Assessment of Water Quality Status of Son River near Sidhi district (Madhya Pradesh) using Water Quality Index

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***Abstract*: The Son River of Sidhi district, Madhya Pradesh (MP), Central India, plays a vital role in cultivating a monetary and ordinary relationship with the people. Since it gives satisfactory rich fields and advancement inclines water framework practices and fulfills individuals' step-by-step needs. It is essential for the people of Sidhi and Madhya Pradesh because of the rich regular asset. The water quality index (WQI) tool is used to determine the quality of river Son by selecting four sampling stations. Maximum WQI value gained during the post-monsoon season in all of the stations followed by monsoon and pre-monsoon. Sampling stations upstream of the river experience deteriorating WQI due to the presence of the hydroelectric dam, changing landuse practices, increasing settlements and deforestation in the catchment and river banks. WQI showed good water quality, which can be used for drinking, irrigation and other purposes. The assessment found that pH, DO, and BOD contributes a huge part in affecting the WQI of the stream. Our study found that the condition of water quality necessities to accept suitable organization procedures and assurance attempts. It is inferred that WQI was demonstrated as an instrument or device in differentiating the water quality of different sources. It gives the public a general considered potential water-related issues in a particular area. This tool is very useful for calculating water quality status, which are particularly significant to general society or policymakers and water quality organizations to amass relevant information.**

***Keywords*: Son River, Water Quality Index (WQI), Permissible limit, Seasonal values**

Introduction

Rivers are an essential source of water required for the survival of all living species. But nowadays, it is adversely affected and polluted by both point and nonpoint sources. [1]**.** Anthropogenic influences, as well as natural processes, are the causes that degrade surface water. Due to rapid urbanization, water quality severely deteriorated, which is not suitable for drinking, industrial, agricultural, recreation, or other purposes in many parts of the world.[2]. Son is an essential river in M.P., it originates from the hills of Amarkantak, cuts through the Kaimur Range, and finally merges with the Ganges River near Patna in Bihar, after completing a 487-mile (784-km) course [3] . The water quality record is quite possibly the best devices to screen surface and groundwater contamination. The tool is a numeric calculation that is utilized to determine the changeover gigantic measures of water portrayal information into a solitary worth that addresses the momentum level of water quality [4]. Water quality assessment is helpful to distinguish the wellsprings of water contamination and foster a system for supportable water sources for advancing human wellbeing and other social and monetary growth [5]. Water Quality Monitoring information comprises routine estimations of physical, substance, and natural factors and allows surveying changes in water quality and its patterns. Different WQI uses for sample water are US National Sanitation Foundation Water Quality Index, NSFWQI, Canadian Water Quality list, British Columbia Water Quality Index, BCWQI, and Oregon Water Quality Index OWQI the Florida Stream Water Quality Index, FWQI [6]. Madhya Pradesh has many seasonal and perennial rivers. Narmada and Tapti are two main rivers that complete their course, move toward the West, and fall into the Arabian sea. The Son River goes through the core of Sidhi, hitting every one of the three territories that encompass the whole locale. The waterway has a critical monetary and conventional effect because of its rich fields and reasonable farming slants. Nonetheless, developing turn of events, deforestation, and moving cultivating along the waterway have placed coastal environments in hazard like they've never been. Accordingly, it is presently basic to protecting vegetation along streams and in other helpless submits in request to guarantee environment esteem and keep up with great water quality. To decide physicochemical boundaries, the occasional difference in Son River was thought about. To far, nonetheless, no examination has been led on the water quality evaluation of the Son River using the water quality index. Thus, the water quality index would give us sensible consequences of the Son stream's water quality status at different sampling stations chose at different seasons in the study. The motivation behind applying WQI in this examination is to decide how much urbanization, deforestation, and other human exercises along a stretch of the Son River might decay water quality. This exploration would give us a total image of the Son River's water quality. Future administration and activity intend to shield the climate from the impacts of different land-use rehearses and support water quality improvement.

