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ASSESSMENT OF GEOGENIC CONTAMINATION OF GROUND WATER IN BIKANER CITY (RAJASTHAN)

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ABSTRACT

Groundwater contamination, particularly from geogenic sources, has become an increasingly pressing issue, exacerbated by the limited availability of clean water resources and the widespread pollution affecting these resources. This study focuses on the assessment of geogenic contamination of groundwater in Bikaner city, Rajasthan, highlighting the impact of both natural and anthropogenic factors on water quality. Groundwater, a crucial resource historically used for various purposes, has deteriorated due to excessive use of chemicals and pollutants. Natural processes such as the leaching of contaminants from geological formations and brine intrusion contribute significantly to groundwater contamination. Additionally, hydro-geochemical processes including weathering, dissolution, mixing, and ion exchange play a vital role in determining the concentration of major and minor ions in groundwater. The present study aimed to evaluate the extent of geogenic contamination in Bikaner city's groundwater by analyzing several water quality parameters. These parameters included pH, electrical conductivity (EC), total dissolved solids (TDS), bicarbonate (HCO_3^-), phosphate (PO_4^{3-}), sulfate (SO_4^{2-}), chloride (Cl^-), fluoride (F^-), sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}). The analysis revealed that the groundwater in Bikaner city is significantly affected by the enrichment of certain ions. Specifically, the Piper diagram indicated a predominant presence of calcium (Ca^{2+}) and bicarbonate (HCO_3^-), as well as sodium (Na^+) and potassium (K^+) coupled with chloride (Cl^-). These findings suggest that groundwater, particularly from deep wells, is highly contaminated and unsuitable for drinking

or other domestic uses. This contamination is likely influenced by anthropogenic activities, including the discharge of sewage effluents and other pollutants.

KEYWORDS: “Water Quality”, “Physico chemical Paramenters”, “Geogenic Contamination”, “BIS”.

INTRODUCTION

Water, a fundamental necessity for all life forms, constitutes less than 2% of the total quantity of water on Earth (Muruganandam et al., 2023). Among these limited freshwater resources, groundwater has become a critical source of water, especially in rural and semi-arid regions, where it is relied upon for its cost-effectiveness and the scarcity of surface water [Liu et al., 2015; Karimi et al., 2024]. Groundwater is vital not only for daily consumption but also for the economic development of many regions. However, its quality is susceptible to both natural and anthropogenic influences. The physico-chemical properties of groundwater are significantly affected by various factors. Human activities such as agriculture, urbanization, and domestic sewage contribute to the alteration of groundwater quality, introducing contaminants and affecting its composition (Khatri and Tyagi, 2015). Additionally, natural factors like geology and geochemical processes also play a pivotal role in determining groundwater quality (Yang et al., 2016; Guo et al., 2018). Geogenic sources, which include the natural leaching of minerals from rocks and sediments, contribute to variations in the chemical composition of groundwater over time and space [Madhavan and Subramanian, 2007; Brindha et al., 2014]. These variations are influenced by factors such as the type of parent rock, the intensity of weathering, residence time of water, and external conditions like precipitation and temperature (Zhu and Schwartz, 2011). Geogenic contamination arises from the natural processes of mineral dissolution and rock weathering, which can introduce harmful substances into groundwater. These contaminants include heavy metals and excessive concentrations of ions such as fluoride, arsenic, and uranium, which are naturally occurring but can exceed safe levels due to the geological characteristics of the region.

