Geochemical assessment of groundwater quality for its suitability for drinking and irrigation purpose in rural areas of Sant Ravidas Nagar (Bhadohi), Uttar Pradesh

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ABSTRACT
This study is aimed to assess the groundwater excellence within the rural areas of Sant Ravidas Nagar (Bhadohi), Uttar Pradesh, India. In the current work, estimation of groundwater excellence indices has been done to recognize the water quality for the appropriateness of groundwater resource for drinking and agricultural use. Twenty groundwater samples were collected and investigated for diverse geochemical parameters viz, pH, total dissolved solids (TDS), total hardness, cations and anions. The groundwater of the study region is neutral to slightly alkaline in nature. Piper’s diagram classification shows that majority of the samples belong to CaMgHCO₃ hydrochemical facies. Gibbs plot specifies that majority of samples falls in rock dominance. The water quality index shows that the entire sample is under excellent water category. On the basis of TDS, all the samples are within the range of desirable to permissible for drinking and agriculture purpose. Forty percent samples of the study region are having nitrate content more than permissible limit (>50 mg/l) which is not fine for individual use. Poor drainage, domestic waste and use of N fertilization on farming land may be the main sources of nitrate in groundwater of the study region. On the basis of different water quality indices, groundwater of the study region is fit for agricultural use.

Introduction
Water is the most precious natural resource among all natural resources found on the Earth. Earth is known as a blue planet due to the presence of abundant water on its surface (Iqbal & Gupta, 2009; Maruyama et al., 2013). In previous few decades, there has been unprecedented amplify in the requirement for fresh water supply is owing to a tremendous increase in population, industrialization, urbanization, and intense agricultural activities (Dhanasekarapandian, Chandran, Devi, & Kumar, 2016; Raju, Shukla, & Ram, 2011). Due to unplanned urbanization and rapid industrialization, this scarce resource has reached a point of crisis (Singh, 2002). Due to insufficient availability of surface water which is further aggravated by pollution, urbanization, and industrialization, and also due to the notion that groundwater is pollution free, the majority of the populace in India depends on groundwater assets for drinking and household, industrial, and agricultural uses (Raju et al., 2011).

In India, there is a majority of the rural population depending mainly on groundwater. Globally, irrigated farming is the largest abstractor and chief user of groundwater assets, near about 65% of the total agricultural land is irrigated by groundwater (Foster & Garduño, 2013; Raju, 1998). Earlier groundwater was considered safe as compared to surface water but nowadays due to improper waste management pollution load increases in groundwater also (Iqbal & Gupta, 2009). Natural water is a vibrant chemical system including in its composition a composite group of gases, mineral and organic essences in the form of true solutions, and suspended and colloidal matters as well (Nikanorov & Brazhnikova, 2009). The chemistry of subsurface water is controlled by many natural as well as anthropogenic factors. Natural factors which have control over water chemistry include precipitation pattern and amount, geological factors of watershed and aquifer, meteorological factors, and various rock–water interaction processes in the aquifer (Arnaude, 1999; Raju, Patel, Reddy, Suresh, & Reddy, 2016; Singh, Raju, & Ramakrishna, 2015). Human activities which influence the water chemistry include dumping of solid waste, domestic and industrial waste, and mining and agricultural activities (Hem, 1991; Raju, 2007; Singh, Raju, Gossel, & Wycisk, 2016; Todd, 1980). As and F contamination in groundwater is
due to the natural minerals found in the rocks around aquifer while NO$_3$N, heavy metal, and pesticide contamination is due to human activities. In a shallow aquifer, NO$_3$N is a common pollutant. Point and nonpoint source are responsible for nitrate pollution (Postma, Boesen, Kristiansen, & Larsen, 1991). Application of fertilizers and manure are the non-point source while septic tank, domestic sewage, and dairy lagoons are a point source (Arnade, 1999; Hubbard & Sheridan, 1994).

