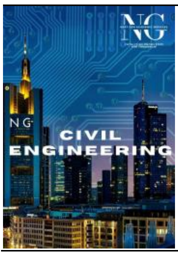

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Assessment of Physico-Chemical Water Quality Parameters of the Brahmani River

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HIGHLIGHTS

- Industrial and domestic pollution affect the river, with seasonal changes impacting depth, flow, and contamination, necessitating continuous monitoring.
- Parameters like pH, DO, BOD, and Conductivity were assessed across multiple stations, showing variations over time and locations, though mostly within permissible limits.
- Developed using CPCB and ICMR standards to simplify complex data for effective decision-making.
- Analysis (2013-2015) revealed fluctuating water quality, with industrial and anthropogenic activities as key contributors to pollution.

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ABSTRACT

This research analyzes the Brahmani River water quality in terms of the important physicochemical parameters. The river is exposed to huge industrial effluents and impacted by extensive agricultural and human practices. To assess the effect of these activities, water samples were gathered from nine points over the river basin between August 2014 and September 2015, with sampling done on the first working day of every month. Parameters like pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Conductivity were examined. It is found from the results that the water quality of the river remains within acceptable ranges. The physicochemical parameters play a significant role in evaluating the overall water quality of the river. The research highlights the need for constant monitoring to make the river a sustainable resource for both ecological and human purposes.

1. INTRODUCTION

Water is essential for sustaining life on Earth and is one of the most abundant substances, covering over 70% of the planet's surface. Despite its abundance, billions of people worldwide still lack access to clean and sufficient water resources. Among different countries, India is blessed with substantial land and water resources. However, due to uneven precipitation patterns, rapid population growth, and

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rising living standards, the demand for fresh water keeps increasing. Consequently, the per capita availability of water is declining over time.

River water quality is a crucial aspect of environmental health, sustainability, directly influencing aquatic ecosystems, human health, and economic activities. Rivers serve as primary water sources for domestic, agricultural, and industrial purposes, making their quality essential for maintaining ecological balance and public health. However, increasing anthropogenic pressures, including industrial effluents, agricultural drainage, and urban sewage, have significantly altered the water quality of many river systems worldwide.

Evaluating river water quality entails examining a range of physico-chemical parameters, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity (EC), and nutrient levels (such as nitrates, phosphates, and sulfates). These metrics offer valuable information about the river's ecological condition and assist in pinpointing pollution sources, whether they stem from natural processes or human activities.

Inadequate water quality can trigger detrimental environmental and socio-economic impacts. Polluted rivers can harm aquatic biodiversity, resulting in habitat destruction and species extinction. Moreover, declining water quality can compromise drinking water sources, boost the incidence of waterborne illnesses, and diminish the usability of water for irrigation and industrial purposes. To address these challenges, consistent monitoring and evaluation of river water quality are crucial for sustainable water resource management, pollution mitigation, and the development of sound regulatory policies.

Despite India's abundant surface water resources, groundwater remains a crucial source, especially during dry months. Climate change is impacting river flow and overall water availability, while pollution from both point and non-point sources is degrading the quality of both surface and groundwater. Rivers in India show significant variability in discharge volume and quality across different regions. Most medium and minor river basins originate in mountainous areas, leading to fast-flowing, rain-fed rivers during the monsoon season. As these rivers reach the plains, they become slow-moving water bodies. Untreated or partially treated industrial and domestic discharges often enter these rivers, causing significant pollution. During heavy rainfall, pollutants are diluted and dispersed, but seasonal fluctuations affect river depth, flow rate, and contamination levels.

