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Contamination of Heavy Metals in Water, Sediments and Fish-Focusing Kirtankhola River Pollution

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Abstract: River water plays a vital role in various sectors such as domestic, agricultural, and industrial activities in Bangladesh. However, recent research indicates that the condition of river water is concerning. This study aimed to assess the pollution levels and heavy metal contamination in both water and fish species inhabiting the Kirtankhola River. Sampling was conducted at three designated sites, labeled as Sampling Site 1, Sampling Site 2, and Sampling Site 3. Physicochemical parameters including temperature, transparency, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), alkalinity, and concentrations of heavy metals (Pb, Cr, Cd, Cu, Ni, Zn) in water, as well as in three fish species (*Tenualosa ilisha*, *Otolithoides pama*, and *Polynemus paradiseus*), were analyzed. The findings revealed that temperature and pH levels were in close proximity to standard values. The average values for temperature, transparency, pH, TDS, EC, DO, BOD, and alkalinity were (25.23±0.46), (32.33±1.53), (7.57±0.10), (214±7.94), (351.67±3.51), (3.47±0.25), (3.9±0.31), and (103.3±5.69), re-spectively. Additionally, the average concentrations of Pb, Cr, Cd, Ni, Zn, and Cu in water were (0.02±0.004 mg/L), (0.01±0.002 mg/L), (0.01±0.002 mg/L), (0.034±0.02mg/L), (0.02±0.07 mg/L), and (0±0 mg/L), respectively. Furthermore, the concentrations of Pb, Cd, Cr, Cu, Ni, and Zn in *Tenualosa ilisha*, *Otolithoides pama*, and *Polynemus paradiseus* fish species were assessed, revealing values of (0.22, 0.17, 0.19, 0, 0.31, 0.49 mg/L), (0.25, 0.21, 0.17, 0, 0.25, 0.58 mg/L), and (0.27, 0.23, 0.22, 0, 0.29, 0.48 mg/L), respectively. Notably, the Zinc content in fish species (0.58 mg/L) exceeded acceptable limits, while the Copper content (0 mg/L) remained below. In conclusion, the findings suggest that the water quality of the Kritankhola River is moderately polluted, empha-sizing the urgent need for measures to safeguard its aquatic ecosystem.