Groundwater quality acts a crucial role in groundwater security and excellence preservation. Hence, evaluation of the groundwater quality is essential not only for use by present generation but also for future consumption. Groundwater resources of the alluvial plains in the Indo Gangetic basin show a qualitative and quantitative descent through time (Haritash, Kaushik, Kaushik, Kansal, & Yadav, 2008; Kumar, Kumari, Ramanathan, & Saxena, 2007). Therefore, monitoring of groundwater quality is essential in any basin or population area which affects the fitness of water for household, industrial and agriculture use.

Many researchers have worked on hydrochemical features, groundwater pollution, and its quality status for utilization in drinking and agriculture purposes in various basins and urban regions (Ahamed & Loganathan, 2017; Alaya, Saidi, Zemni, & Zargouni, 2014; Gowd, 2005; Patel et al., 2016; Raju, Ram, & Gossel, 2014; Raju et al., 2016; Singh, Tewary, & Sinha, 2011; Umar, Ahmed, Alam, & Khan, 2008). In the current study, an effort has been made to calculate the groundwater quality indices for the aptness of groundwater resource for drinking and agricultural purpose and identify the influences of natural and anthropogenic actions on groundwater chemistry.

### Study area

#### Location

The samples were collected from the rural areas of Sant Ravidas Nagar (Bhadohi) region which is the floodplain of the Ganga River. Figure 1 shows the sampling location map of the study region. The dependency of entire area on the groundwater is the main reason behind the choice of this particular study area. Groundwater is being used in domestic, agricultural as well as commercial purposes in this area.

#### Geology and hydrogeology

The study region is situated in Indo-Gangetic plain underlain by the quaternary alluvial sediment from Pleistocene to recent age made up of fine to coarse-grained sand, clay, and clay with Kankar. Alluvial plain of the study region is geologically divided into three distinct zones, i.e., older alluvial upland (upper Pleistocene to recent), newer alluvial plain (middle to upper Pleistocene), and Holocene to Recent active channels and floodplains. The underlying unconsolidated near surface of most of the Gangetic plain, comprise Pleistocene to recent alluvial sediments, are generally potential aquifer. Due to the presence of alternative sand and clay layers, a multilayer aquifer system is found in the study region. The groundwater of the study region founds under phreatic condition. The shallow groundwater in the back swamp deposit (clay and Kankar beds) is generally unconfined and static water level is only a few meters below the water level (at about 20–60-m depth) (Mohan, Srivastava, & Rai, 2011; Raju, 2012; Shukla & Raju, 2008).

### Fieldwork

Twenty groundwater samples were collected to evaluate groundwater chemistry. In the current study, prior to data assortment, a selection measure was established to aid in the recognition of proper sampling sites for the groundwater quality evaluation. Those hand pumps were chosen for collecting the samples, which were active and functional and constantly in employ for human ingestion and other daily use functions. For collection, conservation, and investigation of the samples, standard methods APHA 2005 were followed.

Samples were collected in Polyethylene containers cleansed with sampled groundwater before filling and adequately labeled. Groundwater samples were collected after flushing water 5–10 min in order to eliminate the intervention of the stagnant water in the metal shell and to even out the electrical conductivity (EC). Groundwater samples were stored at 4°C to evade any key elemental modification.

Figure 1. Location map of the study area. Source: Author.
Laboratory analysis

Electrical conductivity (EC), pH, and total dissolved solids (TDS) were calculated using pH and conductivity meters after calibration of the meter with standard buffers of respective parameter. The samples were filtered by 0.45-μm Millipore filter paper in vacuum filtration unit to eliminate suspended sediments. The samples were then examined for key cations (Ca, Mg, Na, and K), anions (HCO₃, Cl, F, SO₄, and NO₃), hardness, and dissolved silica. The chemical analysis was carried out as per the procedure is given in APHA (2005). The investigative data obtained were practice for comprehensive geochemical investigation. The interionic relation graphs, Wilcox (1948) diagram, US Salinity Laboratory (1954) diagram, and Doneen Permeability Index Plot (1964) were prepared using Microsoft Excel Version 2007.