Understanding the hydro-geochemical processes, including weathering, dissolution, mixing, and ion exchange, is crucial as they govern the concentration of both major and minor ions in groundwater [Zhu and Schwartz, 2011]. In Rajasthan, and specifically in Bikaner city, it is essential to investigate and analyze the ionic composition of groundwater in relation to the minerals and weathered products of aquifers. This is important for monitoring and ensuring water quality. Previous research has highlighted that high concentrations of contaminants such as fluoride, arsenic, and uranium are common in groundwater across Rajasthan (Coyte et al., 2019; Keesari et al., 2021; Tanwer et al., 2023). These contaminants pose significant health risks, including chronic diseases and potential cancer risks, and can severely impact public health and safety (Rahman et al., 2021; Rashid et al., 2022). In Bikaner, the presence of such contaminants in groundwater is a growing concern, exacerbated by the region's reliance on groundwater for drinking and agricultural purposes. Groundwater is a crucial resource for sustaining life and supporting economic activities, particularly in arid and semi-arid regions like Bikaner city in Rajasthan. In such regions, groundwater often serves as the primary source of water due to the scarcity and limited availability of surface water. However, the quality of groundwater can be significantly compromised by various natural and anthropogenic factors. In Bikaner, as in many other parts of Rajasthan, groundwater quality is influenced by geogenic. The hydro-geochemical processes that shape groundwater composition in Bikaner include weathering, dissolution, ion exchange, and mixing. These processes can alter the concentration of both major and minor ions in groundwater, influencing its quality. Additionally, the unique geological formations and mineral content of the region contribute to the variability in groundwater composition. Given the importance of groundwater for daily life and economic activities in Bikaner, it is essential to conduct a comprehensive assessment of geogenic contamination. This study aims to evaluate the extent of geogenic contamination in groundwater within Bikaner city, analyzing the concentrations of various contaminants and assessing their potential impact on public health and environmental sustainability. By identifying the sources and levels of geogenic contamination, this research seeks to inform strategies for improving groundwater quality and ensuring the safe use of this vital resource.

MATERIAL AND METHOD

The study area for proposed research is Bikaner district, situated in the north-western part of Rajasthan, India. Bikaner is geographically positioned between latitudes 27°11’ to 29°03’ North and longitudes 71°52’ to 74°15’ East, covering an area of approximately 30,247.90 square kilometers. This district is bordered by several other districts and regions: to the north, it adjoins Ganganagar District; to the east, it is flanked by Hanumangarh and Churu Districts; to the south, it shares boundaries with Nagaur and Jodhpur Districts; and to the west, it is adjacent to Jaisalmer District and the international border with Pakistan. Bikaner experiences an arid climate characterized by extreme temperature variations and low annual precipitation. The district receives an annual rainfall ranging from 260 to 440 millimeters, with nearly 90%

of this precipitation occurring during the southwest monsoon season, which typically begins in the first week of July and withdraws by mid-September. The hottest month is June, with average temperatures around 36°C, while January is the coldest month, with average temperatures around 16°C. Temperature extremes are significant, with summer temperatures reaching up to 48°C and winter temperatures dropping to around 1°C. The climate of Bikaner is generally dry throughout the year, with the highest relative humidity occurring in August. During this month, the mean daily relative humidity is 71% in the morning and 52% in the evening. The district's climate is marked by gradual increases in temperature from April through June, followed by the onset of the monsoon season which provides the primary source of annual rainfall.

