

Water Quality Assessment Using Water Quality Index (WQI) Under GIS Framework in Brahmani Basin, Odisha



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Abstract River water quality has become more important as a result of the numerous human activities that are contaminating it and the need to assure its safe and reliable use. In light of the fact that water quality has been threatened by human activities, apportionments of potential pollution sources are essential for water pollution control. A thorough investigation on the water quality of the Brahmani River has been done while considering these factors in mind. Twelve sampling sites have provided water samples to be examined. Twenty physicochemical parameters were investigated on yearly basis for a period of four year (2017–2021) by using standard procedures. The water quality index (WQI) was generated using the CCME algorithm, and a geostatistical technique called inverse distance weighting (IDW) was employed to create a forecast map for the region. Information from this research also aims to assist policy makers, to take the right decisions for sustainable agriculture in the study area. Between the observed data and the expected values from the predictor maps in both season, regression prediction was conducted on the three predicted stations, namely Biritola, Nandira D/s, and Kabatabandha. The study's quality database is created using the physicochemical analysis results of various water samples collected at various sites. The pH of the river was just mildly alkaline. In the PRM and POM, the overall CCME WQI grades fell into the fair to good and marginal to fair categories, respectively. Regression prediction values of WQI for all parameters in PRM were given the most acceptable values of determination coefficient ($R^2 = 0.82$) than POM. The current investigation reveals that at stations P-3 (Panposh D/s) and P- 4 (Rourkela D/s), the quality of the local surface water has degraded. It was confirmed that both geogenic events and human activities linked to the origin of TC, TDS, TH, TA, Ca^{2+} , and HCO_3^- . At these places, it is necessary to first reduce the causes of deterioration to which the surface water is exposed, and the water should be treated before consumption. Therefore, future studies should be conducted in the area to precisely state the quality of water used for drinking and domestic purposes. Hence, this research should also emphasize identifying factors

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controlling surface water chemistry in the area. Further, measures should be discussed and implemented in managing downstream areas, sewage treatment facilities, and fertilizer and industrial application.

Keywords Brahmani river · Physicochemical parameters · CCME · IDW · Regression

1 Introduction

Water is one of important resources for consumption, as well as for additional uses including farming, industry, and recreational opportunities (Anawar and Chowdhury 2020). One of the main sources of freshwater for the world's human populations is the river. They are part of our natural heritage, yet they are constantly being overused, exploited, and polluted to the point where the surface water and aquatic life are being adversely affected (Patil et al. 2013; Das 2022). Furthermore, many riverine systems all over the world are becoming more and more polluted as a result of mounting human demand. Rivers have the ability to detoxify a specific number of contaminants that are dumped into them, but if that amount is exceeded, the water quality suffers (Chen et al. 2017). For instance, factors like precipitation, soil erosion from weathering, and human-induced factors like overusing water resources can all have an impact on the quality of surface water in a given area (Meshram et al. 2021). The river system has been under tremendous pressure over the past few decades due to population increase, urbanization, industrialization, and encroachments (Muhammad et al. 2018). Therefore, in order to create an effective water management system, it is necessary to comprehend the extent of pollution, create and quantify pollution tracking indices, as well as comprehend spatiotemporal changes in pollution in rivers (Fu et al. 2012). Surface water is a rich natural resource that has often been used for agriculture and consumption, especially in dry and semi-arid countries (Ram et al. 2021). It is significant because it has industrial uses and can be directly converted into drinkable water by desalination (Panagopoulos 2021). Also, recent changes in climatic conditions have affected rainfall patterns in the region, causing a significant decrease in crop yield as well as other agricultural productions. They have resulted in an increased demand for water resources exploration in communities within the region, for sustainable agricultural activities. Surface water quality has been impacted by significant pesticide leaching, salinization, topsoil contamination, landfill, and extensive floods (Islam and Mostafa 2021). Numerous studies have been done to evaluate the nation's surface water quality, including Hasan et al. 2019, Sarkar et al. 2019, Nadikatla et al. 2020, and Parvin et al. 2022. Surface water quality has been the subject of numerous investigations, particularly in coastal regions where water sodicity is a major problem (Islam and Majumder 2020). Therefore, it is critical to maintain continual observation to assess the water's suitability for diverse uses and guard against future deterioration of water quality in the research zone (Rahman et al. 2011). Surface water is usually thought to be the purest source of waterbodies, but studies have found that it is not