Study Area

Madhya Pradesh, India's central-most state, has a total geographical area of 308252 km^2 and its boundary touches five states. Its latitude ranges from 21°2′ N to 26°87′ N and its longitude is from 74°59′ E–82°06′ E. The average rainfall of Madhya Pradesh is 75 cm, and the annual rainfall is 125 cm. The period of monsoon seasons is 4 months, i.e., from June to September, from which June, July, and August experiencing more than average rainfall. Son River, also spelled Sone, is one of the vital rivers in Madhya Pradesh, the southern tributary of the river Ganges. The river covers the Kaimur Range and joins the Ganges above Patna Bihar, after covering a 487-mile (784-km) course. It flows in the northwest direction and finally joins the Holy Ganga River near Patna by

passing through a significant part of the Sidhi district of Madhya Pradesh. Johila and Rihand are the main tributaries of the Son River. This study covers 40–60 km of Son River under Sidhi district, Madhya Pradesh. The hydroelectric station, i.e., the Bansagar project, is located in this river at 24.1917° N Latitude and 81.2875° E Longitude. There are many other land uses practices around the catchment area of the Son. The land use and land pattern map of the present Son basin area is given in figure 1. The characteristics of sampling stations and their coordinates along the Son river is shown below in Table 1.

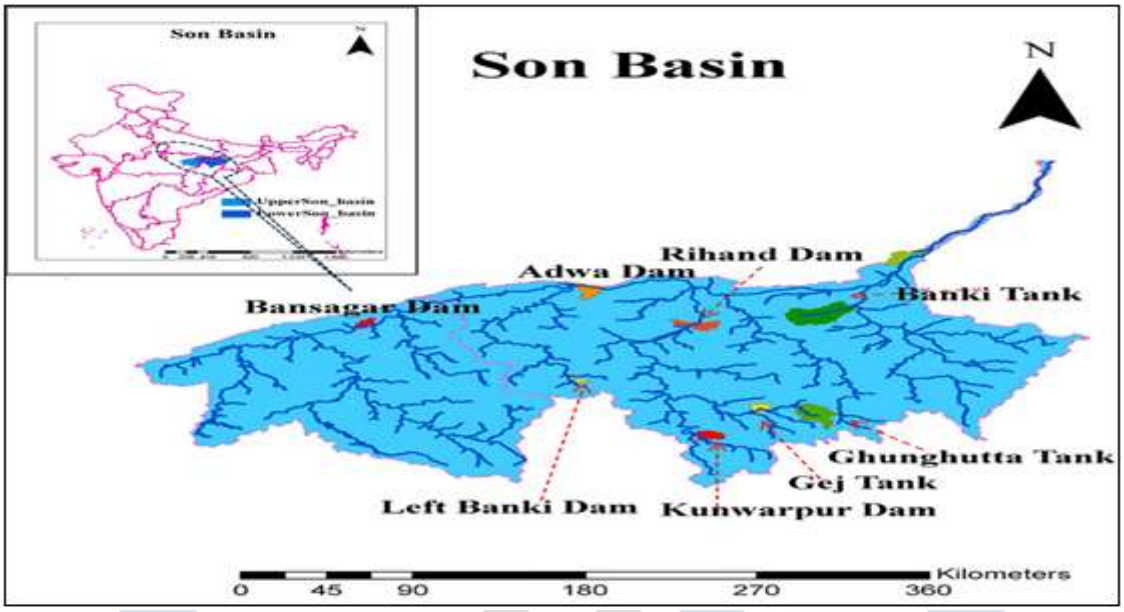


Figure 1- Map showing the land use/landcover (LULC) of the Son basin area.

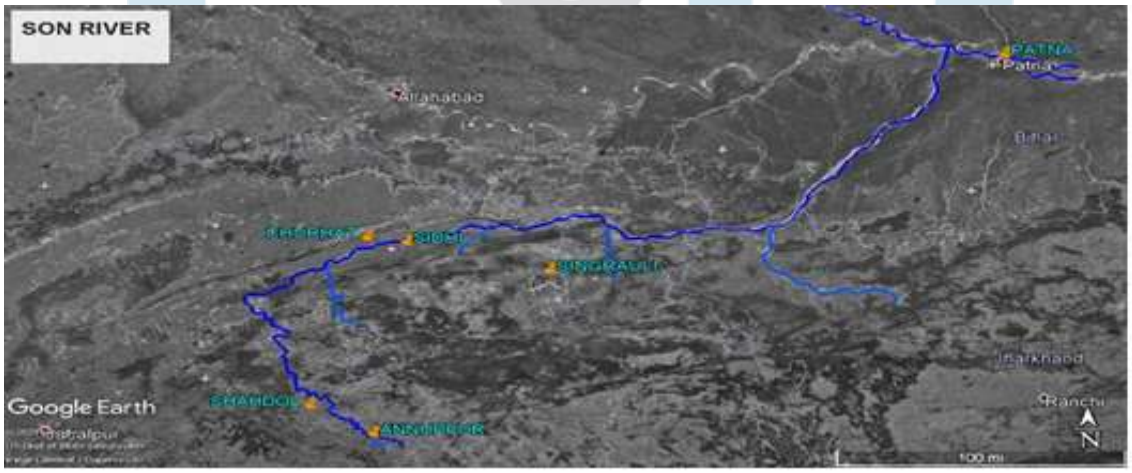


Figure 2- Map showing the Son River course using Google Earth

Table 1- The characteristics features of the selected sampling stations, their coordinates, along with the Son River.