Physicochemical properties of river water are of paramount importance to public health, and thus constant monitoring of water quality is imperative. Water quality has been evaluated and forecasted in numerous studies across the globe. Singkran et al. (2010), for example, examined water status in Northeastern Thailand with the aid of time-series models and water quality indexes based on 14 years' worth of data (1994–2007) to build predictive models of future trends (2008–2012). Sahu et al. (2011) employed a neuro-fuzzy classification model, namely an Adaptive Network-Based Fuzzy Inference System (ANFIS), to forecast water quality indices. Sharma et al. (2011) analyzed the physicochemical properties of the Narmada River at Hoshangabad by conducting a statistical analysis of parameters like pH, EC, turbidity, calcium hardness, nitrite, sulfate, chloride, phosphate, and DO. Akkaraboyina and Raju (2012) analyzed the physicochemical characteristics of the Narmada River at Hoshangabad by statistical analysis of parameters like pH, electrical EC, turbidity, calcium hardness, nitrite, sulfate, chloride, phosphate, and DO. Eneji et al. (2012) analyzed the spatial and temporal variation in Nigeria's Benue River water quality by multivariate analysis. Galavi et al. (2012) explored neuro-fuzzy models for water quality prediction using artificial intelligence (AI) methods of hydrological forecasting. While ANFIS models were widely applied, one model was never superior to all others in all situations. These pieces of research emphasize the need for constant monitoring and sophisticated modeling methods to forecast and manage water quality for future generations to ensure sustainable water resources.

The Brahmani River is pivotal to the hydrology and ecology of eastern India. It begins at the meeting point of the Sankh and South Koel rivers in Jharkhand, travels through Odisha, and ultimately empties into the Bay of Bengal. This river supports numerous ecosystems, underpins agricultural endeavors, and acts as a key water supply for both domestic and industrial needs. Its basin harbors a wide array of plant and animal life, including various wetlands and protected zones that serve as habitats for migratory birds and aquatic creatures.

From a hydrological standpoint, the Brahmani River is a major contributor to groundwater replenishment, sediment conveyance, and nutrient circulation. The river's fluctuating seasonal flow impacts floodplain behavior and agricultural output. However, the rise in industrialization, mining operations, and urban sprawl has resulted in considerable pollution and ecological decline. Evaluating its water quality is crucial for sustainable water resource management, conservation initiatives, and the formulation of effective policies.

This study sets out to evaluate the physicochemical characteristics of the Brahmani River to gauge its water quality and pinpoint potential sources of pollution. The research is driven by several key objectives. Firstly, it involves analyzing crucial physicochemical parameters such as pH, DO, BOD, COD, TDS, EC, and nutrient levels (nitrates, phosphates, and sulfates). Secondly, the study examines how water quality varies spatially and temporally across different monitoring sites along the river. Thirdly, it compares the observed water quality parameters with national and international standards to assess the degree of pollution. Additionally, the research identifies significant human-induced influences, such as industrial discharges, agricultural runoff, and domestic wastewater. Lastly, it puts forward recommendations for sustainable water management approaches to reduce pollution and improve water quality. The insights gained from this study will prove beneficial for policymakers, environmental agencies, and water resource managers in developing effective conservation and pollution control measures for the Brahmani River.

2. STUDY AREA

The Brahmani River is the second-largest river in Odisha. It has its origin from the meeting of two large rivers, the Sankh and Koel, both of which begin on the Chhotanagpur Plateau and meet at Vedavyasa near Rourkela in the Sundargarh district. The river passes through the Sundargarh, Keonjhar, Dhenkanal, Cuttack, and Jajpur districts before finally emptying into the Bay of Bengal near Dhamra. The Brahmani River measures about 799 km in length and has 45 tributaries.

Once it had taken on the name Brahmani, the river flows through the Tamra and Jharbera jungles, alongside National Highway 23. The river then flows through Bonaigarh in the Sundargarh district and is impounded at Rengali in the Anugul district, forming a very large reservoir. The river flows through Talcher and Dhenkanal before it splits into two channels. One of the channels joins the Kharsua River on its left bank and then joins the Baitarani River. A distributary called Maipara diverges and empties into the Bay of Bengal, while the main river moves north for a short distance before emptying into the sea near Chandbali at Palmyras Point.

