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ORIGINAL ARTICLE

Hydrogeochemical assessment of groundwater in shallow aquifer of greater Noida region, Uttar Pradesh (U.P), India

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Abstract

Fresh water is needed for the survival of all living organisms to keep them healthy, safe and clean. Major part of this fresh water is obtained from groundwater. It is observed that the groundwater has been polluting due to anthropogenic activities and affecting the human beings, livestock soil nutrients by mass and environment in certain areas. The paper presents hydrogeochemical assessment of groundwater in shallow aquifers of Greater Noida region. Therefore, various physicochemical parameters such as pH, TDS, EC, TH and major ions, i.e. Cl^-, SO_4^{2-}, NO_3^-, Na^+, K^+, Ca^{2+}, Fe^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^-, have been analysed in the present study using standard procedures. The results of major constituents were compared with the water quality standards prescribed by WHO. From the analysed samples, different indices such as soluble sodium percentage (SSP), sodium adsorption ratio (SAR), residual sodium carbonate, magnesium adsorption ratio, Kelley's ratio and permeability index were characterized in the study. Results delineate that the groundwater is suitable for drinking and irrigational use.

Keywords Water quality · Groundwater pollution · Urban areas · Water indices

Introduction

Water is the most important resource for sustaining life on earth. Human or animal can live without food for few days but cannot live without water. Water is used in different ways such as drinking, bathing, washing, producing energy, irrigating the plants and is also used for recreation and transportation. Polluted water is unsuitable for mankind in terms of health and hygiene. The anthropogenic activities are deteriorating the water quality day by day. This water pollution is due to the rapid growth of population, industrialization and excessive usage of chemicals (Tiwari 2015). It is very important to ensure the quality of groundwater for every human being for the safe health and survival on the earth (Chapman 1996).

Physical, chemical and biological parameters fix the quality of water. Groundwater is one of the most common source of drinking water supply and irrigational use for most of the population of India. Wastewater generated from class-I cities (having more than hundred thousand population) is about 29,000 million L/day and about 45% is generated from class-II towns (having fifty to hundred thousand population) by (Central Pollution Control Board, November 2005), while 35% is generated from metro-cities alone (Mangukiya et al. 2012). The influence of different water quality parameters has been elaborated by Brown et al. (1970). Anthropogenic activities are producing fluoride and arsenic pollution in the groundwater of different parts of India (CGWB 2010).

Farming activities in rural areas are the chief cause of groundwater pollution. Nitrate fertilizers are also increasing nitrate in groundwater (Muntean et al. 2006). The data-based model was formulated for groundwater quality monitoring strategies (Ishaku et al. 2011). Similar studies have also been evaluated in different parts of India by Bathrellos et al. (2008), Ahmed et al. (2002) and Stites and Kraft (2002). Due to rapid urbanization and its continually increasing population at an exponential rate, India has been facing the problem of deteriorating groundwater quality (Brindha et al.

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2011; Brindha and Elango 2010, 2011; Ramesh and Elango 2005).

Periodic changes in groundwater quality occur due to the origin and constitution of the recharged water, hydrological and human factors (Aghazadeh and Mogaddam 2002; Milovanovic 2007; Sreedevi 2002). Many research studies have been carried out by various researchers on water used for industrial activities, domestic and irrigational use (Vasanthavigar et al. 2010; Pritchard et al. 2008; Al-Futaisi et al. 2007; Jalali 2007; Mukherjee and Das 2007; Rivers et al. 1996). Investigation has been carried out on crystalline rocks to cope the needs for safe drinking water for vast population (Ahmed 2007; Lloyd 1999; Wright and Burgess 1992). Many authors have evaluated different geochemical processes in groundwater for governing of the chemical characteristics of such processes in many parts of the world (Nag and Ray 2015; Nag 2014; Nag and Ghosh 2013; Montety et al. 2008; Jalali 2002, Manjusree et al. 2009; Thilagavathi et al. 2012; Sivasubramanian et al. 2013; Nagaraju et al. 2014; Kumar et al. 2005; Islam et al. 2016a, b; Balaji et al. 2016).

Considering the above-mentioned facts in view, it is important to assess the groundwater quality of the area for domestic and irrigational purposes. The objective of this paper is to avail hydrochemical methods to determine the suitability of groundwater in the area for domestic as well as irrigation purposes.

Materials and methods

Study area

Greater Noida is one of the important city located in the Gautam Buddha Nagar district of the state Uttar Pradesh (India). It is located at a latitude of 28.47 44°N and longitude of 77.50 40°E. It comprises of 124 villages with a population of 107,676 (till March 2014). The area of Greater Noida is about 40,000 hectares broadly bounded by national highway NH-24 in the north-west. The city comes under NCR (National capital Territory) region of Delhi and River Hindon flows in the western side of the city. During the last decade, the number of various industries in Greater Noida has grown more than 10 times (Greater Noida Master Plan 2001). Summer season starts from March and remains till July. During this period, the climate remains hot and average temperature ranges between 23 and 45 °C.

