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RESEARCH PAPER

Water quality assessment of Banas River, eastern-south region of Rajasthan, using water quality index

Pankaj Sen[1] · **Rajeev Mehta**[1] · **Preeti Mehta**[1]

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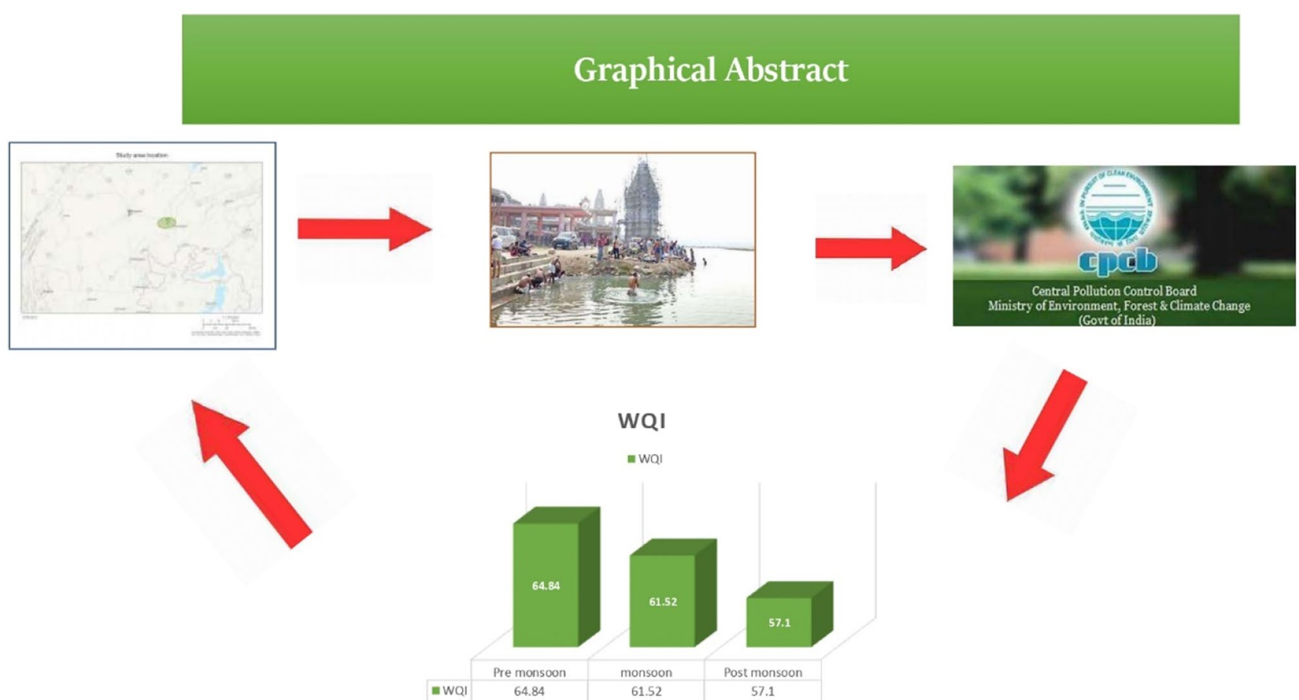
Abstract

The water quality index (WQI) is a numerical representation of total water quality that qualifies it for usage in residential, irrigation, industry, and other applications. The present investigation involves the statistical validation and then determining the WQI of the Banas River, which is located in Rajasthan's eastern south region and is an important source of water supply via the Bisalpur Dam. The main objective of this study is to assess the data provided by CPCB in this way we analyzed the various physicochemical characteristics like pH, electrical conductivity, Total Dissolved Solids (TDS), Dissolve Oxygen (DO), Fluoride, Sulphate, and Total Hardness in pre-monsoon, monsoon, and post-monsoon data for the year 2018–2021, then calculate the WQI of those data. The result of Pre-monsoon WQI was 64.84, indicating an Indian water quality index grading C, whereas post-monsoon WQI was 57.10, which was closer to an Indian water quality index grading B. During the monsoon, the WQI was 61.52. It can be inferred from the abovementioned finding that the water quality improves after the monsoon.