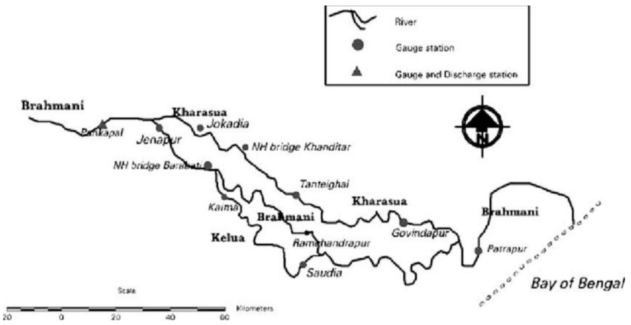

Figure 1. Brahmani River in Odisha

3. METHODOLOGY

Water samples were taken every month from August 2014 to September 2015 from nine different stations, as described in the above table, in clean, waterless polyethylene bottles. pH and biochemical oxygen demand (BOD) are important water quality tests carried out. pH is an important parameter for determining water quality, while BOD is a well-established measure of organic water pollution.

Field-testing techniques for chemical water quality measurement are divided into three categories: (1) Test strips, (2) Color plate packs, and (3) Hand-held digital meters.

The construction of a WQI proceeded according to the steps outlined: Determination of the water quality parameters to be used in the future in a water body. The parameters were chosen according to their importance and applicability for the proposed water use.

The scale of rating for different standards of each parameter has been created as presented in Table 1. The scale puts a number for each parameter for its measured concentration, which enables the computation of the total WQI.

The allowable limits of the water quality parameters in drinking water, as established by the Central Pollution Control Board (CPCB), are given in Table 1. The water quality rating qi of the ith water quality parameter is determined by the formula qi=100(Si/Vi), where vi is the observed value and Si is the standard value for the parameter.

Table 1 Permissible Limits for Drinking Water Quality (CPCB)

S. No	Water Quality Parameter	Permissible Ranges
1	pH	6.5-8.5
2	DO	4.0-6.0
3	BOD	2.0-3.0
4	Conductivity	0-1000

Based on the detailed analysis, the increase or decrease in the levels of water quality parameters in the river water was observed at the selected stations, such as downstream of the Brahmani River. This area is significantly influenced by industrial activities and various effluents. Therefore, the sum of the unit weights of the 11 water quality parameters can be expressed as:

$$\sum_{i=1}^{11} Wi = 1 \quad (1)$$

Table 2 Water Quality factors: ICMR/CPHEEO Standards assigned

S. No	Water Quality Factors	ICMR/CPHEEO Standards (xi)
1	pH	6.5-8.5
2	DO	>5
3	BOD	<5
4	Conductivity	<300

ICMR Standards (1975), CPHEEO Standards (1991), the general WQI of River Brahmani is then determined by collecting these sub-indices (SI) straightly. In this way, WQI can be composed as:

$$\text{WQI}= [\sum_{i-1}^{11} \boldsymbol{qiWi}/\sum_{i=1}^{11} \boldsymbol{Wi}]=\sum_{i=1}^{11} \boldsymbol{qiWi} \qquad (2)$$

Where, $\sum_{i=1}^{11} \boldsymbol{Wi}=1$

4. RESULTS

The assessment of water quality parameters across various time frames and locations along the Brahmani River highlights substantial fluctuations, primarily driven by seasonal shifts and human-induced actions. In monsoon periods, heightened runoff tends to dilute specific contaminants, thereby enhancing parameters like dissolved oxygen (DO). Conversely, post-monsoon phases typically witness an upsurge in biochemical oxygen demand (BOD) and chemical oxygen demand (COD), attributable to diminished flow rates and the buildup of organic materials. Spatial disparities reveal that upstream sites, experiencing less human impact, preserve superior water quality relative to downstream areas impacted by industrial and urban effluents.