Sampling sites	Station Code	Characteristics	Coordinates
Station 1	S1	River son at Bansagar hydroelectric multipurpose dam	24.1917° N 81.2875°E
Station2	S2	The forested area including residential families of village and highway bridge near Churhat	24.4197°N 81.6747° E
Station3	S3	River son at Bhavarsen near Rampur	24.3423° N 81.4760° E
Station 4	S4	River son at Jogdaha breeding center for Son Gariyal	24.60° N 82.77°E

Figure 3- Map showing the sampling stations of Son River using QGIS

Materials and Methods

Surface water tests were gathered from the four sampling stations close to the catchment of the Son. Analysis was accomplished for 1 year, i.e., 2019. Concerning this current investigation, occasional variety was thought of. Hence, for data calculation, months were arranged into three remarkable seasons: pre-monsoon, Monsoon, and post-monsoon. The current assessment district's land use/land cover (LULC) picked along the stream catchment was displayed on a map. Tests were collected from the depth of 20 cm of the water fragment utilizing a base weighted polyethylene bottle. The bottle was washed in the laboratory with lapoline, a 10% HCl, and then water sample was collected from the field. pH, electrical conductivity (EC), Total dissolved solids (TDS), total alkalinity (TA), total hardness (TH), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^{-}), nitrate (NO_3^{-}), sulfate (SO_4^{2-}), dissolved oxygen (DO). Biological oxygen demand (BOD) was picked for this assessment. A pen-type modernized pH and TDS meter was used to measure pH and TDS on the field. A modernized conductivity meter was used to evaluate conductivity in the laboratory. Total alkalinity, total hardness, calcium, magnesium, and chloride were thoroughly assessed using titration methods. Dissolved oxygen was assessed in the lab. In any case, a few additives must be applied on the field before the sample was taken to the lab, and the examination was finished utilizing Winkler's methods. For BOD computation of water tests, separate water tests were gathered from the destinations, put the sample at 20 °C for 5 days, and analyze for BOD after 5 days. The UV–Spectrophotometer is utilized for the investigation of nitrate and sulfate. Each parameter is analyzed in the laboratory by using the standard method given by APHA 1992 [7]. At long last, the WQI was determined by using the Weighted Arithmetic Index strategy created by BIS 2005 [8], which is given in the accompanying condition:

$$WQI = \frac{\sum QiWi}{\sum Wi}$$

The quality rating scale (Qi) for each parameter was calculated by using the expression:

$$Qi = 100 * (\frac{Vi - Vo}{Si - Vo})$$

Where,

Vi=concentration of the ith parameter in the water sample analyzed.

Vo=ideal value of parameter in pure water, i.e., Vo=0 (except pH 7.0 and DO = 14.6 mg/l)

Si = recommended standard value of the ith parameter.

The unit weight (Wi) for each water quality parameter is calculated by using the following formula:

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

Where K=proportionality constant calculated by using the equation,

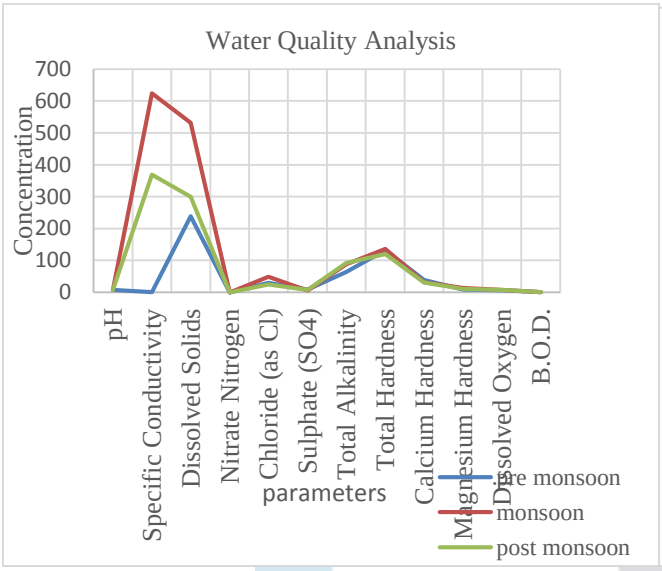
$$K = \frac{1}{\sum \frac{1}{Si}}$$

Result and Discussion

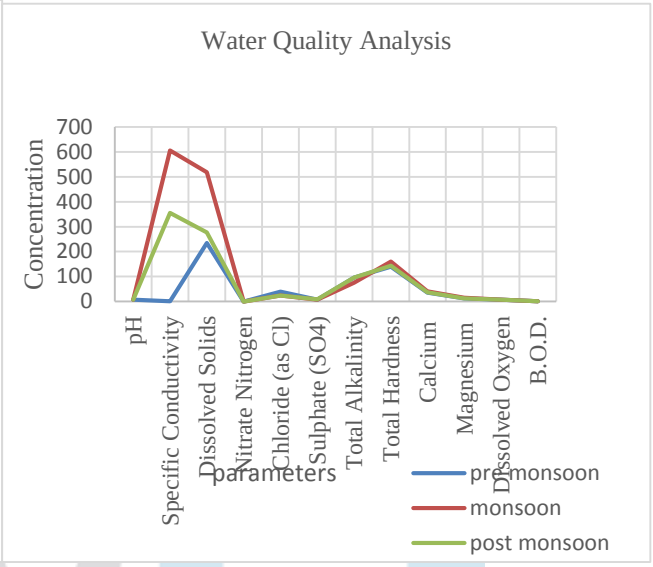
The tables underneath depicted water quality range valid for all the sampling stations in three unique seasons. pH is a significant marker of water quality which estimates the acridity or basicity of water and decides if the water is appropriate for different purposes or not. By doing investigations of water tests, it is recorded that pH is neutral or alkaline in nature. The mean pH upsides of all the inspecting stations during Pre-Monsoon, Monsoon, and Post Monsoon were 7.430, 7.637, and 7.737, respectively. In normal water, the standard pH value is between 6 to 8, and in our analysis, it came under this range. It falls in this classification. Electrical conductivity (EC) was utilized to measure salinity of water sample. When these salts are available in an extreme amount, it will fundamentally influence the taste and acknowledgment of the water as consumable to the clients. The average value of EC of the Son river was 144.1603 µS/cm during Pre-Monsoon, 529.75 µS/cm during the Monsoon, and 329.5 µS/cm in the Post Monsoon.

Table 2: - Water Quality Index (WQI) range, status, and possible water usage. [9]

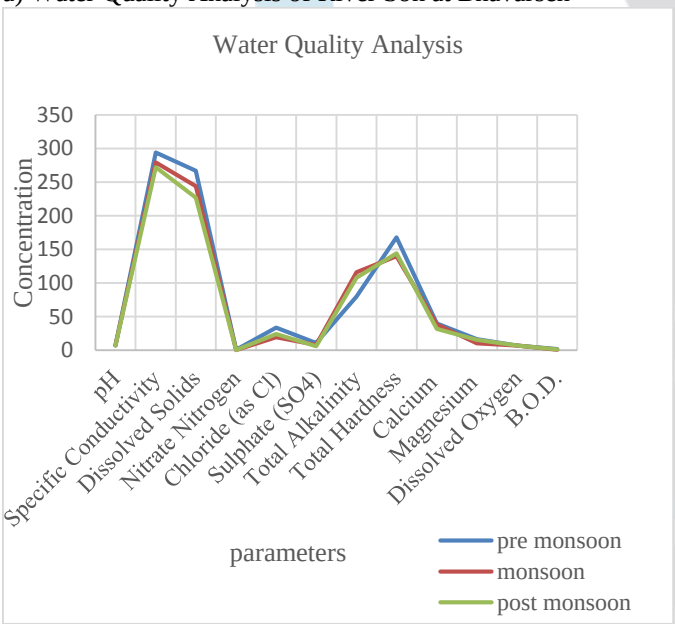
WQI Range	Water quality status	Uses
0-25	Excellent	Drinking, Irrigation and Industrial purpose
26-50	Good	Drinking, Irrigation and Industrial purpose
51-75	Poor	Irrigation and Industrial purpose
76-100	Inferior	Irrigation purpose
Above 100	unsuitable	Proper treatment is required before any usage.