entirely free of contaminants (Ahmed et al. 2018). The fundamental issue is that once it is corrupted, it can never be made pure again (Sarkar et al. 2019). Water quality is impacted by the direct discharge of industrial waste, which includes detergent, toxic substances, acids, pigments, inorganic salts, and other contaminants (Roy and Shamim 2020a). Almost all of Odisha, India's drinking and irrigation water needs are met by the Brahmani River, the state's primary waterway. Over the past several decades, its river water has been continuously degrading as a result of the emission of untreated effluents and human intrusions (Bhadra et al. 2014). However, there is a lack of pollution source analysis concerning mixing the elements of nutrients, salinity, and heavy metals. This highlights the need for and issue of managing and conserving surface water quality (Said et al. 2004). The water quality index (WQI), that is employed to comprehend the overall water quality role of water supplies, has been employed to determine the water quality including both surface and ground water (Das 2022). Number of studies are carried out related to water quality index (WQI). WQI was initially used as a measure of water contamination by Horton in 1965. Over the past fifty years, literatures on water quality have also addressed the frequent fluctuations of WQIs (Banda and Kumarasamy 2020). It is imperative to create a WQI that is widely accepted and adaptable enough to reflect water that is fit for drinking or other uses for consumers everywhere (Othman et al. 2020). A newer WQI, the Canadian Council of Ministers of Environment Water Quality Index (CCME-WQI), which may be known as the Canadian Water Quality Index (CWQI) in 2001, was introduced in the middle of the 1990s (Lumb et al. 2011). The WQI was evaluated in this model based on the frequency of sample variables, failed variables, and variance from the standard values (Das 2023). This approach has helped to identify the pollution sources in the surface water. In fine, it evaluate contributions of potential pollution sources, have been widely used in the apportionment of water pollution and riverine pollution sources. Later, the United Nations Environmental Program acknowledged this model as a suitable model for evaluating the quality of drinking water around the world (Bharti and Katyal 2011). In the Talcher-Angul Industrial Vicinity, this approach has been used to estimate the grade of water in rivers including the Sabarmati River in Gujarat (Shah and Joshi 2017), the Dokan Lake Ecosystem (Hameed et al. 2010), the Ganges River along various sites in Allahabad (Sharma et al. 2014), and also the Brahmani River (Bhadra et al. 2014) (Mishra et al. 2014). Assessing surface water quality, mapping, vulnerability and appropriateness assessments, and other tasks connected to the management and development of water resources all need the use of geographic information system (GIS). These programmes provide tools for geographical analysis that can handle large amounts of data. An efficient method for interpreting and analysing spatial data has been demonstrated using the Inverse Distance Weighted (IDW) interpolation method with GIS technology (Soujanya et al. 2020). IDW relies on a method of precise local deterministic interpolation (Watson and Philip 1985). IDW was thought to produce the bathymetry of the Panchganga River Basin more precisely than Kriging and Topo to Raster. The WQI and IDW interpolation method has been employed by many researchers, including (Balamurugan et al. 2020; Soujanya et al. 2020), who are interested in evaluating surface water for drinking reasons. Surface water is a

significant supplier of potable water, residential use, and farming in the current field of research (Das 2022). However, just a small amount of study has been done on the Brahmani River's WQI report. There has not been a single study that blends WQI, GIS, and IDW to determine the score of this region. As a result, there is a study gap, and further discussion is required to comprehend the scope and reasons behind its decline. The following study's primary goal is to formulate an improved WQI in attempt to explore how human activities affect the water quality of the Brahmani River throughout the city of Odisha and ascertain whether it is acceptable for human consumption. These latest results could be useful in developing a successful drinking water management framework for the locals who live close to the sampling points. By applying the findings in this study, governments could take more flexible and targeted measures, such as treating eutrophic sewage in villages and controlling vehicle emissions.

2 Study Area

The Brahmani River is an important river in the Odisha state in eastern India. It is formed when the South Koel and Sankh rivers confluence at $22^{\circ} 15' N$ and $84^{\circ} 47' E$. It passes through the districts of Sundergarh, Kendujhar, Dhenkanal, Cuttack, and Jaipur. A total of about $39,628 \text{ km}^2$ of the river basin's drainage area is in the states of Jharkhand ($15,405 \text{ km}^2$), Odisha ($22,516 \text{ km}^2$), and Chhattisgarh (1347 km^2). The river basin's projected annual renewable water resources total 21,920 million cubic metres. Before it merges with the Bay of Bengal, the river passes through a sizable portion of an agricultural region and a number of industrial facilities. The river basin is in a climate zone with tropical monsoons, and it has three distinct seasons: winter, summer, and rainy season (Das et al. 2023). This region has a semi- arid to arid environment with an annual rainfall average of 1400 mm and a mean temperature of $25.7^{\circ} C$. The river basin provides an ideal environment for economic expansion since it has abundant mineral resources and inexpensive manpower. The Sundergarh district's Rourkela integrated steel mill, which also includes nearby mines, ancillary by product, and downstream product facilities, has significantly increased the town's development. In order to collect data for the study, 12 key sample stations were chosen, including Sankh U/s (P-1), Koel U/s (P-2), Panposh D/s (P-3), Rourkela D/s (P-4), Bonaigarh (P-5), Rengali (P-6), Samal (P-7), Talcher U/s (P-8), Dhenkhanal U/s (P-9), Bhuban (P-10), and Dharmsala (P-12). Figure 1 portrays the stream and the sampling spots chosen throughout its length. The water quality indicators taken into account in this study are TC, COD, pH, DO, BOD, TA, B, Fe^{2+} , TDS, TH, and EC, cations like Ca^{2+} , Mg^{2+} , Na^{+} , and K^{+} , and anions like CO_3^{2-} , HCO_3^{-} , Cl^{-} , F^{-} , and SO_4^{2-} . These data were obtained annually for a duration of four years, i.e. (2017–2021).