Water quality parameters were benchmarked against national (BIS, CPCB) and international (WHO) standards to gauge pollution levels. While parameters like pH and dissolved oxygen (DO) typically stay within permissible ranges, certain areas show elevated levels of heavy metals, nitrates, and phosphates that surpass allowable limits. These exceedances signal potential threats to aquatic life and human health, highlighting the necessity for consistent monitoring and robust pollution control measures.

Pollution hotspots have been pinpointed in industrial zones, urban centers, and agricultural regions through spatial mapping and statistical analysis. Elevated concentrations of heavy metals in water samples gathered near mining and industrial sites imply that effluent discharge is a principal source. Likewise, heightened levels of nitrates and phosphates in agricultural areas indicate that fertilizer runoff is a significant contributor. Moreover, domestic sewage discharge further worsens water quality in urban locales.

pH is a quantitative measure of the hydrogen ion concentration of a solution and thus its acidity or alkalinity. It is defined as the negative logarithm of the hydrogen ion concentration. The pH ranges from 0 to 14. In fresh water, the natural pH range usually ranges from around 4.5 for peaty acidic upland waters to more than 10.0 for alkaline waters. The most frequent pH range found in fresh water is between 6.5 and 8.0.

Table 3 provides the pH level for different stations measured in 2014 and 2015. The pH levels are also graphically shown in Figures 2 and 3. The pH level is highest at Gomlai and lowest at Tilga station, as evident from Fig. 2. Figure 2 further indicates that Gomlai, Jaraikala, Jenapur, and Talcher stations exhibit the highest pH values, with Tilga station having the lowest. Significantly, all water samples have pH levels that are within acceptable limits.

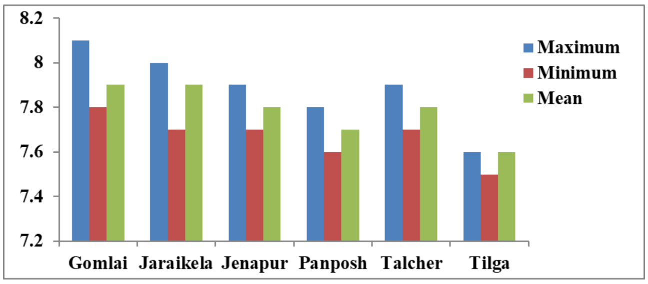

Figure 2. pH value of 2014

Table 3. pH Level

S. No.	Name of the sampling Station	Standard pH value	pH value (2014)	pH value (2015)	pH value (2015)
1	Gomlai	6.5-8.0	7.9	7.73	7.73
2	Jaraikela	6.5-8.0	7.9	7.73	7.73
3	Jenapur	6.5-8.0	7.8	7.76	7.76
4	Panposh	6.5-8.0	7.7	7.6	7.6
5	Talcher	6.5-8.0	7.8	7.73	7.73
6	Tilga	6.5-8.0	7.6	7.43	7.43

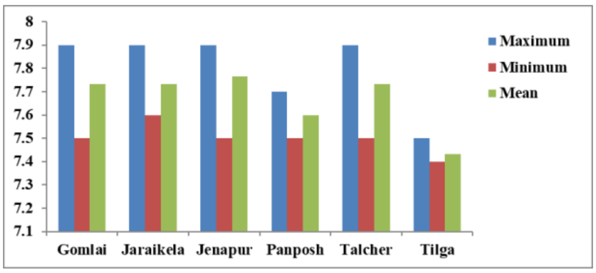

Figure **3.** pH value of 2015

The significance of dissolved oxygen (DO) was already mentioned in the context of biochemical oxygen demand (BOD). The DO concentrations in a stream are usually minimum in summer, at which time the danger of inflicting harm to water supply resources or to ecological pollution is highest, particularly in tourist- or agriculturally developed regions. When DO levels decrease to near zero, septic conditions may arise, resulting in the anaerobic breakdown of any remaining organic material, yielding compounds like methane and ammonia. Most natural water sources usually contain DO levels ranging from 4.0 to 6.0 mg/L.