Graphical abstract



Keywords Assessment · Drinking water · Dissolve oxygen · Physicochemical water quality index

Extended author information available on the last page of the article

Introduction

The demand for clean water has increased in correlation with the increase in the population and the number of industries. Emerging nations with rapid population growth face a greater challenge in meeting their clean water needs than established ones (Giller et al. 2021). Surface water as well as ground water contamination has been exacerbated 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 (Priyan 2021). Water pollution not only affects water quality but also threatens human health…… (Wang et al. 2021). The safety standards for these parameters are set by the Bureau of Indian Standards (BIS), the Indian Council for Medical Research (ICMR), and the World Health Organization (WHO). It is difficult for a common man to understand the significance of each of these parameters and the role it plays in estimating the quality of water (Reddy 2022). As a result, to transmit the quality of water, a single figure termed the Water Quality Index (WQI) must be reported, which comprises the impact of all the variables. The Water Quality Index can be used to evaluate water bodies into grades such as Excellent, Good, Poor, Unfit for Drinking, and so on. As a result, WQI, like the Ambient Air Quality Index, will be useful for the general public in determining the level of water body degradation (Jeevarathinam et al. 2022). The current study aims to assess the surface water quality of a particular river basin by the implementation of a novel approach WQI on the mandatory monitoring data. The proposed approach applies factors used for WQI calculation to obtain additional important information concerning surface water quality like:

(i) To illustrate the composite WQI's "structure" for selected water quality conditions and
(ii) To find groups of surface water samples with particular WQI profiles among the whole river basin.

Water quality for surface water and groundwater can be easily assessed by analyzing physical, biological, and chemical parameters like alkalinity, dissolved oxygen (DO), hardness, temperature, turbidity, nutrients, etc. If these criteria are presently more than the limits set by the standards, the water can be considered inappropriate for its intended use. Therefore, water suitability for domestic or any specific purpose can be represented in terms of the water quality index (Pradhan and Indu 2021).

Data and methodology

Data source

The analyzed data were collected of the eastern-south region of Rajasthan with the help of the central pollution control board via the following link https://cpcb.nic.in/nwmp-data/. Data was in monthly reports of physical and chemical parameters like BOD, COD, DO, total dissolve solid, pH, Conductivity, Alkalinity, Hardness, Na, K, Nitrate, Sulphate etc.

Geography of study area

The eastern-south part of Rajasthan is the Bigod Triveni Sangam situated in the Bhilwara which is 50 km away from the district headquarters. The three rivers Banas, Manali, and Badach joined together Banas is the main river and flowed 512 km with a drainage area of 33,760 makings is the longest river in Rajasthan. Its geographical coordinates are 25° 14′ North and 75° 1′ East (Fig. 1).

Data process

The analyzed data was open excess data provided by CPCB i.e., secondary data the process of the data was done by some staistiacl tools with the help of MS Excel first monthly data arranged in monsoon wise like pre-monsoon, monsoon, and post-monsoon, further the statistical validation done with the measured average and standard deviation of the data then the data were compared with the WHO standard for drinking and domestic uses. After analyzing the data, WQI was introduced to the validated data, and the water quality index applying to the data in the following manner.

The World Health Organization's recommended drinking water quality standard was used to calculate the WQI by The weighted arithmetic method, which was created by Brown et al. after being first proposed by Horton (1965).

$$\mathrm{WQI} = \sum \mathrm{W_iQ_i} \Big/ \sum \mathrm{W_i}, \tag{1}$$

where W_i = Unit weight for the ith parameter, Q_i = quality rating (sub-index) of the ith water quality parameter.

The unit weight (W_i) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameter.

$$\mathrm{W_i} = \mathrm{K}/\mathrm{S_n}, \tag{2}$$

where W_i = unit weight for the ith parameter, S_n = standard value for ith parameters, K = proportional constant.