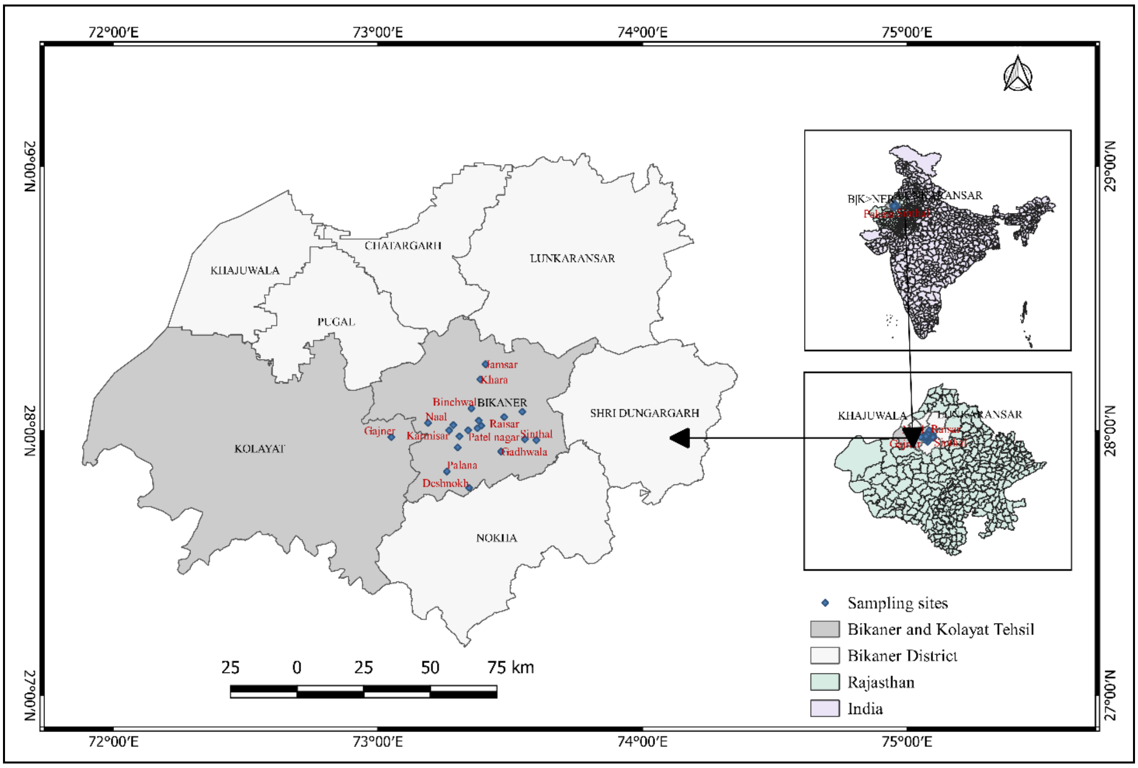

Figure 1: Sampling Location Showig in Map of Bikaner City.

For this study, water samples were collected from various tube wells across the district to assess the geogenic contamination of groundwater. The sampling locations were chosen to provide a representative overview of the groundwater quality in different parts of the district.

The specific sampling sites included:

Table 1: Geographical Coordinates and Nature of Water Sources at Various Sampling Sites in Bikaner Region.

S.N.	Sampling Site	Geographical coordinates		Nature of water	Source
		Latitude	Longitude		
1	Raisar	28.05255	73.4779	GW	Well
2	Naurangdesar	28.0727	73.5455	GW	Well
3	Sagar	28.0196	73.3906	GW	Well
4	Ridmalsar	28.0101	73.3762	GW	Well
5	Gadhwala	27.9221	73.4662	GW	Well
6	Sinthal	27.9653	73.5991	GW	Well
7	Napasar	27.9688	73.5558	GW	Well
8	Udasar	27.5619	73.2647	GW	Well
9	Naal	28.0306	73.1898	GW	Well
10	Gajner	27.9364	73.0621	GW	Well
11	Deshnokh	27.7851	73.3446	GW	Well
12	Palana	27.8470	73.2608	GW	Well
13	Udayramsar	27.9377	73.3016	GW	Well
14	Gangasahar	27.9795	73.3082	GW	Well
15	Patel nagar	28.0024	73.3410	GW	Well
16	Khara	28.1950	73.3868	GW	Well
17	Jamsar	28.2521	73.4068	GW	Well
18	Antyodaya Nagar	28.0221	73.2851	GW	Well
19	Binchwal	28.0854	73.3533	GW	Well
20	Karmisar	28.0020	73.2692	GW	Well

Sampling and Analysis Method

Groundwater samples were collected from tube wells at various depths ranging from 50 to 800 feet across the Bikaner district. For each sample collection, 1-liter clean bottles were utilized, filled completely with water, and tightly sealed to prevent contamination. To ensure sample integrity, 50 ml aliquots of the water were filtered on-site using Whatman's 0.45 µm filter paper. These filtered samples were then preserved with ultra-pure nitric acid (HNO_3). For further analysis, 100 ml of the filtered water was combined with 5 ml of concentrated nitric acid and 5 ml of concentrated sulfuric acid, then allowed to cool to room temperature. The final volume was adjusted to 100 ml with double-distilled water before being transported to the laboratory, where it was stored at 4°C until analysis. In the laboratory, various physicochemical parameters were measured. The pH and electrical conductivity (EC) of the groundwater were determined using a pH meter and an electro-conductivity meter, respectively. Major cations and anions were analyzed using established methods: sodium (Na) and potassium (K) concentrations were measured with a flame photometer, while magnesium (Mg) and calcium (Ca), along with total hardness (TH), were assessed using the