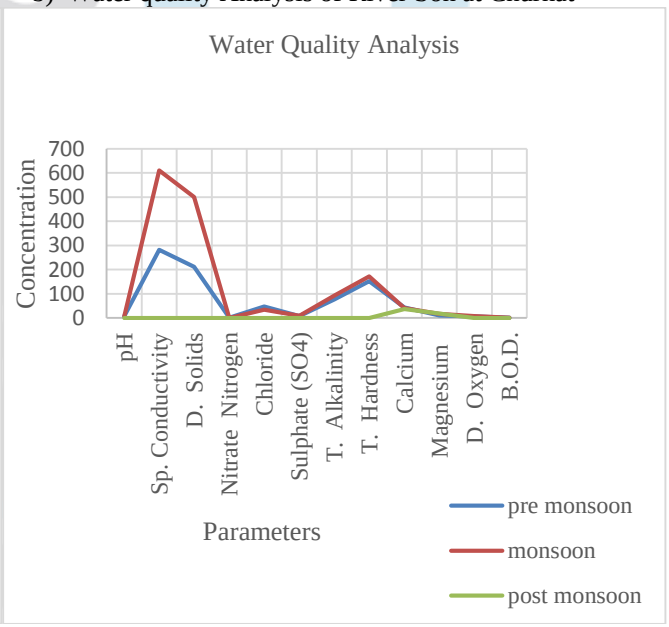
a) Water Quality Analysis of River Son at Bhavarsen



