Analysis of Groundwater Quality in Semi-arid Region of Eastern - South Rajasthan on the Basis of Water Quality Index (WQI)

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Abstract: The present study was conducted to evaluate the groundwater quality for drinking purposes in selected locations of the Eastern- South Rajasthan of India. Thirty-two groundwater samples were collected from eight sites during 2022 and the samples were analyzed for physicochemical parameters i.e., pH, total hardness, total dissolved solids, nitrate, sulphate, fluoride, chloride, and alkalinity were calculated. The results of the study are illustrated with the help of descriptive statistics, diagrams, and the water quality index. The focus of this research was to assess the current state of groundwater quality and the spatial distribution of characteristics in order to determine the quality of drinkable water. The water quality index was used to categorize the samples into categories based on its acceptability for consumption. It is noted that the majority of the samples are classified as unfit for human consumption, with a small number falling into the category of really poor water.

Keywords: Drinking water, WQI, Alkalinity, Human health, Fluoride

1. Introduction

This study is mainly based on the fluoride concentration in groundwater of some villages of southeastern part of Rajasthan of India. Around 177 districts in 20 of the 29 states in India, including Rajasthan, have significant quantities of fluoride in their groundwater. Between 60 and 65 million people reside in these states where fluoride has poisoned their groundwater (Ali 2016**)**. Fluoride-rich minerals and alkaline conditions play a significant role in fluoride enrichment of groundwater. The people from the rural part of the Bhilwara district of Rajasthan, India depend upon the groundwater for their drinking and domestic use. They suffer from health disorders due to using groundwater containing fluoride (Tiwari et al., 2020**).** The present study has been carried out to evaluate the chemistry of fluoride enriched groundwater (Deepali et al., 2020). Thirty-two (four time from each site and taken average of them) water samples were taken from hand pumps at eight different locations in rural Bhilwara, Rajasthan, which are utilized for residential and drinking purposes. The samples were then analyzed to determine the fluoride content. One of the main ways that individuals consume fluoride is through drinking water. Due to this, high dose of fluoride replaces bone calcium in the form of calcium fluoride, and bones become soft, crumble, and chalky white. Temperature, pH, fluorine soluble minerals, drained by water, and interaction with water all influence fluoride quantity in natural water. **(**Naseem et al 2021**).** Fluoride is present in abundance in that area where the geographical part is frequently enclosed by granitic materials that be full of minerals bearing fluoride such as fluorite (CaF_2). (Ashwini K et al 2021) In this world, all the domestic, industrial, and agricultural works are done by groundwater (Obinna C., et al., 2021). People in the study area are bare to high levels of fluoride consumption through drinking water, thus making dental fluorosis a major public health concern in the area (Singh, et al 2022). The World Health Organization currently sets water quality guidelines for the element. Fluorine is most electronegative and reactive so it does not occur in nature but is found as fluoride mineral complexes (Neeraj et al 2021). Minute information on biological risk consideration of fluoride level in drinking water has been recognized and relative disease is endemic fluorosis in the human body (Mridha, Deepanjan, et al 2021). Fluorosis is a common problem in the state of Rajasthan and it is also found in somevillages of Bhilwara and it affects the physical development of individuals. Groundwater is the main source for drinking, irrigation, and domestic uses in all over India and its toxicology properties depend upon on the fluoride concentration. Water demand is unabated as a result of the significant rise in population, the extension of economic activity, and uncontrolled urban development. Due to the depletion of existing supplies and degradation of their quality, unregulated exploitation of both surface and groundwater supplies is disrupting the balance of numerous water resources. Water quality degradation is becoming a major concern not only in India, but also in several other countries around the world, and thus monitoring the quality of both surface and subsurface waters is unquestionably one of the most important factors to consider in conserving this priceless resource and developing policies to protect it. Groundwater, on the other hand, is widely accessible due to its dispersed availability and makes up a large portion of India's agriculture and drinking water supply. About half of municipal water needs are met by groundwater, and 85 % of rural domestic water requirements are met by groundwater. However, in recent years, India has been rapidly approaching a catastrophe of groundwater contamination and abuse**.** Groundwater contamination has been intensified by the rapid development of population, industrialization, the use of agricultural pesticides, and the disposal of urban and industrial waste, all of which have exacerbated the demand for water supplies **(**Ram et al. 2021). Water quality can be evaluated using physical, chemical, and biological factors; once it exceeds well-defined limitations, it is considered hazardous and unfit for various human and agricultural uses (ICMR 1975; BIS 2003). As a result, the suitability of water for its intended use can be classified or described using the Water Quality Index (WQI), which is one of the most effective methods for describing water quality. It is determined by the availability of surface water for human consumption (Rabia, et al 2021**).**

