.56	0.31	0.84	0.78	1.19
5	Jani	3.14	0.40	0.79	0.68	1.41

4.12 Concentration of sulphate in underground water
The concentration of sulphate in water varied from 10.32 to 18.10 mg L^{-1} with a mean value of 15.85 mg L^{-1} (Table 13). The maximum sulphate was recorded in Nanu location (18.10 mg L^{-1}) at 3000 m away from canal and the minimum in Bhola Jhal location (10.32 mg L^{-1}) at 1000 m away from canal. According to classification of water based on sulphate (Table 13), all water samples fall within the desirable limit of 200 mg L^{-1} as suggested by BIS and 250 mg L^{-1} suggested by WHO. Therefore, the results clearly indicate that there is no significant effect on the health. The similar findings were also made by Panaskar *et al.* (2016) [17].

Table 13: Sulphate (mg L^{-1}) concentration of water samples collected at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	15.74	17.32	15.68	17.46	17.10
2	Nanu	13.88	16.69	18.10	14.29	17.42
3	Pooth Khas	16.32	16.44	16.78	15.18	16.68
4	Bhola Jhal	10.32	15.66	15.46	15.38	16.62
5	Jani	15.57	13.75	15.64	16.12	16.73

4.13 Collin's ratio of underground water
Collin's ratio is the ratio of Cl^- ions of the sum of CO_3^{--} and HCO_3^- ions in epm. For drinking water this ratio should be < 1. The concentration of Collin's ratio in water varied from 0.91 to 1.62 epm with a mean value of 1.04 epm (Table 14). 76% of the water samples fall in safe limit for drinking purpose while 24% samples slightly contaminated which may be harmful for drinking purpose and can be used for irrigation purpose.

Table 14: Collin's ratio of water at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	0.99	0.99	0.97	0.97	0.97
2	Nanu	0.96	1.15	1.62	0.98	0.96
3	Pooth Khas	1.32	0.95	1.02	0.97	0.99
4	Bhola Jhal	0.99	0.97	0.97	0.97	1.14
5	Jani	0.98	0.91	0.94	1.30	0.98

4.14 Suitability of underground water for irrigation purpose on the basis of sodicity hazard (SAR)
The concentration of SAR in water varied from 1.23 to 1.93 with a mean value of 1.40 (Table 15). Based on SAR classification, 100% samples come under S-0 class (Non sodicity water), that belong to the excellent class for irrigation usage. The similar findings were also made by Joshi *et al.* (2009) in river Ganga in Haridwar district of Uttrakhand (India).

Table 15: SAR (me L^{-1}) of water at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	1.30	1.23	1.35	1.25	1.28
2	Nanu	1.93	1.30	1.23	1.66	1.39
3	Pooth Khas	1.33	1.29	1.27	1.50	1.32
4	Bhola Jhal	1.91	1.32	1.33	1.32	1.30
5	Jani	1.36	1.76	1.37	1.30	1.28

4.15 Suitability of underground water for irrigation purpose on the basis of alkalinity hazard (RSC)
The RSC in water varied from -2.13 to -0.09 meq L^{-1} with a mean value of -1.39 meq L^{-1} (Table 16). Based on classification of RSC, 100% water sample comes under non alkaline water and considered safe for irrigation purpose. The similar findings were also made by Madhav *et al.* (2018) [16].

Table 16: RSC (me L^{-}1) of water at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	-1.40	-1.42	-1.47	-1.30	-1.51
2	Nanu	-1.74	-1.50	-1.24	-1.61	-0.09
3	Pooth Khas	-1.43	-1.47	-1.22	-1.24	-1.38
4	Bhola Jhal	-2.13	-1.12	-1.44	-1.58	-1.41
5	Jani	-1.46	-1.27	-1.53	-1.44	-1.42

4.16 Kelly's ratio
Kelly's ratio in water varied from 0.41 to 0.58 epm with a mean value of 0.47 epm (Table 17). The analyzed samples suggest that 100% samples are excellent for irrigation purpose. The similar findings were also made by Madhav *et al.* (2018) [16].

Table 17: Kelly's ratio (epm) of water at different locations and distance on west side from Ganga canal.

S. No	Locations	Water samples distance (m) from Ganga canal				
		1000	2000	3000	4000	5000
1	Nagla Order	0.42	0.44	0.44	0.46	0.45
2	Nanu	0.57	0.44	0.47	0.50	0.51
3	Pooth Khas	0.44	0.43	0.44	0.46	0.45
4	Bhola Jhal	0.55	0.43	0.44	0.41	0.43
5	Jani	0.44	0.52	0.43	0.43	0.44

5. Correlation studies
The relationship among hydro-chemical parameters of underground water was studied using correlation analysis and the results are shown in Table 18. The pH of water was found negatively and non-significantly correlated with nitrate (r = -0.062) similar results were reported by Algamal (2015) [12]. A negative and significant correlation of pH with sulphate r = -0.914** was found. It was positively and significantly correlated with EC (r = 0.983**), TDS (r = 0.983**), calcium (r = 0.973**), magnesium (r = 0.982**), sodium (r = 0.947**), potassium (r = 0.956**), bicarbonate (r = 0.885**) and chloride (r = 0.602**).

The EC of water recorded negative and non-significant correlation with nitrate (r = -0.057) while negative and significant correlation with sulphate (r = -0.955**). It was positively and significantly correlatied with pH (r = 0.983**), TDS (r = 1.000**), calcium (r = 0.978**), magnesium (r = 0.994**), sodium (r = 0.931**), potassium (r = 0.972**), bicarbonate (r = 0.872**) and chloride (r = 0.606**) similarly, results reported by Devi and Kumar (2018).

Table 18: Correlation coefficient (r) between different water quality parameters in study area

	pH	EC	TDS	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}
pH	1.00										
EC	0.983**	1.00									
TDS	0.983**	1.000**	1.00								
Ca^{2+}	0.973**	0.978**	0.978**	1.00							
Mg^{2+}	0.982**	0.994**	0.994**	0.974**	1.00						
Na^{+}	0.947**	0.931**	0.931**	0.880**	0.930**	1.00					
K^{+}	0.956**	0.972**	0.972**	0.918**	0.969**	0.974**	1.00				
HCO_3^-	0.885**	0.872**	0.872**	0.891**	0.875**	0.841**	0.838**	1.00			
Cl^-	0.602**	0.606**	0.606**	0.580**	0.634**	0.595**	0.566**	0.684**	1.00		
NO_3^-	-0.062	-0.057	-0.057	-0.045	-0.070	-0.072	-0.071	-0.096	-0.234	1.00	
SO_4^{2-}	-0.914**	-0.955**	-0.955**	-0.893**	-0.923**	-0.923**	-0.979**	-0.805**	-0.544**	0.102	1.00

6. Conclusion

In the present study water samples from five different locations in Meerut district of Uttar Pradesh were assessed by comparing each parameter with the standard desirable limit prescribed by Bureau of Indian Standard (BIS) and World Health Organization (WHO). It can be concluded that the underground water of the study area is normal in salinity and can be used for both drinking and irrigation purpose. The underground water of the study area is non problematic on the basis of EC, SAR and RSC respectively. According to Collin's ratio most of the underground water is safe for drinking purpose. According to Kelly's ratio the underground water of the study area is safe for irrigation purpose.

7. References

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