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Retraction

Retracted: Investigation of Groundwater Hydro-Geochemistry, Excellence, and Anthropoid Wellbeing Hazard in Dry Zones Using the Chemometric Method

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] M. S. Ahmed, G. Ramkumar, S. Radjarejesri et al., “Investigation of Groundwater Hydro-Geochemistry, Excellence, and Anthropoid Wellbeing Hazard in Dry Zones Using the Chemometric Method,” *Advances in Materials Science and Engineering*, vol. 2022, Article ID 4903323, 10 pages, 2022.

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Research Article

Investigation of Groundwater Hydro-Geochemistry, Excellence, and Anthropoid Wellbeing Hazard in Dry Zones Using the Chemometric Method

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This work deals with the groundwater hydro-geochemistry, intake and irrigation water quality, and noncarcinogenic human healthiness concerns in a dry environment. Water quality characteristics were measured in samples which were gathered from the countryside and city. The findings showed that the composition of groundwater is acidic and stony. There was a wide range of nitrate and fluoride concentrations, with a mean concentration of 1.4 mg/ltr, 65.7 mg/ltr, and 0 to 13.3 mg/ltr. Only 14% of the samples were rated excellent by the water quality index, while 38% were rated good, 28% were rated bad, and 12% were classified unfit/unsuitable for eating. The quantities of nitrate and fluoride in groundwater are estimated to be 68% higher than the permitted range for noncarcinogenic ingestion, posing a major health risk to the local people. A range of indicators and graphical approaches were used to assess the appropriateness of groundwater. The geogenic origin of fluoride was demonstrated to be followed by the anthropogenic source of NO_{-}^{3}, K^{+}, Na^{+}, Cl^{-}, and HCO-3, and the predominant hydro-chemical facies Ca_{-2}^{+} and HCO-3 are done.

1. Introduction

Groundwater in dry and semidry areas around the world is under threat as a main supply of water for both residential consumption and agricultural irrigation [1]. Groundwater is the principal basis of water for humans in dry and semidry regions of the world, but environmental issues about quantity, quality, and accessibility are critical [2]. A multitude of factors influence groundwater quality, including interactions between groundwater and the host aquifer materials, invading water quality and more [3, 4]. Toxic human activities such as excessive use of agrochemicals, leaching from urban and industrial waste, and sewage leakage can also impair groundwater quality. According to the Indian government, groundwater accounts for 78% of the total irrigation capacity of the country's farms [5]. The annual amount of groundwater withdrawn exceeds the annual amount of groundwater recharge, resulting in overuse of groundwater resources. Drinking groundwater with fluoride levels above 2.6 mg/L can lead to dental fluorosis, kidney and neurological disorders, and other health problems [6–8]. Chemometrics is a scientific discipline which use quantitative, analytic, or other methodologies based on logical reasoning to develop or choose appropriate measuring processes and studies, as well as to give the most pertinent data by evaluating chemical data and the compensation are shown in Figure 1 [9].

For fluoride and nitrate contaminated groundwater, the most common means of exposure are ingesting, inhalation, and skin contact [10, 11]. In terms of human health, inhalation and cutaneous exposure are of little concern. As a result, ingestion is the primary mode of exposure for humans. The US Environmental Protection Agency developed a four-step health risk valuation process which are as follows: (i) threat identification, (ii) dose-response assessment, (iii) exposure assessment, and (iv) hazard assessment. This work by Gibbs [12] researched fluoride and nitrate-enriched groundwater, while Giggenbach [13]investigated groundwater quality. Although the hydrogeology and source apportionment of essential elements as well as the human wellbeing risk calculation have been studied, the hydrogeology and source apportionment of essential elements as well as the human health risk valuation have not been fully investigated [14]. To fill this knowledge gap, we performed this investigation into the quality of groundwater. Gibbs plot research was made as the primary factors of groundwater chemistry including weathering of the aquifer host rock, evaporite salt dissolution, and ion exchange mechanisms. Geochemical markers and a multivariate statistical method were used to characterize and identify groundwater.

2. Methodology

2.1. Groundwater Sampling and Analysis. For the study's goals, fifty samples of groundwater were gathered from nine rural areas. The samples of groundwater were collected in 1-liter plastic bottles after a 10-minute preflushing to remove stagnant water and get fresh water. Using the American Public Health Association standard methods, groundwater samples were tested for 15 water quality constraints, ranging from pH and EC to total hardness (TH) and total alkalinity (TA), potassium, magnesium, sodium, sulphate, calcium, bicarbonate, and fluoride (F). The instruments for pH and EC measurements were employed by ELICO L1614 and ELICO CM183 electrochemical analyzers, respectively [15, 16]. The concentrations of TH and Ca^{2+} were restrained using the EDTA titrimetric method. The content of total hardness and CO_3^{2-} was then used to calculate, Mg^{2+}. The neutralisation titration method was used to estimate TA, $CO_3 2^-$, and HCO_3. To estimate Cl^-, an argentometric titration with a standard solution of $AgNO_3$ was utilized. The solution and potassium chromate (K_2CrO_4) indicator was used, while systronics flame photometers were used to measure K^+ and Na^+, and a spectrophotometric technique was used to measure $SO_4 2^-$, F^-, and NO_3^-. A blank and standard solution was used to calibrate the flame photometer before beginning the experiment. Every single groundwater sample was subjected to a three-way analysis. The water used in this experiment was either twice distilled or deionized. The test findings were compared to the BIS and WHO drinking water quality criteria [17]. Then, graphs and other irrigational indicators were used to assess the suitability of groundwater for irrigation. Statistical package for social sciences was used to calculate the Karl Pearson correlation coefficients between the water quality values. SPSS was used to conduct a range of statistical studies in addition to PCA and HCA. Aquachem software was used to construct a box and whisker plot as well as a USSL salinity diagram.