Various research on the water quality index has been conducted by various organizations and scientists. As a result, various national and international organizations have developed a large number of indicators. The water quality index is a useful arithmetical instrument for assessing the quality of surface and groundwater. Water quality indexes are calculated by combining multiple biological, physical, and chemical aspects of a water source to provide a single number that is not unitless but acts as an effective indication of water quality (Pfaff, M., 2022). Physical, biological, and chemical factors like as alkalinity, dissolved oxygen (DO), hardness, temperature, turbidity, and nutrients can all be used to assess the quality of surface and groundwater. If these criteria are present in excess of the limits set by the standards, the water can be considered inappropriate for its intended use. As a result, water quality indexes can be used to reflect water appropriateness for home or other purposes. WQI is a tool for gathering data on a variety of characteristics and translating it into a single measure that is easily understood by the general public. It may also be used by various regulatory authorities to develop policies for water pollution prevention**.**

WQI method is a powerful tool that enables easy communication of the quality of water to the public especially for the policymakers. (M. Farhad, et al. 2021) It is an unambiguous tool that enables the integration of the water parameters, which are deemed important to the quality of the water accordingly (Irene, et al 2021). A set of 8 most commonly used water quality parameters namely pH, Total dissolved solids (TDS), Total Alkalinity (TA), Total Hardness (TH), Chloride, fuoride, Nitrate and Sulphate which together reflects the overall water quality of the groundwater are selected for generating the water quality index. The calculation of WQI has been Carried out following the 'weighted arithmetic index method' by using following equation.

$$WQI = \frac{\sum Q_n W_n}{\sum W_n} \ldots\ldots\ldots 1$$

Where Q is the quality rating of nth water quality parameter, W_n is the unit weight of nth water quality parameter.

Table 1: Water quality Index: Grading and water quality rating

WQI value	Grading	Water Quality Rating
0 -25	A	Excellent
26 – 50	B	Good
51 – 75	C	Poor
76 – 100	D	Very Poor
Above 100	E	Unsuitable for drinking purposes

The criteria of water quality rating has been shown in the Table 1. The purpose of this study is to observe the physicochemical analysis of ground drinking water in reference to fluoride in western India, and calculate the water quality index for particular sampling site to categorizations of sampling site as drinking quality wise, and health effects (Ajay et al. 2021).

2. Materials and methods

Digital meters were used to measure physical parameters like pH, TDS, while laboratory titration procedures assessed the concentrations of key cations and anions i.e. chloride (Cl^-), total hardness, and alkalinity. Total hardness (Ca and Mg) was analyzed by titration with the EDTA method. The chloride concentration was analyzed by titration using silver nitrate as a reagent. While the concentration of nitrate measured by UV Visible spectrophotometer.

Table 2: Sampling: Sampling site code, Description, period and location

Code	Decription	Period	Location	Height (m)
I	Shangar chavari,	Feb, 2022	25.5386^{0}N and 75.2535^{0}E	377
II	Agadia,	Feb, 2022	25.5471^{0}N and 74.9730^{0}E	392
III	Mata ji ka Khera,	March, 2022	25.5345^{0}N and 75.0572^{0}E	366
IV	Kanjar Basti,	March, 2022	25.6088^{0}N and 75.1586^{0}E	370
V	Amargarh,	March, 2022	25.4319^{0}N and 75.1706^{0}E	394
VI	Sundergarh,	May, 2022	25.5032^{0}N and 75.2511^{0}E	411
VII	Sabalpura	June, 2022	25.5216^{0}N and 75.2624^{0}E	385
VIII	Sawaipura	June, 2022	25.5058^{0}N and 75.2215^{0}E	373