During mid-June to mid-September, the monsoon season gains with an average rainfall of 93.2 cm (36.7 in.), average temperature falls substantially down to as lower 3 to 4 °C at the apex of winter. The total land use cover is 13,570.00 hectares with 30.0 hectares of commercial area and 1970.03 hectares of the total institutional area. The water supply in the area congregates through overhead tanks, tube wells, trunks and other supply lines. At present, nearly 460 km length of sewerage network, 500 km length of drainage and nearly 500 km length of water supply lines subsist in the area. Under phreatic conditions, groundwater occurred in shallow aquifers declines to the depth of 100 mbgl in intermediate and it occurs in deeper aquifers under confined to semi-confined conditions. Groundwater monitoring wells have been established in the district to monitor the nature of water level and four times water table are being monitored in a year. Depth to water level of the study area can be divided into various zones on the basis of depth to water ranges. Water level varies from 3.35 to 14.40 mbgl in phreatic aquifer whereas it exceeds greater than 9 mbgl in most of the non-command areas of the study area. The general inclination of the area is from eastern side towards River Hindon in the west as shown through (Wikipedia Greater Noida) (Fig. 1).

Sampling and analysis

Groundwater samples were collected before pre-monsoon (April 2016) from various sources of shallow aquifers such as Government hand pumps (GHP), General hand pumps (HP) located in the study area (Franson 1992). The samples were analysed as per the methods prescribed in American Public Health Association manual (APHA-2320 1999). pH meter (micro processor pH meter, NIG334) was used to measure the pH of the groundwater samples. TDS, EC and salinity were measured by portable EC meter (NDC737). Standard EDTA method was used to determine Ca^{2+} and Mg^{2+}, Cl^- by standard $AgNO_3$ titration, HCO_3^- by titration with HCl. Flame photometry was used to evaluate Na^+ and K^+. Samples for major ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, NO_3^- and HCO_3^-) were analysed by collecting the groundwater samples in 500 ml polyethylene bottles. Na^+ and K^+ were analysed by Gallenkamp Flame Analyser. Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-} and NO_3^- were analysed by ICS-5000 DIONEX SP, ion chromatography (IC). To evaluate the suitability of the groundwater for agricultural purposes, soluble sodium percentage (SSP), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), magnesium adsorption ratio (MAR), Kelley's ratio (KR) and permeability index (PI) were evaluated.

Methods for hydrogeochemical and water quality evaluation

Parameters such as Ca^{2+} and Mg^{2+} were considered to assess the water quality and geochemical process. The equation prescribed by Todd (1980), Ragunath (1987) and Hem (1991) has been used to determine the total hardness (TH) in ppm (Eq. 1):

