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Assessment of Impact of Human Interferences including Mining Activities on Water Quality of Banas River, Rajsamand City, India

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An attempt has been made in the present study to assess various physico-chemical parameters and heavy metal analysis of water quality in Banas river, Rajsamand city, India. To maintain a balance in an aquatic ecosystem, the inter-relationship between varieties of factors is essential to maintain the water potability at a high level. It is confirmed that mining has a substantial influence. Present study examined pre- and post-monsoon physico-chemical variables, heavy metal analysis and computed water quality index, eutrophication index, organic pollution index and heavy metal pollution index. The pH, EC, COD, total hardness, zinc, silver and iron were within the acceptable limit, whereas the TDS, phosphate, dissolved oxygen, BOD and lead were found beyond the permissible limit. Therefore, the present study provides the essential information about deteriorating river water quality. Most crucially, a number of external factors like mining, soil erosion, religious activities, daily human needs activities, *etc.* are responsible for the degradation of water quality of nearby Banas river.

Keywords: Physico-chemical, Heavy metal analysis, River-ecosystem, Water monitoring, Mining activities.

INTRODUCTION

A river is a natural flowing watercourse flowing towards an ocean, sea, lakes or another river. Drinking water arises from rivers, even in many cities and rural places. Anthropogenic activities such as population development, exploitative agricultural techniques and large-scale sewage leaks from nearby areas have increased the nutrient load of the rivers, which leads to eutrophication of water bodies [1,2]. The river is used for many purposes such as electricity generation, tourist destinations, or recreational locations with water sports and other facilities, in addition to addressing drinking water issues and mitigating ecological elements like local climate [3-5]. Major contribution is provided by river to the regional economy and also fulfills the social and economic requirements of the populace. Increase in environmental pollution deteriorates the water quality. Nevertheless, the water quality management is hindered by several issues like urbanization, increase in population and mining activities [6,7].

Banas river in Rajasthan state is also known as the lifeline. The catchment areas of Banas river have been extensively deteriorated throughout the last couple of decades due to forest loss on a large scale and inefficient land management, building dams and improper mining have also increased the inflow of silt into these areas. Due to increase in population in once uninhabited regions near Banas river flow of organic sewage of humans waste has been directly flowing from those river banks. Solid and liquid wastes produced by neighboring villagers also contaminate Banas river. Aside from that deposits of rocks and mining wastes also affect the water quality of Banas river which is carried out by the wind in the monsoon. In current study, an effort has been made to evaluate the effect of human induced stress and climate fluctuation on the general water availability of the Banas river and the determination of organic load and the nutritional state along with heavy metal analysis has been done.

Study area: Banas river (Figs. 1 and 2), the name Banas, which means "Hope-of-the-Forest" or "Van Ki Aasha," is literally

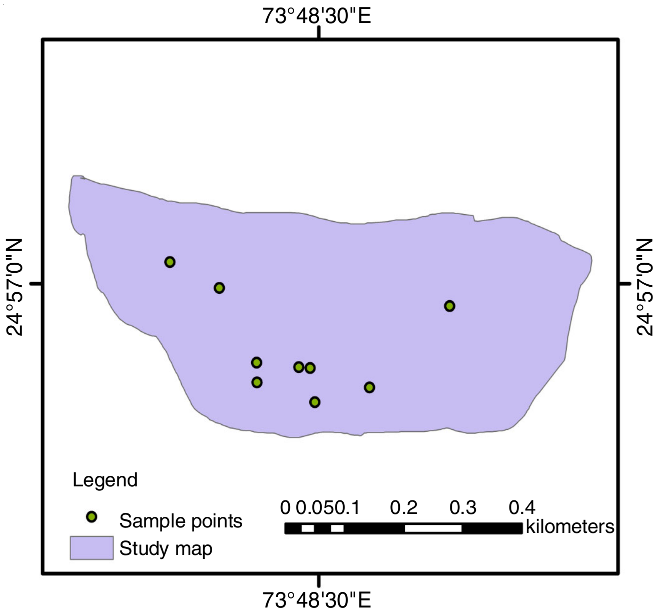

Fig. 1. Banas river study area

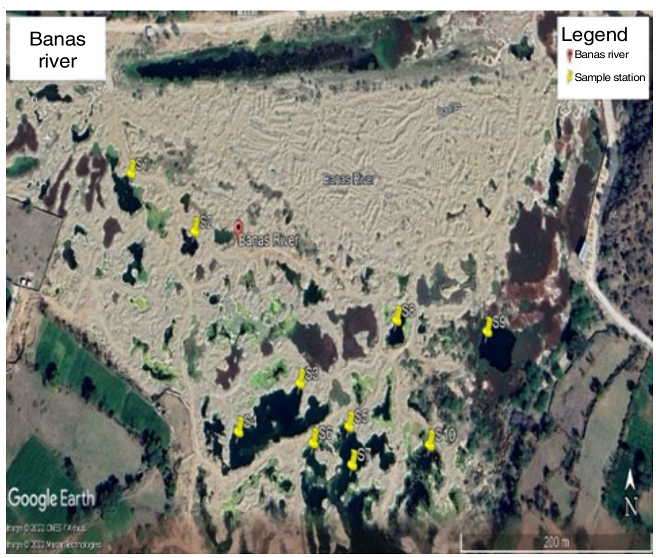

Fig. 2. Banas reiver google earth map view

is literally translated as "forest-hope" (Banas). The Veron ka Math, in the Khamnor Hills of the Aravalli Range, about 5 km from Kumbhalgarh in the Rajsamand district, is where the river originates. Banas river is wholly enclosed within Rajasthan state and it drains a basin that is 45,833 km^2. Banas river stretches between 24º19′55.98″ to 24º54′51.02″ North latitude and 72º35′22.07″ to 73º10′03.50″ East longitudes, and is situated entirely within western Rajasthan state, India. The Banas river is a branch of Chambal river, which itself is a branch of Yamuna river and further merge with Ganga river. It is approx. 512 km long. The selected study site (Banas river) is situated near a cluster of mines in Rajsamand District, Rajasthan, India.