The value of K has been considered '1' here and is calculated using the following formula:

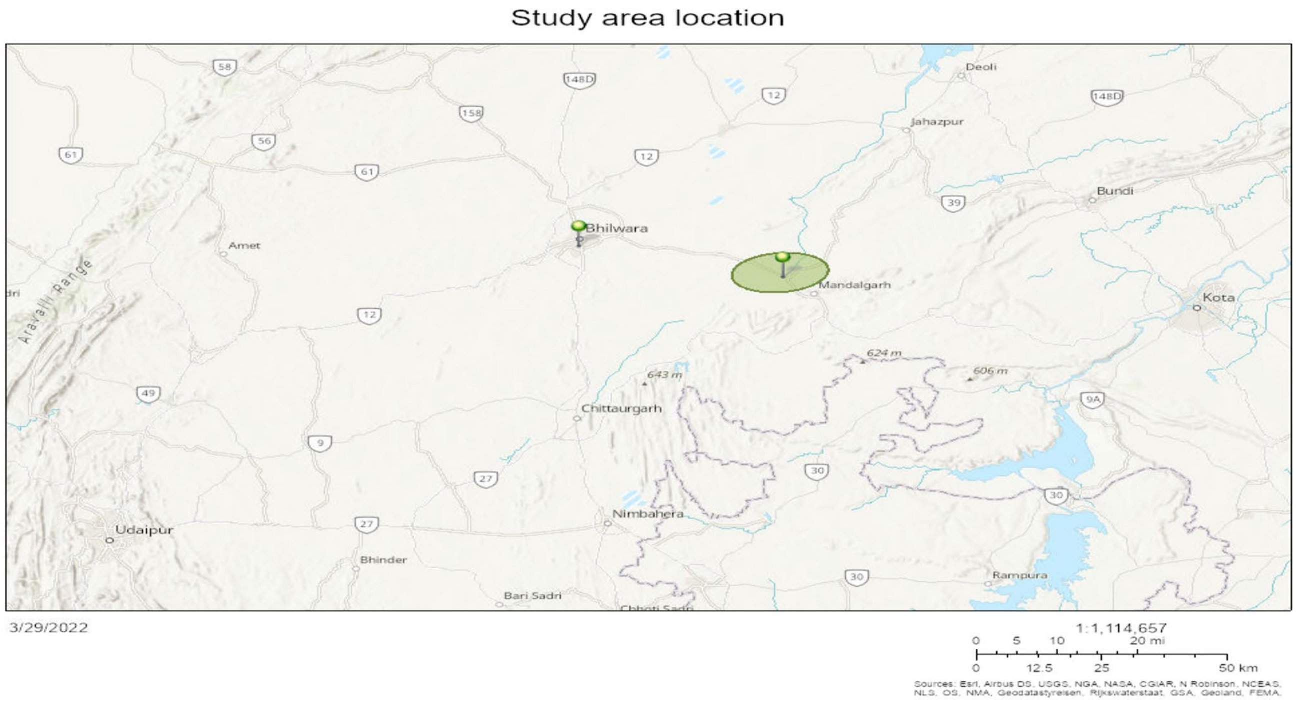


Fig. 1 Location of the study area

$$K = 1 \Big/ \sum \left(1/S_n\right) \quad (3)$$

According to Brown et al. (1972), the value of quality rating or sub-index (Q_i) is calculated using the equation given below:

$$Q_i = \left[\left(V_n - V_i\right) / \left(S_n - V_i\right)\right] * 100, \quad (4)$$

where V_n = Observed actual value, S_n = Standard value to be present for good condition, V_i = Ideal value.

All the ideal values (V_i) are taken as zero for drinking water except pH and dissolved oxygen (Tripathy and Sahu 2005). In the case of pH, the ideal value is 7.0 (for natural/pure water) while the permissible value is 8.5 (for polluted water). Similarly, for dissolved oxygen, the ideal value is 14.6 mg/L while the standard permissible value for drinking water is 5 mg/L (Tables 1, 2).