Results and discussion

Hydrogeochemical facies

Piper trilinear diagram is used to categorize the water facies on the basis of dominant ions (Piper, 1944). In piper diagram, major ions are plotted in two base triangles as major cations and major anions. Piper trilinear diagram is used to categorize the water facies on the basis of dominant ions. Analysis of Piper diagram reveals that alkaline earth and bicarbonate are the dominant ions in the study area (Figure 2) and major water type of study area is the CaMgHCO₃ type.

Gibbs plot

Gibbs (1970) proposed two diagrams to understand the hydrogeochemical procedures with reverence to atmospheric precipitation, rock–water interaction, and evaporation over the administration of geochemistry of groundwater. Gibbs plots are the graph of ratio of cations [(Na + K) / (Na + K + Ca)] and anions [Cl/(Cl + HCO₃)] against TDS. Gibbs plot specifies that all the sample of the study region is from rock dominance (Figures 3a and 3b). In alluvial plains, the rock–water interface is the key procedure that controls the chemistry of groundwater (Alam, 2013; Raju et al., 2011).

Estimation of water quality for different uses

Categorization of groundwater for domestic uses

Water excellence acts a vital function in determining the standard of human health. Groundwater contamination is a worldwide problem that has economic and human health impact (World Health Organization [WHO], 1997). Groundwater quality of a particular area reflects input rain, water–rock interaction as well as human activities as agriculture, domestic and industrial waste of that area (Patel et al., 2016; Raju et al., 2016). As the groundwater chemistry is very dynamic may possess different water quality in very close proximity and varies to seasonal and climatic factors (Ackah et al., 2011; Raju, 2007), analysis of groundwater excellence is significant to deduce aptness of subsurface water for household and agriculture uses. The water used for human consumption should be “safe and wholesome,” i.e. odorless, colorless, good in taste, and free from harmful chemical agents and pathogen (Jinwal & Dixit, 2008). Physicochemical parameters of groundwater of the study region judge against with guidelines suggested by WHO (1997) to deduce the aptness of groundwater for human consumption and domestic purpose.

All the samples are alkaline in nature having pH and TDS values within the permissible limit as prescribed by WHO (1997). According to Davis and De Wiest (1966) categorization, all samples are permissible for drinking use. According to Freeze and Cherry (1979) categorization, all the samples fit into a freshwater category.

Figure 2. Trilinear diagram showing the relative cation and anion composition of groundwater samples.
Majority of the parameters are within the permissible limit according to WHO (1997). The concentration of NO$_3$ in 40% of samples is above the permissible limit laid down by WHO (1997) (Table 1). The high value of Nitrate in the study region may be due to poor drainage of domestic waste and runoff of agricultural effluents (Majumdar & Gupta, 2000; Singh, Mishra, Madhav, Kumar, & Singh, 2013).

**Water quality index (WQI)**

WQI is a central parameter to find out the groundwater excellence and its aptness for human consumption (Avvannavar & Shrihari, 2008; Mishra & Patel, 2001). WQI describes as a method of ranking that gives the combined control of major water quality parameters on the whole excellence of water for human utilization (Singh et al., 2016). The standards for human

**Figure 3a.** Mechanism controlling groundwater chemistry (Gibbs I).

**Figure 3b.** Mechanism controlling groundwater chemistry (Gibbs II).

**Table 1.** Ranges of chemical parameters and their comparison with World Health Organization (1997) standard for drinking water.