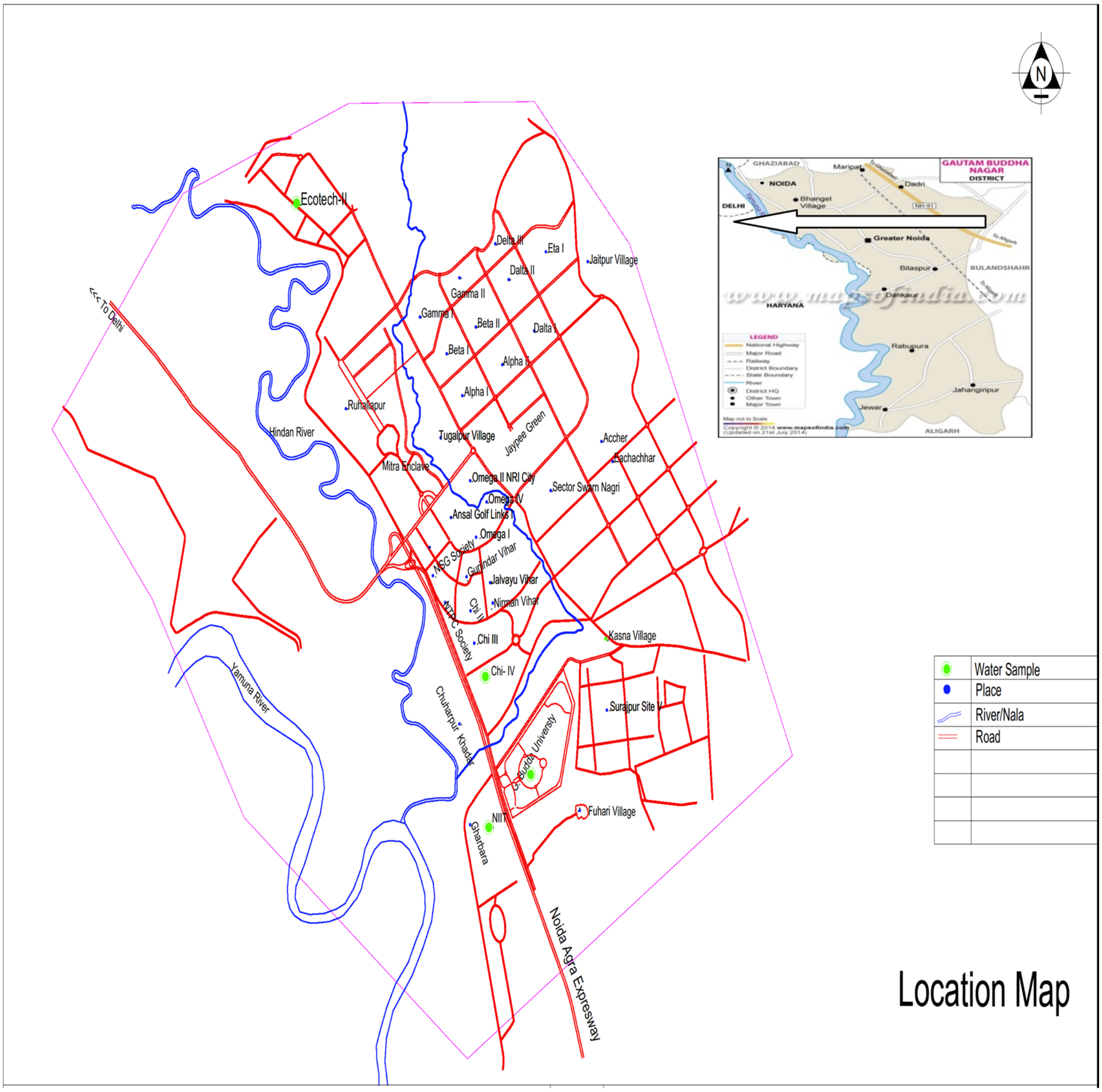


Fig. 1 Greater Noida map with locations of sampling sites of the study area. *Source*: Wikipedia

$$\text{TH} = 2.497\ \text{Ca}^{2+} + 4.115\ \text{Mg}^{2+} \quad (1)$$

Irrigation suitability

Using the assessed water quality parameters, the following other parameters were determined in order to check the quality of the water used for irrigation:

1. Soluble sodium percentage (SSP).
2. Sodium adsorption ratio (SAR).
3. Residual sodium carbonate (RSC).
4. Magnesium adsorption ratio (MAR).
5. Kelley's ratio (KR).
6. Permeability index (PI).

Soluble sodium percentage (SSP or Na %)

Sodium is normally expressed in terms of percentage of sodium or soluble sodium percentage (% Na). Irrigation water is classified based on the reaction of sodium with soil. For assessing the suitability of water for irrigation purposes, percentage of Na^+ is widely used (Wilcox 1955). To evaluate the sodium hazard in soil, the term soluble sodium percentage

(SSP) or Na % is used. Todd (1980) explained soluble sodium percentage (SSP) or Na % as (Eq. 2):

$$\text{SSP or Na\%} = \frac{(Na^+ + K^+) \times 100}{(Ca^{2+} + Mg^{2+} + Na^+ + K^+)} \tag{2}$$

Sodium adsorption ratio (SAR)

SAR is a term used to express sodium or alkali hazard of the water quality for irrigation purpose (Bhuiyan et al. 2015; Islam et al. 2016a, b). Excess amount of Na^+ and low value of Ca^{2+} destroy the soil structure (Todd 1980). The SAR value of irrigation water expresses the relative proportion of Na^+ to Ca^{2+} and Mg^{2+} (Arajhi et al. 2015) and is calculated as (Eq. 3):

$$\text{SAR} = \frac{Na^+}{\sqrt{\frac{(Ca^{2+}+Mg^{2+})}{2}}} \tag{3}$$

However, the concentrations of Na, Ca and Mg ions in water are expressed as Na^+, Ca^{2+} and Mg^{2+}, respectively (Ayers and Westcot 1985).