Table 1 Statistical validation of groundwater quality parameters with mean and SD

Parameters	Pre-monsoon (mean ± SD)	Monsoon (mean ± SD)	Post-monsoon (mean ± SD)
B.O.D. (mg/L)	1.68 ± 0.87	1.68 ± 0.8115	1.48 ± 0.6449
C.O.D. (mg/L)	21.93 ± 12.73	19.80 ± 16.9581	12.529 ± 6.8412
Conductivity (mho/cm)	611 ± 124.14	503 ± 158.9726	527 ± 103.17
Dissolved oxygen (mg/L)	4.65 ± 1.75	5.0 ± 1.0047	5.39 ± 1.2099
Fluoride as F (mg/L)	0.83 ± 0.21	0.8 ± 0.1889	0.74 ± 0.2294
Nitrate as N (mg/L)	1.95 ± 0.3572	1.82 ± 0.5223	1.62 ± 0.5738
pH	8.16 ± 0.1889	8.08 ± 0.3056	8.07 ± 0.2852
Potassium as K (mg/L)	3.0 ± 1.7091	3.0 ± 1.4986	2.9 ± 0.9151
Sodium (mg/L)	80 ± 42.6898	49 ± 26.7250	42 ± 19.1083
Sulphate (mg/L)	75.3 ± 41.3750	47.0 ± 26.9187	67 ± 35.9057
Total alkalinity (mg/L)	119 ± 23.3030	77 ± 19.5540	77 ± 13.1031
Total dissolved solids (mg/L)	468 ± 87.3607	329 ± 108.1064	280 ± 93.8454
Total hardness as $CaCO_3$ (mg/L)	157 ± 20.4713	152 ± 34.9064	127 ± 19.5854

Table 2 Comparison parameters with WHO standards

Parameter	Pre-monsoon	Monsoon	Post monsoon	WHO standard
B.O.D. (mg/L)	1.68	1.68	1.48	3
C.O.D. (mg/L)	21.93	19.8	12.529	100
Conductivity (mho/cm)	611	503	527	1150
Dissolved oxygen (mg/L)	4.65	5	5.39	5
Fluoride as F (mg/L)	0.83	0.8	0.74	1.5
Nitrate as N (mg/L)	1.95	1.82	1.62	45
pH	8.16	8.08	8.07	8.5
Potassium as K (mg/L)	3	3	2.9	200
Sodium (mg/L)	80	49	42	50
Sulphate (mg/L)	75.3	47	67	150
Total alkalinity (mg/L)	119	77	77	200
Total dissolved solids (mg/L)	468	329	280	500
Total hardness as $CaCO_3$ (mg/L)	157	152	127	300

Result and discussion

On the basis of the above statistical data analysis study of the selected parameters which was given by CPCB. The World Health Organization (WHO 2017) drinking water standard has been considered as the reference in this study.

Biological oxygen demand

BOD is the measure of the quantity of oxygen required by bacteria and other microorganisms under aerobic conditions in order to biochemically degrade and transform organic matter present in the water bodies (Abrevaya et al. 2015). It indicates the amount of perishable organic matter present in water. As a result, a low BOD indicates good water quality, whereas a high BOD suggests contaminated water (Pachepsky et al. 2011). The BOD of Triveni Sangam Bigod was found within the permissible limit (5 mg/L) of WHO.

Chemical oxygen demand (COD)

Chemical oxygen demand is a metric that accounts for both biologically oxidizable and chemically inert organic materials (Fereja et al. 2020). In the present investigation, the highest amount was recorded during the pre-monsoon season (21.93 mg/L) which may be due to a decrease in water level, increase in salinity, temperature, and microbial utilization of oxygen during the time of decomposition (Roache et al. 2006). The concentration of COD decreased after the monsoon season probably because of the inflow of rainwater, decreased temperature, and salinity. Increased COD levels suggest a higher concentration of organic and inorganic pollutants that requires more oxygen to oxidize in thermal conditions (Puri et al. 2010).

Dissolved oxygen

Dissolved oxygen is a critical measure in water quality assessment since it indicates whether or not a water body is polluted (Akkoyunlu and Akiner 2012) The concentration of DO depends upon the water temperature, water agitation, types, the number of aquatic plants, light penetration, and the amount of dissolved or suspended solids (Cheremisinoff 2019). The mean values of DO records in the post-monsoon period were well above the prescribed limit (5 mg/L) of WHO standards were 5.39 mg/L, while the lowest average (4.65 mg/L) was obtained during the pre-monsoon and pre-monsoon seasons, which was slightly different from the monsoon season.