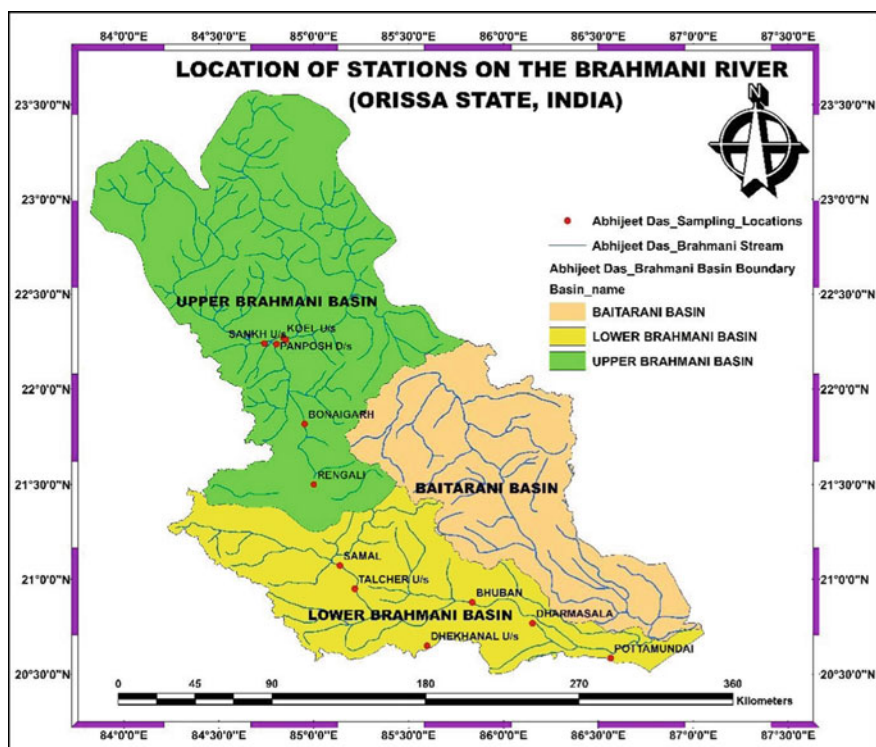


Fig. 1 Map showing study area and sampling locations

3 Data Collection and Analysis

Water samples were taken for the current study from 12 (Twelve) previously chosen sampling stations throughout the pre- and post-monsoon periods (PRM and POM), i.e. (2017–2021). The samples were taken between 10:00 am and 12:00 pm following downstream in both seasons. All samples indicate the current water quality at a particular time. Fresh surface water was collected for sampling using dry, clean, and sanitized plastic bottles. Following the steps outlined in APHA (2012), the samples were transferred to the laboratory at a favourable temperature ($< 4\text{ }^{\circ}\text{C}$) after being collected and sealed in airtight bottles. The global positioning system (GPS) was used to gather global references for each place. During the analytical phase, techniques such as procedural blank, duplicates samples, and repetitive tests were carried out as needed for quality assurance. While the other parameters were determined in a laboratory, pH was measured on the spot using a portable metre. The Systronics Water Quality Analyzer 371 instantly measured total dissolved solid (TDS), electrical conductivity, and dissolved oxygen (DO) using a digital DO metre. Sodium (Na^+), potassium (K^+), iron (Fe^{2+}), and calcium (Ca^{2+}) were determined by flame photometer. Fluoride (F^-), chloride (Cl^-), sulphate (SO_4^{2-}), carbonate (CO_3^{2-}), and

bicarbonate (HCO_3^-) were determined by ion chromatography. The majority of the samples were submitted to the Central Water Commission's water quality lab in Bhubaneswar for inspection and analysis. The proportion of TDS/EC is now within acceptable limits, and the charge balance remained typically less than 10%, verifying the accuracy of the data obtained. Below 5% indicated the relative standard deviation values.

4 Methodology

4.1 CCME WQI

The Canadian Water Quality Index (CWQI), which was first created by the Canadian Council of Ministers of the Environment (CCME WQI), offers a common framework that was created by Canadian jurisdictions to communicate water quality information to managers and the general public (CCME 2001). The following expression can be used to calculate index values, i.e. $\text{CWQI} = 100 - ([F_1^2 + F_2^2 + F_3^2]^{0.5} / 1.732)$. There are three components to it, with Scope (F_1) equal to the number of elements whose objective limitations are not reached. $F_1 = (\text{Number of failed variables} / \text{Total number of variables}) * 100$. Frequency (F_2) = The quantity of times the goals were not achieved. $F_2 = (\text{Number of failed tests} / \text{Total number of variables}) * 100$. Amplitude (F_3) = The extent by which the test results that failed to pass did not attain their objectives. When the test value must not exceed the objective then $\text{Excursion}_i = (\text{Failed test value}_i / \text{Objective}_j) - 1$. For the cases in which the test the test value must not fall below the objective then $\text{Excursion}_i = (\text{Objective}_j / \text{Failed test value}_i) - 1$. Finally, normalized sum of excursions (NSE) is calculated as $\text{NSE} = (\sum_{i=1}^N \text{excursion} / \text{Number of tests})$. However, after scaling the normalizing summation of the excursions towards objectives (NSE) to generate a number ranging from zero and 100, an asymptotic function calculates F_3 . The equation is represented as $F_3 = (\frac{\text{NSE}}{0.01\text{NSE}+0.01})$. The rating has been scaled from 0 to 100 using a proportion of 1.732. The five essential criteria are used to rate the quality of water: Excellent (95–100), good (80–94), fair (60–79), marginal (45–59), and poor (0–44).