EXPERIMENTAL

Sample collection and sampling strategy: The fieldwork for this study was performed in 2021 during the pre- and post-rainfall seasons. For the analysis of water 10 sampling sites in Banas river were selected and three replicas were taken from each sample. The sample location was carefully chosen to deliver water samples from the river's interior and exterior. The samples were collected at two distinct time of year 2021 *i.e.* before and after the monsoon seasons. The river water samples were taken in 1 L PVC bottles which had been pre-acid washed and then fully rinsed with deionized water before being filled with sample water. River water samples were taken at a depth of 1 foot below the surface to avoid air being trapped.

Analytical method: Measurements of parameters such as pH, electrical conductivity (EC) and total dissolved solids (TDS) were recorded by using a portable analyzer (HI 9813-6). Water samples were kept in ice-crested coolers under 4 ºC to avoid any reasonable chemical or biological response to quantify other physiochemical parameters [8]. Within 48 h of collection, the remaining water quality metrics underwent laboratory analysis using the standard procedures [9].

Quality control assurance: Quality approach [10] method was used for the sampling, storage and evaluation. Extreme caution was employed during the sample collection, preservation and analysis process. All the laboratory equipments were cleaned and treated with diluted HNO_3 solution (2%), double distilled water was used for washing and further placed in an oven at 40 ºC for whole night to avoid for any contamination. Before being examined for the quantitative measure, the obtained water samples were first filtered through the 0.45µ Millipore membranes. Each experiment was performed thrice for precision and accuracy and the mean was taken for subsequent data analysis, tabulation and calculation. The finest reagents and standard solutions were applied in the laboratory. All standards and intermediate solutions were made using ultrapure water. A blank determination of the reagent was conducted to obtain an accurate instrument output.

Quantifying the quality of river water using a range of indexes: In this study, some influencing factors *e.g.* disposal of solid waste and sewage, weathering, erosion, sedimentation, communities' activity, religious activities, recreational activities, mining activities around selected study site were observed and with the use of water WQI index, OPI index, EI index, HMPI index, the results were computed.

Organic pollution index (OPI): Organic pollution index (OPI) was applied to evaluate the impact of dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), chemical oxygen demand and dissolved oxygen (DO) for the measurement of water surface quality measurement. The following equation was used to determine the OPI value.

$$OPI = \frac{COD}{COD_S} + \frac{DIN}{DIN_S} + \frac{DIP}{DIP_S} + \frac{DO}{DO_S}$$

where COD_S, DIN_S, DIP_S and DO_S are the standard concentrations of above parameters as mentioned elsewhere [11,12]. The OPI is classified accordingly: 0-1 Unpolluted (Class I), 1–2¼ beginning to be polluted (Class II), 2–3¼ Lightly contaminated (Class III), 3–4¼ moderately contaminated (Class IV) and more than 4¼ heavily contaminated (Class V).

Water quality index (WQI): Experts use the weight based arithmetic water quality index (WQI) to rate the quality of drinking water, to evaluate the water quality of drinking water, WQI evaluates the effects of geological and anthropogenic activities on several crucial factors, indicating the combined effects of several physico-chemical parameters [13,14]. During this study, both pre-monsoon and post-monsoon intervals are taken into account for pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chloride, total hardness (TH) and phosphate as well as their mandatory limits proposed by WHO [11] and BIS [12]. Each criterion is assigned as final weight (W_a) ranging from 1 to 5, based on how much influence it has on the overall excellence quality of the water. The relative weight (W_r) is first determined by the following formula:

$$W_r = \frac{W_a i}{\sum_{i=1}^{n} W_a i}$$

The relative weights and assigned weights of each physico-chemical parameter are represented by W_r and W_a, respectively, where n stands for the numbers of parameters. The quality rating scale (Q_i) is then developed for each parameter as follows:

$$Q_i = \frac{C_i - V_i}{S_i - V_i} \times 100$$

where Q_i stands for quality index, C_i stands for each chemical parameter's concentration. Except for pH 7 and DO, V_i is the ideal value for each parameter and is regarded as 0. The standard tolerance (S_i) for each metric was established by WHO [11] and BIS [12].

While calculating the WQI, the partial index (SI) of each chemical parameter is first determined and then the overall WQI is determined according to the following formula:

$$SI_i = W_r \times Q_i$$

$$WQI = \Sigma SI_i$$

The calculated WQI was categorized as follows using the proposed water quality classification [15]: excellent (WQI less than 25, good (WQI 25-50), middling (WQI 51-75), awful (WQI 76-100) and extremely poor (WQI more then 100).

Eutrophication index (EI): EI defines the appropriate usage of seawater and shows its nutritional condition. On the basis of three indicator measures, such as COD, DIN and DIP [16], it shows the eutrophication status of the river basin. Below are the formulas for EI.

$$EI = \frac{COD \times DIN \times DIP}{4500} \times 10^6$$

The chemical oxygen demand concentration, or COD. DIP stands for dissolved inorganic phosphate, whereas DIN stands for dissolved inorganic nitrogen. It falls under the classification as EI, ≤ 0: no eutrophication; EI ≥ 0: eutrophication [17]. Although, the EI is high significant eutrophication in the waters of the river was observed.