2.2. Water Quality Index (WQI). The water quality index was created to assist in determining whether groundwater is safe to drink. It is a way of calculating a composite influence on water quality by examining water quality characteristics. It can also be measured in terms of human water use. According to the World Health Organization (WHO) and the Bureau of Indian Standards (BIS), the quality of groundwater for drinking has an impact on a number of purposes, including irrigation and drinking water. Equation (1) provided below was used to determine WQI:

$$WQI = \frac{\sum_{i=1}^{n} WiQi}{\sum Wi} where, Qi = \frac{Va - Vi}{Vs - Vi} * 100. \tag{1}$$

For a total of n water quality parameters, Qi is the quality rating of the I^{th} water quality parameter, Va is the actual value acquired from investigation, V_i is constant for water quality, and Vs to be the BIS standard parameters for quality of water.

Quality rating scale (Qi) and weightage factor (Wi) were derived for each parameter using the following equation :

$$\begin{aligned} Wi &= \frac{K}{V_s} where, K(constant) \\ &= \frac{1}{(1/V_{S1}) + (1/V_{S2}) + \ldots + (1/V_{Sn})}. \end{aligned} \tag{2}$$

3. Results and Discussion

In terms of freshwater supply, groundwater is the main essential and dependable source on the planet. For the vast majority of rural Indians, groundwater is their primary source of drinking water. People who depend on groundwater must therefore have the quality of their water assessed. Residents relay heavily upon drinking water that is sourced from the ground. There has been no groundwater monitoring study done in some areas according to a literature review. EC, pH, total alkalinity, and total hardness were measured in 48 samples collected from 9 rural and 1 urban location, as well as chloride, carbonate and bicarbonate, calcium, nitrate, fluoride, sulphate, and magnesium.

3.1. Box and Whisker Plot. The plot depicts the 5 number immediate of a dataset. In this 5-number summation, you will get the minimum 24th percentile and median 74%. This visualization allows you to compare two or more sets of data.

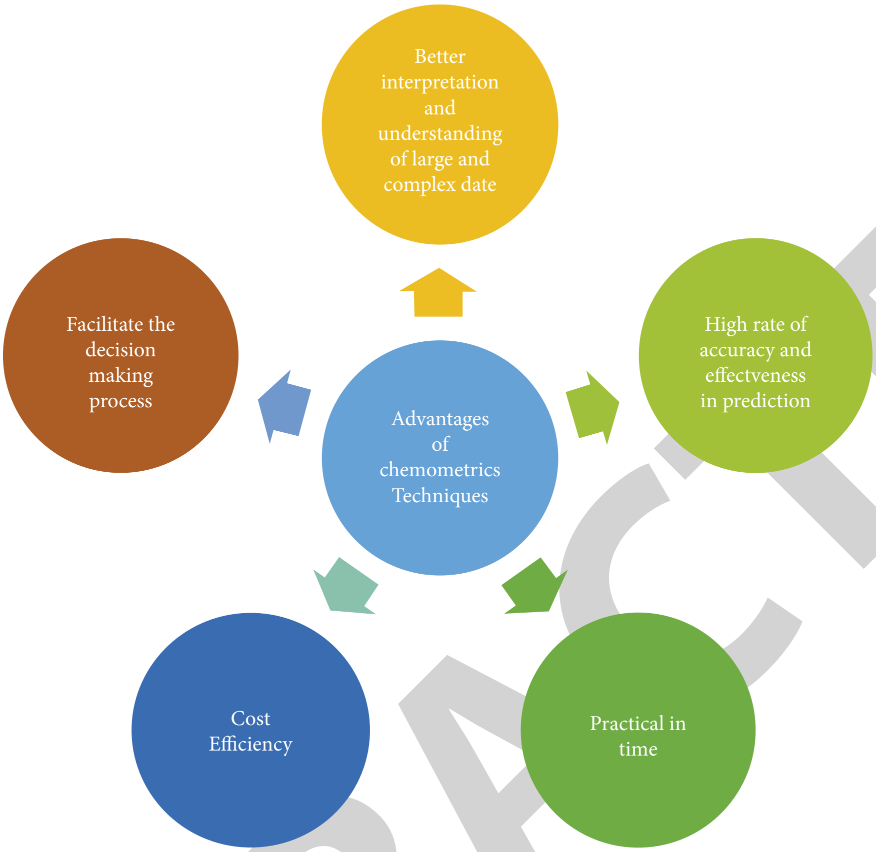


Figure 1: Shows advantages of the chemometric method.

Cations like Na−+ and anions like Cl^- were discovered to have wide ranges of variance, whereas K^+ and F^- are shown in Figure 2 to have narrow ranges of variation.