Fluoride

In groundwater, fluoride is geogenic in nature. It is the lightest halogen, and one of the most reactive elements (Biswas et al. 2017). It usually occurs either in trace amounts or as a major ion with high concentration (Ayotte et al. 2015). The Surface water contains fluoride released from various fluoride-bearing minerals mainly as a result of groundwater-host rock interaction (Ram et al. 2021). In addition to fluorite, it is also abundant in other rock-forming minerals like apatite, micas, amphiboles, and clay minerals (Fuge and Andrews 1988). In the present study, the fluoride concentration ranges within the permissible limit (1.5 mg/L) given by WHO.

Nitrate

Nitrate is a vital nutrient that influences the productivity of aquatic ecosystems and speeds up the growth of algae and macrophytes (Lukwambe et al. 2019). Nitrates enter freshwater through the discharge of sewage and industrial wastes and runoff from agricultural fields (Chowdhary et al. 2020). In this study, the nitrate value was found in the range of standards given by WHO.

pH

The pH defines the concentration of proton ions (H^+) found in the water. The optimal pH for drinking water is described in the range of 6.5–8.5 by WHO standards. The water was alkaline in nature throughout the year (Sánchez-España et al. 2011). When pH exceeds 8.5, the taste of water becomes saltier, causing eye discomfort and skin disorders. The average mean value of pH during the investigation was 8.07 during post-monsoon, 8.16 during pre-monsoon, and 8.08 during monsoon. There was no significant difference in pH throughout the study period.

Potassium

It is present in many minerals and most of the rocks. Many of these rocks are relatively soluble and release potassium, the concentration of which increases with time in groundwater (Lu et al. 2010). In this study, it varies between 2.9 and 3.0 mg/L.

Sodium

It is a highly reactive alkali metal. It is present in most of the groundwater as well as surface water. Many rocks and soils contain sodium compounds, which easily dissolve to liberate sodium in water (Ram et al. 2021). In the study area, it ranges from 42 to 80 mg/L. The high concentration of Na^+ indicates weathering of rock-forming minerals i.e., silicate minerals (alkali feldspars), and dissolution of soil salts present therein due to evaporation (Pokrovsky et al. 2005). In aquifers, the high Na^+ concentration in groundwater may be related to the mechanism of cation exchange (Ahmed et al. 2013).

Sulphate

It is dissolved and leached from rocks containing gypsum, iron sulfides, and other sulfur-bearing compounds. Sulphate is a common anion present in low concentrations in natural waters (Essilfie-Dughan et al. 2017). Sulphate sources in water bodies include rainfall run-off, fertilizers, sewage effluents, and dissolution of sulphide minerals present in granite (Khatri and Tyagi 2015). The sulfate concentration is found in the range (47–75.5 mg/L) of the permissible limit prescribed by WHO.

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize a strong acid (Boyd et al. 2011). Surface water alkalinity is predominantly determined by carbonate and hydroxide concentration, but also includes contributions from borates, phosphates, silicates, and other bases (Saladino et al. 2019). The highest alkalinity was recorded during pre-monsoon 119 mg/L and the lowest during the monsoon (77 mg/L) season. The low alkalinity value in surface waters during the monsoon was most likely due to rainwater dilution (Saha et al. 2021).

Total dissolved solids

The total dissolved solids (TDS) in water are a measurement of the combined contents of all inorganic and organic components present in water as molecules, ions, or micro-granular suspended forms (Saravanakumar and Kumar 2011). The observed average total dissolved solids value was 280 mg/L during post-monsoon, 468 mg/L during pre-monsoon, and 329 mg/L during monsoon season. The mean value of TDS was found below the prescribed limit (500 mg/L) of WHO.