1. Introduction

Water, a fundamental element of the environment, is essential for sustaining life worldwide. However, the pervasive pollution resulting from human activities poses a significant threat to water bodies, with rivers particularly affected by industrial discharge, municipal waste, and agricultural runoff (Chapman, 1996; Daily, 2004; De, 2005; Ellis *et al.*, 1946; Foisal *et al.*, 2004; Alaqarbeh *et al.*, 2022; Boutebib *et al.*, 2023). Bangladesh, amid rapid industrialization and population growth, confronts substantial water pollution challenges, prominently exemplified by untreated waste discharge into its rivers, notably the Kritonkhola River (Abida & Harikrishna, 2008; Ahmed *et al.*, 2012; Alam *et al.*, 2003). The contamination of heavy metals stands as a significant concern for water quality, originating from geological processes, industrial operations, improper waste disposal, and agricultural activities (Alam *et al.*, 2007; Ideriah *et al.*, 2012). These hazardous substances, including cadmium, chromium, and lead, accumulate in aquatic ecosystems, presenting risks to wildlife and human health. In Bangladesh, intensified agriculture exacerbates pollution, as excessive fertilizer and chemical usage lead to runoff into water bodies like the Kritonkhola River (EQS, 1997; Faisal *et al.*, 2004). Fish, crucial for food security and economic sustenance, serve as vital indicators of freshwater ecosystem pollution (Ellis *et al.*, 1946; Forti *et al.*, 2011; Nasri *et al.*, 2021). The Kritonkhola River, once abundant in fish, now witnesses declining populations and deteriorating water quality due to agricultural runoff and industrial pollution (Alam *et al.*, 2003; Ahmed *et al.*, 2009; Karim *et al.*, 2016). An understanding of heavy metal contamination in fish tissues is imperative for evaluating food safety and ecological integrity (Ahmed *et al.*, 2010; Bakali *et al.*, 2014). This study aims to assess water quality and heavy metal concentrations in fish from the Kritonkhola River. By examining contamination levels in water, sediments, and fish tissues, it seeks to provide insights into the river's ecological health and the suitability of fish species as pollution bio-indicators (Abida & Harikrishna, 2008; Alam *et al.*, 2007). This research is critical for informing policymakers and stakeholders about the urgent necessity for sustainable water management practices to safeguard both ecosystems and public health (Daily Star, 2004; Hadiuzzaman *et al.*, 2006; Elmouaden *et al.*, 2015). As water is indispensable for all life forms and various human activities, increasing population, industrialization, and urbanization exacerbate global water pollution concerns (Bolger *et al.*, 2000; FAO/WHO, 1984). Pollutants from agricultural, municipal, and industrial sources contaminate water bodies, endangering ecosystems and human health alike (Alam *et al., 2007;* Chaerun *et al.*, 2004). The Kritonkhola River in Bangladesh confronts severe pollution due to untreated wastewater discharge, industrial effluents, and inadequate waste management practices (Arfin *et al.*, 2014; Ahmed *et al.*, 2009). This pollution jeopardizes aquatic life and the livelihoods of communities reliant on the river (Ahmed *et al.*, 2009; EQS, 1997). Physio-chemical parameters such as pH, dissolved oxygen, and heavy metal concentrations serve as crucial indicators of water quality, underscoring the urgent need for conservation and sustainable management efforts (Islam *et al.*, 2014; Islam *et al.*, 2012; Islam *et al.*, 2020; Islam *et al.*, 2021). This research delves into the multifaceted aspects of water quality assessment, encompassing a range of physical and chemical parameters pivotal for evaluating environmental health and human well-being (Islam *et al.*, 2015; Islam *et al.*, 2010). It scrutinizes properties such as color, odor, taste, temperature, turbidity, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), electrical conductivity (EC), and alkalinity (Islam *et al.*, 2021; Rahman *et al.*, 2016; Hanif *et al.*, 2020; Tuhin *et al.*, 2024). Moreover, it highlights the looming threat posed by heavy metal contamination in water bodies, stemming from diverse anthropogenic sources (Alam *et al.*, 2007; Ideriah *et al.*, 2012). The detrimental impact of heavy metals on aquatic ecosystems and human health is emphasized, particularly their bioaccumulation in fish and subsequent toxicological implications (De 2005; Ahmed *et al.*, 2010). The research advocates for stringent monitoring and effective management strategies to mitigate contaminant proliferation, safeguarding both aquatic biodiversity and public health. In essence, it advocates for a comprehensive approach to water quality management, integrating scientific assessment, regulatory frameworks, and public awareness initiatives to mitigate pollution's adverse effects and ensure the sustainable utilization of this indispensable resource (Alam *et al.*, 2003; Faisal *et al.*, 2004).

2. Methodology

2.1. Water sample collection

The study was conducted along the Kirtankhola River in the Barishal district. Each study area was divided into three sampling locations, designated as Sampling Site 1, Sampling Site 2, and Sampling

Site 3 (refer to Fig. 1). Table 1 provides details of the location names, latitude, and longitude within the study area.

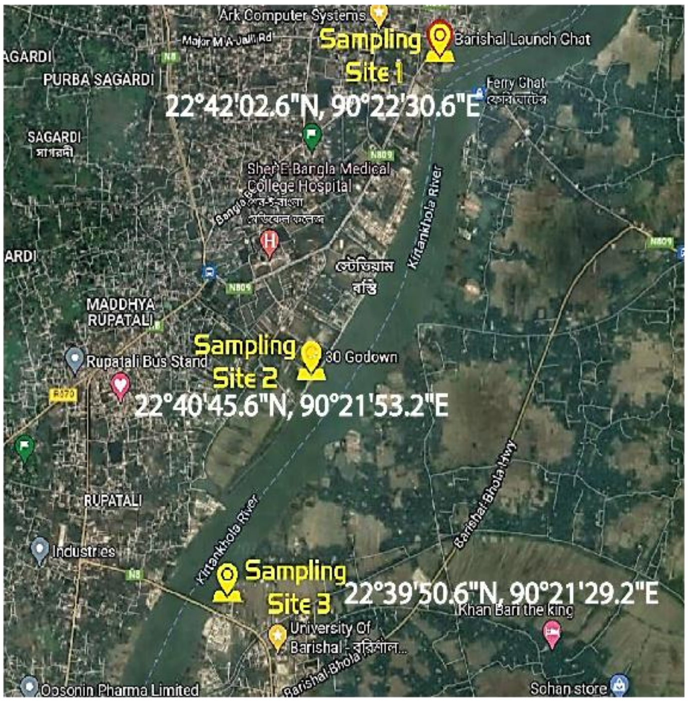


Figure 1: Map showing the study sites and three sampling locations in the Kirtankhola River (Source: Google Earth satellite image, 2023).