Residual sodium carbonate (RSC)

Considering the alkaline earths and weak acids, the residual sodium carbonate (RSC) is computed as per Ragunath (1987) and Rao et al. (2012) as (Eq. 4):

$$\text{RSC} = \left(CO_3^{2-} + HCO_3^-\right) - \left(Ca^{2+} + Mg^{2+}\right) \tag{4}$$

Magnesium adsorption ratio (MAR)

MAR also recognized as magnesium hazard (MH) and is calculated as per method suggested by Ragunath (1987) as (Eq. 5):

$$\text{MAR} = \frac{(Mg^{2+}) \times 100}{(Ca^{2+} + Mg^{2+})} \tag{5}$$

Kelley's ratio (KR)

Excess amount of sodium over calcium and magnesium is determined by Kelley's ratio (KR). To find out the suitability of groundwater for irrigation, Kelley's ratio equation (Kelley 1963) can be used as (Eq. 6):

$$\text{KR} = \frac{Na^+}{(Ca^{2+} + Mg^{2+})} \tag{6}$$

Permeability index (PI)

Due to the long-term use of irrigation water, the permeability of soil gets influenced by sodium, calcium, magnesium and by carbonate contents in the soil. Permeability index (PI) of the groundwater samples was determined by using the formula given by Doneen (1964) (Eq. 7):

$$\text{PI} = \frac{Na^+ + \sqrt{(HCO_3^-)}}{(Ca^{2+} + Mg^{2+} + Na^+)} \times 100 \tag{7}$$

All ionic concentrations are represented in milliequivalent per lire (meq/L). All these hydrogeochemical parameters were compared with national and international standards to assess the groundwater suitability for drinking and irrigation purposes (Table 1).

Results and discussion

Drinking water suitability

pH

pH value is defined as the logarithm of the reciprocal of the H^+ ion concentration. It determines the nature of the solution whether it is acidic or alkaline. The strength of water is represented by pH and is controlled by CO_2, $CO_3{}^{2-}$ and $HCO_3{}^-$ concentrations (Hem 1991). The acceptable limit of pH for drinking water varies from 6.5 to 8.5. Higher pH values above the permissible limit affect the mucous membrane of cells (WHO 2012). The pH of the study area is slightly alkaline and is ranging from 7.27 to 8.08 with a mean value of 7.53 (Fig. 2).

Chloride concentration

Chlorides are found in natural water due to leaching of chloride containing rocks and soils discharges of effluents from chemical industries, ice cream plant effluent, sewage disposal and irrigation drainage. Concentration greater than 250 mg/L is associated with sodium which exerts salty taste to the water. Chloride determination in natural water is useful in the selection of water supplies for human use. Higher concentration of chloride is harmful to heart and kidney diseases. Indigestion, taste, palatability and corrosion are also affected. The desirable limit of chloride in water is 250 mg/L (WHO 2012). The chloride ion concentration of the study area varies from 34 to 138 mg/L with a mean value of 94 mg/L (Fig. 3).

Total hardness

Hardness due to bicarbonate of calcium or magnesium is termed as temporary hardness and the hardness due to chloride, sulphates and nitrates of calcium and magnesium is

Table 1 Physicochemical parameters analysis of different samples of the present study

Location	pH	Cl^- (mg/L)	TH (mg/L)	SO_4^{2-} (mg/L)	TDS (mg/L)	NO_3^- (mg/L)	EC (µS/cm)	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	CO_3^{2-} (mg/L)	HCO_3^- (mg/L)	Fe^{2+} (mg/L)
L-1	7.64	138	232	58	650	18	770	182	4	53	24	0	298	0.14
L-2	7.27	103	376	102	818	9	806	190	5	53	28	252	96	0.14
L-3	8.08	34	116	57	398	9	1059	333	3	30	11	453	105	0.10
L-4	7.37	104	352	84	634	9	334	66	3	32	18	67	176	0.12
L-5	7.31	88	420	34	570	12	534	107	8	45	41	0	458	0.75
Min.	7.27	34	116	34	398	9	334	66	3	30	12	0	96	0.10
Max.	8.08	138	420	102	818	18	1059	333	8	53	41	453	458	0.75
Mean	7.53	94	299	67	614	11	700	176	5	42	24	154	227	0.25
Median	7.37	104	352	58	634	9	770	182	4	45	24	67	176	0.14
STD	0.34	38	124	26	151	4	276	102	3	11	11	196	152	0.28

Cl^- chloride (mg/L), TH total hardness (mg/L), SO_4^{2-} sulphate (mg/L), TDS total dissolved solids (mg/L), NO_3^- nitrate (mg/L), EC electrical conductivity (µS/cm), Na^+ sodium (mg/L), K^+ potassium (mg/L), Ca^{2+} calcium (mg/L), Mg^{2+} magnesium (mg/L), CO_3^{2-} carbonate (mg/L), HCO_3^{2-} bicarbonate (mg/L), Fe^{2+} iron (mg/L)

considered as permanent hardness. The permanent hardness results in greater amount of soap consumption. It leads to the calcification of arteries in human being as well as affects water supply system by forming scale. The acceptable limit is 200 mg/L (WHO 2012). The total hardness of the study area ranges from 116 to 420 mg/L with a mean concentration value of 299 mg/L (Fig. 3).