5 Results and Discussions

The surface water quality maps for this research have been created utilizing ArcGIS 10.5, focusing on the parameters that have been chosen and explained previously. The many parameters taken into account for the study are explained in the paragraphs that follow. Table 1 illustrates the characteristics of water chemistry. The World Health Organization's (2011) recommendations for safe drinking water have been employed as a guide in this work. During PRM and POM periods, respectively, surface water

had a pH range of 6.6–8.4 and 7–8.1, which is between the upper acceptable limits of WHO criteria (6.5–8.5). The slight alkalinity may indeed be caused by the outflow of household and industrial wastewater into the river and the action of green organisms, which absorb CO₂ dissolved in water. (Driche et al. 2008). The amount of oxygen freely available in water is measured by dissolved oxygen (DO). The values are in the range of 6.8–8.3 and 6.9–8.3 during PRM and POM period. Increased temperature hampers the chemical interactions and reduces the DO concentration from water (Talling et al. 1957). DO numbers are high everywhere because they depend on a variety of variables, including temperature, microbial population, pressure, and sample period (Patnaik 2005). BOD is the amount of oxygen consumed for microorganisms to digest the organic compounds found in a particular water sample at a particular temperature for a certain period of time. COD describes the amount of DO required for any organic waste dissolved in the air to be oxidized (Das et al. 2023).

The reported BOD values are comparatively low to the WHO threshold of 5 mg/l, during which phase they constitute a risk to aquatic life owing to inadequate oxidative metabolism, and in both seasons varied from 0.75 to 4.5 mg/l. The presence of organic materials and bacterial load may be the cause of the low BOD value (Kumar and Puri 2012). In all seasons, COD ranged from 6.3 to 18.3, which is extremely low when compared to the WHO-recommended minimum limit of 250 mg/l. Reduced COD readings convey the existence of commercial and homemade effluents in the watercourse and give us a sense of the level of toxicity in the river water; the more waste, the lower the oxygen demand (Sharma et al. 2014). Coliform (TC) contamination has a deleterious effect on the river's DO to varying degrees. The waters close to industry, municipal sewage systems, or hospitals have been observed to contain high quantities of coliform bacteria (Niyoyitungiye et al. 2020). In the present study, values are in the range 1310–13,222 in both seasons. P-3 and P-4 levels during PRM and P-6 and P-7 levels during POM are much higher than the WHO-recommended standards (5000 MPN/100 ml). These high readings are an indication of dangerous chemicals and are also caused by bacterial pollutants in river water, household waste, industrial discharge, and food manufacturing runoff. The measuring capacity of alkalinity (TA) of water is to neutralize acids. These values varied as 40–250 and 50–880 during PRM and POM. The WHO's preferred threshold for alkalinity seems to be 120 mg/l. But in our study, maximum locations in both periods were high above the permissible limits and should be the effect of continuous, heavy deposition of domestic sewage, agricultural runoff along with effluents of industry (Sahni et al. 2011). A neutralizing agent can be used to increase the quality of water. The amount of organic matter and inorganic salts inside the water body dictate the TDS of the water; the lesser the TDS, the greater the purity of the water. During the PRM and POM seasons, the TDS of the water was determined to be 150–1200 and 74–622, respectively. Greater TDS observed in P-3 (1200) in PRM when compared with the values given by WHO (1000 mg/l). Extremely high values are a result of industrial discharge, home sewage, and agricultural runoff contaminating river water, and they are a sign of dangerous toxins in mineral form (Ibrahim and Nofal 2020). We can estimate the quantity of calcium and magnesium compounds in water by looking

Table 1 Statistics of chemical parameters (all in mg/l, TC in MPN/100 ml and EC in $\mu\text{S/cm}$)

Parameters	Pre-monsoon (PRM)		Post-monsoon (POM)	
	Min	Max	Min	Max
PH	6.6	8.4	7	8.1
DO	6.8	8.3	6.9	8.3
BOD	0.75	4.5	0.75	4.5
TC	1310	13,222	1310	13,222
COD	6.3	18.3	6.3	18.3
TA	40	250	50	880
TDS	150	1200	74	622
TH	48	244	55	365
EC	55	590	90	240
B	0	0.17	0.03	0.17
F ⁻	0.08	0.66	0.2	0.66
Ca ²⁺	6.7	57.1	12.6	109.2
Mg ²⁺	7.6	31.6	3.2	30.4
Na ⁺	8	66	7	123
K ⁺	0.2	1.32	0.7	5.3
Fe ²⁺	0.01	0.2	0.02	0.09
CO ₃ ²⁻	0.01	36	0	180
HCO ₃ ⁻	48.8	292.8	61	1073
Cl ⁻	15	179.9	15	129.9
SO ₄ ²⁻	0.5	45.7	0.7	48.8

