A Case Study on Sustainable Tourism: Water Quality Assessment for Kaptai and Karnaphuli Areas of Chattogram, Bangladesh

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Abstract: Access to high-quality, domestic and potable water are crucial for public health, especially in areas with growing tourism, where poor water quality can lead to significant health risks, including waterborne diseases. This study evaluates the water quality in scenic areas near Chattogram, situated close to the hills and the Karnaphuli River. While Kaptai in Rangamati is a well-known tourist destination. However, visitors often rely on local water sources without being aware of potential contamination, increasing health risks. Water samples were collected from various locations around Raozan and analyzed according to World Health Organization (WHO) guidelines, Department of Environment (DoE) and the Bangladesh Environmental Conservation Rules (BECR-2023). This study will evaluate water quality using necessary indicators such as color, pH, iron (Fe) content, total dissolved solids (TDS), and turbidity. This study also focused on Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) to evaluate the Karnaphuli River's water quality. The Department of Environment's (DoE) reports and data from other comparable research were used to contextualize the analysis. Preliminary results have revealed significant variations in key water quality parameter. A multi parameter and turbidity meter have been used to measure pH, TDS and turbidity respectively. Using Geographic Information System (GIS), maps are developed to analyze water quality. This research underscores the importance of regular water quality monitoring, community awareness, and policy interventions to ensure safe water for both tourists and local residents. It supports sustainable tourism and promotes environmental stewardship in the study area.

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1. Introduction

The infrastructure and terrain of Chattogram (CTG) have been greatly altered by urbanization, but it has also led to environmental problems, most notably water contamination (Hoque et al., 2024). Alongside Chattogram, the Karnaphuli River serves as a crucial water source for the area (Karim et al., 2018) and it is essential for domestic usage, transportation, and agriculture. However, the amount of solid waste, industrial effluents, and untreated sewage that are released into rivers has increased due to the fast growth of cities. . Urban rivers have also been associated to issues with water quality because untreated household and industrial trash is frequently dumped into them, raising the concentration of hazardous metals in the water (Parvin et al., 2022).These contaminants raise the concentrations of dangerous compounds and deteriorate the quality of the water. The Karnaphuli River's pollution may have an indirect impact on Kaptai Lake due to the common hydrological systems between both water bodies. It is essential to evaluate the water quality in these areas, especially in tourist destinations, to make sure the water is suitable for drinking and domestic use. Kaptai reservoir was established with the construction of an earth dam across the Karnaphuli River in Kaptai (Karim et al., 2018). Popular tourist destination in the nearby Kaptai area is Kaptai Lake, which is susceptible to pollution from both urban and tourism-related activities. Plastics, organic garbage, and chemical residues are among the pollutants that may be introduced by the lake's overpopulation and insufficient waste management systems. Water quality is a critical factor influencing public health, environmental sustainability, and overall quality of life. Ecological balance and public health of Kaptai Lake could be at risk if such contamination is allowed to continue unchecked.

Poor water quality can pose significant health risks to both locals and tourists, undermining the region's reputation as a sustainable tourist destination. Ensuring access to safe and clean water is important in tourist destinations, where the influx of visitors increases the demand for potable and domestic water. Kaptai, one of the most renowned tourist spots in Bangladesh, is a region of significant ecological and economic importance. This study aims to assess the water quality of two different sites in the Karnaphuli River basin: the Panorama Viewpoint in the Kaptai region, a well-known tourist destination, and the Godown area in Rangunia, which is a major supply of water for drinking and domestic use. A fundamental evaluation of the water's physical quality was provided by the measurement of the physical parameters of pH, turbidity, and TDS using conventional laboratory techniques. The concentration of iron, a criterion of special significance because elevated levels can pose health hazards, was also determined by a chemical test. Since BOD only takes into account biodegradable organics, COD catches both biodegradable and non-biodegradable organics, which is why COD levels are typically greater than BOD.

Experimental

In this study, the water samples were tested for both physical and chemical parameters to determine their suitability for drinking and domestic use. The water's aesthetic and sensory qualities were evaluated by measuring physical parameters like turbidity, color, and total dissolved solids (TDS), and the presence of organic and inorganic contaminants was assessed by analyzing chemical parameters like pH, Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD). The tests were carried out according to standard procedures to ensure accurate and dependable results, and the results were compared with acceptable limits established by national and international guidelines to determine whether the water met quality standards.

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1.1 Materials

Water samples were collected for this investigation from two different locations (Fig 1):

Sample 1 (Godown Area, Rangunia): This sample was taken from the Godown area of Rangunia with the primary goal of evaluating the quality of the water for drinking and domestic use. Geographically, the collection site is located at 22°27'32.1"N and 92°01'59.6"E. This area is a significant site for assessing possible water quality issues because it is impacted by nearby residential and industrial operations.