b) Water quality Analysis of River Son at Churhat

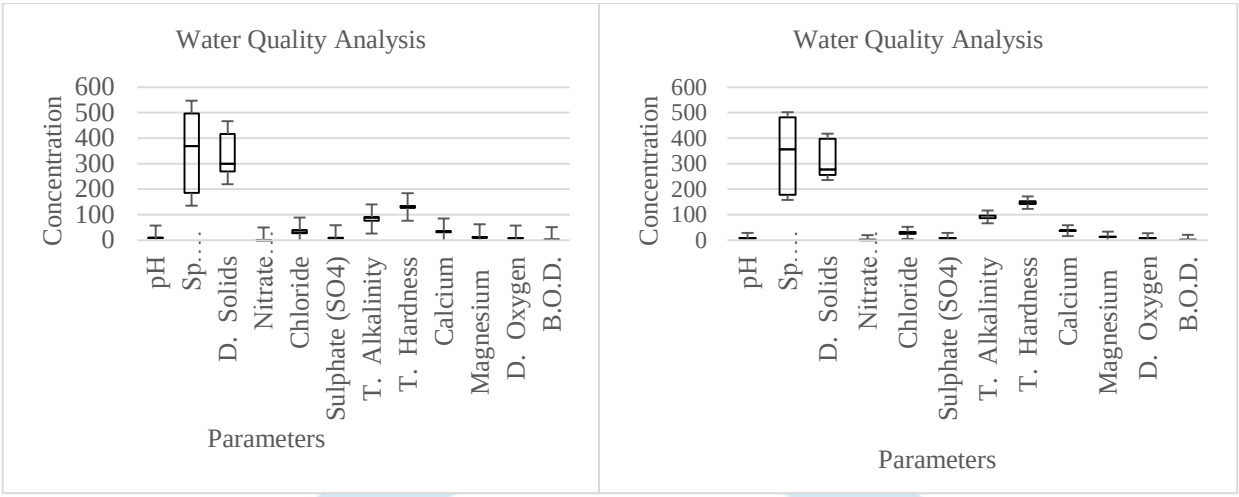


c) Water Quality Analysis of River Son at Jogdaha



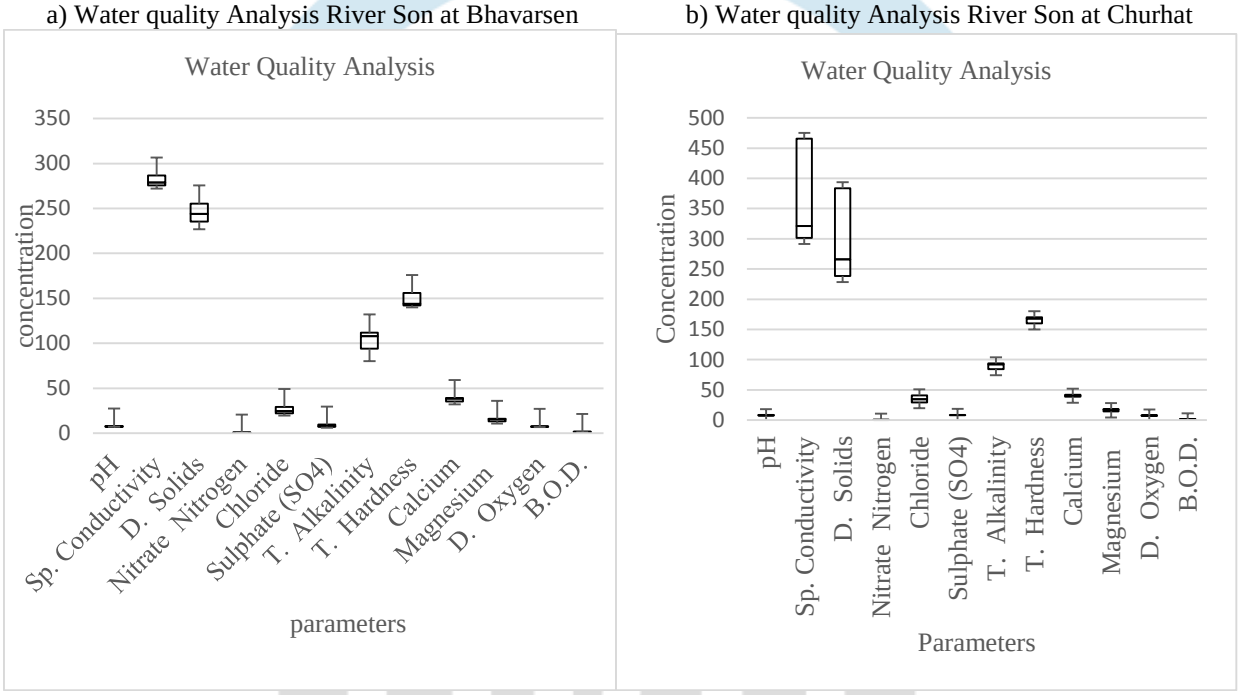
d) Water quality Analysis of River Son at Khairpur

Figure 4: - Plots for Water quality analysis of different sample sites.



a) Water quality Analysis River Son at Bhavarsen

b) Water quality Analysis River Son at Churhat



c) Water quality Analysis River Son at Jogdaha

d) Water quality Analysis River Son at Khairpur

Figure 5: - Boxplots for water quality analysis for different Sample sites.

Table 3: - Statistical analysis of all four Sampling Sites

Characteristic	Unit	Pre-Monsoon		Monsoon		Post Monsoon	
		Mean	std. deviation	Mean	std. deviation	Mean	std. deviation
pH	pH Unit	7.43	0.144	7.6375	0.115	7.7375	0.307
Specific Conductivity	µs/cm	144.1603	166.16	529.75	167.34	329.5	43.36
Dissolved Solids	mg/1	238.0	22.94	448.75	137.08	267.5	30.49
Nitrate Nitrogen	mg/1	0.4	0.338	0.159	0.229	0.11675	0.147
Chloride	mg/1	37.4825	7.782	31.795	12.945	24.46	0
Sulphate (SO_4)	mg/1	8.875	1.547	7.5	1.290	7.5	1
T. Alkalinity	mg/1	79.0	13.216	93.0	16.772	98.0	6.928
T. Hardness	mg/1	148.0	15.663	152.0	16.97	144.0	19.595
Calcium	mg/1	39.275	3.335	37.675	3.817	34.065	3.304
Magnesium	mg/1	12.145	3.320	14.09	2.804	14.2125	3.487
D. Oxygen	mg/1	6.75	0.435	7.225	0.095	7.425	0.275
B.O.D.	mg/1	1.175	0.419	1	0.141	1	0.216

From the calculation to find physiochemical effects in water quality, all parameters have a significant role in water quality. Total dissolved solids are calculated to determine the dissolved particle present in the water and indicate the nature of water quality or salinity. During Pre-monsoon, TDS was 238.0mg/l. In the monsoon season, the maximum mean value observed was 448.75 mg/l and for post-monsoon observed mean value was 267.5 mg/l. All the values come under the desirable limit of 500 mg/l, given by the Bureau of Indian Standards. (BIS, 2005). The mean of total alkalinity in post-monsoon was 98.0 mg/l which is highest from monsoon and pre-monsoon. The minimum average value of total alkalinity was observed in pre-monsoon with a value of 79.0 mg/l. However, there was an increase in total alkalinity in the monsoon, with a mean value of 93.0 mg/l. Total hardness is referred to as the concentration of multivalent cations in the solution. It is mainly divided into two parts carbonate hardness and non-carbonate hardness. The primary source of hardness in water is surrounding rocks disintegration. The maximum mean value during analysis for calcium was 39.275 mg/l in pre-monsoon. The increase in calcium hardness of water is domestic waste, low water level, and increase in temperature. Due to the decomposition of the river bedrock, magnesium occurs in natural water. The mean value for magnesium hardness obtained during analysis was 12.145 mg/l,14.09 mg/l, and 14.21 mg/l for pre-monsoon, monsoon, and post-monsoon, respectively. The study made it clear that total hardened concentration didn't show much variation in all the seasons. The mean value for total hardness was 148 mg/l,152 mg/l, and 144 mg/l for pre-monsoon, monsoon, and post-monsoon. According to obtained value, water quality falls under the hard water category. Chloride in water comes from inorganic fertilizer from agricultural fields, sewage discharge, etc.