| Parameter | Min.  | Max.  | Mean | World Health Organization (1997) Permissible limit | Sample No. (% Samples) Exceeding permissible limit |
|-----------|-------|-------|------|---------------------------------------------------|---------------------------------------------------|
| pH        | 7.40  | 8.20  | 7.78 | 9.2                                               | –                                                 |
| EC (μS/cm) | 622   | 2034  | 1037 | –                                                 | –                                                 |
| TDS (mg/l) | 312   | 998   | 529.55 | 1500                                             | –                                                 |
| Hardness (mg/l) | 192 | 502   | 320.7 | 500                                               | –                                                 |
| Ca$^{2+}$ (mg/l) | 28  | 120   | 65.70 | 200                                               | –                                                 |
| Mg$^{2+}$ (mg/l) | 17.56 | 62.44 | 38.16 | 150                                               | –                                                 |
| Na$^+$ (mg/l) | 34.6 | 149.6 | 62.56 | 200                                               | –                                                 |
| K$^+$ (mg/l) | 1.51  | 6.51  | 2.72  | 12                                                | –                                                 |
| HCO$_3^-$ (mg/l) | 196 | 424   | 303   | 600                                               | –                                                 |
| SO$_4^{2-}$ (mg/l) | 25.80 | 65.10 | 48.30 | 600                                               | –                                                 |
| Cl$^-$ (mg/l) | 32.00 | 128.0 | 47.55 | 600                                               | –                                                 |
| F$^-$ (mg/l) | 0.38  | 1.20  | 0.69  | 1.5                                               | –                                                 |
| NO$_3^-$ (mg/l) | 17.50 | 86.70 | 47.55 | 50                                                | 2, 5, 6, 7, 8, 11, 15, 17 (40)                     |
| SiO$_2$ (mg/l) | 29.40 | 42.60 | 34.44 | –                                                 | –                                                 |
consumption as suggested by WHO (1997) have been taken for the estimation of WQI. Firstly, special weights ($w_i$) in a scale of 1 (slightest consequence on water quality) to 5 (highest outcome on water quality) was allocated to every elemental parameter, on the basis of their supposed impact on primary health and their relative magnitude in the quality of drinking water (Sener & Davraz, 2013). The parameters having serious health impact and whose occurrence above the critical concentration amount could result in confined usage of the resource for household and drinking purposes were given the highest weight five (Varol & Davraz, 2014). The highest weight of 5 has been allocated to the parameters like nitrate, TDS, chloride, and fluoride because of their foremost significance in water excellence evaluation. Weight and relative weight of different physiochemical parameters is given below in Table 2.

The relative weight ($W_i$) has been worked out using the equation:

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i}$$

(1)

where $W_i$ is relative weight, $w_i$ is the weight of each parameter, and $n$ is a number of parameters. Then, a quality rating ($q_i$) for each parameter is determined by dividing its concentration in each water sample by its limits values given by the WHO and the result is multiplied by 100:

$$q_i = \left( \frac{C_i}{S_i} \right) \times 100$$

(2)

where $q_i$ is the quality rating, $C_i$ is the amount of every physiochemical parameter in every water sample (mg/l), and $S_i$ is the drinking water standard for each chemical parameter (mg/l) as stated by WHO. To compute WQI, firstly SI value should be concluded by the subsequent equations, where,

$$SI_i = W_i \times q_i$$

(3)

$$WQI = \sum SI_i$$

(4)

$SI_i$ is the sub-index of the $i$th parameter; $q_i$ is the quality ranking depends on the amount of $i$th parameter. WQI standards are divided into five categories: Excellent (<50), Good (50–100), Poor (100–200), and Unsuitable for drinking (>300) (Sahu & Sikdar, 2008; Singh et al., 2016). The WQI value of the study region ranges from 14.28 to 29.23. The entire water samples are excellent water types on the basis of WQI (Table 3).

