Available online at **www.joac.info**

ISSN: 2278-1862

Journal of Applicable Chemistry

2024, 13 (6): 693-704

(International Peer Reviewed Journal)

Assessment of Physico-Chemical Parameters and Seasonal Variation of Sone River Water in Dehri Block of Rohtas District (Bihar)

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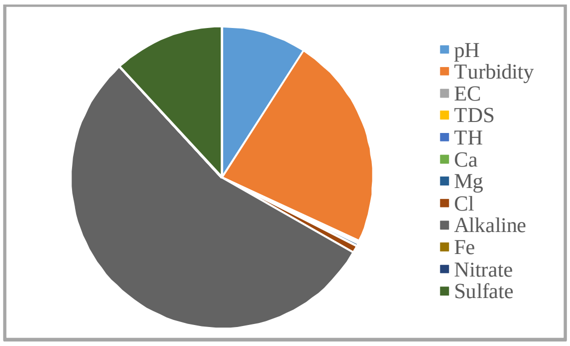
Accepted on 26th October, 2024

ABSTRACT

Sone River is one of the major sources of water nearby Dehri block of Rohtas district in Bihar. It has been used for drinking and irrigation purpose by the people in this area. Sand mining and other human activities lead to deterioration of water quality of the river. In this present study different water physico-chemical characteristics of Sone River water of selected three sites have been studied and compared with the guidelines provided by world health organization (WHO) to understand its suitability for public consumption. Water Quality Index (WQI) has been used for the water quality measurement. For this the WQI has been calculated taking average of all the samples collected from different locations in the pre-monsoon, monsoon and post-monsoon seasons. Concentration of various physico-chemical parameters like pH, Turbidity, TDS, TH, EC, Alkalinity and major cations like Ca^{2+}, Mg^{2+}, Fe^{3+}, and anions like Cl^-, I^-, SO_4^{2-} have been considered for the water quality determination. Most of the parameters were observed within the limit as per WHO guidelines. WQI of the water samples was also found to be 43, which makes it suitable for washing and bathing purposes.

Graphical abstract:



WQI variation with Physico-chemical Parameters.

Keywords: Sone River, WQI, Monsoon season, Water quality, Physico-chemical Parameters.

INTRODUCTION

It has been well known that the rivers have been the origin of the development of ancient civilization [1, 2]. It maintains and supports the river ecology, cultural significance, living species, animals, human beings, and ecosystem biodiversity [3-5]. River water is a vital irrigation resource for agriculture and recharging groundwater in the nearby area. In most of the cities drinking water has been supplied from rivers in large strength since long ago. The Sone River is the tributary of the Ganga River and flows along the states of Chhattisgarh, Madhya Pradesh, Uttar Pradesh, Jharkhand, and Bihar. The river lies between 22° 43' N to 25° 42' N and 82° 03' E to 84° 51' E. It originates from Amarkantak hill located in the Maikal region at an elevation of 1030 meters and comes in the light in the form of a kund at sonbachawar village of Gaurela-Pendra-Marwahi district of Chhatisgarh and after passing 784 kilometers of the various districts of these five states, it merges with Ganga at Haldichapra village of Danapur subdivision of Patna district, Bihar. The river has both left and right tributaries which are Banas, Gopad, Rihand, North Koel, Johila, Ghaghar and Chhoti Mahanadi. Banas joins the Sone River at Sikarganj village and the Gopad River merges in Sone at Bardi Khairapur village located at 24°33' N and 82°23' E. It lies in Chhatisgarh and Madhya Pradesh at 500 kilometers, Uttar Pradesh at 82 kilometers, and Jharkhand & Bihar at 202 kilometers. The total catchment area of the Sone River is 71259 kilometers square. Sone is the major source of water for millions of rural populations. It has been used for procuring fish, fish seeds, fingerings, and for irrigation purposes [6-8].

The uncontrolled population growth, agricultural modernization, unplanned urbanization, and indiscriminate industrialization are the root causes of pollution and degradation of river water [9-12]. The assaulting river water affects the water quality index and physico-chemical character of water which ultimately hazards human health and creates waterborne infectious diseases [13, 14] by disrupting web food. Disposal of untreated municipal sewage, domestic discharge, agricultural run-off hazardous chemicals; pesticides, fertilizers, a large variety of industrial effluents, mining activities, etc are the major causes of river water pollution.