Sample 2 (Panorama Viewpoint, Kaptai Region): A tourist spot, close to the Kaptai region, the second sample was taken from the Panorama Viewpoint tourist destination. Like Sample 1, this sample was gathered for the purpose of analyzing drinking and household water. This area is a well-liked travel destination, and the environmental factors there may have an impact on the quality of the water.

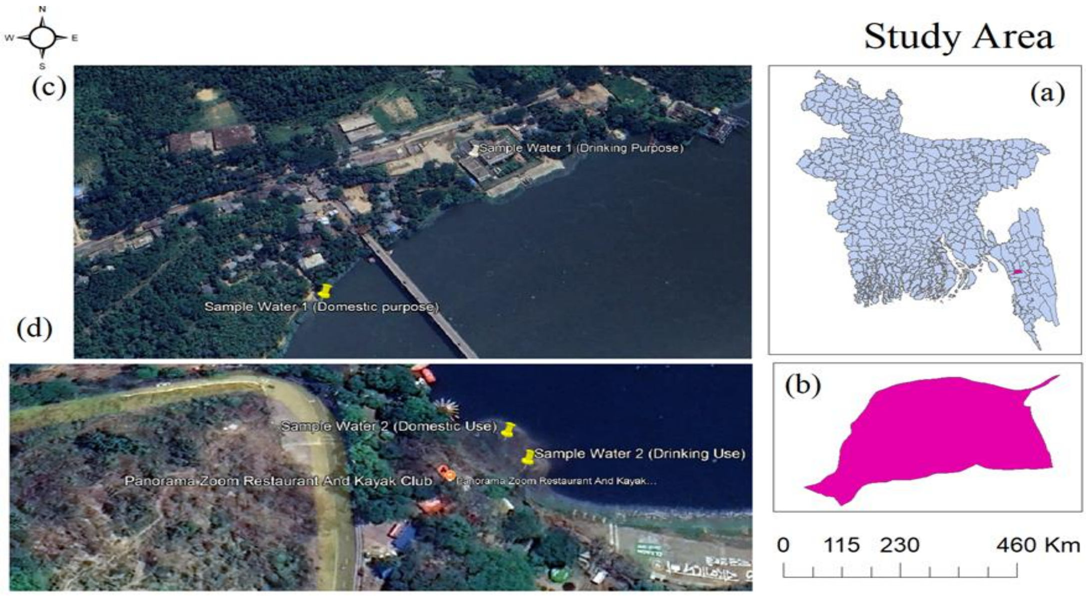

Fig 1: Study Area (Sample 1 and Sample 2)

1.2 Sample preparation

Water samples taken at the two study sites were transferred to the laboratory under controlled conditions to preserve their integrity and prevent contamination. To ensure accurate results, materials were stored in sterile, airtight containers and examined within 24 hours of collection. The water's physical and chemical characteristics were examined by a combination of chemical reaction and physical parameter testing. To ensure accuracy in the readings, calibrated analytical instruments were used to test physical parameters such as pH, turbidity, and total dissolved solids (TDS) (Baruah & Baruah, 2024). Following accepted laboratory practices, chemical tests were performed to measure the iron contents and evaluate the water's color.

1.3 Experimental procedure

Water samples were taken for this research from two different locations, two samples each location, for a total of four samples (Fig 2). Both chemical and physical parameter testing were used in the analysis.

Tests of physical parameters: A multi parameter is used to measure the pH and TDS which is a measure of the concentration of dissolved chemicals. A turbidity meter is used to measure turbidity.