The DO values for different stations measured in 2014 and 2015 are given in Table 3. These values are also graphically represented in Figures 4 and 5. As evident from Fig. 4, the maximum DO value in the Brahmani River is found at Talcher, whereas the minimum is at Gomlai station. Fig. 5 further shows that the maximum DO value is at Tilga, and the minimum is at Panposh station. Significantly, there are DO values in all the water samples within acceptable ranges.

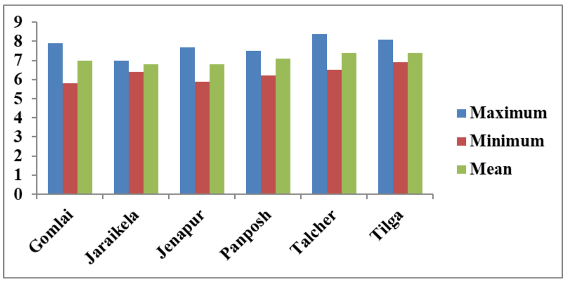

Figure 4. DO in mg/L 2014

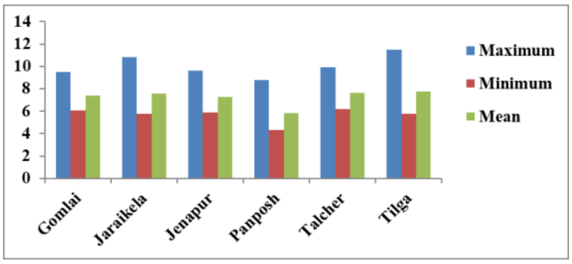

Figure 5. DO in mg/L 2015

Whenever organic matter is released into a river, it will act as an energy source to the microorganisms in the environment. The microorganisms start degrading the organic matter into low-molecular-compound natural material, ultimately into clear solutions such as carbon dioxide and water. If the volume of waste is large enough, the amount of bacterial uptake of oxygen will be greater than the amount replaced by dissolved oxygen (DO) renewed from the atmosphere and via photosynthesis, eventually making the receiving water anaerobic. The majority of raw water sources have a BOD ranging from 2.0 to 3.0 mg/L.

The BOD values of different stations measured in 2014 and 2015 are presented in Table 4. These values are also shown graphically in Fig. 6 and 7. From Figure 6, it is observed that the maximum BOD value in the Brahmani River is found at Gomlai and the minimum at Jaraikela station. Fig. 7 shows that the highest BOD value is at Panposh, and lowest at Tilga station. Notably, all samples of water are having a BOD value within acceptable bounds.

Table 4 BOD mg/L

S. No.	Name of the sampling Station	Standard BOD value	BOD value (2014)	BOD value (2015)
1	Gomlai	2.0-3.0	0.7	1.16
2	Jaraikela	2.0-3.0	0.5	1.03
3	Jenapur	2.0-3.0	0.5	0.466
4	Panposh	2.0-3.0	0.5	1.73
5	Talcher	2.0-3.0	0.5	0.86
6	Tilga	2.0-3.0	0.3	0.26