Total hardness

The hardness of the water is a feature resulting from the presence of alkaline earth metals in natural waters, particularly calcium and magnesium (Tsogas et al. 2010). The dissolution of soil minerals and rocks causes this feature, but it can also be induced by direct contamination by the trash from a variety of anthropogenic sources (Bhateria and Jain 2016). The water is divided into three categories based on hardness values: 0–60 mg/L soft, 61–120 mg/L moderately hard, 121–160 mg/L is hard, and greater than 180 mg/L is very hard (Haritash et al. 2017). The highest concentration of hardness in the water sample was recorded during pre-monsoon 157 mg/L, which was well within the permissible limit (300 mg/L) of the WHO standards.

Correlation among physicochemical variables

Table 3 shows the correlation between the various physicochemical parameters like fluoride is strongly correlated with BOD and COD; Nitrate is strongly correlated with BOD, COD, and fluoride; pH is strongly correlated with COD, EC, Fluoride, and Nitrate; Potassium is strongly correlated with BOD, COD, Fluoride, and Nitrate; Sodium strongly correlated with COD, EC, Fluoride, Nitrate, and pH; sulfate is strongly correlated with only EC; Total Hardness is correlated with EC, Fluoride, Nitrate, pH, Sodium, and sulfate; Total Dissolved solid strongly correlated with COD, EC, Fluoride, Nitrate, pH, Sodium and Total Hardness; and Total

Table 3 Correlation matrix of analyzed groundwater quality parameters

Column	B.O.D.	C.O.D.	EC	DO	F	Nitrate	pH	K	Na	Sulphate	TA	TDS	TH
B.O.D.	1												
C.O.D.	0.97	1											
EC	0.3	0.5	1										
DO	− 0.88	− 0.96	− 0.71	1									
F	0.94	0.99	0.6	− 0.98	1								
Nitrate	0.92	0.98	0.65	− 0.99	0.99	1							
pH	0.58	0.74	0.95	− 0.89	0.81	0.85	1						
K	1	0.97	0.3	− 0.88	0.94	0.92	0.58	1					
Na	0.64	0.79	0.92	− 0.92	0.85	0.89	0.99	0.64	1				
Sulphate	− 0.23	− 0.016	0.85	− 0.25	0.09	0.16	0.65	− 0.23	0.59	1			
TA	0.5	0.67	0.97	− 0.85	0.75	0.79	0.99	0.5	0.98	0.72	1		
TDS	0.7	0.83	0.89	− 0.95	0.89	0.92	0.98	0.7	0.99	0.53	0.97	1	
TH	0.98	0.99	0.44	− 0.94	0.98	0.97	0.7	0.99	0.75	− 0.07	0.63	0.8	1

Hardness is strongly correlated with the BOD, COD, Fluoride, Nitrate, Potassium and with TDS.

Water quality index (WQI)

The summary of WQI values for all seasons is given in Tables 4, 5, 6, 7, and Fig. 2 shows the graphical presentation of WQI. The calculated WQI implies that the Triveni Sangam water quality was "least poor" during post-monsoon, poor during monsoon, and "Unsuitable" during pre-monsoon season. The high WQI score during the Pre-monsoon season can be attributed to a higher pollution load during summer than during the rainy and winter seasons, which is also attributed to high conductivity, pH, and chloride concentrations (Panikkar et al. 2022). The overall WQI of Triveni Sangam fell within the 'very poor category of WQI classification and is not suitable for daily needs. The major source of pollution was from agriculture runoff and domestic sewage inputs. Overall, it can be concluded that the water quality of the Triveni Sangam is poor and needs to be treated before human usage; however, it is suitable for agriculture and fisheries with proper treatment. The findings of this study