3.2. Water Quality for Drinking. In terms of acid-base neutralisation, water softening and other applications, pH is the most essential parameter. The concentration of hydrogen ions is related to the–ve logarithm of pH. It has a range of 0 to 14 points. Water with a pH of less than 7.0 is acidic, while water with a pH of more than 7.0 is basic. The water is considered neutral if its pH is exactly 7.0. Drinking water's pH ranges from 6.5 to 8.5. There was a pH range of 6.51 to 8.62 in the research area with an arithmetic mean of 7.61. Except for SC3 which had a pH of 8.62, all of the samples were within the acceptable range. With an average of 3.05 milliseconds per cm, the electrical conductivity (EC) ranged from 1.02 to 6.96 milliseconds per cm. From one location to the next, large differences in EC were discovered. Dissolved inorganic compounds in ionised form can be found at high levels of EC. TDS is one of the most important water characteristics. Water with a high total dissolved solid (TDS) level is highly mineralized. TDS levels should not exceed $500mgL^{-1}$, however they are allowed to go up to $2000mgL^{-1}$ (BIS 2012). TDS concentrations ranged from 144.64 to $4907.52mgL^{-1}$ in the current investigation, with a mean value of $1700.61mgL^{-1}$. Only 20 of the 50 samples tested fell inside the allowed level, while the other 30 fell outside of it.

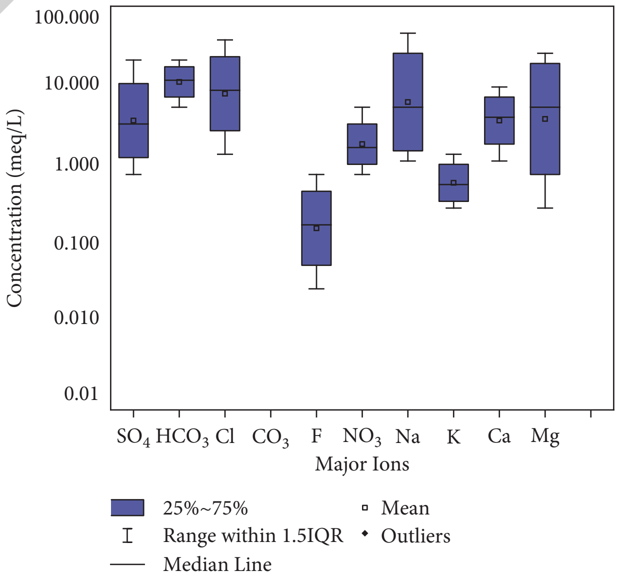


Figure 2: For significant cations and anions, a box and whisker plot.

Water with a salinity of $< 1000mgL^{-1}$ is classified as fresh by Hwang et al. [18–20],while water with a salinity of $1000 - 10000mgL^{-1}$ is classified as brackish. Freshwater makes up only 40% of the groundwater samples, with brackish water accounting for the remaining 60%. Acid-neutralizing properties of water are determined by its alkalinity. Carbonate, bicarbonate, and hydroxide are the primary natural ingredients. The acceptable level for alkalinity is $200mgL^{-1}$ and the allowed maximum level is $600mgL^{-1}$. Nearly all samples (92%) were within the legal limit of BIS and only 8% had TA levels over the permissible limit; the average TA concentration in this research region was $311.44mgL^{-1}$. In addition to the bicarbonates, chlorides, and sulphate, calcium (Ca^{2+})and magnesium (Mg^{2+})salts are responsible for the water's hardness. Scale formation in boilers and other equipment is one of the effects of hardness [21]. Stomach problems are caused by an excess of hardness, which weakens the stomach over time. $CaCO_3$ equivalent calcium carbonate concentration is used to measure potable water hardness. Hardness ranged from 80 to $1652mgL^{-1}$ in the examined area, with a mean of $371.73mgL^{-1}$. For TH, the reachable level is $200mgL^{-1}$ and the allowed value is $600mgL^{-1}$; 74% of samples were within the permitted range of BIS, whereas 24% of samples were outside the allowable range of BIS [22, 23]. Four levels of hardness were established by Durfor and Becker (1964): $60mgL^{-1}$, moderate (60–120 mgL^{-1}), difficult (120- $180mgL^{-1}$), and extremely difficult ($> 180mgL^{-1}$.). One hundred and forty-four % of samples fell into the very hard category, with only a single sample falling into the soft category. Cations are the most important. Because calcium is the most prevalent cation in water, hardness has an adverse effect on calcium concentrations. In terms of calcium, the acceptable limit is 75 mgL^{-1} and the allowed maximum is 200 mgL^{-1} [24]. The calcium concentration in the study region range is 11.2 to 134.4 mgL^{-1} and was found to be 45.58 mgL^{-1}. The BIS legal level for calcium was found in 88% of samples, which is within the acceptable limit set by the BIS and WHO. The human body's magnesium tolerance is lower than that of calcium, and a high concentration of magnesium acts as a laxative and imparts an off-putting flavor to water. Drinking water and Mg^{2+}levels should not exceed 30 mgL^{-1} and 100 mgL^{-1}, respectively. An appropriate level is 50 mgL^{-1}, according to the WHO. Table 1 shows the drinking water standard for ground water hydro-chemical parameters.