Heavy metal pollution index (HMPI): The HMPI is a metric which is used to determine the presence of total heavy metal content in water. The weighted arithmetic quality means approach provides the foundation for the HMPI, which was created in two phases. Before establishing a grading scale with weights for each pollutant characteristic, the variables on which the index will be based are selected. The rating system is subjective, with values ranging from 0 to 1 and its selection is based on how significant each quality concentration is in comparison to other concentrations. It can also be evaluated by setting values that are negatively correlated to the advised standard for the relevant parameters [18,19].

$$HMPI = \frac{\sum_{i=1}^{n} W_i \times Q_i}{\sum_{i=1}^{n} W_i}$$

where Q_i is the I_{th} parameter's sub-index. The number of variables taken into consideration is n and W_i is the unit weightage of the I_{th} parameter.

The sub-index (Q_i) of the parameter is calculated by

$$Q_i = \sum_{i=1}^{n} \frac{[M_i (-) I_i]}{[S_i - I_i]} \times 100$$

where M_i = Monitored value of heavy metal of the i_{th} parameter, I_i = Ideal value of the i_{th} parameter, S_i = Standard value of i_{th} parameter, Q_i is the sub-index of the I_{th} parameter, W_i is the unit weight of the I_{th} parameter and n is the total number of parameters considered.

Statistical methods: This study focused at relationships between potential sources, relative behaviour and water quality measures in the waters close to the river bottom by using multivariate statistical methods including Pearson correlation and principal component analysis (PCA). Multivariate statistical analysis correlation analysis and PCA (rotational component matrix supporting Kaiser normalization) calculation was required for the dependency evaluation. The relationship between the Banas river water quality measurements were examined for each of the two seasons using correlation matrix tables (*i.e.* pre-monsoon and post-monsoon). Estimation of PC1, PC2 and PC3 were performed using the PCA technique. The water quality assessments after PCA mostly indicated the load or weight that was linked to each component. The rotations converged with ten sampling sites for both seasons.

RESULTS AND DISCUSSION

Evaluation of physical variables: Evaluation of variables of Banas river has shed light on the river water's quality in a significant way and the results have been summarized in Table-1. The measured surface water temperature ranged from 30.1-31.6 ºC in the pre-monsoon season and 21.1-24.8 ºC in the post-monsoon season in Banas river. During both seasons, the pH levels of river water samples obtained were somewhat acidic in nature. The electrical conductivity (EC) results reflect seasonal variations, with higher values in the post-monsoon season (EC 970-1570 S cm^{-1} in post-monsoon & EC 113-150 S cm^{-1} in pre-monsoon). While total dissolved solids (TDS) were found to be in the range of 705-780 ppm in pre-monsoon and 770-940 ppm in post-monsoon. It may be related to the sudden rush of overland flow during the brief monsoon season. The acidity of the river water was at a higher end in the pre-

TABLE-1
STATISTICAL ANALYSIS OF BANAS RIVER WATER THE VARIABLES AFFECTING WATER QUALITY IN PRE- AND POST-MONSOON SEASON

Parameter	Pre-monsoon season						Post-monsoon season					
	Min	Max	Mean	WHO std.	BIS std. desirable	Column 1 permissible	Min	Max	Mean	WHO std.	BIS std. desirable	Column 1 permissible
pH	7.3	7.9	7.73	6.5-8.5			7.4	8.5	7.9	6.5-8.5		
Temperature	30.1	31.6	30.86				21.1	24.8	22.79			
EC	113	150	131.4		200	600	970	1570	1273		200	600
Acidity	401	430	410.36				122.5	134.3	127.94			
TDS	705	780	738.43	1000	200	600	770	940	860.8	1000	200	600
Phosphate	0.01	0.95	0.325	0.3			0.6	1.3	0.91	0.3		
Chloride	60	180	111.1	250	>5	NX	58	178	118	250	>5	NX
DO	3.4	7.9	6.09	5	2000	NX	8.8	11.3	10.43	5	2000	NX
BOD	14.5	18.6	16.61				34	40.8	37.2			
COD	12.78	18.76	15.6		250	1000	38	48	41.6		250	1000
TH	110	140	127.46	200			105	138	122.6	200		
DIN	0.001	0.04	0.013				2.8	4	3.61			
DIP	0.001	0.005	0.003		45	NX	0.01	0.018	0.014		45	NX
Zinc	0.1	0.13	0.115	15			0.1	0.13	0.115	15		
Silver	0.002	0.13	0.003	0.1			0.002	0.13	0.034	0.1		
Iron	0.002	0.13	0.04	0.3			0.002	0.13	0.05	0.3		
Lead	0.2	0.23	0.214	0.001			0.15	0.23	0.208	0.001		

monsoon study period (401-430 mg/L) compared to the post-monsoon study (122.5-127.94 mg/L). The diluting factor, affecting the acidity value, may also be responsible for lower values in the post-monsoon. The total hardness and Cl^- revealed marginally reduced values in the post-monsoon analysis than in the pre-monsoon analysis. The diluting effect brought on by the inflow of precipitation in season and increased rates of evaporation during the summer season may be the reason for reduced values in post-monsoon studies.

Home sewage discharge may primarily source of chlorides in water which is another sign of pollution. One of the most crucial metrics, dissolved oxygen (DO), showed seasonal variations in the Banas river, ranging from 3.4 to 7.9 mg/L and 8.8 to 11.3 mg/L in the pre-monsoon and post-monsoon study periods, respectively. However, chemical oxygen demand (COD) was found to be higher in the post-monsoon season (38-48 mg/L) in comparison to that in the pre-monsoon season (12.78-18.78 mg/L). Biological oxygen demand (BOD) also displayed a similar trend. The obtained results were found to be consistent with surface runoff and an increase in organic matter during the post-monsoon season (34-40.8 mg/L)and in the pre-monsoon season (14.5-18.6 mg/L).The heavy metal analysis was also performed and the metals *viz.* zinc, iron and silver were found within acceptable limits in both pre- and post-monsoon accept lead (Pb),which was found beyond permissible limits in both pre-monsoon (0.20-0.23 mg/L) and post-monsoon season (0.15-0.23 mg/L) studies. This may be attributed to lead mining activity in the nearby area, which is adversely affecting water quality as well as aquatic life.