Anthropogenic activities [15-18] such as mining, quarrying, reclamation of water bodies, and deforestation have deteriorated the water quality of the river. Heavy loading of pollutants from various sources has stressed the water flow, and both eco and aquatic system by reducing the surface area and environmental flow. Incidence of large-scale fish mortality has been found due to pollution in the backwater. The serious impact of organic pollution on the hydrography and hydrochemistry [19, 20] of rivers has been reported by a number of researchers [21-23]. Past studies on the environmental impact of river sand mining highlight the presence of high concentrations of suspended sediments and turbidity arising from sub-aqueous sand extraction which affect the respiratory system of fishes and other invertebrate communities [24-26]. The coating of fine sandy materials over leaves adversely affects the photosynthesis of aquatic macrophytes and benthic algae [27].

The present scenario of the Indian River is abnormal and woeful. The smaller rivers at present have turned into toxic drains in most of the reaches with no water flow in summer while the big ones are far from water clarity portability and purity. In the present paper, the physico-chemical quality and water quality index of the 20 water samples of Sone River of locations SI (Makrain), SII (Pali), and SIII (Inderpuri) of Dehri block of Rohtas district of Bihar have been investigated in the light of water quality parameters such as pH, conductivity, alkalinity, hardness, turbidity, TDS, ions like calcium, magnesium, chloride, fluoride, and sulfate, etc. to provide a piece of big information for common people, administrator, and policymakers as a technical supports regarding river water quality objectives.

Study area: Dehri block of Rohtas district (Bihar) has been chosen as the study area for the present study. Rohtas district is situated in the south western part of the state of Bihar with a geographical extent of 24°30′ N to 25°25′ North latitude and 83°45′ to 84° 22′ East longitude. Dehri Block is one of the 19 blocks, placed along the bank of the Sone River in the eastern part of the district. According to the District Census Handbook 2011, the total population of Dehri block is 275014, living in 140.77 Sq. Km area. Dehri block is a densely populated area with a population density of 1954 persons per Sq. Km. It is a moderately literate block of Rohtas district with 77.7 % total literacy. Figure 1 represents Makrain, Pali and Inderpuri are three sampling sites for collecting river water samples. Makrain lies between 24°55′ North Latitude and 84°12′ East Longitude, whereas Pali is situated between 24°54′ North Latitude and 84°11′ East Longitude and Inderpuri is located at 24°50′ North Latitude and 84°08′ East Longitude.

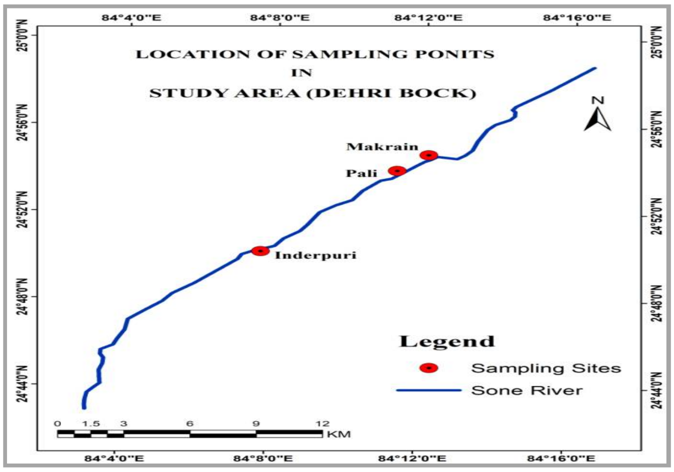


Figure 1. Location map of water quality monitoring sites

MATERIALS AND METHODS

For the study of the physico-chemical parameters of the Sone River water samples were taken from the different sites of the Dehri block of Rohtas in Bihar. The three sampling stations selected for the investigation were Makrine, Pali, and Inderpuri, named S I, S II, and S III respectively. A total of 20 samples including 500 m up streams and down streams of all the three sites were collected in pre-monsoon, monsoon, and post-monsoon seasons in the year 2023-2024. The samples were collected in a clean plastic 1 L bottle and properly labeled with the code, date, time, and name of the collector. The bottle was thoroughly cleaned with deionized water three to four times. After the collection, the pH, turbidity, and conductivity were measured using a portable pH meter (Consort C831), Nephelometer, and conductivity meter (Co11 Eutech model no. ECBO11001K) respectively. The standard titration method (APHA 2005) was used for the alkalinity analysis. Ca^{2+} and Mg^{2+} concentration was determined using titration. The analysis of other major ions was done using an Atomic Absorption Spectrophotometer (Varian 680FS) in flame mode after calibrating the instrument with known standards.