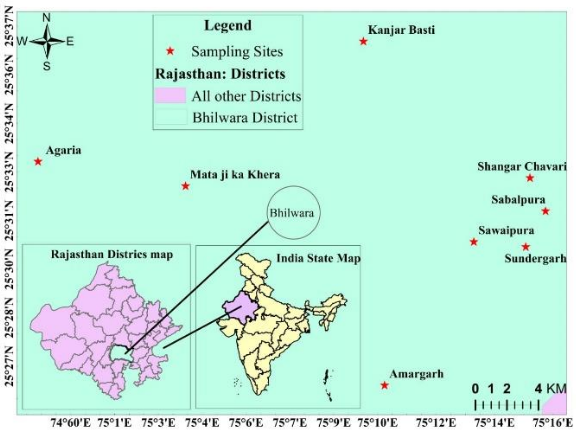

Figure 1. Study Area

Description of site: Figure 1. shows that the samples were collected from different villages of the western part of India, Rajasthan. Table 2 depicted the geographic location sampling sites.

3. Result and Discussion

The results of the above study are arranged in Table 3, all the groundwater samples taken from the hand pumps that the villagers regularly used for drinking and domestic purposes. The finding results compared with the drinking water standard of WHO, are as follows:

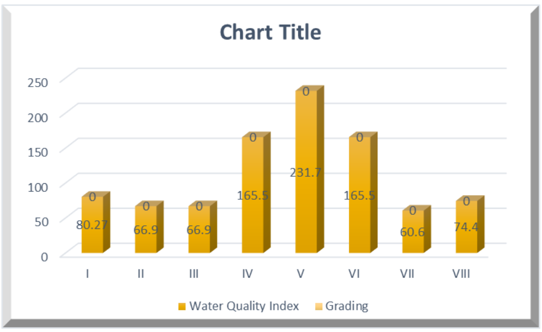

Figure 2. Graphical presentation of WQI Result

(X- axis value of Water Quality Index Y-axis reparents the sample sites)

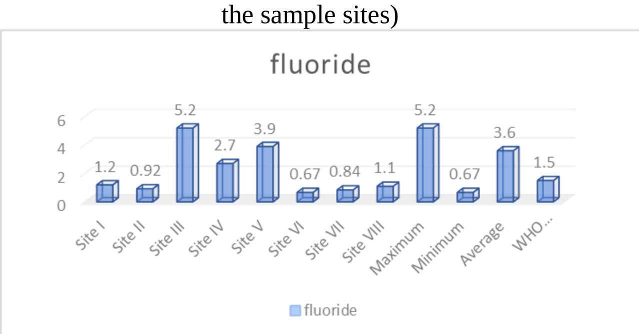

Figure 3 Graphical presentation of fluoride content for all sites

(X- axis the value of fluoride concentration and Y- axis represents the sample sites)

pH

The pH of water is a measurement of how acidic or alkaline it is, and it is used to determine its suitability for various uses. The pH values ranged from 7.2 to 8.5, according to Table 3 the pH of drinkable water must be between 6.5 and 8.5, according to WHO guidelines for drinking water. The outcome was in the middle of the standard specifications, showing that the pH is symmetrical and the values are quite near to one another. (Kaur et al 2021). The high pH level in groundwater can cause irritation of the eyes and cause skin discomfort. Water's natural flavour is frequently changed to a bitter taste by changing the pH (WHO 2017, Khatri et al 2021). Water with a pH of less than 7 is considered acidic, whereas water with a pH of greater than 7 is considered basic. In accordance with WHO criteria, the pH value was generally considered acceptable at all study sites.

Alkalinity

Table 3 indicates that the alkalinity levels ranged from 270 to 841. According to WHO standards for drinking water, alkalinity levels in drinkable water not more than 600.The alkalinity is extremely high, indicating that industrial waste from the adjacent region has contaminated the region's groundwater resources extensively. It is our suggestion that the polymer and textile business (Shahnawaz et al 2021, Kuldeep et al 2021; Jandu et al 2021) be moved as soon as feasible from the Bhilwara region so that the local population has access to safe drinking water. To determine the extent to which these products affect public health, more research is required. Alkalinity is a measure of water's capacity to endure a change in pH that would cause it to become more acidic. The alkalinity value for sites I, III, VI, VII, and VIII was generally considered acceptable according to WHO guidelines.