EDTA titration method. Anions such as bicarbonate (HCO_3^-) were quantified via titration, and chloride (Cl^-) content was determined using the silver nitrate titration method. Fluoride (F^-) and nitrate (NO_3^-) concentrations were estimated using a UV-spectrophotometer, with fluoride measured by the SPADNS method. All analyses adhered to the standard procedures outlined by the American Public Health Association (APHA). The resulting data were instrumental in assessing the quality of groundwater and identifying potential contamination issues.

RESULTS AND DISCUSSION

The analysis of groundwater quality in Bikaner city reveals several key findings related to the physico-chemical parameters of the water (Table 2). The pH of the groundwater samples ranged from 7.5 to 8.4, indicating an alkaline nature. This alkaline pH is consistent with observations in similar arid and semi-arid regions, where groundwater often exhibits higher pH levels due to the dissolution of alkaline minerals such as calcite and dolomite. The electrical conductivity (EC) values ranged from 1010 to 7400 µS/cm, reflecting the high mineral content typical of arid regions. This substantial variability in EC aligns with studies indicating increased salinity in groundwater due to evaporation and mineral dissolution.

Total dissolved solids (TDS) ranged from 650 to 3900 mg/l, supporting the high EC values observed. Elevated TDS levels are often attributed to the presence of dissolved salts and minerals, a common feature in desert environments where evaporation exceeds precipitation. The concentration of bicarbonates in groundwater ranged from 84 to 290 mg/l, primarily due to the dissolution of CO_2 and the weathering of carbonate rocks. These findings are consistent with previous studies that show bicarbonate levels influenced by both natural processes and the geochemical characteristics of aquifers (Rahman et al., 2020; Meena, 2022).

Sulfate concentrations ranged from 16 to 580 mg/l, with sources including dry precipitation and the weathering of sulfate-rich minerals such as gypsum. This variability is comparable to other studies in arid regions, where sulfate levels fluctuate based on climatic conditions and mineral composition. Chloride concentrations ranged from 200 to 1540 mg/l, with sources including atmospheric deposition and the dissolution of chloride-containing minerals. The high chloride levels observed are consistent with research showing elevated chloride concentrations in areas with significant evaporation. Fluoride concentrations varied from 0.4 to 5.0 mg/l, with fluoride primarily sourced from the weathering of fluorapatite and other fluoride-bearing rocks. This range aligns with previous findings in Rajasthan, where fluoride levels often exceed recommended limits due to geological factors (Vikas et al., 2013; Keesari et al., 2021).

Nitrate concentrations in the groundwater ranged from 10 to 337 mg/l, indicating potential contributions from agricultural runoff and urban sources such as chemical fertilizers and animal manure. This observation supports research highlighting the impact of agricultural practices on nitrate contamination. The concentration of potassium (K^+) ranged from 3 to 8 mg/l, while sodium (Na^+) levels ranged from 180 to 890 mg/l. The strong correlation between sodium, potassium, magnesium (Mg^{2+}), and calcium (Ca^{2+}) suggests a common source of these ions, likely related to the dissolution of geological minerals. Calcium and magnesium concentrations ranged from 14 to 558 mg/l and 18 to 178 mg/l, respectively, indicating contributions from the weathering of calcite, dolomite, and magnesite. Heavy metals, including zinc (Zn), manganese (Mn), and uranium (U), were found within relatively low ranges, with zinc ranging from 0.01 to 0.09 mg/l and uranium from 0.02 to 0.22 mg/l. The absence of significant levels of chromium and arsenic in the samples is consistent with findings from similar regions where these contaminants are less prevalent. The correlation analysis revealed a strong positive correlation between EC and TDS (r=0.99), indicating that TDS is a reliable measure of salinity. Additionally, a positive correlation between calcium and sulfate (r=0.94) suggests that gypsum dissolution may influence calcium availability in the groundwater. The groundwater samples exhibited Sodium Absorption Ratio (SAR) values ranging from 0.19 to 8.9. SAR is a critical parameter for assessing water quality for irrigation, with higher values potentially affecting soil health. The observed SAR values indicate a mix of low to high salinity water, which can influence agricultural practices and soil management. Overall, the groundwater quality in Bikaner city is generally within permissible limits set by the World Health Organization (WHO) and Indian standards. Key parameters such as pH, EC, SO_4^{2-}, HCO_3^-, CO_3^{2-}, Ca^{2+}, and NO_3^- are within acceptable ranges, indicating that the water is generally suitable for consumption and use. However, the variation in certain parameters underscores the need for ongoing monitoring and management to ensure water safety and sustainability in this arid region.