WQI method for water quality analysis: The water quality estimation in a single value [**28, 29**] can be done using the water quality index method. It is a very essential parameter that can be used as an effective informative tool for the measurement of water quality and thus is very instructional for getting water state in the river [**30-33**]. It simplifies the large numbers of water parameters into a unit which can be then rated in excellent, good, bad, etc terms (Table 1). In the present study, 12 water variable parameters were considered for calculating the WQI (Table 2). Standard values as provided by the World Health Organization (WHO) and USEPA of all the parameters were used for the estimation of WQI.

WQI can be calculated in the following three steps

(a). Unit weight calculation (Wi): Unit weight (Wi) of the nth parameter is inversely proportional to the standard value recommended by WHO and calculated as

$$Wi = \frac{K}{Sn}$$

Where Sn is the standard value of every parameter as provided by WHO and K is the constant which can be determined as

$$K = \frac{1}{\sum [\frac{1}{Sn}]}$$

$$Wi' = \frac{Wi}{\sum Wi}$$

(b). Quality rating index (Qi): Water quality rating index is the calculation of the relative value of the nth parameter of water using standard value provided by recommended agencies. It can be calculated by the following equation:

$$Qi = \frac{100\ (Vn - Vi)}{(Sn - Vi)}$$

Where, Vn is the observed value of nth parameters and Vi is the ideal value of pure water sample which is 0 for all the parameters except pH (7) and DO (14.6).

(c). Calculation of WQI: WQI is computed adopting the following formula [34-36]

$$WQI = Wi'\ Qi$$

Table 1. Water Quality Index scale

WQI	Water Quality Status
< 25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for consumption

Table 2. Water quality parameters recommended by WHO and USEPA

Parameters	Standard Value (Sn)	Observed Value (AV)	Wi	$Wi' = \frac{Wi}{\sum Wi}$	Qi	WQI= Wi'Qi
pH	6.5	7.6	0.7316	0.0323	120	3.86
Turbidity (NTU)	5	11.56	0.9512	0.0419	231.2	9.687
E. C (µs cm^{-1})	300	202.3	0.0158	0.0007	67.43	0.047
TDS (mg L^{-1})	1000	131.6	0.004	0.0002	13.16	0.0026
TH (mg L^{-1})	500	92.8	0.0095	0.0004	18.56	0.0074
Ca^{++} (mg L^{-1})	100	30.4	0.047	0.0021	30.4	0.0638
Mg^{++} (mg L^{-1})	50	14.98	0.095	0.0042	29.96	0.1258
Cl^- (mg L^{-1})	250	39.33	0.019	0.0008	15.4	0.0123
Alkaline (mg L^{-1})	100	158	0.047	0.0021	158	0.3318
Fe (mg L^{-1})	0.3	0.1	15.85	0.6998	33.33	23.32
NO_3^- (mg L^{-1})	45	0	0.10	0.0044	0	0
SO_4^{--} (mg L^{-1})	250	13.33	0.019	0.0008	5.332	0.0043
F^- (mg L^{-1})	1	0.24	4.756	0.2100	24	5.04
			$\sum Wi = 2.65$			Approx 43

RESULTS AND DISCUSSION

pH: pH determination is one of the necessary water quality parameters which affect the relevancy of water in various uses. The pH of the water samples S-I, S-II and S-III which were collected in pre-monsoon was found to be in the range of 7.9 to 8.15 (figure 2). A slight rise in pH value was observed during monsoon season from 8.02 to 8.47 for all the samples. In the post-monsoon it was found to be in range of 7.31 to 8.1. So, on the basis of these results the alkaline nature of water was found to be obvious. Highest pH value was observed in the monsoon period for the S-III.