Sulphate concentration

Sulphate governs the synthesizing and degradation of proteins. The leaching of sulphates into the shallow groundwater increases more than 500 mg/L. The recommended upper limit of sulphate in water for human consumption is 200 mg/L (WHO 2012). Gastrointestinal irritation is produced due to high concentration of sulphate. The sulphate ion concentration of the study area varies from 34.28 to 102.46 mg/L with a mean value of 67.07 mg/L (Fig. 4).

Total dissolved solids

Estimation of total dissolved solids (TDS) helps in testing the suitability of water for drinking, agriculture and industrial purpose. TDS is the sum of potassium, calcium, sodium, magnesium, carbonates, bicarbonates, chlorides, organic matter, phosphate and other particles. The acceptable limit is 500 mg/L (WHO 2012). The total dissolved solids concentration of the study area varies from 398 to 818 mg/L with a mean value of 614 mg/L (Fig. 3).

Nitrate concentration

Nitrate is found in groundwater due to leaching of nitrate with the percolating water through the soil. Sewage and other wastes rich in nitrates generally contaminate the groundwater. The disease methemoglobinemia found in infants is produced due to high concentration of nitrates in drinking water. It affects cardiovascular system and nervous system and also produces gastric cancer. The concentration should not exceed beyond 45 mg/L (WHO 2012). The nitrate concentration of the study area varies from 9 to 18 mg/L with a mean value of 11 mg/L (Fig. 4).

Electrical conductivity

The electrical conductivity is a measure of capacity of a substance or a solution to carry an electric current. Dissolved and dissociated substances parameters are measured by electrical conductivity. Temperature, ionic valences and ionic mobility affect the conductivity. Electrical conductivity

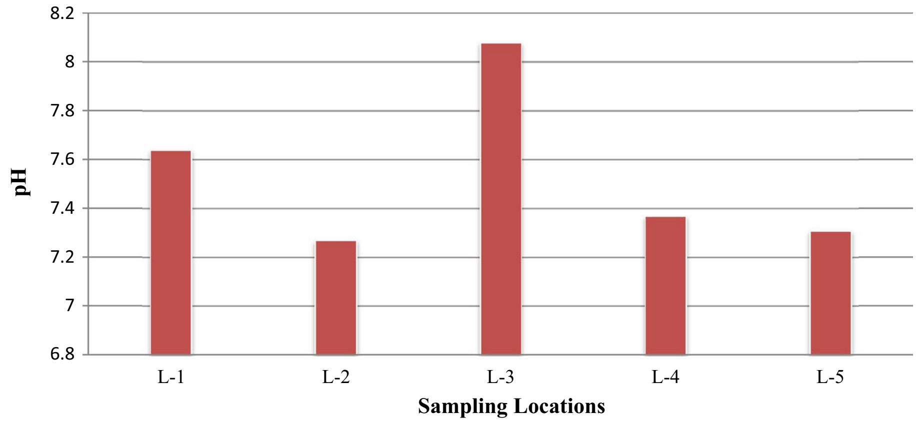


Fig. 2 Variation of pH values at different locations of the present study

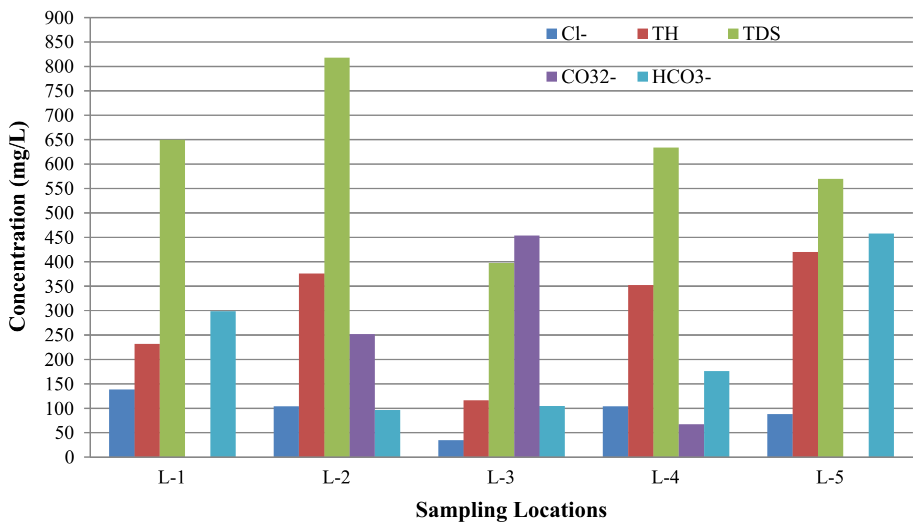


Fig. 3 Variation of Cl^-, TH, TDS, CO_3^{2-} and HCO_3^- concentrations at different locations