Water quality index (WQI): The water quality index (WQI) is a mathematical treatment that represents a numeric value that takes into account all the elements that may have an impact on a water body. Standardization of all the evaluated parameters is achieved in the mathematical equation. The WQI delivers a numerical number that indicates the quality of water by combining numerous water characteristics [20], giving an exhaustive image of the aquatic body under investigation. The water quality can be described as "excellent" if the computed WQI value is between 0 and 25, "good" if it is between 26 and 50, "poor" if it is between 51 and 75, "extremely bad" if it is between 76 and 100 and "unsuitable" for drinking if it is over 100.

All the physico-chemical factors were taken into account for the estimation of the WQI of Banas river water. The WQI results for both pre-monsoon and post-monsoon clearly indicated "unsuitable for drinking," which is quite alarming. The values varied between 12.38-297.2 for pre-monsoon studies and between 196.63-406.27 for post-monsoon studies. WQI of pre-monsoon and post-monsoon suggested that the water of the river is not appropriate for drinking except at three stations, however, WQI was found to be better. The WQI values of pre-monsoon qualities are somewhat better then post monsoon but, in both conditions, water is unsuitable for drinking propose (Fig. 3a). Post-monsoon WQI value was observed to be greater, which may be attributed to the increased concentration of phosphate due to mining activities in nearby area (Fig. 3b). The geographical distribution of WQI of Banas river water before and after the monsoon is shown in Fig. 4.

Organic pollution index development (OPI): The organic pollution index is a metric used to assess how COD, DIN, DIP and DO together affect the quality of surface water. The OPI values evaluated for Banas river ranged from 0.85 to 1.76 in pre-monsoon and from 1.96 to 2.47 in post-monsoon season, respectively. Pre-monsoon data inferred that a small number of sites with low pollution levels and the majority of sample sites with light pollution levels, *i.e.*, sites were just begin to pollute. Reverse to it the pre-monsoon observation. Graphical representation of OPI of Banas river during the pre-monsoon and post-monsoon season is shown in Fig. 5 while the geographical distribution of Banas river OPI before and after the monsoon is presented in Fig. 6. The study conclusively proved that higher OPI levels of Banas river water occurs following the monsoon. This observation can be attributed to surface runoff

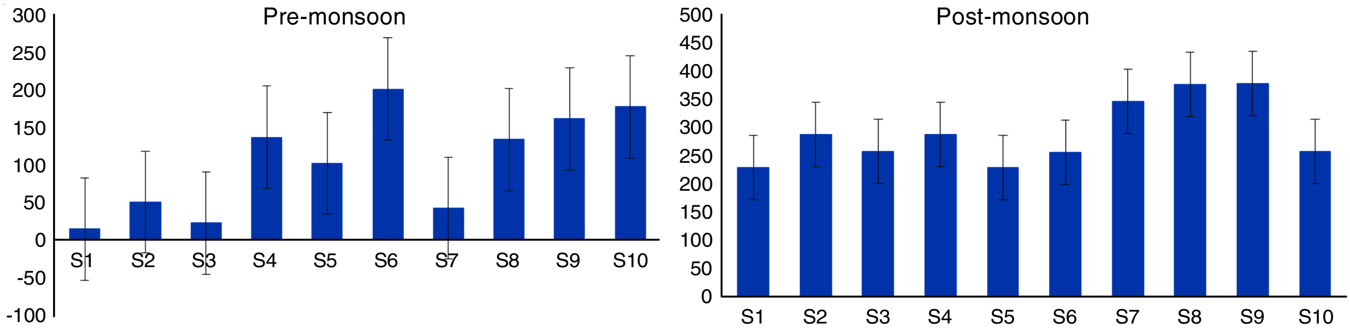

Fig. 3. Graphical representation of water quality index (WQI) of Banas river water during pre- and post-monsoon season