The highest concentration was recorded during the pre-monsoon with a mean value of 37.48 mg/land least average concentration was 24.46 mg/l during post-monsoon. Due to sewage waste, agricultural waste by using fertilizer, etc., are significant sources of nitrate in natural water. Excess nitrate can cause eutrophication, death of aquatic animals, affects infants, and severe health hazards. The highest average concentration of nitrate was found at 0.4 mg/l during pre-monsoon. Due to weathering of igneous and sedimentary rocks, sulfate occurs in natural water. Leachate from abandoned mines, air deposition from the combustion of fossil fuels, and industrial wastewater are the other sources of sulfate in natural water. The average sulfate value in the water sample during pre-monsoon was 8.875 mg/l in pre-monsoon, 7.5 mg/l in monsoon, and 7.5 mg/l in post-monsoon. But all values come within the acceptable limit of 150 mg/l. Dissolved oxygen is the measurement of oxygen dissolved in water, and its levels are required to check water quality and stream pollution. If oxygen is present in water, then it means the organic matter is absent. Organic matter consumes oxygen during the process of decomposition. Dissolve oxygen is an indicator of water quality. It should be less than 4 mg/l for good quality water. But for river son, DO concentration is higher with an average value of 7.425 mg/l. The concentration of DO increases due to the rugged nature of the water bodies, photosynthesis, and a decrease in temperature. Biological oxygen demand is the amount of oxygen required to decompose biodegradable organic matter in the system. It is used to determine the strength of oxygen to stabilize domestic and industrial waste. If the BOD level is higher, then it has high organic pollutants present in the sample. The observed value for BOD of son water sample was 1.175 mg/l, 1 mg/l, and I mg/l for pre-monsoon, monsoon, post-monsoon, respectively. The low level of BOD in this study indicates less organic matter present in the water sample. All the twelve physicochemical parameters of water analyzed were within the permissible drinking water limit given by APHA. [10].

Table 4: - Parameters ICMR/BIS standards unit weight (*Wi*)

Parameters	ICMR / BIS Standards	Unit Weight
pH	6.5-8.5	0.192
EC	300	0.005
TDS	500	0.014
Total Hardness	300	0.022
Total Alkalinity	120	0.054
Ca 2+	75	0.007
Mg2+	30	0.036
Cl-	250	0.007
NO3-	45	0.036
SO4-	150	0.011
Dissolved Oxygen	5	0.326
Biological Oxygen Demand	5	0.326

Water Quality Index (WQI) calculation

The appraisal of 'unit weight' relegated to each physicochemical limit demonstrated is expected to determine WQI using the Weighted Arithmetic Index. Various units and assessments of as far as possible are changed into a solitary scale utilizing the dispatching units. Table 4 records the drinking water quality measures and the unit loads for each breaking point used in the WQI appraisal. In view of the importance of water quality determination and its effect on the WQI score, both DO and BOD are given the greatest weightage of 0.366. The qualities noticed for the physicochemical attributes from the four sampling sites throughout each season are displayed in figure 4 and 5. The main parameter for calculating WQI are pH, DO, and BOD. Occasional changes were found to affect WQI well. Except for one station, every one of the three stations had greatest WQI esteems recorded during the post-monsoon season. The most extreme WQI happened during the post-monsoon season, followed by the monsoon and pre-monsoon seasons. WQI value was found to be 42.66, 49.24, and 50.12 for all stations separately during pre-monsoon, monsoon, and post-monsoon.

Table 5: - Water Quality Index of River Son at Bhavarsen, near Road Bridge, Sidhi 2019

S. No	Characteristic	Pre-monsoon WiQi	Monsoon WiQi	Post Monsoon WiQi
1	pH	19.456	19.6608	20.2752
2	Specific Conductivity	0.000605	1.04	0.615
3	Dissolved Solids	0.1434	0.3192	0.18
4	Nitrate Nitrogen	6.66667E-05	0.00001	1.33E-05
5	Chloride	0.342416667	0.570733	0.285367
6	Sulphate (SO_4^{2-})	0.264	0.176	0.234667
7	T. Alkalinity	11.52	15.84	16.56
8	T. Hardness	0.3696	0.3808	0.336
9	Calcium	3.0776	2.5648	2.4368
10	Magnesium	0.064093333	0.099733	0.078393
11	D. Oxygen	41.728	47.596	50.204
12	B.O.D.	0.5868	0.5216	0.652