at its total hardness (TH). The WHO has established a 600 mg/l hardness standard for drinking water. In the degree of hardness, water is commonly classified as soft (0–75 mg/l), moderately hard (75–150 mg/l), hard (150–300 mg/l), and very hard (> 300 mg/l). As per WHO standard of drinking water, total hardness values are in the range of 300–600. In the present study, the values varied as 48–244 and 55–365 during PRM and POM. P-3 (365 mg/l) in PRM has extremely hard water, and a significant concentration of hardness is visible. Water systems, frequent soap use, artery calcification, urinary concretions, kidney and bladder problems, and stomach disorders can all be impacted by high levels of hardness. Water's EC is typically correlated with the quantity of ions dissolved in the liquid. The river water samples in both seasons met the WHO's recommended maximum permitted limits of EC (750 S/cm), making them fit for human consumption. Higher EC readings can occasionally signify salt enrichment and may result from improperly disposing of nearby home and industrial wastewater. During PRM and POM, the content of boron (B) varied between 0 and 0.17 and 0.03 and 0.17. According to WHO criteria, the ideal level is close to 2 mg/l. A noticeable increase in the boron content of surface water can occasionally be brought on by the entry of wastewater with washing solutions containing borate compounds or leaching from sediment or rock containing borates or borosilicates (Danish et al. 2019). The activity of human cells, hormones, cancer, heart disease, fluid balance within the body, muscle contraction, neurological illness, and testicular descent are all significantly influenced by calcium (Ca^{2+}) (Heaney et al. 1982). Although excessive ingestion of calcium damages the brain and causes hypercalciuria, kidney and vascular illness, urinary tract concretion, and compression of bone restoration, it is beneficial for bones and prevents osteoporosis (Nerband et al. 2003). During PRM and POM, it had levels between 6.7 and 57.1 and 12.6 and 109.2, respectively. According to WHO, the acceptable level for drinking water is 75 mg/l. Except for P-3 and P-10, all of the sampling locations are within the permissible ranges both before and after the monsoon. These sites saw the establishment of some cement and oil refinery companies, which mostly caused the river water's higher Ca^{2+} concentration (Potasznik and Szymczyk 2015). Magnesium (Mg^{2+}) supports strong bones, robust nerve and muscle function, and a strong immune system. It also supports the regulation of blood glucose levels and the synthesis of protein and energy. Several different types of rocks, sewage, and industrial wastes are the main sources (Murphy 2007). During PRM and POM, Mg^{2+} values vary from 7.6 to 31.6 and 3.2 to 30.4, respectively. The required allowable level of magnesium for drinking is 35 mg/l (WHO). The bulk of the surface water is below the allowable magnesium limit. Additionally, the findings showed that sodium (Na^+) was a dominant cation in both seasons. High Na^+ concentrations can cause alkaline soils, which can negatively influence the structure and permeability of the soil. 200 mg/l of sodium is the acceptable amount in drinkable water (WHO). During PRM and POM, the values vary between 8 and 66 and 7 and 123, respectively, staying within allowed limits. Due to the physical structure of the soil and rocks, as well as the humidity and temperature of the semi-arid region, low concentrations may be seen in PRM and POM (Nwankwo et al. 2020). When ingested in excess, potassium (K^+) can have laxative consequences such as elevated blood pressure, arteriosclerosis, hyperosmolarity, and

oedema (El-Aziz and Hassanien 2017). According to the WHO, the acceptable potassium limit is 12 mg/L. The limits encompass all sites. The most pertinent issue with rural drinking water is iron (Fe) (Islam and Mostafa 2021). Although a low iron level is necessary for human nutrition and plant metabolism and cannot cause significant harm, it promotes undesirable bacterial growth (iron bacteria) in waterworks and supply systems, which leads to the deposition of a slushy coating on the pipes (Can 1990). The recommended iron limit for drinking water is 1 mg/l (WHO). During PRM and POM, Fe concentrations vary between 0.01 and 0.2 and 0.02 and 0.09, respectively, satisfying the acceptable limits. The hardness and alkalinity of water are influenced by the presence of carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-). Salts made of carbonates and bicarbonates are produced as a result of rock weathering. Low carbonate levels were found within the WHO's (100 mg/l) permissible limits in PRM and POM. Bicarbonate levels in PRM and POM range from 48.8 to 292.8 and 61 to 1073, respectively. According to WHO regulations, 300 mg/l is the permitted maximum. The results showed that carbonate from weathering sources contributed to POM's results, which were marginally greater than those for PRM. From P-6 to P-12, the threshold of bicarbonate greater than 500 mg/l was noticed. The rise in bicarbonate in these locations may be related to agricultural runoff, where the prevalent process in such arid agricultural areas is the dissolution of carbonate minerals being precipitated in the soil by the action of high evaporation rates (Selvam et al. 2013). Chloride (Cl^-) is a sign of sewage-related contamination. According to the WHO, the permissible level of chloride is 250 mg/l (Kumar and Puri 2012). Plants and living things both eat chloride in tiny levels, but at higher doses, it is harmful. The recorded values for PRM and POM, which ranged from 15 to 179.9 and 15 to 129.9, respectively, are well within the permitted limits. Gypsum leaching and anthropogenic activity in a metamorphic environment result in the emission of sulphur gases, which decompose and enter surface water systems, resulting in the formation of sulphate (SO_4^{2-}), which is naturally present in water (Shukla and Saxena 2020a). Throughout PRM and POM, the values ranged from 0.5 to 45.7 and 0.7 to 48.8, respectively. 200 mg/l is the acceptable limit for sulphate in drinking water (WHO 2011). In the current investigation, all SO_4^{2-} values are within the permissible range. Numerous studies have found that endemic fluorosis disease affects the rural population, especially children, as a result of excessive fluoride levels in drinking water (Adimalla et al. 2018). The readings were determined to be under the maximum permissible level of 1.5 mg/l of WHO, and they ranged from 0.08 to 0.66 and 0.2 to 0.66 during PRM and POM (2011). Although the human body needs these ions in modest amounts, when they are present in drinking water in large quantities, they can lead to a number of acute and chronic disorders. The current study evaluates the impact of water quality on ecosystem initiatives and makes use of the recently developed CCME WQI (procedure is discussed in the methodology section), which offers an easy way to summarize complicated water quality data that the general public, water distributors, planners, managers, and policymakers can easily understand. To evaluate regional and temporal changes in water quality, the CCME WQI calculator has been used in conjunction with the Canadian Water Quality Guidelines (Magesh and Chandrasekar 2011). This mechanism also, suggesting the