Total dissolved salts

Total dissolved solids (TDS) are an assessment of the dissolved particles in a water sample that represent the general quality or salinity of the water. According to WHO drinking water standards, the maximum amount of total dissolved salts acceptable is 500 mg/L. All of the measurements were not desirable limits of 500 mg/l. TDS levels in the studied area range from 628 to 3140 mg/L is shown in table3. Due to the dense residential area and intense irrigated in that site, the maximum concentration of total dissolved solids was reported at Site V, which was 3140 mg/L. TDS levels in groundwater are generally not dangerous to people, but concentrations can harm people with kidney and heart problems (Pandey et al 2021; Dubey et al 2021). Water with a high solids content might have a laxative or chronically constipated effects (Kuldeep et al 2021).

Table 3. Different parameters and results for drinking water

Parameters / Site	pH	TDS	Fluoride	Nitrate	Chloride	Sulphate	Alkalinity	Total hardness
Site I	7.4	680	1.2	84	116	36	340	370
Site II	8.5	1320	0.92	17	240	123	715	240
Site III	7.2	1462	5.2	131	2140	103	513	892
Site IV	7.9	2243	2.7	23	840	43	841	728
Site V	7.2	3140	3.9	116	1440	107	617	862
Site VI	7.5	628	0.67	39	125	34	270	448
Site VII	8.1	672	0.84	128	119	32	352	480
Site VIII	7.3	1486	1.1	176	480	67	276	976
Maximum	8.5	3140	5.2	176	2140	123	841	976
Minimum	7.2	672	0.67	17	116	32	270	240
Average	7.6	1453.8	3.6	89.25	687.5	68.1	490.5	624.5
WHO standard	**8.5**	**500**	**1.5**	**50**	**1000**	**400**	**600**	**500**

Water Quality Index for all sites:

$$K = \frac{1}{\frac{1}{8.5}+\frac{1}{500}+\frac{1}{1.5}+\frac{1}{250}+\frac{1}{1000}+\frac{1}{400}+\frac{1}{600}+\frac{1}{500}}$$

$$K = \frac{1}{o.7952} = \mathbf{1.25}$$

Table 4: WQI of site I –

Parameters	S_n	V_n	Q_n	W= K/S_n	W×Q	WQI	Grade (IWQI 2001)
pH	8.5	7.4	87.05	0.147	12.79	80.27	D
TDS	500	680	136.0	0.0025	0.34		
Fluoride	1.5	1.2	80.0	0.833	66.64		
Nitrate	250	84	33.6	0.005	0.168		
Chloride	1000	116	11.6	0.00125	0.0145		
Sulphate	400	30	7.5	0.0031	0.023		
Alkalinity	600	340	56.6	0.002	0.1132		
Total Hardness	500	370	74.0	0.0025	0.185		

Table 5: WQI of site II –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	$W\times Q$	WQI	Grade (IWQI 2001)
pH	8.5	8.5	100.0	0.147	14.7	66.927	C
TDS	500	1320	264.0	0.0025	0.66		
Fluoride	1.5	0.92	61.33	0.833	51.08		
Nitrate	250	17	6.8	0.005	0.0034		
Chloride	1000	240	24.0	0.00125	0.03		
Sulphate	400	123	30.75	0.0031	0.0953		
Alkanity	600	715	119.16	0.002	0.2383		
Total Hardness	500	240	48	0.0025	0.12		

Table 6: WQI of site III –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	$W\times Q$	WQI	Grade (IWQI 2001)
pH	8.5	7.2	84.7	0.147	12.45	66.927	C
TDS	500	1462	292.4	0.0025	0.731		
Fluoride	1.5	5.2	346.6	0.833	288.71		
Nitrate	250	131	52.4	0.005	0.262		
Chloride	1000	2140	218.4	0.00125	0.273		
Sulphate	400	103	25.75	0.0031	0.079		
Alkanity	600	513	85.5	0.002	0.171		
Total Hardness	500	892	178.4	0.0025	0.446		