Table 4 The value of WQI of pre-monsoon

Parameters	WHO standards (S_n)	$1/S_n$	$\sum 1/S_n$	$K=1/(\sum 1/S_n)$	$W_n=K/S_n$	Ideal value V_0	Pre-monsoon value (V_n)	V_n/S_n	$Q_n=V_n/S_n*100$	W_n*Q_n
B.O.D.	3	0.3333	1.3927	0.7180	0.2393	0	1.68	0.56	56.00	13.4028
C.O.D.	100	0.01	1.3927	0.7180	0.0071	0	21.93	0.2193	21.93	0.1574
EC	1150	0.0008	1.3927	0.7180	0.0006	0	611	0.5313	53.13	0.0331
DO	5	0.2	1.3927	0.7180	0.1436	14	4.65	1.055	105.5	15.15
F	1.5	0.6666	1.3927	0.7180	0.4786	0	0.83	0.5533	55.33	26.4865
Nitrate	45	0.0222	1.3927	0.7180	0.0159	0	1.95	0.0433	4.33	0.0691
pH	8.5	0.1176	1.3927	0.7180	0.0844	7	8.16	0.7733	77.33	6.5321
K	200	0.005	1.3927	0.7180	0.0035	0	3	0.015	15	0.0053
Na	50	0.02	1.3927	0.7180	0.0143	0	80	1.6	160	2.2976
Sulphate	150	0.0066	1.3927	0.7180	0.0047	0	75.3	0.502	50.2	0.2402
TA	200	0.005	1.3927	0.7180	0.0035	0	119	0.595	59.5	0.2136
TDS	500	0.002	1.3927	0.7180	0.0014	0	468	0.936	93.6	0.1344
TH	300	0.0033	1.3927	0.7180	0.0023	0	157	0.5233	52.33	0.1252
		1.3927			1					*64.84*

Italic indicates specification of WQI

Table 5 The value of WQI of monsoon

Parameters	WHO standards (S_n)	$1/S_n$	$\sum 1/S_n$	$K = 1/(\sum 1/S_n)$	$W_n = K/S_n$	Ideal value V_0	Monsoon value (V_n)	V_n/S_n	$Q_n = V_n/S_n*100$	W_n*Q_n
B.O.D.	3	0.3333	1.3927	0.7180	0.2393	0	1.68	0.56	56.00	13.4028
C.O.D.	100	0.01	1.3927	0.7180	0.0071	0	19.8	0.198	19.8	0.1574
EC	1150	0.0008	1.3927	0.7180	0.0006	0	503	0.4373	43.73	0.0331
DO	5	0.2	1.3927	0.7180	0.1436	14	5.0	1.0	100	15.15
F	1.5	0.6666	1.3927	0.7180	0.4786	0	0.8	0.5333	55.33	26.4865
Nitrate	45	0.0222	1.3927	0.7180	0.0159	0	1.82	0.0404	4.04	0.0691
pH	8.5	0.1176	1.3927	0.7180	0.0844	7	8.08	0.72	72.00	6.5321
K	200	0.005	1.3927	0.7180	0.0035	0	3	0.015	1.5	0.0053
Na	50	0.02	1.3927	0.7180	0.0143	0	49	0.98	98	2.2976
Sulphate	150	0.0066	1.3927	0.7180	0.0047	0	47	0.3133	31.33	0.2402
TA	200	0.005	1.3927	0.7180	0.0035	0	77	0.385	38.5	0.2136
TDS	500	0.002	1.3927	0.7180	0.0014	0	329	0.658	65.8	0.1344
TH	300	0.0033	1.3927	0.7180	0.0023	0	152	0.5066	50.66	0.1252
		1.3927			1					*61.52*