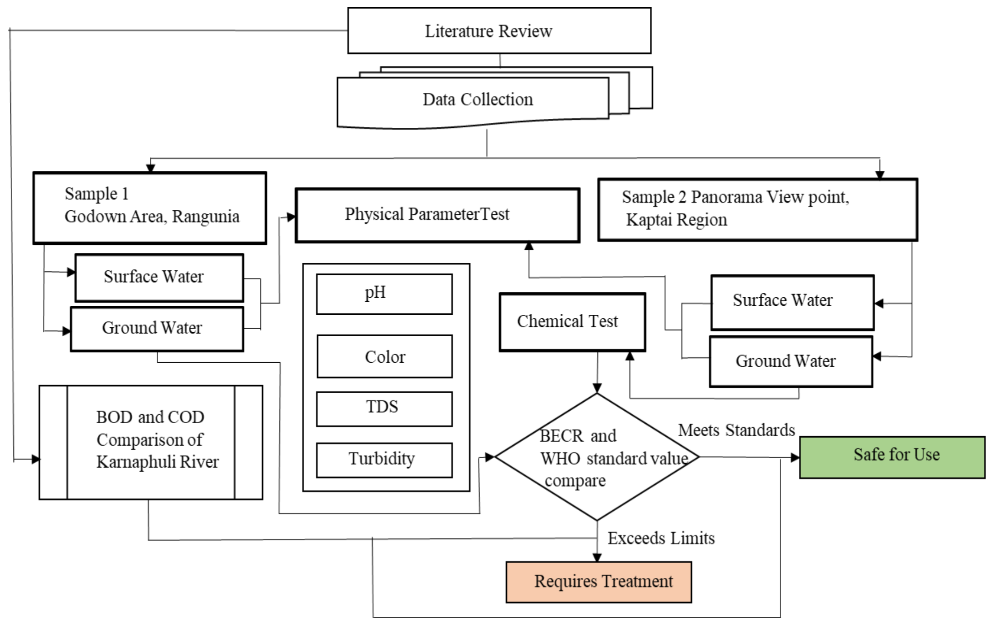

Fig 2: Adopted Methodology

Chemical Test: The iron content of the samples was measured using a conventional chemical testing method.

2. Theory

Water quality characteristics such as pH, TDS, turbidity, and iron content have a direct impact on water's safety, aesthetics, and usage. It is crucial for a well-known tourist attraction like Kaptai to keep these criteria within reasonable bounds to preserve tourists' enjoyment and protect the public's health,

Color- An important factor in assessing the quality of water is color, which can reveal the presence of metals, dissolved organic matter, or industrial pollutants. While natural color comes from decomposing vegetation and minerals, anthropogenic color can be exacerbated by wastewater discharge and industrial effluents. Water that is too colored can be unsightly, which lowers its acceptability for drinking and household use.

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pH -The pH scale, which ranges from 0 to 14, tourists that drink such water run the danger of health problems. An excessively high pH (alkaline water) can result in a harsh taste and less effective chlorine disinfection, which promotes the growth of dangerous germs. Water pH of Kaptai reservoir in rainy season varies than that in dry season in both 0.2-and 0.8-fractional depth (Karim et al., 2018).

TDS-TDS is the total concentration of dissolved materials in water, expressed in milligrams per liter (mg/L) (Fig 3), including organic matter, minerals, and salts. Water with high TDS levels may taste bitter or salty, which turns off tourists. Overly high TDS could be a sign of dangerous pollutants such heavy metals (Karim et al., 2018), which can cause health problems.

Turbidity- Turbidity is caused by suspended and dissolved organic and inorganic materials. Higher turbidity levels are expected in surface water and shallower ground water sources. Lower levels of turbidity are found in deeper groundwater.Water with high turbidity is less visually appealing to tourists.

Fig 3: (a) Turbidity, TDS, pH measurement (b) Chemical Test Ingredient (c) Iron test in drinking water sample

Iron- The concentration of iron in water is usually expressed in milligrams per liter (mg/L) dissolved iron (ferrous or ferric ions).Unnecessary iron can give water a metallic flavor and discolor garments, fixtures, and sinks, which is inconvenient for visitors. The titration method was implemented to test for iron in this study. After collecting 50 mL of samples, 2.5 mL of sulfuric acid (HCl) was added. Following the addition of two to three drops of potassium permanganate (KMnO4), the samples were shaken and it became pink. After adding 2.5 milliliters of potassium thiocyanate (KSCN), the solutions turned crystal clear (Fig 4). No iron was found when they were compared to iron-standard distilled water.No dilution was necessary in this case.

Fig 4: (a) Iron test in Drinking Water (b) Comparison with Iron Water vs Sample Water

In distilled water, a standard iron sample was also provided to recheck the sample's iron color against the standard, but the sample came out clear, indicating no iron.

BOD-The amount of oxygen needed by microorganisms to break down organic materials in water is reflected in BOD. It shows the amount of pollutants that is biodegradable. According to a 2023 research, the Karnaphuli River's BOD levels ranged from 3 mg/L to 14 mg/L (DOE, 2017). It may be deduced that the BOD values for the current analysis are in line with previous published findings because the water samples used in this investigation were taken from the same river. This range represents moderate pollution levels, which are probably caused by industrial effluents, household wastewater discharge, and other human activities near the river.

COD-The total oxygen demand needed to oxidize organic matter in water, both biodegradable and non-biodegradable, is measured by COD. It offers a comprehensive evaluation of water quality. In 2022, the BOD values for the Karnaphuli River were reported to vary between 3.0 mg/L and 21 mg/L, indicating significant variations in organic pollution levels. Similarly, in 2023, the COD values ranged from 17 mg/L to 64 mg/L, reflecting the presence of both biodegradable and non-biodegradable organic pollutants. Given that the water samples in this study are sourced from the same river, the observed BOD and COD values are consistent with these reported findings.