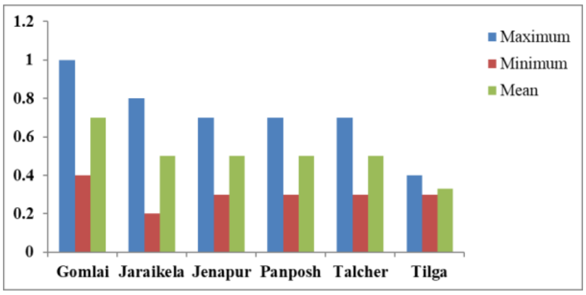

Figure 6. BOD in mg /L 2014

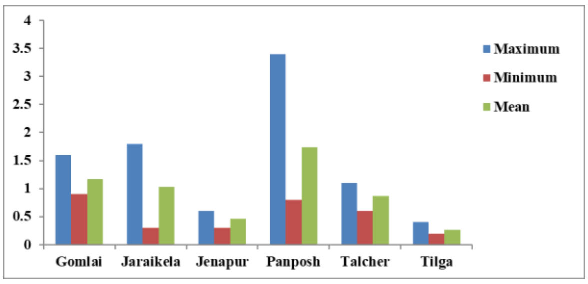

Figure 7. BOD in mg /L 2015

Conductivity is the capacity of water to carry an electric current. Conductivity is associated with the ionic content of the sample, which is part of the total dissolved solids (TDS). Conductivity is an important measurement to know the ionic content of water. Although conductivity itself may not directly interest a water specialist, it is an important measure of the range in which hardness and alkalinity values should occur, together with the amount of dissolved solids in the water. Conductivity for most raw water sources would generally be around 0 to 1000 µS/cm. A standard conversion factor is frequently applied: Conductivity (µS/cm) × 2/3 ≈ Total Dissolved Solids (mg/L).

The conductivity values for various stations recorded in 2014 and 2015 are listed in Table 5. These values are also depicted graphically in Fig. 8 and 9. As seen in Fig. 8, the highest conductivity value in the Brahmani River is recorded at Panposh, while the lowest is at Tilga station. Figure 9 further illustrates that the highest conductivity value is at Gomlai, and the lowest is at Tilga station. Importantly, all water samples have conductivity levels that fall within acceptable limits.

Table 5 Conductivity in µ mho/cm

s. No.	Name of the sampling Station	Standard Conductivity Value	Conductivity value (2014)	Conductivity value (2015)
1	Gomlai	0-1000	177.3	264.6
2	Jaraikela	0-1000	164.0	244
3	Jenapur	0-1000	131.3	184.3
4	Panposh	0-1000	185.7	282
5	Talcher	0-1000	119.3	166
6	Tilga	0-1000	84.0	137

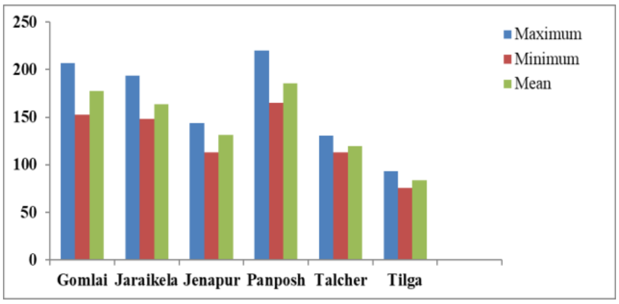

Figure 8. Conductivity in µ mho/cm 2014

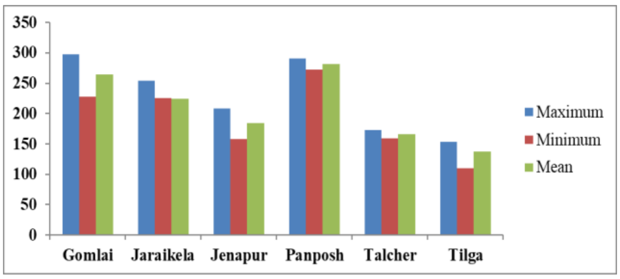

Figure 9. Conductivity in µ mho/cm 2015

4.1 Comparison of Physicochemical Parameters for Different Years (2013-2015)

The mean pH values for 2013, 2014, and 2015 are shown in Fig. 10. It is seen that the maximum pH values were recorded at Gomlai and Jaraikela in 2014, whereas the minimum pH values were recorded at Tilga in 2015, when compared for all three years. In particular, in 2013, the mean minimum pH value of 7.9 was recorded at Panposh. In 2014, the mean maximum pH of 8.1 was recorded at Gomlai, while the minimum pH was 7.5 at Tilga. In 2015, the mean minimum pH was 7.4, and the mean maximum pH was 7.7, both recorded at Tilga. Comparing the mean maximum and minimum means over the three years, the maximum mean maximum was 7.9, while the minimum mean minimum was 7. 4.