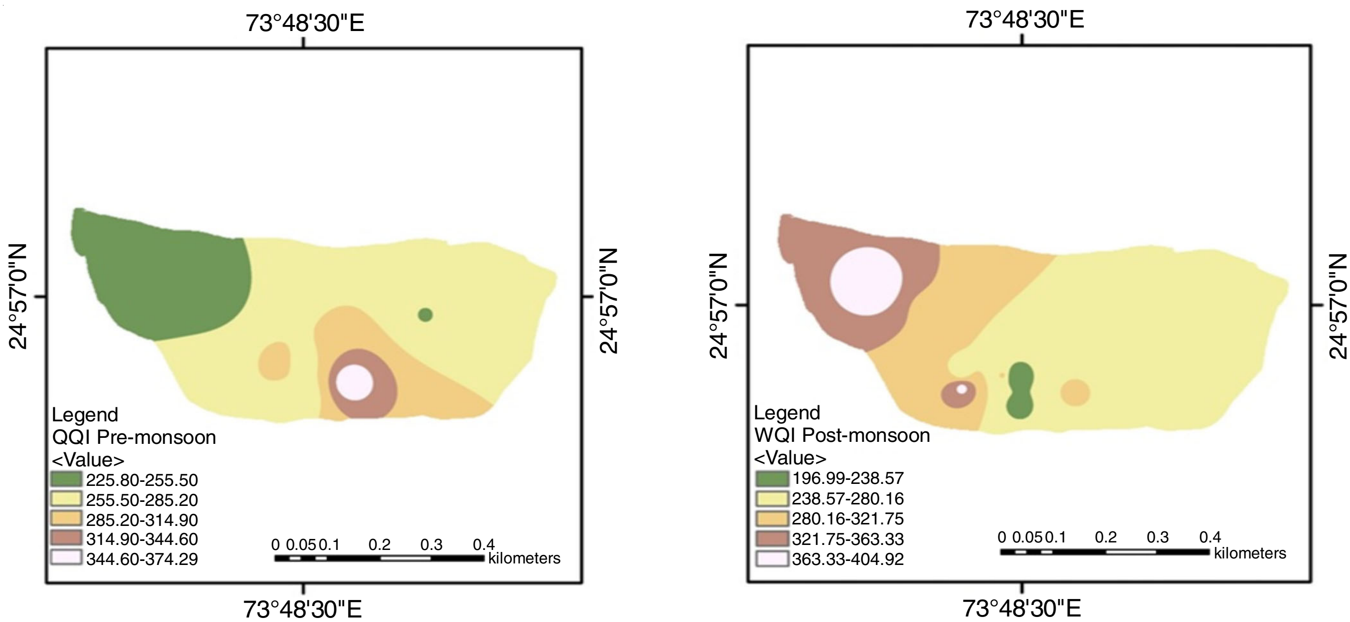

Fig. 4. Geographical distribution of water quality index (WQI) of Banas river water during before and after the monsoon

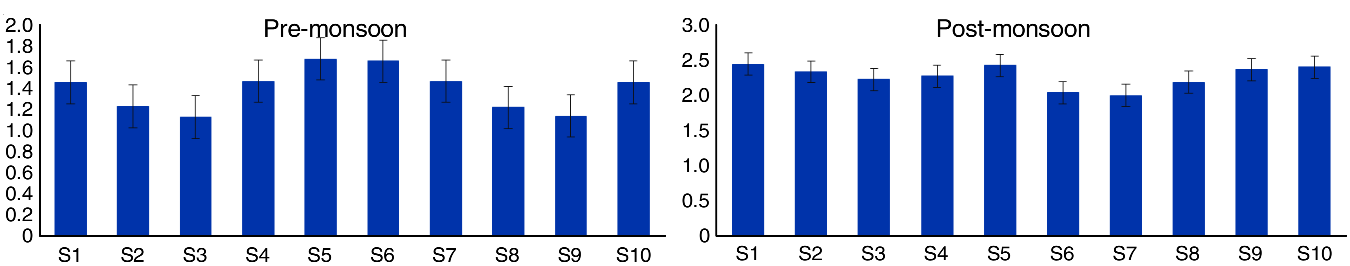

Fig. 5. Graphical representation of organic pollution index (OPI) of Banas river water during pre- and post-monsoon season

because of the larger water inflow during the monsoon season, which may be explained by the fact that wastewater discharged from populous areas, agricultural croplands and Banas river water catchment forest regions contaminated the water in Banas river with significant levels of fertilizers and organic pollutants [16,17].

Eutrophication index (EI): The cumulative impact of chemical oxygen demand (COD), dissolved inorganic nitrogen (DIN) and dissolved inorganic phosphorus (DIP) was measured in terms of eutrophication index. High EI values were recorded for the pre-monsoon season (28-173.33) than for the post-monsoon season (115.58-261.28). The higher EI values are generally associated with the presence of solid garbage and the direct discharge of sewage at certain places. The highest EI values were measured at sampling stations S1 (261.28 in post-monsoon conditions) and S10 (173.33 in pre-monsoon conditions) (Fig. 7). The dilution brought on by precipitation and the influx of surface runoff can be linked to the decline in EI values during the pre-monsoon season. The OPI and EI were found to be positively correlated with each other, particularly in the post-monsoon season. This may be due to the considerable accumulation of sewage water in the river ecosystem resulting in increased organic pollutant load and eutrophication state [17].

Heavy metal pollution index (HMPI): The heavy metal pollution index (HMPI) is a procedure to detect the presence of heavy metals, there by assessing the water quality. It was observed that during pre-monsoon studies (1.79-2.06), higher