Table 7: WQI of site IV –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	$W\times Q$	WQI	Grade (IWQI 2001)
pH	8.5	7.9	92.941	0.147	13.662	165.55	E
TDS	500	2243	448.6	0.0025	1.1215		
Fluoride	1.5	2.7	180.0	0.833	149.94		
Nitrate	250	23	9.2	0.005	0.046		
Chloride	1000	840	84.0	0.00125	0.105		
Sulphate	400	43	10.75	0.0031	0.0333		
Alkanity	600	841	140.16	0.002	0.2803		
Total Hardness	500	728	145.6	0.0025	0.3625		

Table 8: WQI of site V –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	W×Q	WQI	Grade (IWQI 2001)
pH	8.5	7.2	84.705	0.147	12.45	231.73	E
TDS	500	3140	628.0	0.0025	1.57		
Fluoride	1.5	3.9	260.0	0.833	216.58		
Nitrate	250	116	46.4	0.005	0.232		
Chloride	1000	1440	144.0	0.00125	0.18		
Sulphate	400	107	26.75	0.0031	0.0829		
Alkanity	600	617	102.83	0.002	0.2056		
Total Hardness	500	862	172.4	0.0025	0.431		

Table 9: WQI of site VI –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	W×Q	WQI	Grade (IWQI 2001)
pH	8.5	7.9	92.941	0.147	13.66	165.55	E
TDS	500	2243	448.6	0.0025	1.125		
Fluoride	1.5	2.7	180.0	0.833	149.94		
Nitrate	250	23	9.2	0.005	0.046		
Chloride	1000	840	84.0	0.00125	0.105		
Sulphate	400	43	10.75	0.0031	0.033		
Alkanity	600	841	140.16	0.002	0.2803		
Total Hardness	500	728	145.6	0.0025	0.364		

Table 10: WQI of site VII –

Parameters	S_n	V_n	Q_n	$W= K/S_n$	W×Q	WQI	Grade (IWQI 2001)
pH	8.5	7.5	88.235	0.147	12.970	60.606	C
TDS	500	672	134.4	0.0025	0.336		
Fluoride	1.5	0.84	56.0	0.833	46.648		
Nitrate	250	128	51.2	0.005	0.256		
Chloride	1000	119	11.9	0.00125	0.0148		
Sulphate	400	32	8.0	0.0031	0.0248		
Alkanity	600	352	58.66	0.002	0.1173		
Total Hardness	500	480	96.0	0.0025	0.24		

Table 11: WQI of site VIII –

Parameters	S_n	V_n	Q_n	W= K/S_n	W×Q	WQI	Grade (IWQI 2001)
pH	8.5	7.3	85.88	0.147	12.624	75.490	C
TDS	500	1486	297.2	0.0025	0.743		
Fluoride	1.5	1.1	73.33	0.833	61.08		
Nitrate	250	176	70.4	0.005	0.352		
Chloride	1000	480	48.0	0.00125	0.06		
Sulphate	400	67	16.75	0.0031	0.0519		
Alkanity	600	276	46.0	0.002	0.092		
Total Hardness	500	976	195.2	0.0025	0.488		

Table 12: Water Quality Index and Grading for all Sites

Site	Water Quality Index	Grading
I	80.27	D
II	66.9	C
III	66.9	C
IV	165.5	E
V	231.7	E
VI	165.5	E
VII	60.6	C
VIII	74.4	C

IWQI = Indian water quality Index

Chloride

Chloride is a commonly available element that can be found in various forms in all types of rocks. It has a great affinity for sodium. As a result, it has a high concentration in groundwater where the temperature is high and rainfall is minimal at all sites, from table 3, the chloride concentration is between 116-2140 mg/L. The porosity and permeability of the soil also play a significant role in the accumulation of chlorides. Chloride from all observation points. Except for sites III and V, chloride levels in the observed period were within the WHO limit of 1000 mg/L. The high Chloride levels are most likely the result of wastewater discharge from nearby industries**.** The dominance of calcium and sodium in groundwater at these sites is shown by chloride, nitrate, and sulphate. This is most likely attributable to the interaction of deposition sediments with water and/or the influence of fertilizers leaching and water evaporation (Pandey et al 2021; Gupta et al 2021).