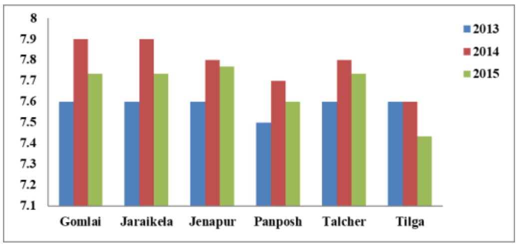

Figure 10. Comparison of the pH mean values

The average DO values for 2013, 2014, and 2015 are represented in Fig.11. The highest DO values were observed in 2015 at Jaraikela, Talcher, and Tilga, whereas the lowest DO values were found in 2015 at Panposh when compared for all three years.

In particular:

During 2013, the mean minimum DO value of 6.8 was observed at Gomlai and Panposh.

In 2014, the average maximum DO value of 7.4 was recorded at Talcher, while the minimum value was 6.8 at Jenapur.

In 2015, the average minimum DO value was 5.8 at Panposh, while the maximum value was 7.8 at Tilga.

Comparing the average maximum and minimum means for the three years, the maximum average maximum mean was 7.8 and the minimum average minimum mean was 5.8.

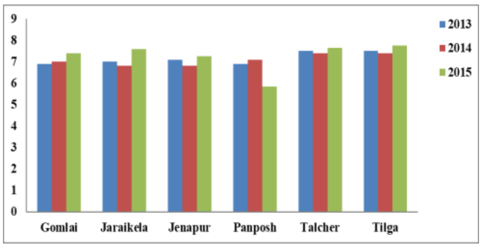

Figure 11. Comparison of the DO mean values

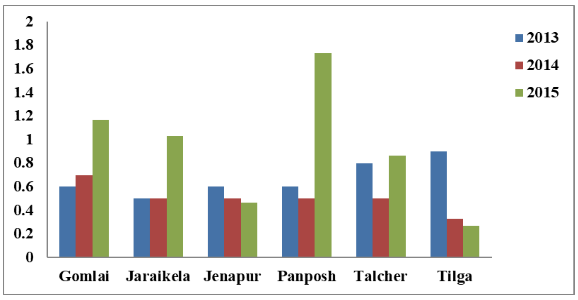

Figure 12. Comparison of the B.O.D mean values

The average conductivity values during the years 2013, 2014, and 2015 are presented in Fig. 13. The maximum conductivity value was recorded at Panposh during the year 2015, whereas the minimum conductivity value was recorded at Tilga during the year 2014, when compared for all three years.

Particularly:

During the year 2013, the average minimum conductivity value of 104 was recorded at Tilga.

In 2014, the average highest conductivity value of 177.3 was recorded at Panposh, with the lowest value being 84 at Tilga.

In 2015, the average lowest conductivity value was 137 at Tilga, and the highest value was 264 at Panposh.

On comparing the average highest and lowest means for all three years, the highest average highest mean was 264, and the lowest average lowest mean was 84.

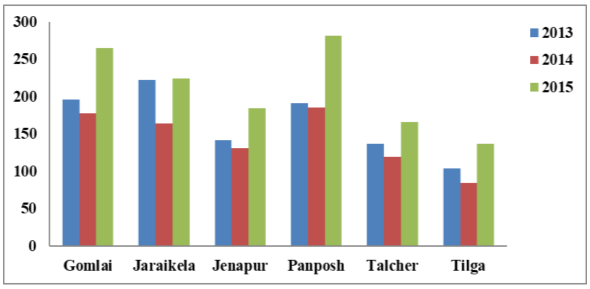

Figure 13. Comparison Conductivity in µ mho/cm mean values

5. DISCUSSION

The analysis of the water quality parameters of the Brahmani River provided valuable insights into the river's health and causal factors. The examination of physicochemical parameters like pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and conductivity at various stations and over seasons highlighted the intricate relationship between natural and anthropogenic forces (Bhatt et al. 2024).