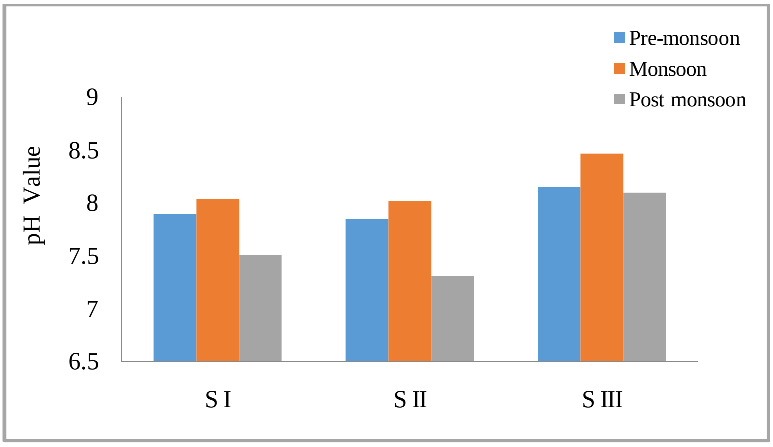


Figure 2. Variation of pH with sample sites.

Turbidity: It is the extent of precipitation or muddiness present in the water sample. The optical characteristic that allows light to be absorbed and scattered by the water sample is being measured by turbidity. Here the turbidity concentration was measured to be 20.8, 91.8 and 11.33 for S-I in pre-monsoon, monsoon and post-monsoon season respectively (figure 3). Similarly for S-II 7.4, 245 and 7.43 for the three seasons respectively. Lastly, S-III data was found to be 6.5, 530, and 8.84 in pre-monsoon, monsoon and post-monsoon season respectively. It was clearly observed that the highest turbidity was of S-III in monsoon season. The higher value in monsoon season is expected due to increase in the water level of the Sone River. The overall turbidity level was found to be higher in all the seasons than the permissible limit i.e, 1 NTU.

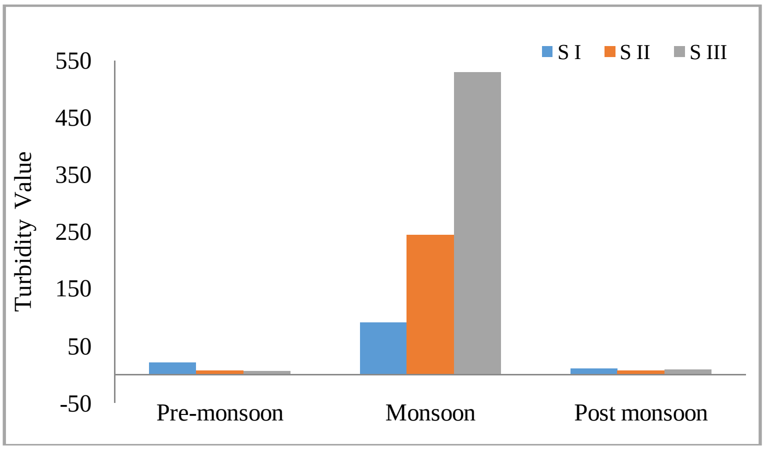


Figure 3. Variation of Turbidity with sample sites.

Electrical Conductivity (EC): The number of cations and anions in water increases the conductivity of water. EC determines the potentiality of solution to conduct current in response to the ion particles present in the water. The EC value was found to be in the range of 180-546, which was higher than the WHO guidelines. As shown in figure 4, the highest EC value was obtained during post-monsoon for all the three sites with average value of 265.3 µS/cm. Higher EC value in post-monsoon was due to presence of high mineral content and concentrated ions in the water body at all the study sites.

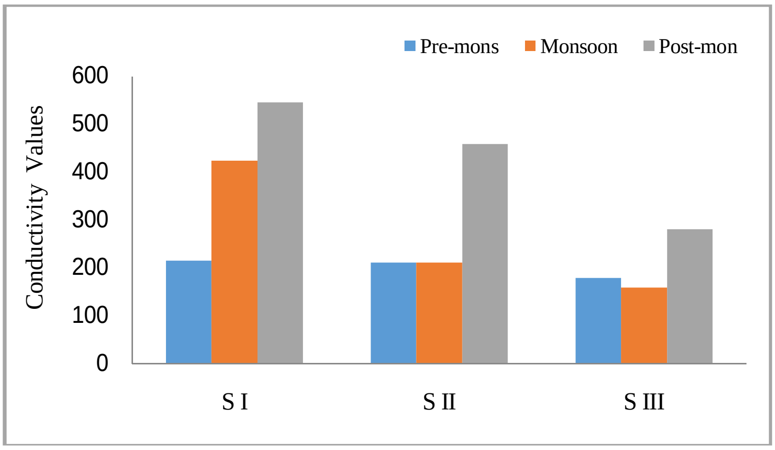


Figure 4. Variation of EC with the sample sites.