reliability and feasibility of using the variables, that helps in examining the apportionment of water pollution sources. The index was calculated taking into account all water quality factors. Table 2 displays the overall water quality index value for all sampling stations. According to the classifications of water quality assessed by the CCME WQI scores, the majority of the study area is classified as fair to good in the PRM and marginal to fair and fair to good in the POM. In PRM, stations like P3, P4, P2, P5, P9, and P10 indicate fair water quality, and P1, P6, P7, P8, P11, and P12 indicate good water quality. P-3, P-4, and P-9 in POM stand for marginal zone, P-2, P-11, and P-12 for fair, and P-1, P-5, P-6, P-7, P-8, and P-10 for good water quality. To identify the various water quality classifications, such as excellent, good, fair, marginal, and low at each hydro-station for drinking purposes, the spatial distribution map (Fig. 2a and b) was created using ArcGIS 10.5 software. In the case of PRM, the decline in water quality at the aforementioned locations P-3 and P-4 may be felt by domestic and industrial wastewater sources, agricultural runoff including fertilizers, and untreated water discharges. The station (P-1) in the area where the river flows through a mountainous region before approaching the Odisha belt has a good status in both periods owing to the presence of a few smaller towns on both of the river's banks and the unavailability of irrigation projects in the vicinity prior to it and surrounding the place. Owing to the river's capability to self-purify, rising water levels in its channel can also result in lower concentrations of the parameters. Major cities with dense populations grow from Station (P-1) to Station (P-12), indicating that the river's downstream has a significant effect on the water quality. The CWQI categorization indicates an overall good quality, but when it approaches the city, significant WQI alterations were noticed because of contaminating activities, encroachments, and burying activities.

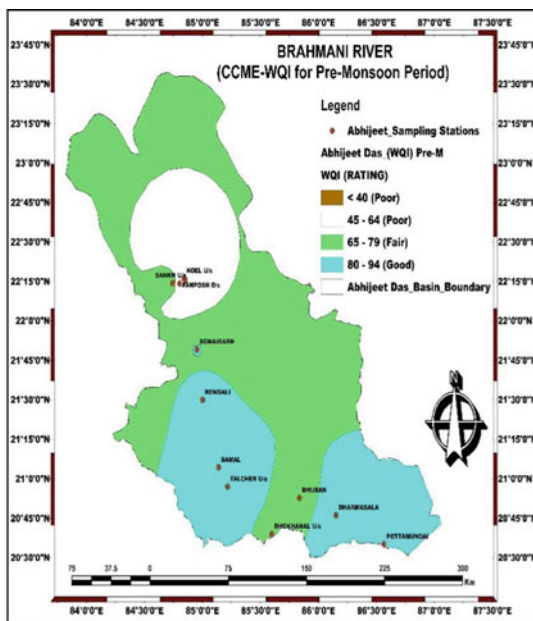
5.1 Prediction Maps

In this study, PRM and POM seasons were used to create prediction maps for 20 physicochemical variables measured from all sites for a period of 4-year timeframe, i.e. (2017–2021) along the Brahmani River. Using IDW and Arc GIS 10.5 tool, predicted maps for three anticipated stations had been created employing 12 observations. The prediction stations are Biritola, Nandira D/s, and Kabatabandha as shown in Fig. 3. The predicted values for the three stations (Fig. 4a and b) for PRM are Biritola (WQI = 69.56) indicates fair, Nandira D/s (WQI = 63.26) indicates fair, and Kabatabandha (WQI = 85.37) indicates good status whereas in POM, Biritola (WQI = 80.16), Nandira D/s (WQI = 55.22), and Kabatabandha (WQI = 78.08). Additionally, the forecast maps include information on the parameter dosages at each place along the river. Regression predictions were conducted across three measured data (observed values) and estimated values (results from predictor maps) for all variables in order to verify the values acquired from either the prediction maps developed by using the IDW and GIS connected to the Brahmani River. Overall, three sites had strong significance level for the coefficient value (R^2) among actual and predicted