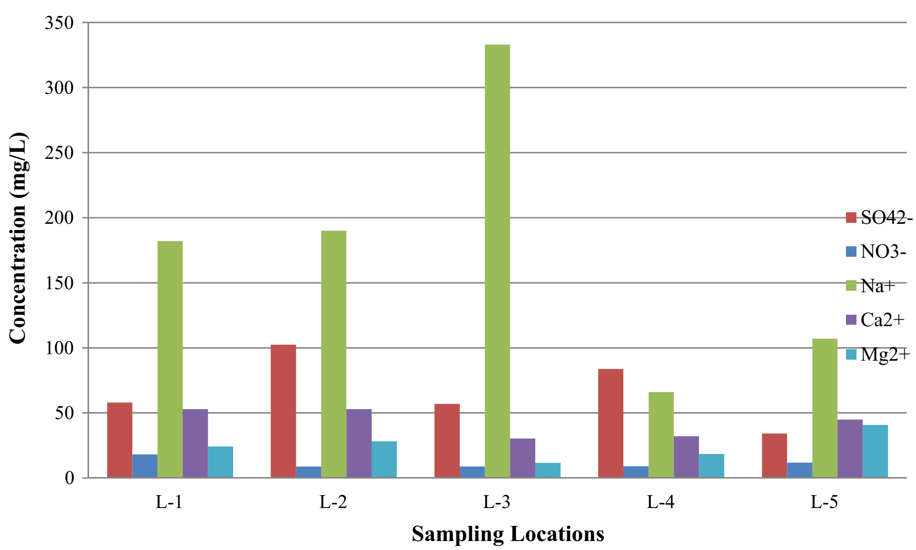
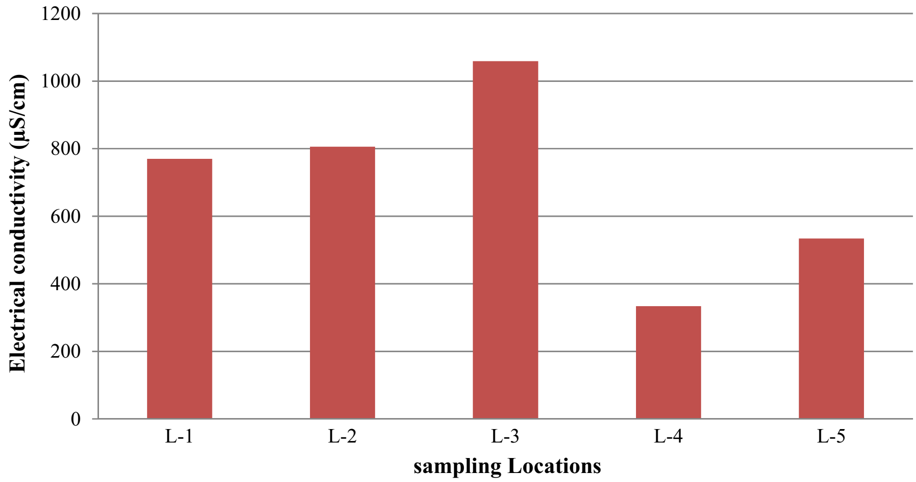


Fig. 4 Variation of SO_4^{2-}, NO_3^-, Na^+, Ca^{2+} and Mg^{2+} concentrations at different locations

Fig. 5 Variation of electrical conductivity at different sampling locations of the study area



measurements are employed to monitor desalination plants and to decide the extent of intrusion of sea water into groundwater. Conductivity data are very useful to determine the suitability of water and wastewater for disposal on land. The allowable limit of conductivity in groundwater should be in between 700 and 3000 µS/cm (WHO 2012). Electrical conductivity (EC) of the study area varies from 334 to 1059 µS/cm with a mean value of 700 µS/cm (Fig. 5).

Sodium

Sodium salts produce foam in steam boilers. Sodium is a naturally occurring element in groundwater. High concentration of sodium in groundwater causes heart problem and cardiovascular problems. Concentration of sodium less than 20 mg/L is recommended for high-risk peoples. The allowable limit of sodium in drinking water is 200 mg/L (WHO 2012). The sodium concentration of the study area varies from 66 to 333 mg/L with a mean value of 175 mg/L (Fig. 4).