Total Dissolve Solids (TDS): It contributes to any type of ionizable inorganic salts or minerals present in water bodies. It is responsible for the hardness, corrosion properties, and taste of the water. High TDS value makes water unfit for drinking. Figure 5 shows that the TDS value for the sample sites was found to be in the range of 104 to 354 with a maximum value of site S-I in post-monsoon and a minimum value of site S-III in the monsoon season. World Health Organization tabulated the TDS value in different categories for its uses, like TDS level below 300 mgL^{-1} to be excellent, 300–600 mgL^{-1} is good, 600–900 is fair, 900–1200 is poor, and above 1200 mgL^{-1} is not acceptable for drinking purposes. So according to this, our water samples were found to be in a good category.

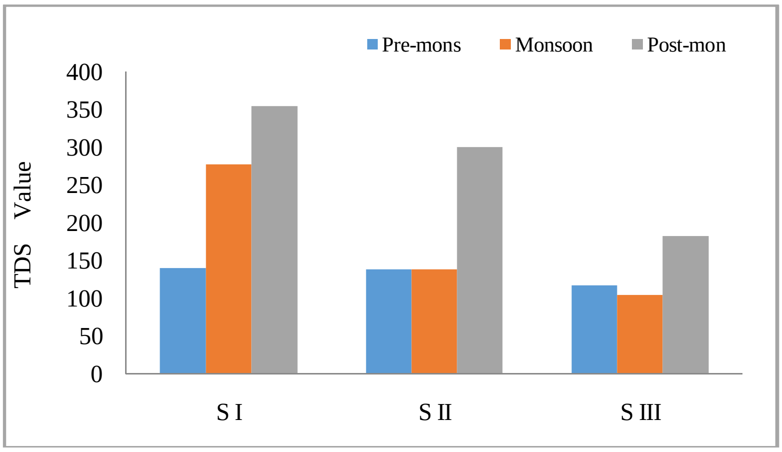


Figure 5. Variation of TDS with the sample sites.

Total Hardness (TH): Several cations and anions like Ca, Mg, Sr, Mn, Al, CO_3^{2-}, HCO_3^{2-}, Cl^- S^{2-}, sulfates, nitrates, and silicates are responsible for the hardness of water, making it unsuitable for drinking and washing purposes. Two types of water hardness known are temporary hardness and permanent hardness. Temporary hardness is one which is due to Ca and Mg bicarbonates and permanent hardness is due to chloride and sulfate salts of the same element. Figure 6 represents the total hardness analysis for all three sites in different seasons and was found to be highest in post-monsoon in the range of 66-214 mgL^{-1} whereas, the average TDS value in the pre-monsoon season was found to be 131.6 for all the sites which was minimum in comparison to other monsoon period.

According to WHO standards, it was found to be less than the permissible limit of 500 mgL^{-1} in all seasons.

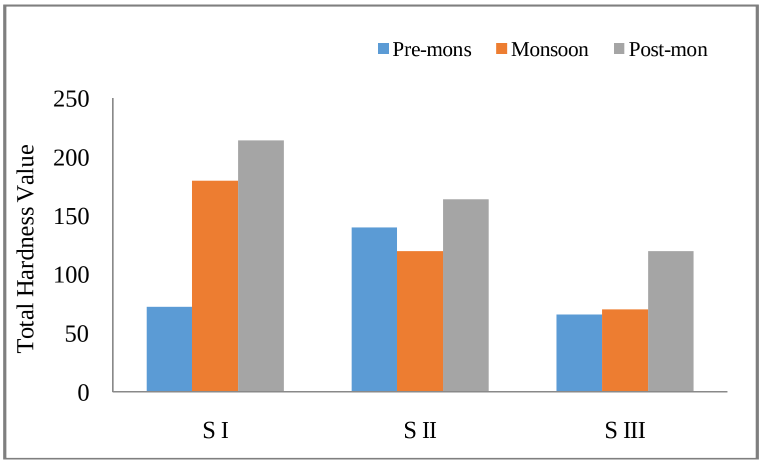


Figure 6. Variation of Total Hardness with sample sites.