Except for pH and EC, all data are in mg/ltr. EC is measured in milliseconds per centimetre squared. Most samples (76%) were under the BIS acceptable limit for magnesium, and only 24 % reached this limit; the mean concentration of the magnesium range is 0.7–317.84 mg/ltr with an average of 60 mg/ltr. The body requires at least 98 milligrams of potassium on a regular basis. The supplementation of calcium improves blood pressure, bone health, cardiovascular health, and muscle strength. Hyperkalemia is a disorder caused by an excess of potassium in the body. The potassium concentration range starts from 0.0 to 28.22 mgL^{-1} in the studied area, with an average concentration of 8.416 mg/ltr. It is essential for the transmission of electrical messages between cells and the regulation of fluid balance in our bodies that sodium be present. Too much or too little sodium has a significant impact on human health. Hyponatremia is caused by a low sodium concentration in the blood. From 12.25 to 1327.13 mg/ltr of sodium was discovered in the research region, with an average of 403.81 mg/ltr. The WHO recommends that the highest amount of sodium in drinking water be 48 mg/l. Only 44% of the samples met WHO requirements, whereas 56% fell outside of this range. Village-to-village, the concentration of sodium differed. Anions of major important bicarbonate is a salt of carbonic acid, not a mineral. It neutralizes the acidic taste of carbonic acid by neutralizing its acidic content. With an average of 380 mg/ltr, bicarbonate range starts from 163.78 to 857.72 mg/ltr. There is a 30 mg L bicarbonate limit. The bicarbonate concentration exceeded the BIS limit in all samples. The Sardarshahar Tehsil groundwater samples contained no carbonate. Nitrate, a harmful chemical, is found in groundwater. The condition known as "blue baby syndrome" in infants can be caused by drinking water tainted with too much nitrate. According to the BIS and the World Health Organization, groundwater nitrate concentrations should not exceed 48 mg/l and 52 mg/ltr, respectively. Nearly two-thirds (65%) of the groundwater samples had nitrate levels above the BIS and WHO allowed limits, whereas just 46% of samples were within the safe range. There is chloride in all-natural waterways. One way Cl^- ends up in groundwater is by dissolving salt-bearing rock formations, weathering soil, or sewage discharge, among other possibilities. Increased water conductivity and hypertension may result from excessive Cl^- concentrations in the body [25]. According to the results, chloride levels in the research region ranged from 19.99 mg/l to 2285.29 mg/l on an average. 250 mg/l is the reasonable level also 1000 mg/ltr is the allowed limit, for chloride samples that was within the allowed limits of both the BIS and WHO were just 44% of the times. Chloride levels surpassed the BIS limit in only 22% of the samples tested. Groundwater naturally contains fluoride. Teeth mottling, skeletal fluorosis, and dental cavities can result from fluoride ingestion. In accordance with BIS (2012), the permissible level is 1.0 mg/l, but the WHO recommends a limit of 1.65 mg/ltr (2017). From 0 to 13.25 mg/l, the average fluoride concentration was 1.3084 mg/l. On the other hand, fluoride levels were below the detectable limit (BDL) in all but one of the 50 samples examined only in 10% of the samples (NA3, CH2, PH3, and DA4. No more than 400 mg/ltr of the sulphate can be tolerated in the water. An average of 231.83 mgL^{-1} of sulphate was found in the groundwater of the examined area. The BIS acceptable level was surpassed by 12% of the samples, out of a total sample pool of 50 samples tested. Sardarshahar Tehsil groundwater WQI ranged from 25.70 to 1079.87; 14% of the samples were excellent, 42% were good, 32% were bad, and 12% were unfit/inappropriate for drinking.

3.3. Base Exchange Index.

Using equation (3), the BEI was derived:

$$BEI\left(r_1\right) = \frac{Na^+ - Cl-}{SO_4^{2-}}. \tag{3}$$

As part of the calculation of BEI(r_1), the following quantities are stated in meqL^{-1};Na^+, Cl^-, and SO_42^-. It ranged in value which starts from −24.2 to 8.54 millie quivalent per litre. There are two sorts of groundwater

Table 1: Drinking water standard for ground water hydro-chemical parameters.

Parameters	Samples			WHO standards (2017)	BIS standards		The no. of samples as per WHO limits	The no. of samples within BIS parameters		Weightage for water quality index (WI) $\sum_{i=1}^{n} WiQi\text{Wi} = 1$
	Minimum	Maximum	Average		Acceptable	Permissible		Acceptable limit	Permissible limit	
pH	6.48	8.75		6.2–8.2	6.6–8.6	6.6–8.6	98	50	50	0.09412
Electrical conductivity	0.19	8.12		—	—	—	—	—	—	—
TH	138.32	4912.24		700–1100	550	2100	25	25	25	0.00165
TDS	128	734		—	250	650	—	18	48	0.00401
TA	78	1648		110	250	650	3	29	40	0.00401
Ca^{2+}	9.8	135.3		80	80	250	45	45	55	0.01273
Mg^{2+}	1.02	318.42		55	35	120	34	28	40	0.02767
Na^{+}	15.16	2951.56		260	250	420	43	40	45	0.00412
CO_3^{-}	0	0		—	80	210	—	50	55	0.01234
NO_3^{-}	164.82	891.24		—	35	35	—	0	0	0.03148
K^{+}	20.16	2281.96		210	260	1200	23	23	40	0.00412
F^{-}	0	14.18		1.8	1.2	1.6	46	37	48	0.8673
HCO_3^{-}	1.35	197.28		55	50	50	24	24	25	0.01883
Cl^{-}	0	29.11		-	—	—	—	—	—	
SO_4^{2-}	13.15	1334.36		55	—	—	22	—	—	

sources based on the value of r_1. As long as the r_1 value is lesser than 1, the sources of groundwater are $Na^+ - SO_42^-$ type, and if > 1, it specifies the groundwater resource type is$Na^+ - HCO_3^-$; 76% groundwater specimens were classified as $Na^+ - SO_42^-$; 24% are of $Na^+ - HCO_3^-$form. Figure 3 shows the total health hazard index shown by a box and whisker plot (THHI). The meteorological genesis index (meteorological genesis index) is a metric, the meteoric genesis index described below is used to classify groundwater samples in equation (4) and in Table 2.