**Categorization of groundwater for agricultural use**

The amount and composition of dissolved elements in water establish its excellence for agricultural use. Excessive concentrations of dissolved ions in farming water alter soil configuration, permeability, and aeration that directly distress plant development (Masood, Sumbul, & Mohd, 2012; Rao et al., 2002). Excessive salt in irrigation hinder the growth of a plant by physical means as restricting the uptake of water through alteration in osmotic pressure and/or by chemical means as altering the metabolic reactions. (Todd, 1980). Drainage is an important factor associated with plant growth. If a soil is open and fine plowed, irrigation with the generous amount of saline water may lead to the production of the crop, but a poorly drained area may fail to grow the satisfactory crop even when irrigated with good-quality water (Todd, 1980; Raju, Ram, & Dey, 2009). The parameters like EC, salinity, percent sodium (%Na), sodium adsorption ratio (SAR), RSC, permeability index (PI), and magnesium ratio are important to establish the fitness of groundwater for agricultural use (Mitra, Sasaki, Enari, Matsuyma, & Fujita, 2007; Selvakumar, Ramkumar, Chandrasekar, Magesh, & Kaliraj, 2017; Wang, 2013).

**Residual sodium carbonate**

It is used to know about the harmful consequences of carbonate and bicarbonates on the excellence of water for agricultural use (Eaton, 1950). RSC can be estimated by the formula given below:

$$\text{RSC} = \left( \frac{\text{CO}_3 + \text{HCO}_3^-}{- (\text{Ca} + \text{Mg})} \right) \text{ (All values in meq/l)}$$

On the basis of RSC basics, water can be categorized into three categories such as safe (<1.25 meq/l), marginally suitable (1.25–2.5 meq/l), and unsuitable (>2.5 meq/l). In the present study, it was found that all the samples fall into the safe category (Table 4).
soil permeability as a consequence soil becomes hard to plow and inapt for the seeds germination (Jeevanandam et al., 2012). Percent Sodium (%Na) is an expression to find the Na content in irrigational water. The percent sodium is obtained by the formula given below:

$$\% \text{Na} = \frac{(Na + K)}{(Ca + Mg + Na)} \times 100 \text{ (All values in meq/l)}$$

Wilcox (1948) projected a scheme to categorize groundwater for agricultural use based on percent sodium and electrical conductivity in form of a diagram. Wilcox (1948) classified the water in five distinct degrees of suitability for irrigation such as excellent to good, good to permissible, permissible to doubtful, doubtful to unsuitable, and unsuitable. When classified on the basis of percent sodium alone, out of 20 samples, 6 samples were excellent to good, 13 are good to permissible, and 1 is doubtful to unsuitable (Figure 4).

### U S Salinity Diagram (1954)

More comprehensive agricultural fitness investigation can be obtained by scheming a USSL diagram. The US Salinity Laboratory’s diagram is employed broadly

### Table 3. Type of water based on WQI in the study region.

| SN | WQI | Water type |
|----|-----|------------|
| 1  | 20.91| Excellent  |
| 2  | 27.35| Excellent  |
| 3  | 17.01| Excellent  |
| 4  | 18.77| Excellent  |
| 5  | 23.29| Excellent  |
| 6  | 26.73| Excellent  |
| 7  | 29.23| Excellent  |
| 8  | 26.04| Excellent  |
| 9  | 21.04| Excellent  |
| 10 | 17.22| Excellent  |
| 11 | 24.02| Excellent  |
| 12 | 22.27| Excellent  |
| 13 | 19.82| Excellent  |
| 14 | 18.82| Excellent  |
| 15 | 24.44| Excellent  |
| 16 | 19.20| Excellent  |
| 17 | 21.25| Excellent  |
| 18 | 14.28| Excellent  |
| 19 | 18.25| Excellent  |
| 20 | 19.44| Excellent  |