Calcium: Although calcium is considered an important constituent of the human body excess of calcium causes diseases like arthritis, stones, hypertension, etc. Here in the present studies, the Ca value was found within the desirable limit i.e. 100 mgL^{-1}. Figure 7 shows that the maximum concentration of Ca^{2+} was in the post-monsoon season i.e. in the range of 45-60 for all three sites and minimum in the pre-monsoon for S-I i.e. 17.6.

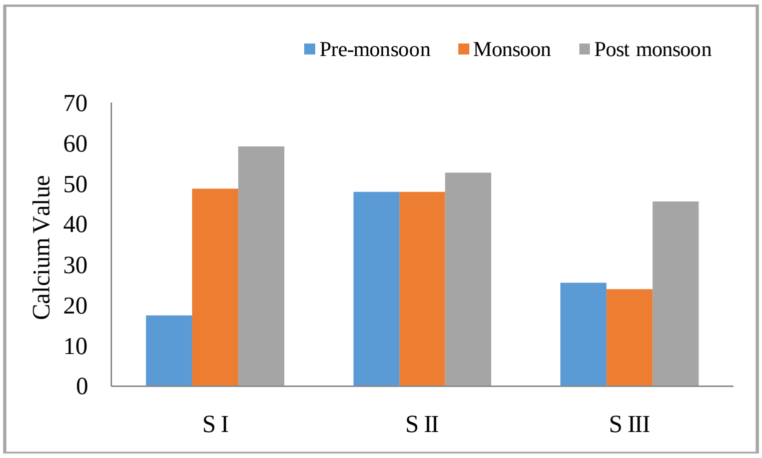


Figure 7. Variation of Calcium with the sample sites.

Magnesium: Excess magnesium is responsible for the alkalinity of the soil. The river water which is used for irrigation purposes should be within the limit of 50 mgL^{-1}. In the present study Mg variation for our water sample was measured in all three seasons for various sites. As depicted in figure 8, the highest value of Mg was 37.15 for the S-I site in post-monsoon whereas, the minimum concentration was 9.7 for site S-III in the pre-monsoon. The Mg concentration in all three sites was found to be within the permissible limit of 50 mgL^{-1}. Thus, they are suitable for agricultural uses.

Chlorine and Fluorine: Samples were collected from all three sites in all three seasons. The chlorine value was found to be highest for site S-II in post-monsoon season i.e., 103 whereas minimal for site S-III in monsoon period (figure 9). However, the concentration of chlorine was found within the permissible limit according to the WHO which is 250 mgL^{-1}. As shown in figure 10, the fluorine concentration for the three sites was also within the permissible range of 1.0 mgL^{-1}. The values of fluorine range from 0.1 to 0.27 mgL^{-1}.

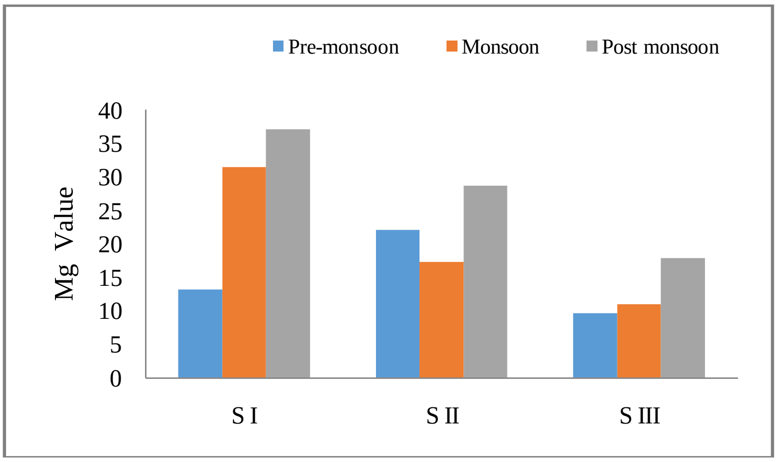


Figure 8. Variation of magnesium with the sample sites.