$$MGI\left(r_2\right) = \frac{\left(K^+ + Na^+\right) - Cl^-}{SO_4^{2-}}. \qquad (4)$$

The meteoric genesis index (MGI) can be calculated as $(r_2), Na^+, K^+,\ Cl^-$, and SO_42^- are expressed in milli equivalents per litre. This ranged from −24.2 to 9.14 milli equivalents per litre for the MGI. It suggests shallow meteoric percolation ifr_2 is less than 1, while it indicates deep meteoric percolation ifr_2 is greater than 1. In the study area, the samples of shallow meteoric percolation is made up of 76% of the samples, whereas the samples of deep meteoric percolation is made up of 24% of the samples.

3.4. Sodium Adsorption Ratio. Sodium is an extensively used indicator and wateris suitable for irrigation. The sodicity of a water sample is determined by the ratio of Na^+ ions to the sum of Ca_2^+ and Mg_2^+ ions. Irrigation cannot be done with extremely salty water [26]. If the SAR is greater than 10, soil permeability issues may arise [27]. According to Li et al. [28, 29] evaluation of SAR, 49% of the samples were exceptional, 23% were respectable, 8% were questionable, and 18% were inappropriate.

3.5. USSL Salinity Diagram. According to the USSL salinity diagram (USSL), as shown in Figure 4, which shows sodium dangers on the *X*-axis while salinity dangers are on the *Y*-axis, 50% examples had extremely high salinity, 10% had high salinity, 40% had average saltiness, and 3% had low saltiness. Based on the plot, the groundwater samples were arranged in the following manner, as shown in equation (5).

$$C_2S_1\,(38\%) > C_4S_2\,(22\%) > C_4S_4\,(20\%) > C_4S_1\,(6\%) > C_4S_3\,(4\%) > C_3S_2\,(4\%) > C_3S_3\,(2\%) > C_3S_1\,(2\%) > C_1S_1\,(2\%). \qquad (5)$$

3.6. Residual Sodium Carbonate. Remaining sodium carbonate(RSC) from the irrigation point is an important metric for monitoring water quality. The appropriateness of groundwater for irrigation depends on the concentration of CO_3^{2-} and HCO_3 in the groundwater. There is greater probability of Ca^{2+} and Mg^{2+} precipitation if the water has high bicarbonate content. As a whole, the range of the RSC values was −22.239 to 10.898 meq L^{-1} of these, 64% were suitable for irrigation, 14% were dubious or slightly safe, 12% were unsuitable, and 10% were dangerous.

3.7. Percentage Sodium (% Na). It shows the percentage of sodium (% Na) in irrigation water, which can be used to calculate the concentration of Na^+. There was a range of 8.522 to 94.291$meqL^{-1}$ of Na in the research region. There are 8% exceptional samples, 34% decent samples, 6% permitted samples, 28% questionable samples, and 24% inappropriate for irrigation.

3.8. Kelly's Index. In the evaluation of irrigation water, Kelly's index (KI) is a useful metric. Na^+ is computed against Mg^{2+} and Ca^{2+} in order to determine KI. It is OK to use this

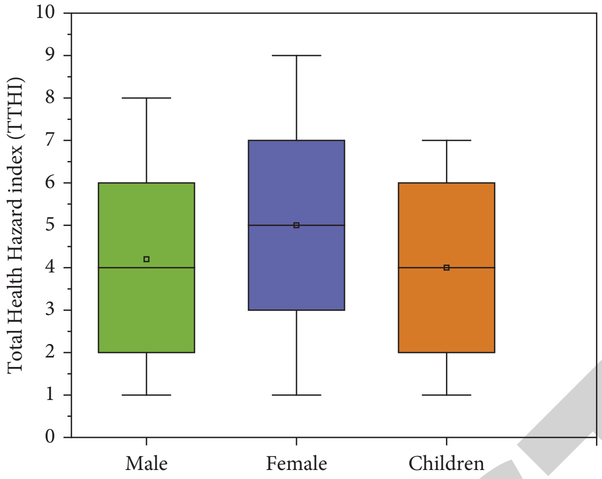


FIGURE 3: The total health hazard index is shown by a box and whisker plot (THHI).

TABLE 2: Risk assessment for noncancerous substances.

Noncarcinogenic risk	Hq NO_3^-		Hq F^-		THHI	
	Hq less than one NS (%)	Hq greater than one NS (%)	Hq less than one NS (%)	Hq greater than one NS (%)	THHI less than one NS (%)	THHI greater than one NS (%)
Male	25	30	35	20	12	40
Female	25	30	35	20	12	40
Children	25	30	36	15	12	40