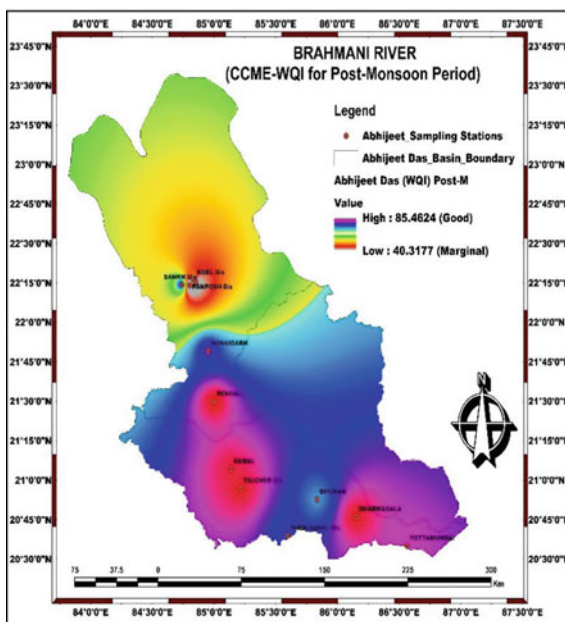
Table 2 Water quality index classification

Location no	CWQI (PRM)	CWQI status (PRM)	CWQI (POM)	CWQI status (POM)
P-1	80.48	Good	81.49	Good
P-2	70.98	Fair	74.87	Fair
P-3	39.52	Poor	45.11	Marginal
P-4	43.48	Poor	53.16	Marginal
P-5	79.44	Fair	82.84	Good
P-6	85.47	Good	84.88	Good
P-7	84.6	Good	81.2	Good
P-8	85.19	Good	84.82	Good
P-9	77.66	Fair	52.52	Marginal
P-10	75.18	Fair	83.85	Good
P-11	85.08	Good	73.71	Fair
P-12	82.02	Good	60.46	Fair

Fig. 2 CCME WQI map of the study area



(a)



(b)

values in PRM. The results (Fig. 5) showed the determination coefficient ($R^2 = 0.82$) for values during PRM is quite acceptable whereas in POM, $R^2 = 0.29$, shows weak correlation. Evidence shows that a variety of non-point inputs, including fertilizer runoff, urban runoff, toxic pollution, and trash dumping, are contaminating river water. As a corollary, these contributors lower the WQI ratings in the river.

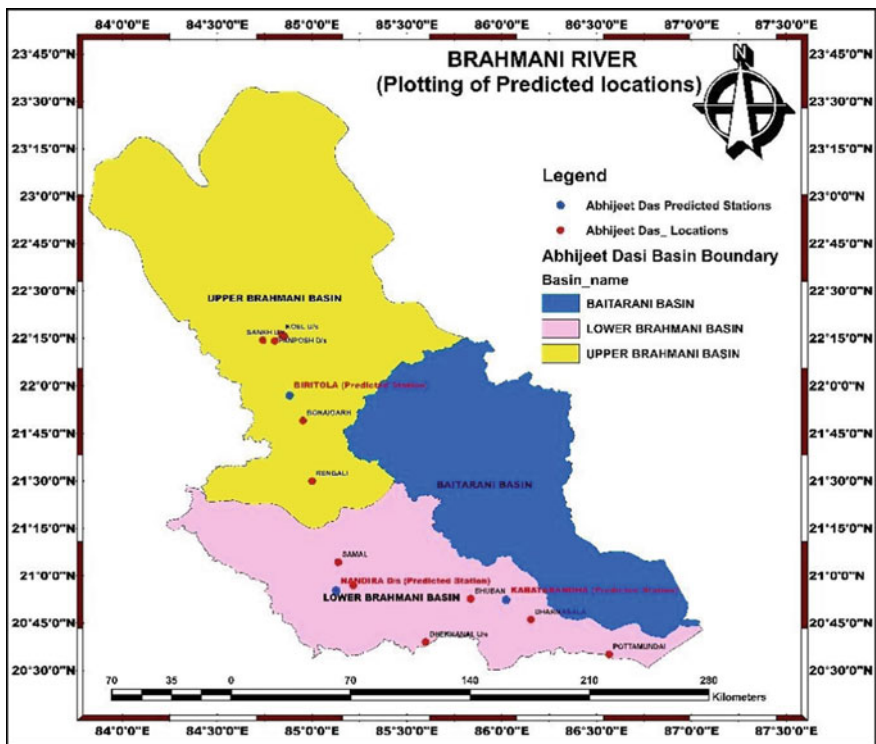
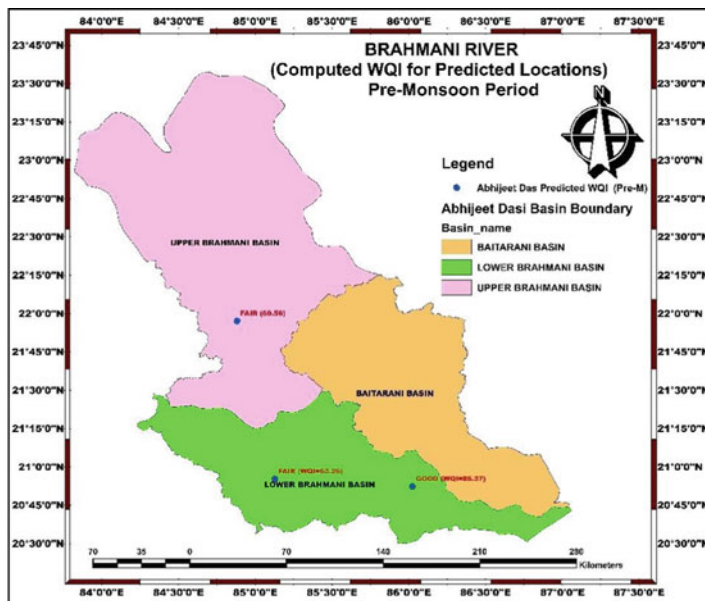
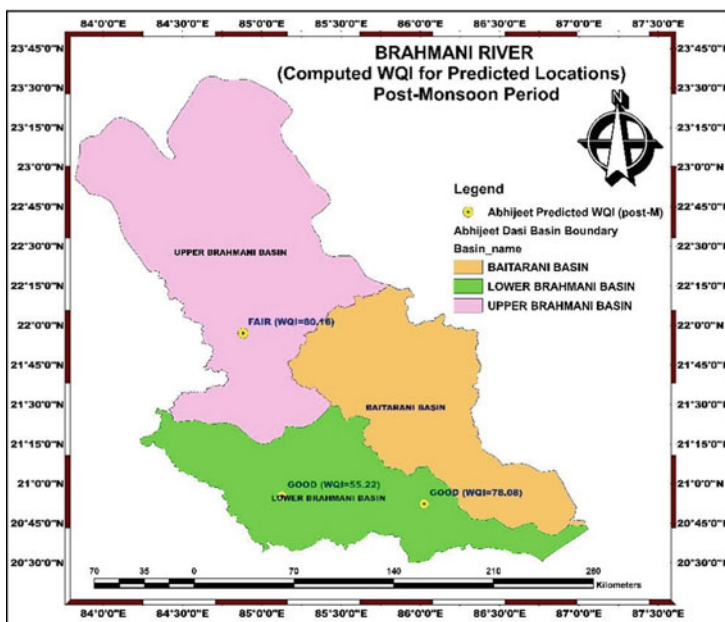