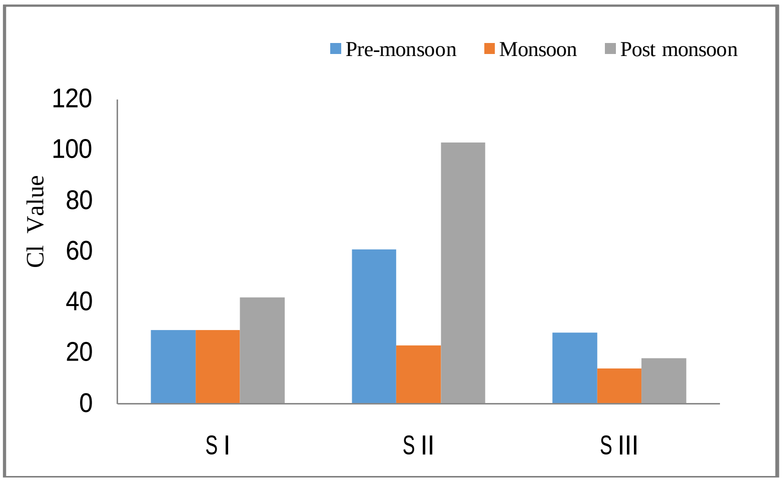


Figure 9. Variation of chlorine with sample sites.

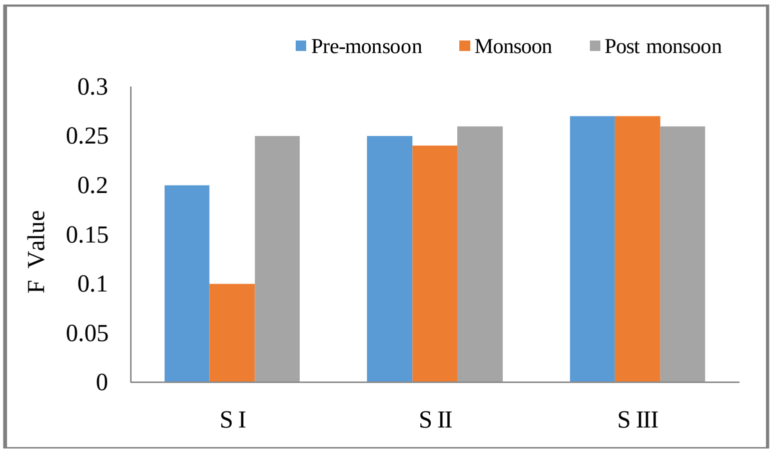


Figure 10. Variation of Fluorine with the sample sites.

Iron: The reddish-brown appearance of water is the indication of high concentration of water. It mostly occurs in handpump or ground water. The iron concentration for the samples collected from all the sites in the three seasons was found to be constant i.e., 0.1 mgL^{-1} (figure 11).

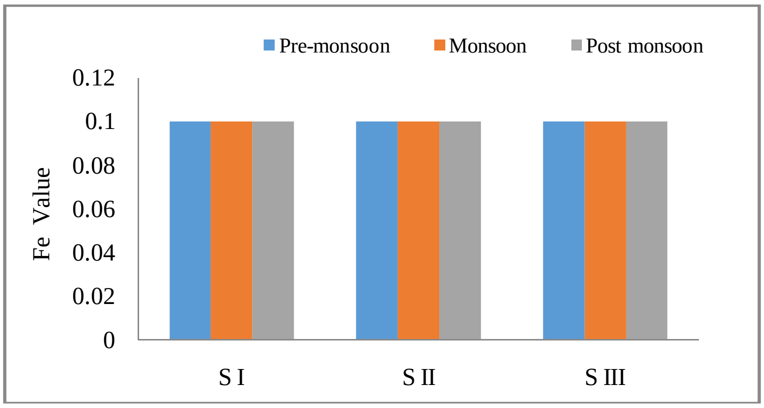


Figure 11. Variation of Iron with the sample sites.

Sulphate ion: Figure 12 shows the sulphate ion concentration for the S I site in the pre-monsoon was found to be zero, whereas, the highest sulphate ion concentration was found for the site S III in pre-monsoon which was 20 mgL^{-1}. However, the sulphate ion concentration was within the range determined by WHO i.e., 200 mgL^{-1}. High concentration of sulphate causes foul taste of water.