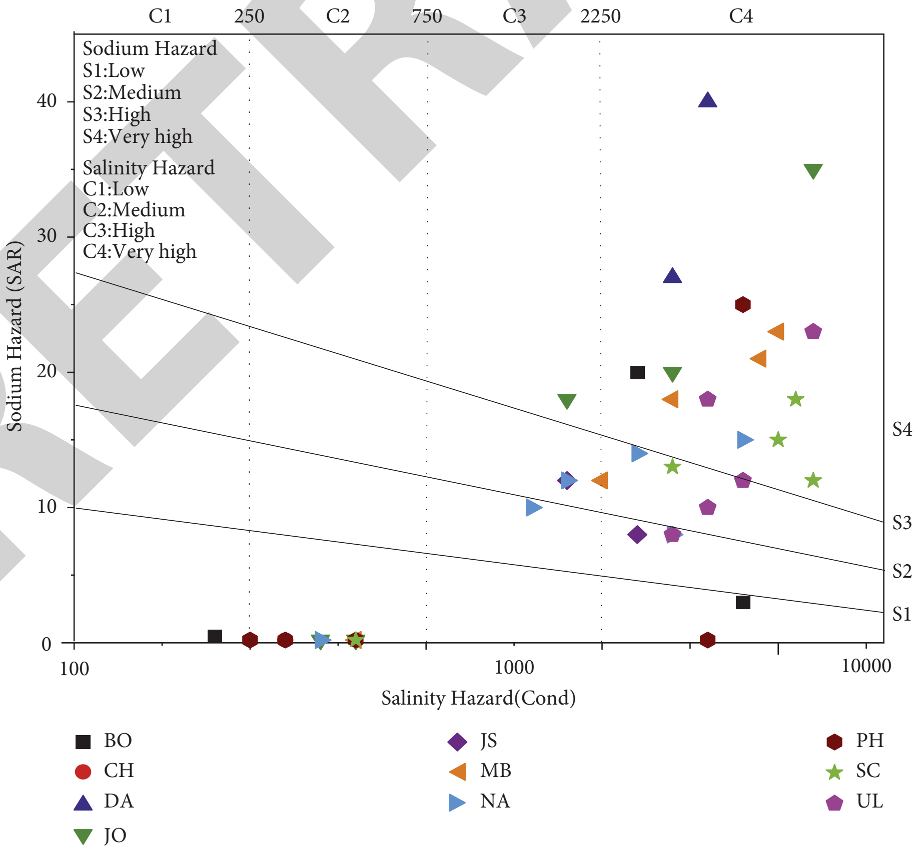


FIGURE 4: USSL salinity diagram.

water for irrigation if the KI value is < 1, but it is unfit for irrigation if the KI value is > 1. It is used to compute KI. KI values ranged from .078 to 15.8 milli equivalents per litre during the experiments. Based on the categorization proposed by Kelly (1951), 44% of samples were appropriate and 56% of samples were unfit for testing and research purposes.

3.9. Magnesium Hazard. The level of Mg_2^+ in the water is the most important factor in determining its appropriateness for irrigation. When it comes to groundwater, it is common for the ions of calcium and magnesium to be in equilibrium. Magnesium, if present in excessive concentrations, alters the soil's pH and decreases the crop's productivity presented was used to calculate MH. MH concentrations ranged from 4.324 to 96.244 milli equivalents per litre. This work (31) found that only 48% of the samples remained appropriate for irrigation, though the other 52% were inappropriate.

3.10. Permeability Index. The permeability index (PI) is a measure for determining the quality of irrigation groundwater. Mg^{2+}, HCO_3^-, Na^+, and Ca^{2+} all have an effect on soil permeability According to PI's analytical data, just 2% of groundwater samples are categorized as class III, 34% as class II, and 64% as class I. In Richard's [30] classification, water from classes I and II is often suitable for irrigation. As a consequence, 98% of the samples tested passed the PI inspection and can be used for irrigation.

3.11. Residual Sodium Bicarbonate (RSBC). RSBC is a measurement used to gauge irrigation water quality. There is a clear correlation between bicarbonate and calcium concentrations in water, which affects its quality as shown in the following equation:

$$RSBC = HCO_3^- - Ca^{2+}. \tag{6}$$

RSBC ranged from 0.3 to 11.9 mill equivalents per litre. Samples suitable for irrigation accounted for 72% of the total samples analyzed.

3.12. Hydro-Geochemical Analysis of Groundwater. The key hydro-geochemical processes that influence groundwater chemistry in the most fundamental way are silicate weathering, carbonate dissolution, ion exchange, and precipitation. Conventional graphs and ionic connection plots can be created from the findings of chemical analysis to aid in determining the processes/mechanisms that influence water's hydrochemistry, which, in turn, aids in understanding how groundwater's hydrochemistry is formed. Groundwater geochemistry has been analyzed using chemometric approaches, conventional graphical plots, ionic cross plots, and chloro-alkaline indices in the present work.

3.13. Gibbs Plot. The use of the Gibbs diagram helps us comprehend the effects of the three hydro-geochemical mechanisms on the groundwater geochemistry (interplay between water and rocks, condensation, and evaporation). Groundwater chemical composition relies on systems like these, and understanding how they work might shed light on how groundwater forms. There is a formula that may be used to calculate the anions and cations Gibbs ratios. According to Figure 5, all of the samples are concentrated in one of two Gibbs plots: either the region dominated by evaporation or the region dominated by rock. As a result, evaporation and dissolution of ions in groundwater are the most important factors in influential the chemical configuration of groundwater. Neither of the two Gibbs plots shows a precipitation dominance zone for any sample. It is, therefore, negligible that precipitation affects groundwater chemistry in an arid area where precipitation is sparse.