### Table 4. Agricultural suitability of groundwater samples in the study region.

| S. No. | SAR | % Na | RSC | Kelly’s index | Mg ratio | Permeability index | Gibbs I | Gibbs II |
|--------|-----|------|-----|--------------|----------|-------------------|--------|---------|
| 1      | 2.31| 42.81| −1.14| 0.73         | 28.68    | 64.84             | 0.51   | 0.39    |
| 2      | 4.43| 61.32| 0.79 | 1.51         | 44.57    | 80.98             | 0.74   | 0.41    |
| 3      | 2.21| 41.38| −0.81| 0.69         | 38.58    | 64.58             | 0.53   | 0.40    |
| 4      | 1.18| 26.57| −1.94| 0.35         | 69.75    | 51.28             | 0.54   | 0.36    |
| 5      | 1.18| 26.36| −2.48| 0.35         | 73.69    | 49.23             | 0.58   | 0.37    |
| 6      | 1.62| 27.98| −2.34| 0.38         | 56.27    | 48.15             | 0.47   | 0.29    |
| 7      | 1.36| 23.97| −3.09| 0.30         | 40.36    | 43.41             | 0.35   | 0.32    |
| 8      | 0.81| 17.31| −2.28| 0.20         | 36.99    | 41.81             | 0.25   | 0.17    |
| 9      | 0.77| 16.97| −1.73| 0.20         | 45.90    | 43.24             | 0.27   | 0.14    |
| 10     | 1.95| 40.07| 0.07 | 0.65         | 59.95    | 68.29             | 0.63   | 0.30    |
| 11     | 1.72| 30.42| −1.49| 0.43         | 43.20    | 52.19             | 0.43   | 0.25    |
| 12     | 1.16| 22.42| −1.60| 0.28         | 55.32    | 46.08             | 0.39   | 0.19    |
| 13     | 1.40| 28.29| −1.58| 0.39         | 36.09    | 52.40             | 0.38   | 0.27    |
| 14     | 1.47| 30.98| −1.02| 0.44         | 55.48    | 57.08             | 0.50   | 0.23    |
| 15     | 0.96| 21.58| −2.78| 0.27         | 62.85    | 44.59             | 0.43   | 0.27    |
| 16     | 1.06| 23.86| −0.77| 0.31         | 50.79    | 52.41             | 0.39   | 0.17    |
| 17     | 1.19| 26.06| −1.68| 0.34         | 65.12    | 51.35             | 0.50   | 0.22    |
| 18     | 1.12| 29.25| −0.24| 0.40         | 63.66    | 63.92             | 0.53   | 0.20    |
| 19     | 2.05| 38.68| −1.76| 0.61         | 35.83    | 59.69             | 0.50   | 0.46    |
| 20     | 1.49| 29.63| −1.16| 0.41         | 27.81    | 54.05             | 0.37   | 0.27    |

These bold value shows the sample unsuitable for irrigation as per kelly and magenism hazard indices.

Figure 4. Classification of groundwater samples on the basis of electric conductivity and percent sodium (Wilcox, 1948).
Based on this classification, most of the groundwater samples fall in class 1 and rest of the samples fall in class 2 types; thus, all the samples are appropriate for agricultural uses (Figure 6).

Kelly index

For the irrigation, purpose water is also classified on the bases of Kelly index. If Kelly index is more than 1 it indicates an excess of sodium; on the other hand, Kelly index less than 1 signifies deficit of Na in water (Kelly, 1951). On the basis of Kelly index, water is categorized into three classes. If the value of Kelly index is less than 1, water is suitable for irrigation. If the Kelly index is between 1 and 2, water is marginally suitable, and when Kelly index is more than 2, water is unsuitable for irrigation (Srinivasamoorthy, Gopinath, Chidambaram, Vasanthavigar, & Sarma, 2014). KI is computed by the formula:

\[ KI = \frac{(Na + \sqrt{HCO_3})}{(Ca + Mg + Na)} \times 100 \] (All values in meq/l)

Permeability index

Doneen (1964) developed a PI-based diagram to categorized the water for irrigation. Long-term irrigation water imposes the impact on soil quality. Sodium, calcium, magnesium, and bicarbonate ions present in water influence the soil permeability (Raghunath, 1987).