To ensure the integrity of the samples, rigorous protocols were followed during col-lection and transportation. Prior to sampling, all equipment was thoroughly cleaned with acid and distilled water. Additionally, nitric acid solution was used to prevent fungal contamination (Abida & Harikrishna 2008). Samples were promptly sealed upon collection, labeled with relevant information including date, location, and ID, and transported in an icebox to the Environmental Science laboratory (Alam *et al.*, 2007). Upon arrival at the laboratory, the samples underwent filtration and were stored under appropriate conditions to maintain their integrity. Samples earmarked for heavy metal analysis were subsequently forwarded to the Analytical Laboratory for further processing and assessment (Ahmed *et al.*, 2010).

2.2. Collection of Fish sample

In this study, three fish species were collected from the Kirtankhola River in October: Tenualosa ilisha, Otolithoides pama, and Polynemus paradiseus. These fish were ob-tained directly from local fishermen operating in the area (Ahmed *et al.*, 2007). Upon collection, the samples were carefully transported to the laboratory using an icebox to maintain their freshness and integrity (Islam *et al.*, 2014; Tuhin *et al.*, 2024). In the laboratory, the fish samples were immediately stored in a freezer to preserve them for precise analysis (Ahmed *et al.*, 2009; Rahman *et al.*, 2016). This ensured that the samples remained in optimal condition for subsequent examination and assessment.

2.3. Analysis of Sample

The water samples collected from the Kirtankhola River underwent a comprehensive analysis covering various physicochemical parameters, including color, odor, temperature, transparency, pH, dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TDS), electrical conductivity (EC), and alkalinity (Alam *et al.,* 2003; Ahmed *et al.,* 2009; Islam *et al.,* 2021). This extensive examination aimed to assess the water quality and identify potential pollutants present in the samples (Chapman 1996). Analyzing these parameters is vital for gaining insights into the environmental health of the Kirtankhola River, pinpointing sources of contamination or pollution, and ensuring effective management strategies (Bolger *et al.*, 2000).

Subsequent analysis of both the water and fish samples revealed the presence of several heavy metals, namely Lead (Pb), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Copper (Cu), and Zinc (Zn) [16]. The detection of these heavy metals signals potential contamination of the aquatic environment, posing threats to both aquatic organisms and human health (De, 2005). These heavy metals have the capacity to accumulate and magnify in the food chain through processes like bioaccumulation and biomagnification (Ellis, 1994). Consequently, monitoring and managing these heavy metal pollutants are imperative to protect the ecosystem and guarantee the safety of water resources and aquatic life within the Kirtankhola River (EQS, 1997).

- **Physicochemical parameters of water sample**

The assessment of water quality involves a meticulous examination of various physi-cochemical parameters, each offering valuable insights into the environmental health of aquatic ecosystems (FAO/WHO, 1994). Through careful observation and measurement, essential characteristics such as color, odor, temperature, transparency, dissolved oxygen (DO), biological oxygen demand (BOD), total dissolved solids (TDS), electrical conductivity (EC), pH, and alkalinity are evaluated (Forti *et al.*, 2011; Islam *et al.*, 2021).

Color and odor are assessed through direct observation and sensory perception, providing initial indicators of water quality (Garcia-Leston *et al.*, 2010; Islam *et al.*, 2015). Temperature measurements offer crucial insights into thermal conditions, influencing various biological processes and habitat suitability (Islam *et al.*, 2015).