3.14. Ion Exchange Mechanisms Using Ionic Cross Plots. Another hydro-geochemical mechanism has a significant impact on the groundwater chemistry evolution. These ion exchange activities occur when water circulates or stagnates in the host aquifer and is described by two terms: Schoeller indexes and chloro-alkaline indexes (CAIs). The below equations (7) and (8) are used to calculate CAI-1 and CAI-II, respectively.

$$CAI - I = \frac{Cl - (K^+ + Na^+)}{Cl}, \tag{7}$$

$$CAI - II = \frac{Cl - (K^+ + Na^+)}{\left(CO_3^{2-} + SO_4^{2-} + HCO_3^- + NO_3^-\right)}. \tag{8}$$

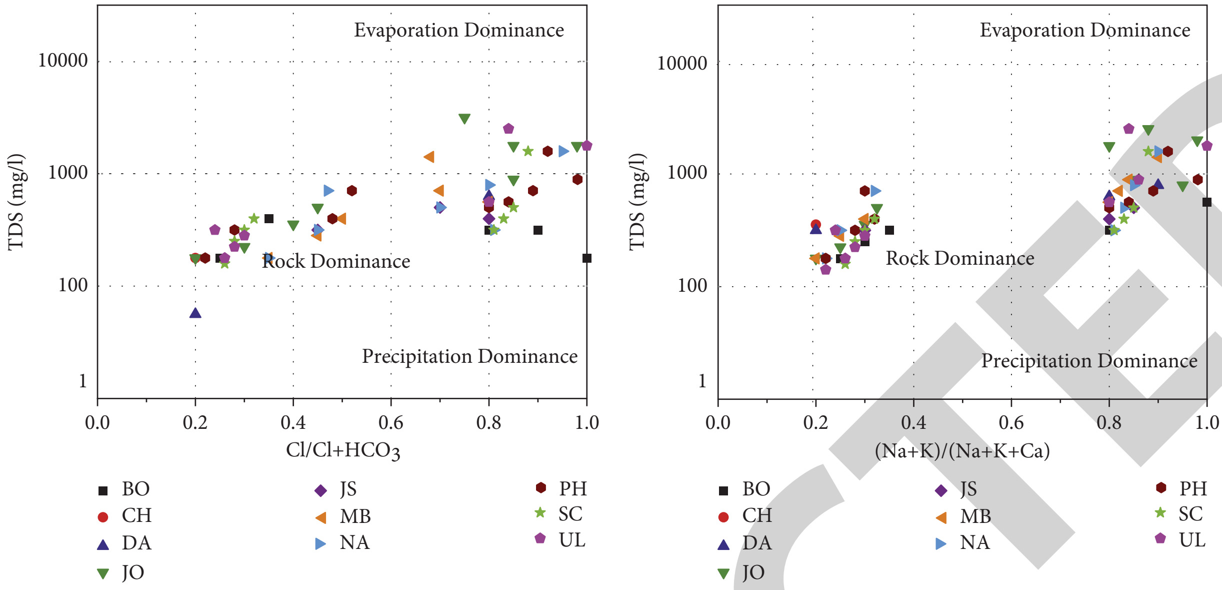
Milliequivalent/L measurements of $Cl^-, K^+, Na^+, CO_3 2^-, HCO3^-, SO_4 2^-$, and NO_3- were made. Groundwater in Sardarshahar Tehsil contained CAI-I and CAI-II, which ranged from −20.485 to 0.9432 and −1.968to 2.7478, respectively. 66% of the samples show positive CAI results, while only 44% of the groundwater samples have negative results. The hardness of groundwater is caused by the exchange of sodium and potassium in the groundwater for magnesium and calcium in the host aquifer material. Nevertheless, the negative values of the two CAIs suggest that the sodium and potassium ions from the aquifer rock resources are being swapped with the calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. Chloro-alkaline imbalance can be detected by CAIs that are negative. The base ion exchange results in water softening and sodium (Na^+) enrichment in this case is shown in equation (9).

Aquifer material $-(Ca^{2+}/Mg^{2+}) + 2(Na^+/\mathbf{K}^+)aq \longrightarrow$ Aquifer material $-2(Na^+/K^+) + (Ca^{2+}/Mg^{2+})aq$.

$$Aquifer\ material - 2\left(\frac{Na^+}{K^+}\right) + \left(\frac{Ca^{2+}}{Mg^{2+}}\right)aq$$

$$\longrightarrow Aquifermaterial - \left(Ca^{2+}/Mg^{2+}\right) + 2\left(Na^+/K^+\right)aq. \tag{9}$$

The scatter plot showing the relationship between the concentrations of $\{(Ca^{2+} + Mg^{2+}) - (HCO_3^- + SO_4 2^-\}$ vs. $\{(Na^+ + K^+) - Cl\}$ supports the idea that ion exchange and reverse ion exchange occur. Because of the importance of



(a)

(b)

Figure 5: Gibbs plot (a) cations (b) anions.