Total hardness

Total hardness (TH) in natural water is primarily contributed by dissolved calcium and magnesium ions, with all other divalent cations adding to its concentration (Ikomi and Emuh 2000; Pandey et al 2021; Gupta et al 2021). The majority of its source comes from the rocks that surround the water bodies. The results show that the total hardness level of groundwater collected from eight different sampling sites exceeded the drinking water quality standards' maximum permitted level (500 mg/l). The increased temperature, low water level, and other residential trash may have led to its greater Total hardness (Pandey et al 2021; Dubey et al 2021). Table 3 depicted that TH varies from 240 to 976 mg/l, and the water is classed as moderately hard. TDS levels in drinking water that are too high can lead to vascular disease and cardiovascular problems (Pandey et al 2021; Dubey et al 2021).

Fluoride

It is a core part of the regular growth of bone and teeth. Fluoride in groundwater can come from a variety of sources, such as the weathering of fluoride-bearing minerals, muscovite, biotite, fluorite, and fluorapatite that exist as minor minerals in granites and granitic gneisses, along with agricultural and manufacturing sources. over four times the prescribed BIS upper limit of 1.5mg/L. Beyond this level, it may cause dental fluorosis, skeletal fluorosis, and thyroid disease in adults. Approximately 200 million people from across the globe have been suffering from endemic fluorosis. Figure3 represents that fluoride concentrations were found to be significant in sites III, IV, and V, as per groundwater quality studies conducted in Bhilwara District. Because of the differences in control factors, variations in Fluoride concentration indicated preferential dissolution of Fluoride containing minerals. Furthermore, it was found that high Fluoride values were caused by bedrock containing fluorine minerals.

A considerable amount of Fluoride may have been produced caused by anthropogenic causes, such as the use of Fluoride salts across several industries, mainly the steel, brick, tile, and aluminum industries, in addition to some of the inevitable processes Fluoride concentrations at dangerously high levels have made 37% of samples unacceptable for use or non-potable.

Nitrate

Table 3 shows the concentrations of nitrate (NO_3^{2-}) in the groundwater examined samples varied from 17.0 to 176 mg/L, with an average of 89.25 mg/L. The BIS (2012) and

WHO (2017) acceptable standards for nitrate in drinking water are 45 mg/L and 50 mg/L, respectively. Only three groundwater samples from the eight sampling sites had nitrate levels below the WHO (2017) and BIS (2012) allowable guidelines, whereas the remaining 63% results showed nitrate values over the WHO (2017) and BIS (2012) limits. The high nitrate values found in this study are consistent with nitrate levels seen in prior studies conducted in Rajasthan's semiarid to arid regions. The sharp rise in nitrate levels in groundwater sources over the last 20 years is due to an increase in the use of chemical fertilizers, the dumping of wastes (particularly from animal farming), and land use changes use.

Sulphate

The concentrations of sulphate (SO_4^{2-}) in the groundwater samples varied from 32 to 123 mg/L, with an average of 68.1 mg/L. The acceptable standard of sulphate is 200 mg/L, whereas the allowed maximum is 400 mg/L, according to the Bureau of Indian Standards. All the parameters found in between the rang given by Bureau of Indian Standards.

Table 4 – 11 show the WQI values and grading of the particular site according to table 1, which represent that all the source of drinking groundwater is not suitable for drinking. Table 12 show that site IV, V, and VI have very poor water sources i.e., hazardous for their peoples. Only site VI has the value of WQI nearer to B grading this batter than other sites but not good.

4. Conclusion

After analyzing all the parameters, the study concludes that none of the sites' groundwater is suitable for drinking, gardening, farming, or industrial use. However, it does appear that TDS, total hardness, nitrate, sulphate, and fluoride are highly significant parameters in conjunction by safety standard values, the southeastern region water has an extremely high alkalinity level, making it unfit for human consumption. The region's groundwater is heavily contaminated by the industrial effluent in the vicinity, as evidenced by the extremely high alkalinity. We urge that the textile printing business be relocated from the Bhilwara district as soon as possible to enable the local population to have access to potable water. The extent to which these things affect people's well-being will likely require more investigation.

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