This study emphasizes the significance of ongoing monitoring and sustainable management strategies to ensure water safety and environmental health in tourist-heavy places such as Kaptai by comparing measured values to set recommendations and existing previous data.

3. Result and Discussions

Physical water quality indicators such as pH, turbidity, TDS, and iron content were analyzed in compliance with the BECR and WHO. DoE data for the Karnaphuli River was compared with the biological characteristics, particularly the chemical and BOD and COD. In order to make well-informed decisions on the water quality, this study examined the DoE's earlier documentation of the river's BOD and COD levels. This investigation also verified that there was no detectable iron concentration in the water samples, which supports the water's appropriateness for drinking and household use.

3.1 Units

Standard units applicable to the investigation of water quality were used to express the parameters measured in this study. Hazen units, a commonly used metric for evaluating the apparent color produced by dissolved and suspended chemicals, were employed to quantify the water's color. The pH is a dimensionless unit based on a logarithmic scale that shows how acidic or alkaline the water is. Turbidity and TDS which indicate the amount of dissolved materials and the concentration of particle matter in the water, respectively, were measured in milligrams per liter (mg/L). Likewise, indices of organic pollution, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), were also given in mg/L.

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Sample 2's physical characteristics were evaluated in Table 1 in accordance with the World Health Organization's (WHO) recommendations for drinking, and the Bangladesh Environment Conservation Rules (BECR) 2023 standards for domestic use.

Physical Parameter Test	Sample 1 (Domestic Purpose)	BECR-2023	Sample 1 (Drinking Purpose)	WHO Guidelines
Color	5 Hazen Unit	15 Hazen Unit	2.34 Hazen Unit	15 Hazen Unit
pH	7.20	6.5-8.5	7.30	6.5-8.5
Turbidity	2.41 NTU	10 NTU	1.17 NTU	5 NTU
TDS	50 mg/L	1000 mg/L	70 mg/L	1000 mg/L

Table 1: Sample 1 Laboratory Test Results

Sample 2's physical characteristics were evaluated in Table 2 in accordance with the World Health Organization's (WHO) recommendations for drinking, and the Bangladesh Environment Conservation Rules (BECR) 2023 standards for domestic use.

Physical Parameter Test	Sample 2 (Domestic Purpose)	BECR-2023	Sample 2 (Drinking Purpose)	WHO Guidelines
Color	4.0 Hazen Unit	15 Hazen Unit	3.5 Hazen Unit	15 Hazen Unit
pH	7.31	6.5-8.5	7.30	6.5-8.5
Turbidity	1.81 NTU	10 NTU	1.19 NTU	5 NTU
TDS	60mg/L	1000 mg/L	50 mg/L	1000 mg/L

Table 2: Sample 2 Laboratory Test Results

The Department of Environment's (DoE) 2023 report on BOD (3-14 mg/L) and COD (17-64 mg/L) values in the Karnaphuli River provides a solid baseline for assessing water quality. It is anticipated that our water samples, which were taken at the same time, will closely match these levels. The water's physical wellness for drinking and domestic use is confirmed by the lack of iron and the BOD and COD values matching DoE's 2023 data. These results highlight how crucial sustainable practices are to preserving the Karnaphuli River's water quality, especially in tourist-heavy places like Kaptai. These ranges demonstrate how human activities, such the release of industrial and domestic trash, affect the quality of the river. There were no measurable levels of iron in the drinking water samples from the Godown area in Rangunia or the Panorama Viewpoint near Kaptai region, according to the results of the iron test. These results are consistent with the BECR and WHO drinking water safety criteria. As a result, the iron level of the water is deemed ideal for human consumption.

4. Conclusion

Increased human activity in the area, poor waste management, and urban runoff could all be contributing factors to this contamination. Even while some water bodies may still be appropriate for recreational use, safety for drinking and other household uses depends on routine monitoring and efficient water treatment measures.

According to the results of the water quality examination performed on samples taken from the Godown neighborhood in Rangunia and the Panorama Viewpoint in the Kaptai district, the water is safe for drinking and household use. It was discovered that all of the assessed parameters—pH, turbidity, color, total dissolved solids (TDS), and iron content—were within the permissible values specified by Bangladeshi water quality guidelines. This suggests that the water quality in these locations is still appropriate for usage by both locals and visitors, notwithstanding any anthropogenic and environmental impacts. These results are important for preserving Kaptai's sustainability and standing as a top travel destination by guaranteeing that both tourists and the local population have access to clean, safe water.

Acknowledgment

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