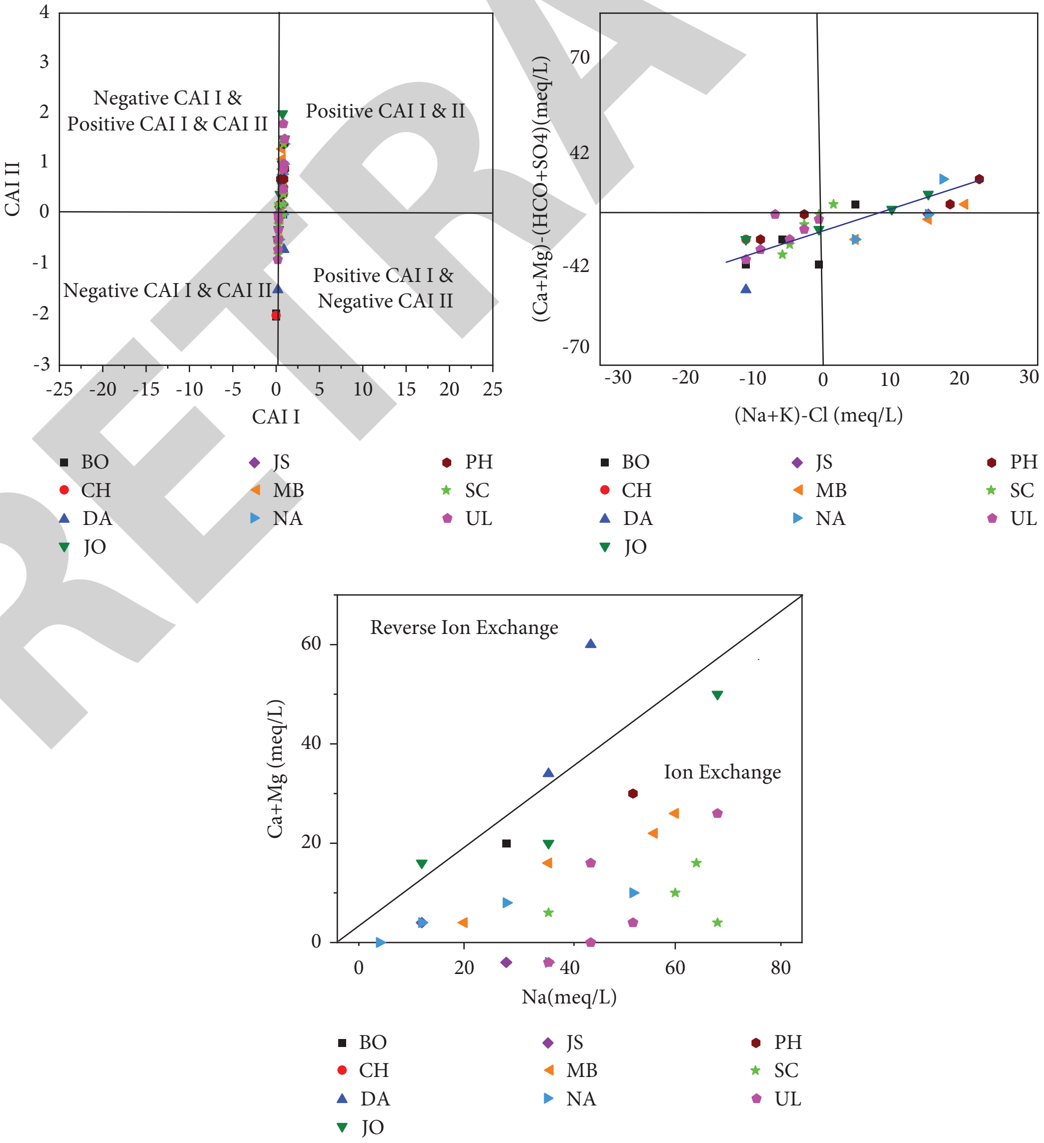


Figure 6: Scatter plots.

this process in controlling groundwater chemical composition, the slope of this scatter plot should be equal or less than 1. At $R^2 = 0.049$, the slope of the bivariate line in this case has been found to be $y = -0.285 \times -3.5562$ with an R-squared value of -0.285.Furthermore, the bivariate plot of $Ca^{2+} + Mg^{2+}$ vs Na^{+} illustrations that the groundwater samples had ion exchange and reverse ion exchange techniques are also used and are shown in Figure 6.

4. Conclusions

Water quality variables investigated in rural and urban samples included human consumption and agricultural usage. We came to the following conclusion as a consequence of our investigation:

(i) The groundwater is alkaline and hard with high amounts of Na^{-+} and HCO-3, brackish groundwater samples are of 62% with overall dissolved solids greater than1000 mg/l. The sample nitrate concentrations ranged from 1.35 to 200 mg/l; fluoride concentrations ranged from 0 to 14 mg/l; 88% of the samples fell inside the BIS and WHO permissible bounds; 12% of the samples went above the permitted range for fluoride in groundwater.

(ii) samples rated exceptional by WQI had 10% of sthe amples rated excellent; 42% rated good; 32% rated poor, and 8% rated poor/unfit for drinking.

(iii) According to the USEPA approach, the overall health hazard index for men ranged from 0.415 to 13.978, for women from 0.460 to 15.485, and for children from 0.434 to 14.60. A significant non-carcinogenic health risk to residents of the study area was revealed when THHI levels were found to be higher than the allowable limit in 70% of groundwater samples taken from men, women, and children.

(iv) Groundwater's suitability for irrigation was evaluated using a variety of criteria. SAR, RSC, PI, and RSC demonstrate that groundwater is possible for irrigation in this dry location with little precipitation. RSC, RSC, and RSCshow that groundwater can be used for irrigation.

(v) Using the principal component analysis, we were able to glean five main explanations for 80.95% of the overall variance. Potash and nitrogenous fertilizers have likely been added to the soil in this agriculturally dominated region, as evidenced by the PCA-based source apportionment. There is no other possible source of fluoride in groundwater, hence this ion's origin can only be traced to geogenic sources. PCA can be used to establish that hydrochemistry in this location is influenced by both geogenic and anthropogenic causes.

(vi) The different ionic species discovered in the groundwater, as well as chemometric tests, all point to a similar foundation of sodium and chloride in this study.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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