PI can be calculated by the formula given below:

\[ PI = \frac{(Na + \sqrt{HCO_3})}{(Ca + Mg + Na)} \times 100 \] (All values in meq/l)
be concluded that nearly all of the samples are safe for the fitness of groundwater for agriculture purpose, it can and ratios which are widely used in the research to assess permission limit. The main source of NO\textsubscript{3} in ground-water is controlled by both natural and anthropogenic factors. Groundwater of the study region is neutral to slightly alkaline in nature, and the nitrate concentration more than the WHO (1997) mmissible limit set by WHO (1997). Nitrate pollution is a major issue in the study region, as 40\% samples possess a state of equilibrium (Raju et al., 2011; Sreedevi, 2004). The magnesium ratio values of the studied samples range from 24.01 to 65.18. Out of 20 samples, 10 samples are not fit for agricultural use on the basis of magnesium ratio (Table 4).

**Magnesium hazard**

Generally, calcium and magnesium ions in groundwater possess a state of equilibrium (Raju et al., 2011; Szabolcs and Darab 1964) recommended a magnesium hazard value of water for agriculture purpose. Magnesium hazard value can be obtained by following formula:

\[
\text{Magnesium Ratio} = \left( \frac{\text{Mg}}{\text{Ca} + \text{Mg}} \right) \times 100 \quad \text{(All values in meq/l)}
\]

If the groundwater posses the magnesium ratio above 50, it seems to be unsuitable for irrigation purpose and application of such water will adversely influence the harvest yield by increasing the basic nature of soil (Raju et al., 2011; Sreedevi, 2004). The magnesium ratio values of the samples vary from 0.20 to 1.51. If the groundwater possesses the magnesium ratio above 50, it seems to be unsuitable for irrigation purpose and application of such water will adversely influence the harvest yield by increasing the basic nature of soil. Four samples have magnesium ratio above 50, it seems to be unsuitable for irrigation purpose and application of such water will adversely influence the harvest yield by increasing the basic nature of soil (Raju et al., 2011; Sreedevi, 2004).

**Conclusion**

The conventional hydrogeochemical techniques and quality indices are used to find out the status of groundwater quality for its utilization to drinking and agriculture purpose. It can be concluded that the geochemistry of the study region is neutral to slightly alkaline in nature, because of the influx of HCO\textsubscript{3} ion in the groundwater aquifer, which is produced by the reaction of the CO\textsubscript{2} present in soil space and rainwater. From the piper triangular diagram, it is viewed that 90\% samples belong to CaMgHCO\textsubscript{3} water type and rest is of mixed type. Hydrogeochemistry discloses that the order of cation abundance is Ca > Na > Mg > K. All the water samples have pH value within the permissible limit perceived by WHO (1997). On the basis of TDS, the entire samples were within the range of desirable to permissible for drinking purpose. Sixty percent samples of groundwater in the study region are fit for drinking purpose with little precaution as most of the parameters are within the permissible limit set by WHO (1997). Nitrate pollution is a major issue in the study region, as 40\% samples possess the nitrate concentration more than the WHO (1997) permission limit. The main source of NO\textsubscript{3} in groundwater is domestic sewage and animal excreta water and excess fertilizer input. After calculating various indices and ratios which are widely used in the research to assess the fitness of groundwater for agriculture purpose, it can be concluded that nearly all of the samples are safe for agricultural use. The outcomes obtained from the study will be helpful to recognize the groundwater quality condition for efficient management and consumption of groundwater resources for drinking and irrigation use. The groundwater samples having high nitrate concentration need remedial measures before potable uses. Bioremediation, physical adsorption, reverse osmosis, and solar distillation are some of the helpful techniques for nitrate elimination for safe drinking water.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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\[ K_I = \frac{\text{Na}}{(\text{Ca} + \text{Mg})} \text{ (All values in meq/l)} \]
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