Italic indicates specification of WQI

Table 6 The value of WQI of post monsoon

Parameters	WHO standards (S_n)	$1/S_n$	$\sum 1/S_n$	$K = 1/(\sum 1/S_n)$	$W_n = K/S_n$	Ideal value V_0	Post-monsoon value (V_n)	V_n/S_n	$Q_n = V_n/S_n*100$	W_n*Q_n
B.O.D.	3	0.3333	1.3927	0.7180	0.2393	0	1.48	0.4933	49.33	11.8072
C.O.D.	100	0.01	1.3927	0.7180	0.0071	0	12.529	0.1252	12.52	0.0899
EC	1150	0.0008	1.3927	0.7180	0.0006	0	527	0.4528	45.28	0.0286
DO	5	0.2	1.3927	0.7180	0.1436	14	5.39	0.9566	95.66	13.7369
F	1.5	0.6666	1.3927	0.7180	0.4786	0	0.74	0.4933	49.33	23.61
Nitrate	45	0.0222	1.3927	0.7180	0.0159	0	1.62	0.036	3.6	0.0574
pH	8.5	0.1176	1.3927	0.7180	0.0844	7	8.07	0.7133	71.33	6.0253
K	200	0.005	1.3927	0.7180	0.0035	0	2.9	0.0145	1.45	0.0052
Na	50	0.02	1.3927	0.7180	0.0143	0	42	0.84	84	1.2062
Sulphate	150	0.0066	1.3927	0.7180	0.0047	0	67	0.4466	44.66	0.2138
TA	200	0.005	1.3927	0.7180	0.0035	0	77	0.385	38.5	0.1382
TDS	500	0.002	1.3927	0.7180	0.0014	0	280	0.56	56	0.0804
TH	300	0.0033	1.3927	0.7180	0.0023	0	127	0.4233	42.33	0.1013
		1.3927			1					*57.10*

Italic indicates specification of WQI

Table 7 The value of the water quality index of Triveni Sangam Bigod

Monsoon	WQI value	Grading	Water quality rating
Pre-monsoon	64.84	C	Poorer
Monsoon	61.52	C	Poor
Post monsoon	57.10	C	Least poor

may aid decision-makers in the sustainable management and protection of the Triveni Sangam.

Conclusion

The results of the current investigation in Rajasthan's Eastern-South region show that both geogenic and anthropogenic activities are to blame for surface water (river water)

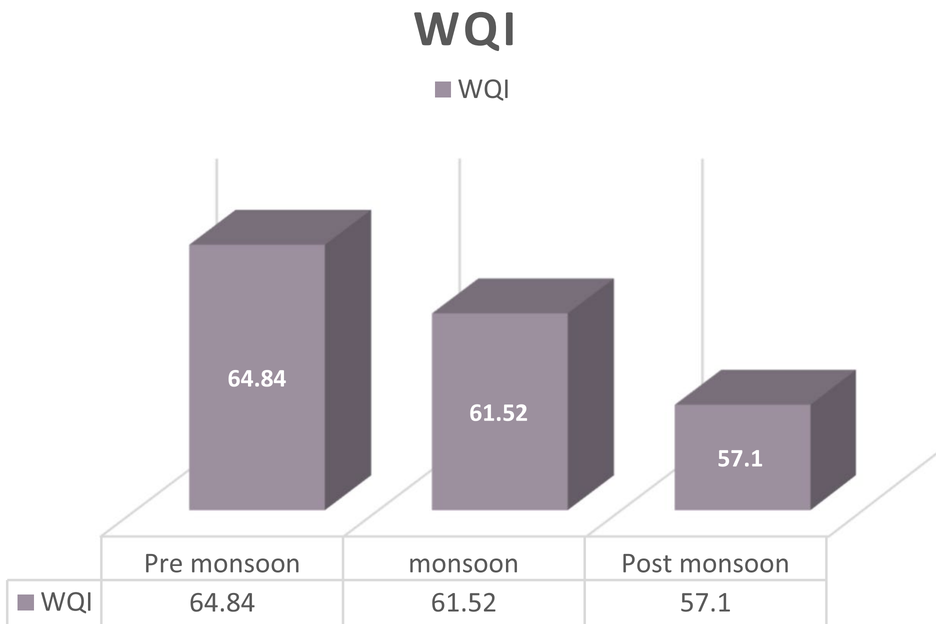


Fig. 2 WQI variation during all monsoon

deterioration. The nitrate concentration in groundwater was caused by anthropogenic activities, particularly in the center and northern regions of the research area where unlined septic tanks and uncontrolled sewage networks were present. One of the main causes of the water's poor quality is industrial waste. Therefore, it is advised that water be first treated with filtering methods before being used for drinking purposes.

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Authors and Affiliations

Pankaj Sen[1] · Rajeev Mehta[1] · Preeti Mehta[1]

✉ Pankaj Sen
pankajsunita2004@gmail.com

[1] Sangam University, Bhilwara, Rajasthan, India