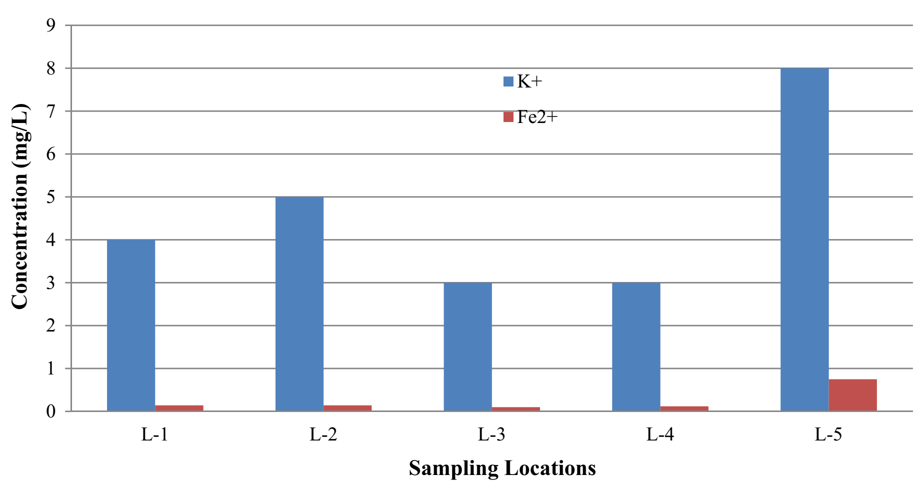
Potassium

Higher concentration of potassium indicates a laxative affect. It causes kidney diseases or other problems such as heart disease, hypertension, diabetes and coronary artery diseases. The allowable limit of potassium is 1–8 mg/L (WHO 2012). The potassium concentration of the study area varies from 3 to 8 mg/L with a mean value of 4.6 mg/L (Fig. 5).

Calcium

Calcium of total body is mostly found in teeth and bones. The function of remaining calcium in body serves as vascular contraction, muscle contraction, blood clotting and nerve transmission. Lesser amount of calcium is associated with increased risk of nephrolithiasis, osteoporosis, hypertension, colorectal cancer and coronary artery diseases obesity and insulin resistance. High content of calcium and magnesium in drinking water should be avoided in the case of kidney stone or bladder stone. The acceptable limit of calcium in drinking water is 75 mg/L (WHO 2012). The calcium

Fig. 6 Variation of K^{+} and Fe^{2+} concentrations at different locations of the present study



concentration of the study area varies from 30 to 53 mg/L with a mean value of 42 mg/L (Fig. 4).

Magnesium

Magnesium is found inside the earth surface due to the dissolution of magnesium-rich minerals. Magnesium plays an important role in ATP, metabolism, glycolysis, transport of element such as Ca, Na and K through membranes, synthesis of nucleic acids and proteins, muscles contraction and neuromuscular excitability etc. The deficiency of magnesium increases risks to human health and results in hypertension, vasoconstrictions, atherosclerotic vascular disease, cardiac, eclampsia in pregnant women, acute myocardial in infection and osteoporosis etc. Magnesium concentration greater than 125 mg/L may shows laxative affects. The allowable limit of magnesium in drinking water is 30 mg/L (WHO 2012). The magnesium concentration of the study area varies from 12 to 41 mg/L with a mean value of 25 mg/L (Fig. 4).

Carbonate and bicarbonate

High concentration of alkalinity in water is harmful for irrigation purpose as it leads to soil damage and reduces crop yields. The permissible limit of alkalinity in drinking water is 200 mg/L as per WHO (2012). Taste of water becomes unpleasant on high concentration of alkalinity. The carbonate concentration of the study area varies from 0 to 453 mg/L with a mean value of 154 mg/L. The concentration of bicarbonate varies from 96 to 458 mg/L with a mean of value of 227 mg/L (Fig. 3).

Iron

Dissolution of rock and minerals, landfill leachates, acid mine, drainage, sewage and industrial effluents is responsible for the presence of iron in groundwater. The allowable limit of iron in drinking water is 0.3 mg/L (WHO 2012). The iron concentration of the study area of all the samples varies from 0.10 to 0.75 mg/L with a mean value of 0.425 mg/L (Fig. 6).

Irrigation suitability

Soluble sodium percentage (SSP or Na %)

Percentage of Na^+ or SSP content is a guideline to assess suitability for agricultural purpose. SSP value less than 200 is considered suitable for irrigation purpose. SSP is determined and summarized in Table 2 which ranges from 46 to 85. The SSP values of all the locations lie within the range as prescribed for suitability for agricultural use.

Sodium adsorption ratio (SAR)

The utility of groundwater for irrigation purpose is determined with the help of salinity and SAR. The SAR value should be less than 20 for the groundwater to be used for irrigation. SAR values for the same have been determined and are tabulated in Table 2. SAR values as determined in the present study lie in the range from 2 to 13. The SAR values of all the samples determined in present study are found to be well within the permissible limits mentioned above.