Table 2: Physico-chemical parameters of ground water samples of Bikaner city.

S. No.	Well Location	pH	TDS mg/l	EC µS/cm	TH mg/l	Ca^{+2} mg/l	Mg^{+2} mg/l	Cl^{-} mg/l	SO_4^{-2} mg/l	NO_3^{-} mg/l	F^{-} mg/l	Na^{+} mg/l	K^{+} mg/l	CO_3^{-2} mg/l	HCO_3^{-} mg/l	SAR
1	Raisar	7.7	2370	3700	820	104	77	1230	180	30	1.0	890	8	46	107	2.4585
2	Naurangdesar	8.1	1790	2800	590	40	29	740	150	10	0.9	615	4	40	261	4.4565
3	Sagar	7.8	1980	3100	410	28	34	590	146	128	0.5	595	6	43	272	4.7983
4	Ridmalsar	8.1	730	1140	260	29	33	260	150	13	1.0	580	8	52	290	4.6774
5	Gadhwala	7.7	670	1050	210	41	42	260	64	38	0.9	180	3	60	134	0.1952
6	Sinthal	8.2	780	1220	250	28.2	19	220	60	337	0.5	278	7	38	128	2.9449
7	Napasar	8.0	1077	1670	360	14	20	411	32	80	1.7	105	4	32	114	1.5441
8	Udasar	8.4	1540	2400	300	40	34	645	90	75	1.0	455	6	33	128	3.0743
9	Naal	8.2	1670	2600	330	30	44	690	412	224	1.9	420	8	20	143	2.8378
10	Gajner	7.9	3070	4800	600	36.4	42.2	1430	320	118	2.5	528	5	28	132	3.3587
11	Deshnokh	7.9	800	1250	290	28	33	340	98	30	0.6	590	5	22	84	4.8360
12	Palana	7.7	920	1440	310	6.2	18	341	16	11	0.5	615	7	20	122	8.9912
13	Udayramsar	7.7	650	1010	230	66	43	200	170	24	0.4	153	6	20	107	0.7018
14	Gangasahar	7.5	370	3700	500	4.5	54	1060	116	83	0.8	310	5	60	240	1.7514
15	Patel Nagar	7.8	2110	3300	510	68	71	650	68	243	1.1	610	7	42	220	1.2761
16	Khara	7.6	3900	6100	1470	288	167	2130	564	15	1.8	755	6	18	196	0.8296
17	Jamsar	7.7	4740	7400	1200	558	178	1540	580	17	5.0	810	7	10	171	0.5502
18	Antonday-nagar	8.2	1790	2800	400	22	24	652	80	125	1.0	414	4	42	220	4.500
19	Binchwal	7.8	1950	3000	330	60	60	750	174	14	2.2	560	8	24	122	2.3333
20	Karmisar	8.0	1860	2900	460	78	78	600	96	163	1.5	580	7	38	210	1.8589

Hydrochemical Facies and Processes: Interpretation of the Piper Diagram

The Piper diagram, also known as a trilinear diagram, is a powerful tool for visualizing the chemical characteristics of groundwater and identifying different hydrochemical facies. The diagram consists of two triangular fields and a central diamond-shaped field. In the left triangle, cations (such as Calcium (Ca^{2+}) and Magnesium (Mg^{2+})) are plotted, while anions (like Chloride (Cl^{-}) and Sulfate (SO_4^{2-})) are plotted in the right triangle. The points in these triangles are then projected into the central diamond to represent the overall water type for each sample.