Fig. 3 Location of predicted stations



(a)



(b)

Fig. 4 Prediction map of PRM and POM season

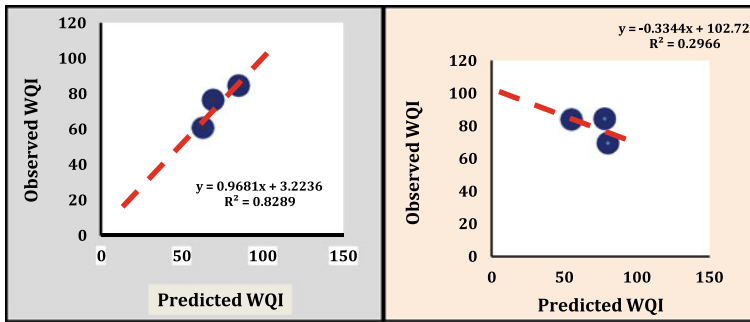


Fig. 5 Results of computed CCME-WQI and observed CCME-WQI

6 Conclusion

The latest study is a landmark in examining the water quality of one of the significant rivers in India, the Brahmani, which flows through the region of Odisha. This work, generally addresses a variety of subjects, such as pollution, and its evaluation on water quality. The collected data is combined using GIS to better illustrate the degree of pollution and its influence on public health. Twenty indices were chosen, and 12 study sites were identified. Because of its slightly alkaline composition, the river's water promotes the growth of phytoplankton. Pollutant addition to river water at several locations has raised the DO value. Excellent results were found for the water samples' BOD and COD. A few parameters like TC, TDS, TH, TA, Ca^{2+} , and HCO_3^- were identified as critical polluting parameters, which may substantially harm the health of the residents in the concerned site. It is evident from the WQI value that areas with a high TC number also have high WQI values. The input of wastewater into the basin, farmers' usage of animal manure, or irrigation of land should be the main causes of this association. On the basis of the CCME WQI scale, it is determined that over 50% of the observations in both periods fit into the good category. Hence, surface water is safe and potable in the study area except for localized pockets such as Panposh D/s and Rourkela D/s. The outcomes of the regression analysis demonstrated that, while the determination coefficients for these three values in the case of PRM were adequate, they are poor in the case of POM. The results of WQI throughout the river for Panposh D/s (P-3) and Rourkela D/s (P-4) could be negatively impacted by anthropogenic sources such as industrial pollution, untreated sewage water, municipal solid waste dumping, and vehicular emissions. With the use of a GIS tool, spatial variability mapping is a viable tactic for surveillance, maintenance, and future modelling. It conveyed potential data regarding the general pattern of water quality in the studied region. Therefore, prior to human intake, the proper treatment and remediation methods are needed. To fill more gaps in our understanding of the water quality aspects in Brahmani River, Odisha, the author may recommend future study efforts in a variety of areas. First of all, an in depth-investigation of how particular pollutants, such as pesticides, heavy metals, and

emerging contaminants, affect the water quality, would provide essential knowledge on potential risks and risk management strategies. Also, more research should be undertaken how climate change impacts water quality parameters including water temperature, DO and nutrient dynamics will also help to understand the long-term effects on the river basin.

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