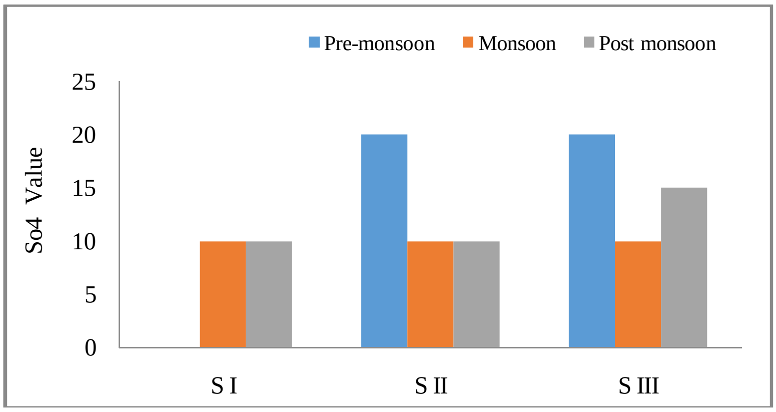


Figure 12. Variation of sulphate ion with the sample sites.

Alkalinity: Alkalinity of water is due to presence of carbonates, bicarbonates, hydroxide ions and salt of weak acid and strong base. The average value of alkalinity was found to be 158, 146.6 and 105.4 in the pre-monsoon, monsoon and post-monsoon seasons respectively for all the three sample sites which was beyond the permissible limit of 100 mgL^{-1}. Figure 13 shows that the maximum alkalinity was found in the pre-monsoon season for the site S II.

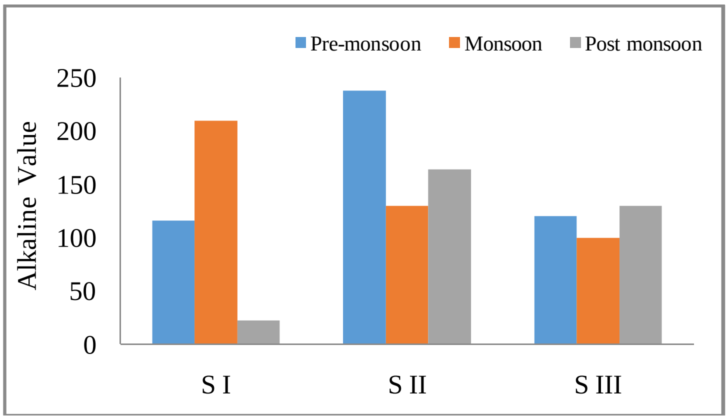


Figure 13. Variation of alkalinity with sample sites.

Water Quality Index: WQI of the Dehri district in all three seasons were calculated and found to be 43 which according to table 1 was found to be less polluted and suitable for the other purposes than drinking.

APPLICATION

The present piece of work has applicability in the use of water for the various purposes like drinking, bathing, washing, irrigation, etc depending on the quality of water and pollution in that area. Here WQI has been used a criterion to assess the quality of Sone River water. It is an important phenomenon for the perception of water quality issues by combining the complex data and generating a score, which mark out the water quality status.

CONCLUSION

The present study has been done to evaluate the physico-chemical parameters of Makrain, Pali and Inderpuri regions in Dehri Block of the Bihar and estimate the water quality by calculating the WQI. The river water from different sites of the Dehri block were examined and it was found that all the parameters like pH, turbidity, EC, TDS, TH, Calcium, Mg, Cl^-, F^-, Fe, SO_4^{2-} and alkalinity in all the seasons were in the permissible limit as described by WHO.

The pH value was found to be slight high in monsoon period. Overall, the river water was fond to be alkaline in nature. Turbidity was high in the monsoon season with site III having the greatest value. The reason behind it could be the anthropogenic activities taking place around. EC, TDS and TH were found to be at high level in post-monsoon season, may be due to more concentrated water in the river. Concentration of Calcium and Mg were also higher in post-monsoon and lowest in pre-monsoon season. The Fe concentration was same for all the seasons at all the three sites.

The WQI value was calculated and found to be approx 43 which rate it in the less pollutant category according to WQI.

ACKNOWLEDGMENT

The author expresses thanks to the Department of chemistry, V. K. S. University for providing laboratory facility.

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