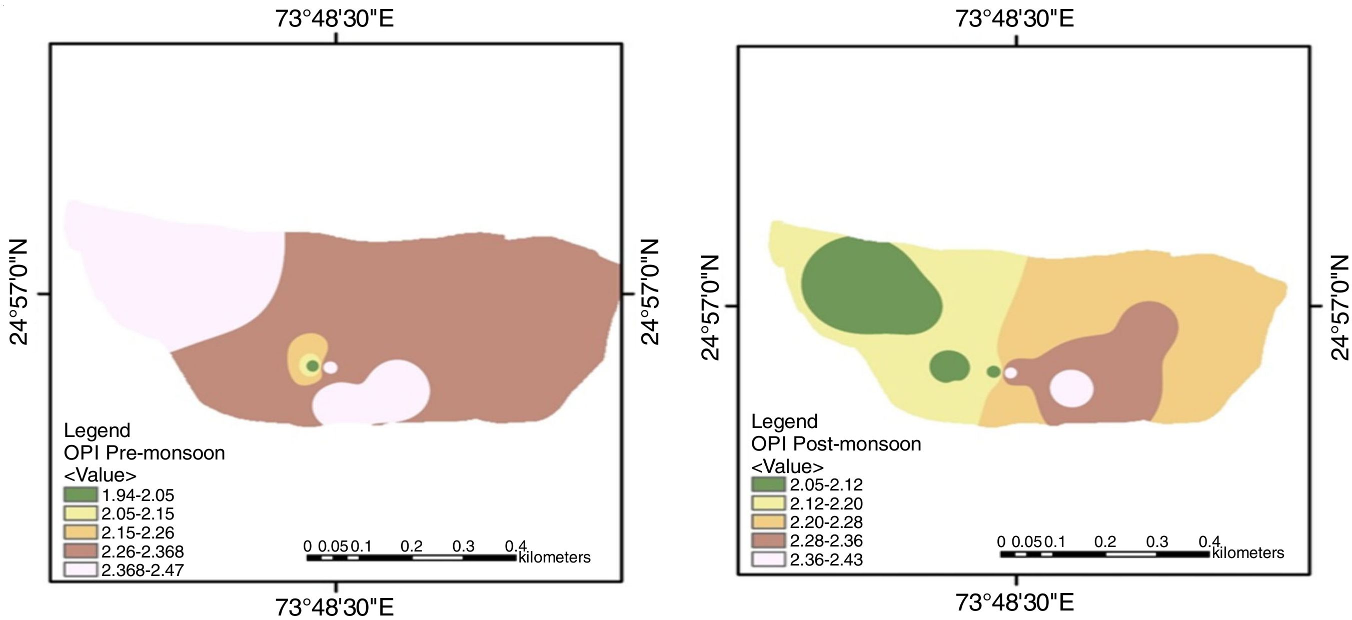

Fig. 6. Geographical distribution of organic pollution index (OPI) of Banas river water during before and after the monsoon

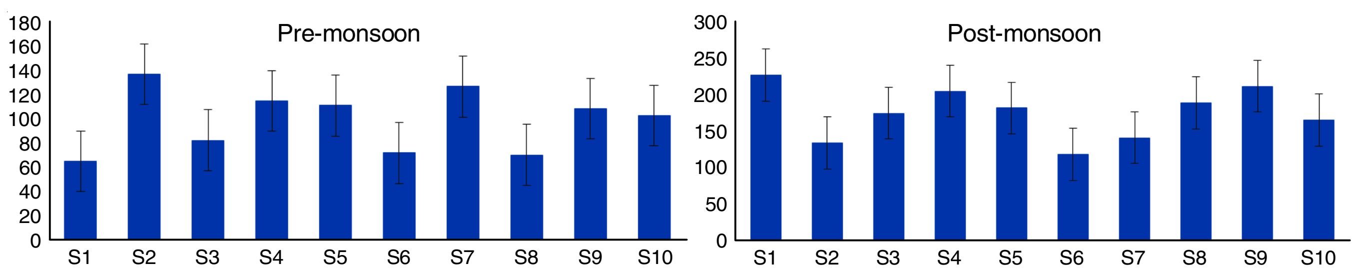

Fig. 7. Graphical representation of eutrophication index (EI) of Banas river water during pre- and post-monsoon season

HMPI was recorded than in post-monsoon studies (1.35-2.06). The higher HMPI value is the direct indicator of heavy metal pollution or leakage in water. This may be due to a mining site near the sampling station. The observed data for both pre-and post-monsoon was found under permissible limits suggested that no heavy metal pollution in Banas river (Fig. 8) and the geographical distribution of Banas river HMPI before and after the monsoon is presented in Fig. 9.

Application of multivariate statistics: Data collected from the pre- and post-monsoon seasons were used to calculate the mean of water quality metrics for Banas river. Multivariate statistical (SPSS statistical software, version 21.0) analysis including Pearson's correlation and PCA was followed throughout to evaluate the likely origins, comparative behaviour and interconnection among the water quality measurements of Banas river water.

Banas correlation analysis of pre- and post-monsoon seasons: The correlation matrix results between 17 water quality variables during the pre-and post-monsoon seasons for Banas river are shown in Tables 2 and 3. The variables such as iron-temperature, temperature-phosphate, DIN-phosphate and silver-temperature were found to be significantly positively correlated in the pre-monsoon; while in post-monsoon COD-EC, DO-TDS, COD-chloride and EC-COD were found to be significantly moderately positively correlated. This clearly indicates that the aspects such as modern activities and geolo-

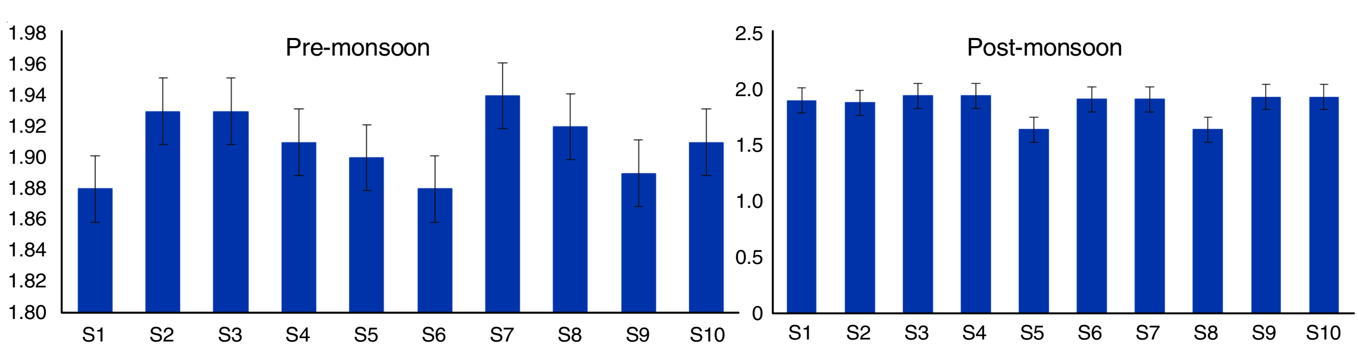

Fig. 8. Graphical representation of HMPI of Banas river during pre- and post-monsoon season