Table 6: - Water Quality Index of River Son at Churhat, near Road Bridge, Sidhi 2019

S. No	Characteristic	Pre-monsoon WiQi	Monsoon WiQi	Post Monsoon WiQi
1	pH	19.2	19.456	20.2752
2	Sp. Conductivity	0.000463	1.01	0.593333
3	D. Solids	0.141	0.3108	0.1662
4	Nitrate Nitrogen	0.00035	0	0.000015
5	Chloride	0.456517	0.285367	0.285367
6	Sulphate (SO_4^{2-})	0.22	0.205333	0.234667
7	T. Alkalinity	17.28	13.68	17.28
8	T. Hardness	0.392	0.448	0.4032
9	Calcium	2.8216	3.2064	2.9496
10	Magnesium	0.09262	0.10692	0.0891
11	D. Oxygen	47.596	46.292	49.552
12	B.O.D.	0.652	0.652	0.5868

Table 7: - Water Quality Index of River Son at Jogdaha, Distt. Sidhi Year 2019

S. No	Characteristic	Pre-monsoon WiQi	Monsoon WiQi	Post Monsoon WiQi
1	pH	18.7392	19.2	18.6368
2	Sp. Conductivity	0.49	0.465	0.453333
3	D. Solids	0.1602	0.1464	0.1362
4	Nitrate Nitrogen	0.001317	0.000817	0.000533
5	Chloride	0.396083	0.2282	0.285367
6	Sulphate (SO_4^{2-})	0.322667	0.234667	0.176
7	T. Alkalinity	14.4	20.88	19.44
8	T. Hardness	0.4704	0.392	0.4032
9	Calcium	3.2064	3.0776	2.5648
10	Magnesium	0.121147	0.078393	0.114033
11	D. Oxygen	44.988	47.596	46.292
12	B.O.D.	1.1736	0.7172	0.8476

Table 8: - Water Quality Index of River Son at Khairpur, Distt. Sidhi Year 2019

	Characteristic	Pre-monsoon WiQi	Monsoon WiQi	Post Monsoon WiQi
1	pH	18.688	19.8912	20.0448
2	Sp. Conductivity	0.47	1.016667	0.535
3	D. Solids	0.1266	0.3006	0.1596
4	Nitrate Nitrogen	0.000933	0.000233	0.000217
5	Chloride	0.554167	0.399467	0.285367
6	Sulphate (SO_4^{2-})	0.234667	0.264	0.234667
7	T. Alkalinity	13.68	16.56	17.28
8	T. Hardness	0.4256	0.4816	0.4704

9	Calcium	3.4624	3.2064	2.9496
10	Magnesium	0.078393	0.12826	0.135373
11	D. Oxygen	41.728	46.944	47.596
12	B.O.D.	0.652	0.7172	0.5216

These findings show that the water samples from all stations are good quality, fit for drinking (25<WQI >50), irrigation, or industrial use as calculated in table 5,6,7 and 8. In all seasons, there is a mixed pattern of fluctuations in WQI. WQI is higher in upstream stations than downstream stations. The pollution level decreases as you travel downstream on the river. [11] observed a decreasing pollution tendency further downstream in their water quality investigation of the Kolong River in Assam. Researchers like [12] have noticed improved water quality upstream. This is not the case in our research. Pollution levels rise sharply around the hydropower dam and traffic bridge in some areas. The stagnant condition of the hydroelectric dam and various land-use activities near sample sites may have contributed to the deterioration of water quality.

Conclusion

The above study provides essential information about the overall state of the Son River. WQI values for the Son River fall into the good water quality category during pre-monsoon, monsoon, and post-monsoon. During the post-monsoon WQI value is high, followed by monsoon season and post-monsoon season. Water quality is poor at some sample points on the river's upstream bank. pH, DO, and BOD was found to impact the river's WQI in this study substantially. Growing settlements in the catchment area harm water quality. Water quality can be jeopardized by shifting cultivation, forest fires, tree logging, eco-tourism, river poisoning, and explosives for fishing. These unchecked activities may exacerbate the decline of water quality. To maintain high water quality, communities living in catchment areas must implement proper treatment and management policies for sewage disposal, agricultural runoff, uncontrolled land-use practices, and unprotected riparian zones. Participation of the community in conservation activities could help to improve water quality. Remedial treatments could help with future water quality monitoring and improvement in the Son River.

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