Residual sodium carbonate (RSC)

The quality of groundwater assessed in terms of alkaline earth with weak acids is expressed in terms of RSC. The permissible limit values suitable for irrigation purpose range from 1.25 to 2.50. However, the values greater than 2.50 are considered to be unsuitable for irrigation purposes. RSC values of the study area are shown in Table 2. All the samples lie in the range of 0.21–14.35. Therefore, from Table 3, it can be concluded that 60% groundwater samples of the study area fall in marginally suitable or good category and remaining 40% samples of the area fall in unsuitable category.

Magnesium adsorption ratio (MAR)

The relationship between magnesium and calcium concentration in groundwater is determined by magnesium adsorption ratio (MAR). MAR value greater than 50 is considered unsuitable for irrigation purposes. MAR has been calculated and is summarized in Table 2 which ranges from 39 to 60.

Table 2 Water quality indices of groundwater samples of different sampling locations

Location	SSP	SAR	RSC	MAR	KR	PI
L-1	63.12	5.17	0.21	43.38	1.69	80.39
L-2	62.66	5.22	4.98	47.00	1.65	71.77
L-3	85.39	12.98	14.35	38.95	5.81	93.05
L-4	48.44	2.29	1.99	49.04	0.91	76.04
L-5	46.23	2.77	1.86	60.28	0.82	71.80

SSP soluble sodium percentage, *SAR* sodium adsorption ratio, *RSC* residual sodium carbonate, *MAR* magnesium adsorption ratio, *KR* Kelly's ratio, *PI* permeability index

Table 3 Samples classification as per specified standards for different water quality parameters

Parameters	Range	Class	No. of samples	Percentage of samples
SSP	< 200	Suitable	5	100
	> 200	Unsuitable	0	0
SAR	< 20	Excellent	5	100
	20–40	Good	0	0
	40–60	Permissible	0	0
	60–80	Doubtful	0	0
	> 80	Unsafe	0	0
RSC	< 1.25	Safe	1	20
	1.25–2.50	Marginally suitable	2	40
	> 2.50	Unsuitable	2	40
MAR (Kacmaz and Nakoman 2010)	< 50	Suitable	4	80
	> 50	Unsuitable	1	20
KR	< 1	Suitable	2	40
	> 1	Unsuitable	3	60
PI	< 80	Good	3	60
	80–100	Moderate	2	40
	100–120	Poor	0	0
EC	< 250	Excellent	0	0
	250–750	Good	2	40
	750–2000	Permissible	3	60
	2000–3000	Doubtful	0	0
	> 3000	Unsuitable	0	0
TH	< 75	Soft	0	0
	75–150	Moderate	1	20
	150–300	Hard	1	20
	> 300	Very hard	3	60
Chloride	< 0.14	Extremely fresh	0	0
	0.14–0.84	Very fresh	0	0
	0.84–4.23	Fresh	0	0
	4.23–8.46	Fresh brackish	0	0
	8.46–28.21	Brackish	0	0
	28.21–282.1	Brackish salt	5	100
	282.1–564.3	Salt	0	0
	> 564.3	Hyperthaline	0	0

The obtained MAR values compared with standard values are summarized in Table 3. It can be concluded that about 80% of water samples are suitable whereas 20% of the samples are unsuitable for irrigation purpose.

Kelley's ratio (KR)

Excess amount of sodium over calcium and magnesium is determined by using Kelley's ratio (KR). KR value less than 1 indicates the suitability of the groundwater for irrigation purpose. The KR values of the study area of all the locations have been determined and are tabulated in Table 2. The KR value of all the samples ranges from 0.82 to 5.8. The obtained KR values compared with standard values are summarized in Table 3. It can be concluded that 40% water is suitable and 60% of water samples are found to be unsuitable for irrigation purposes.

Permeability index (PI)

The long-term use of irrigation water affects sodium, calcium, magnesium and carbonate content in the soil. These contents, in turn, affect the permeability of soil. PI value less than 80 is used for irrigation purpose. The PI values of the study area of all the samples have been assessed and are summarized in Table 2. The PI values of all the samples in the present study range from 72 to 93. The standard values depicted through Table 3 indicate that 60% of groundwater samples fall in good category whereas 40% samples fall in moderate category for the irrigation use.

Conclusion

The study of hydrochemical parameters reports that the shallow groundwater aquifers of the study area indicate that the groundwater is safe for drinking and irrigation purposes. The groundwater quality reveals that pH, TH and TDS are safe for drinking purposes. Other elements are within the permissible limits except one place where iron is moderately high. SAR and SSP values fall in excellent category which makes the groundwater suitable for agriculture activities. MAR and PI also fall in good permissible categories. RSC and KR fall in suitable category. Above conclusion reveals that the groundwater of study area is suitable for drinking and irrigation purposes.

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