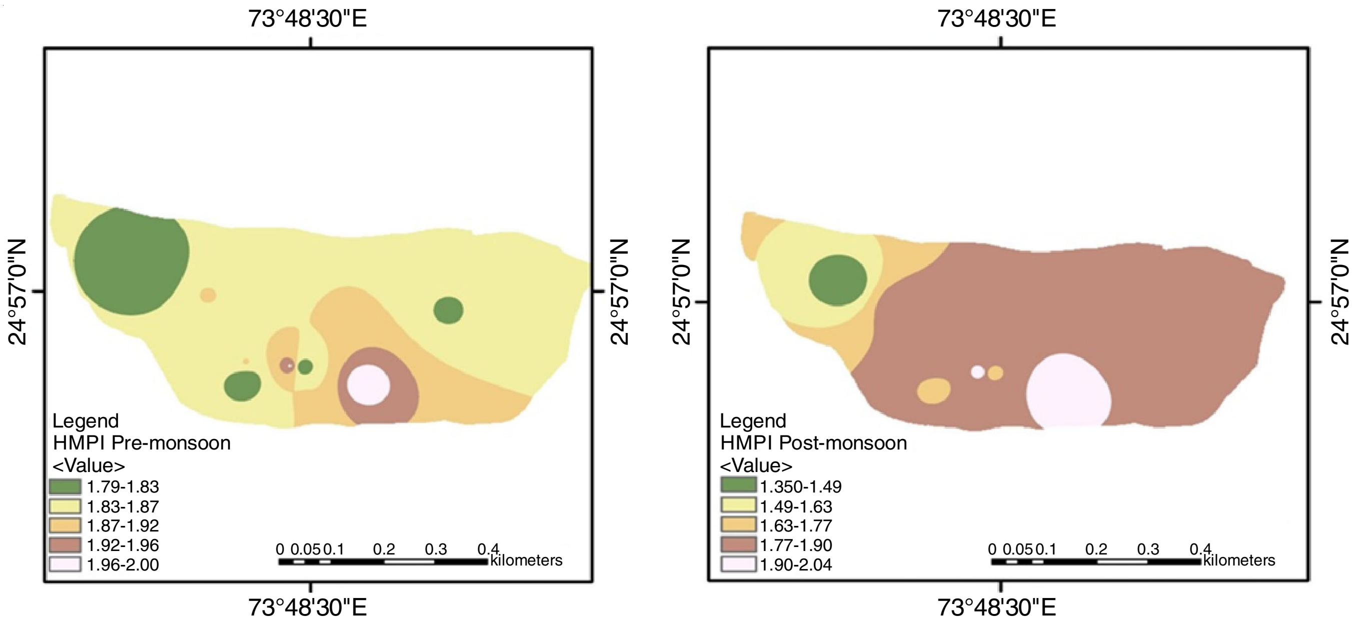

Fig. 9. Geographical distribution of heavy metal pollution index (HMPI) of Banas river water during before and after the monsoon

TABLE-2
CORRELATION STUDY OF MEASURED VARIABLES FROM BANAS RIVER WATER IN PRE-MONSOON SEASON

	pH	Temp.	EC	Acidity	TDS	SO_4	Cl	DO	BOD	COD	TH	DIN	DIP	Zn	Ag	Fe	Pb
pH	1																
Temp.	0.252	1															
EC	0.214	-0.041	1														
Acidity	0.185	0.392	0.029	1													
TDS	-0.029	-0.079	-0.24	0.142	1												
SO_4	0.199	0.458	0.106	0.251	0.172	1											
Cl	-0.086	0.253	-0.065	-0.061	-0.057	-0.038	1										
DO	-0.433	-0.02	0.008	-0.054	-0.177	0.048	0.304	1									
BOD	-0.101	0.062	0.071	-0.091	-0.073	0.111	-0.072	-0.218	1								
COD	0.093	-0.008	0.008	-0.146	-0.08	-0.055	-0.275	0.026	-0.041	1							
TH	0.049	0.166	0.101	-0.085	-0.365	0.077	0.018	0.058	-0.213	-0.175	1						
DIN	-0.129	0.136	0.009	-0.174	0.046	0.403	-0.072	0.044	0.224	0.208	0.107	1					
DIP	0.136	0.128	0.031	0.078	0.068	-0.089	0.031	-0.046	-0.015	-0.092	-0.129	0	1				
Zn	0.041	0.044	0.187	0.005	-0.003	0.522	0.064	0.125	-0.032	-0.17	0.125	0.333	0.084	1			
Ag	0.019	0.623	-0.133	0.414	0.024	0.205	0.079	-0.104	-0.046	-0.218	-0.174	0	0.068	0.192	1		
Fe	-0.058	0.518	-0.211	-0.133	-0.045	0.047	0.547	0.114	0.047	0.047	0.083	0.222	0.215	0.514	0.153	1	
Pb	-0.05	0.06	-0.021	0.039	-0.082	-0.095	-0.1	0.161	-0.323	0.219	0.034	0	0.416	0.018	0.098	0.157	1

TABLE-3
CORRELATION STUDY OF MEASURED VARIABLES FROM BANAS RIVER WATER IN POST-MONSOON SEASON

	pH	Temp.	EC	Acidity	TDS	SO_4	Cl	DO	BOD	COD	TH	DIN	DIP	Zn	Ag	Fe	Pb
pH	1																
Temp.	0.549	1															
EC	0.239	0.69	1														
Acidity	-0.191	-0.049	-0.207	1													
TDS	0.386	0.516	0.443	-0.217	1												
SO_4	-0.257	0.018	0.018	0.275	-0.418	1											
Cl	0.003	0.128	0.288	0.291	-0.271	0.285	1										
DO	0.114	0.179	0.469	-0.641	0.676	-0.439	-0.362	1									
BOD	-0.281	-0.473	-0.351	0.436	0.111	-0.289	0.242	-0.105	1								
COD	0.27	0.298	0.659	-0.126	0.076	-0.049	0.626	0.26	0.001	1							
TH	-0.138	-0.335	-0.36	-0.603	-0.177	0.13	-0.463	0.252	-0.352	-0.196	1						
DIN	0.187	-0.023	0.359	0.285	-0.393	0.286	0.058	-0.417	-0.285	-0.254	-0.059	1					
DIP	-0.197	0.478	0.659	-0.089	0.604	-0.044	-0.307	0.521	-0.136	-0.071	0.108	-0.35	1				
Zn	-0.041	-0.096	-0.032	-0.032	0.107	0.076	-0.03	0.04	0.136	-0.056	0.006	-0.126	0.008	1			
Ag	0.516	0.316	0.088	0.056	-0.03	0.177	0.331	-0.244	-0.093	0.344	-0.094	0.086	-0.235	0.141	1		
Fe	0.461	0.096	-0.04	-0.084	-0.191	-0.242	0.144	-0.225	-0.081	0.111	-0.214	0.235	-0.529	-0.395	0.099	1	
Pb	-0.066	-0.24	0.134	0.134	-0.181	-0.125	0.307	-0.001	0.239	0.438	-0.175	-0.137	-0.281	0.273	0.196	-0.103	1