The pH of river water was within tolerable ranges, meaning that the river's alkalinity or acidity is not a significant issue (Alam et al. 2007). However, the spatial heterogeneity of pH values indicates that local industrial and agricultural practices might affect the river's chemical status. Gomlai and Jaraikela stations had the highest pH values, while those at Tilga station were the lowest. These results highlight the necessity of specific monitoring and regulation in the regions with increased pH levels. Dissolved oxygen (DO) concentrations, a key parameter of aquatic life, exhibited strong seasonal fluctuations. Monsoon periods experienced elevated runoff, which resulted in higher DO concentrations, reflecting improved aeration of river water. In contrast, post-monsoon periods experienced a drop in DO concentrations, especially at stations located downstream of industries and cities. This indicates that effluent release and organic matter deposition significantly contribute to the river's oxygen concentration and may have implications for aquatic ecosystems.

Biochemical oxygen demand (BOD) values, a measure of organic pollution, also showed extreme seasonal and spatial fluctuations (Şener et al. 2017). Increased BOD values were recorded during the summer and winter months, corresponding with low river flow and high organic matter accumulation. Maximum BOD values occurred at Gomlai and Panposh stations, pointing towards major inputs from industrial and domestic effluents. These observations suggest stringent measures and regulation to minimize organic pollution within the river. Conductivity levels, an indication of the ionic load of the water, were within tolerable levels at all stations. Conductivity was, however, higher at Panposh and Gomlai stations, indicating dissolved salts and minerals possibly from industries and agricultural uses. The spatial distribution of conductivity highlights the need for monitoring and regulating the ionic load of the river to avoid impacts on water quality.

The Water Quality Index (WQI) values, calculated based on national and international standards, showed that the water quality of the river was good to excellent during the monsoon season and good to poor during the summer and winter seasons (Sutadian et al. 2016). This implies that although the river's water is generally safe for domestic use, there are times of concern, especially during the dry seasons. The WQI values indicate the necessity of ongoing monitoring and adaptive management practices to maintain the long-term health of the river. The research also compared water quality parameters for three consecutive years (2013-2015), which showed uniform trends and indicated the routine discharge of effluents and human activities as major sources of pollution. The results underscore the necessity of ongoing efforts to monitor and control pollution sources to sustain the water quality of the river.

6. CONCLUSIONS

The comprehensive evaluation of the water quality of the Brahmani River through analysis of the major physicochemical parameters and calculation of the Water Quality Index (WQI) gives insightful information about the present state of the river as well as the factors governing it. From the study, it is evident that although the water quality of the river is mostly within acceptable limits, large fluctuations are noted during different seasons and locations. These changes are mainly caused by seasonal variations in river flow, depth, and discharge of industrial and domestic effluents. The results show that during the monsoon period, more runoff assists in diluting pollutants, resulting in better parameters like dissolved oxygen (DO). In contrast, post-monsoon periods experience an increase in biochemical oxygen demand (BOD) and chemical oxygen demand (COD) because of low flow rates and the buildup of organic matter. Spatially, upstream locations have better water quality than downstream locations, which are greatly affected by industrial and urban effluents. Comparison of the water quality parameters in three consecutive years (2013-2015) indicates uniform trends, and it is reasonable to conclude that routine effluent discharge and anthropogenic activities are major sources of pollution. The values of WQI fall in the range of good to excellent during the monsoon period and good to poor during the summer and winter periods, which shows that although the water of the river is overall adequate for domestic use, there are critical moments. The research emphasizes the importance of ongoing monitoring and effective pollution control measures to maintain the long-term health of the Brahmani River. The application of WQI as an effective and transparent method of communicating water quality information to policymakers and the public is strongly suggested. Since there are growing industrial and human activities along the riverbanks, regular monitoring and sustainable management practices need to be followed to maintain this valuable resource for generations to come.

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