In the analyzed Piper diagram (Figure 2), the hydrochemical facies of the collected groundwater samples predominantly fall into the Ca^{2+}-Mg^{2+}-Cl^{-} and Na^{+}-Cl^{-} types. This distribution indicates that the water is mainly characterized by these ion combinations. The Ca^{2+}-Mg^{2+}-Cl^{-} facies is typically associated with water that has undergone significant interaction with minerals in the aquifer, often reflecting a combination of natural processes and anthropogenic influences.

The diagram also suggests a notable enrichment of Ca^{2+} and Mg^{2+} in many of the groundwater samples, particularly in pre-monsoon times. This could indicate the dissolution of carbonate minerals, such as calcite and dolomite, from the aquifer matrix, which is a common phenomenon in arid and semi-arid regions like the Thar Desert. Additionally, the presence of Na^{+} and Cl^{-} points to processes such as the dissolution of halite (NaCl) and the impact of evaporative concentration, which is consistent with the climatic conditions of the area.

Interestingly, the hydrochemical types observed can be categorized into three major groups: Ca^{2+}-HCO_3^{-}, Na^{+}+K^{+}-Cl^{-}, and a mixed type represented by 50% Na^{+}+K^{+} and 50% Ca^{2+} with CO_3^{2-} + HCO_3^{-} + Cl^{-}. The presence of these mixed water types suggests that the groundwater in this region may be subject to varying degrees of mixing between different water sources, potentially influenced by both fresh recharge and older, mineral-rich groundwater.

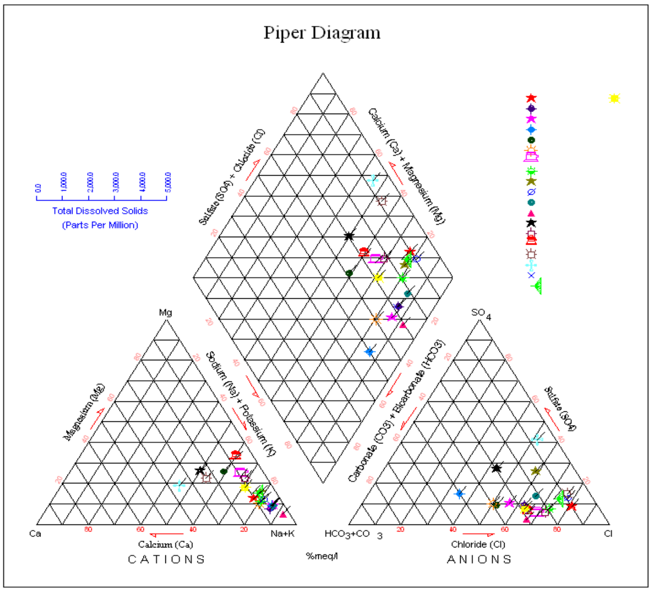

Fig. 2: Piper diagram for premonsoon season showing hydrological facies.

CONCLUSION

The geogenic contamination analysis of groundwater in Bikaner city reveals that the water is predominantly alkaline. While certain parameters such as pH, chloride, potassium, carbonate, and bicarbonate fall within acceptable limits in 95% of the samples, other critical parameters like TDS, total hardness, calcium, magnesium, sulphate, fluoride, nitrate, and electrical conductivity (EC) exceed the maximum permissible limits. The elevated levels of these elements, along with heavy metals, sometimes surpass the WHO's recommended maximum concentration levels. Particularly concerning is the high concentration of uranium, which indicates that the groundwater in these regions poses significant health risks and is unsuitable for drinking. The hazard quotient analysis of the twenty groundwater samples studied suggests that the values are higher than the WHO's recommended safety threshold (unity), implying a considerable health risk to the local population, who primarily rely on hand-dug wells and boreholes for their water supply. The findings underscore that while the groundwater may not be fit for drinking, it could be utilized for irrigation purposes. The contamination is likely influenced by anthropogenic activities, such as sewage discharge, but further investigation is required to comprehensively understand the geogenic and anthropogenic processes impacting groundwater quality in Bikaner city, Rajasthan.

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