gical factors severely responsible to control water quality of Banas river [21]. This study found no strong correlation between parameters, implying that geochemical weathering of rocks, which may lead to mineral dissolution in river water, is not significantly affecting river water quality [21]. The variable's coefficients of measurement in Banas river water indicated that anthropogenic activities such as return flow irrigation of land, animal waste deposition in sewers and geochemical weathering of rocks all have negative impact on the river's water quality [22].

Principal component analysis (PCA): The principal component analysis PCA loading matrix (varimax rotated) for Banas river during pre-monsoon and post-monsoon are shown in Table-4. In the pre-monsoon and post-monsoon seasons, respectively, the findings of using PCA were 38.21% and 54.86% of the total variation for the parameters being measured. The parameters pH (0.226), DO (0.020), TDS (0.048), EC (-0.026) and silver (0.686) in pre-monsoon PC1 indicated a variance of 15.335% of the total variance and suggested the river water was primarily influenced by anthropogenic activities. BOD (-0.227), COD (0.016.), silver (-.099) and phosphate (-0.359) loadings were reported by PC2 (11.927 % variance), indicating that river water is primarily affected by geological deterioration with a small amount of anthropogenic influence. Temperature (-0.116), EC (0.340), acidity (-0.403) and Cl^- (-0.012) were the four water factors that makeup PC3 (10.958 % of the total variation), suggested that the seasonal fluctuations in river water and an increased in surface runoff from the Banas river water catchment regions likely to be the responsible factors. The post-monsoon PCA results showed PC1 (22.459 of variance) is substantially correlated with DO (0.838), COD (0.335), DIP (0.667), TDS (0.822), EC (0.704) and pH (0.353) and these values correspond to lithological inputs and anthropogenic activities. The PC2 result (18.592% of variance) was substantially correlated with pH (0.521) and TDS (-0.038) and these values correspond to geogenic influences. Temperature (0.497), EC (0.504), COD (0.688), Cl^- (-0.751) and BOD (0.735), lead (0.554) were the dominant factors in PC3, which accounts for 13.810% of the variance. PC3 may be related to seasonal impacts, including weathering, erosion and surface inflow from the catchment region of the nearby Banas river.

TABLE-4
PCA LOADING MATRIX (VARIMAX ROTATED) FOR BANAS RIVER WATER DURING PRE- AND POST-MONSOON SEASON

	Pre-monsoon season			Post-monsoon season		
	PCA 1	PCA 2	PCA 3	PCA 1	PCA 2	PCA 3
pH	0.226	-0.48	-0.169	0.353	0.521	-0.49
EC	-0.026	0.272	0.34	0.704	0.504	0.103
Acidity	0.463	0.363	-0.403	-0.544	0.281	0.318
Phosphate	0.641	0.359	0.44	-0.368	0.103	-0.155
Iron	0.483	0.639	-0.059	-0.164	0.41	-0.487
Zinc	0.397	0.188	0.538	0.019	-0.083	0.379
Lead	0.101	0.33	-0.248	-0.131	0.328	0.554
Temp.	0.871	0.062	-0.116	0.639	0.497	-0.3
Silver	0.686	0.099	-0.328	-0.021	0.605	-0.15
TH	0.1	0.189	0.41	0.05	-0.63	-0.335
DIP	0.227	0.137	-0.331	0.667	-0.338	0.16
TDS	0.048	0.273	-0.29	0.822	-0.038	0.158
DIN	0.283	0.009	0.62	-0.481	0.153	-0.541
Chloride	0.332	0.605	-0.012	-0.246	0.751	0.3
DO	0.02	0.591	0.277	0.838	0.277	0.131
COD	-0.21	0.016	0.066	0.335	0.688	0.263
BOD	0.013	0.227	0.244	-0.291	-0.026	0.735

Conclusion

Water samples of Banas river in Rajasthan state (India) were collected from 10 sample points in triplicates during the pre- and post-monsoon seasons in 2021. The water qualities of collected samples were evaluated for 17 physical and chemical parameters. The current study emphasizes the analysis of the physico-chemical properties of Banas river. It was observed that the organic pollutants load in Banas river is in excess. Additionally, the mean organic pollution index (OPI) values in the pre-and post-monsoon (1.76 and 2.47) seasons were beyond the acceptable range. The mining activity and surface runoff caused by the additional water invasion during the monsoon season may be the reasons. Therefore, it may be concluded that during monsoon season, mining activity and other human activities are the major factors resulting in the rise in pollutants in Banas river water. Furthermore, studies evaluating the harmful effects of trace elements in aquatic systems, as well as toxicological studies, are essentially required to measure potential health effects. The Rajsamand city depends heavily on Banas river from an economic perspective; thus, maintaining Banas river water quality is urgent and important. To ensure sustainability, the tourism and mining industries should take the initiative to promote conservation management policies and practices, particularly to reduce the eutrophication level at present sampling sites. The government, NGOs and local municipal authorities, mining management, need to adopt corrective collective efforts so that river water pollution may become less of a problem in the future.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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