Transparency, a key parameter, is calculated using the Secchi disc method, where light penetration is measured as the average of the depths at which the disc disappears and reappears (Islam *et al.*, 2012, 2014). The concentration of dissolved oxygen (DO) is vital for supporting aquatic life, with low levels indicating potential pollution or ecosystem stress (Islam *et al.*, 2010). DO levels were determined using a digital DO meter. BOD, a measure of organic matter decomposition, highlights the oxygen demand re-quired for microbial breakdown, often used to assess water pollution levels (Islam *et al., 2012*). BOD values were calculated based on the difference in DO levels before and after a specified incubation period.

Total dissolved solids (TDS) were measured using a digital TDS meter, providing in-sights into the concentration of dissolved substances in the water (Alam *et al.,* 2007). Electrical conductivity (EC) measurements provide information on water salinity and ion concentration, affecting aquatic organisms and ecosystem dynamics (Ahmed *et al.*, 2009). EC values were measured using a digital EC meter. pH levels indicate water acidity or alkalinity, influencing chemical reactions and biological processes crucial for aquatic life. pH measurements were conducted using a pH meter, with pH7 representing neutrality. Alkalinity, measured through titration methods, indicates water's buffering capacity against pH changes, essential for maintaining stable aquatic environments (Alam *et al.,* 2007). Each parameter's assessment is crucial for understanding water quality dynamics and informing management decisions to preserve and protect freshwater resources for future generations.

- **Analysis of heavy metals in water sample**

In the meticulous analysis of water quality, the detection of heavy metals plays a crucial role in understanding environmental health and potential risks to ecosystems and human health (Bakali *et al.*, 2014). To unveil the presence and concentration of heavy metals such as Lead (Pb), Chromium (Cr), Cadmium (Cd), Copper (Cu), Nickel (Ni), and Zinc (Zn), a precise methodology is employed (Chaerun *et al.*, 2004; Tuhin *et al.*, 2024; Islam *et al.*, 2021; Hanif *et al.* 2020; Islam *et al.*, 2020; Rahman *et al.*, 2016).

Initially, a 100 ml water sample is carefully collected and placed into a beaker. Then, 4 ml of nitric acid (HNO_3) is added to the sample to initiate the preparation process. The solution undergoes meticulous mixing and a controlled evaporation process on a hot plate until its volume reduces to 50 ml. Subsequently, the concentrated sample is transferred into a 100 ml volumetric flask and further diluted with distilled water to achieve a final volume of 100 ml (Afrin *et al.*, 2014).

This meticulously prepared sample serves as the foundation for the subsequent anal-ysis of heavy metals, which is conducted using an Atomic Absorption Spectrophotometer (AAS) (Islam *et al.*, 2012). This sophisticated analytical instrument accurately determines the concentrations of Pb, Cr, Cd, Cu, Ni, and Zn, providing insights into potential pollutants and their impact on water quality (Ellis *et al.*, 1946). Through such meticulous procedures, environmental scientists can unravel vital insights into the health of aquatic ecosystems and make informed decisions to safeguard our precious water resources (Islam *et al.*, 2015).

- **Method of fish sample analysis**

The analysis of the digested fish samples involves the utilization of atomic absorption spectrophotometry, a highly precise analytical technique commonly employed for the determination of heavy metals. In this method, the digested samples undergo analysis using an atomic absorption spectrophotometer, specifically the PG-990 model manufactured in England (Bolger *et al.*, 2000). The procedure follows the guidelines outlined by the Association of Official Analytical Chemists (AOAC), 18th edition, ensuring standardization and accuracy in the analytical process (Chapman 1996). Prior to analysis, standard solutions of the elements of interest are meticulously prepared to establish calibration curves necessary for quantitative analysis (Chaerun *et al.*, 2004).

During the analysis, the digested samples are diluted to three different concentrations, enabling the generation of calibration curves that facilitate accurate quantification of heavy metal concentrations. Through atomic absorption spectroscopy, precise measurements of metal content in the samples are obtained, providing valuable insights into the composition and potential contaminants present in the fish samples (Daily Star, 2004). This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

- **Heavy metal analysis in fish sample**

In the comprehensive analysis of heavy metal content in fish samples, a meticulous process is undertaken to ensure accurate results and to assess potential risks to human health from consuming contaminated fish. Initially, fish samples are collected from designated locations and preserved by freezing to maintain their integrity. Subsequently, the samples undergo meticulous cleaning to remove any external contaminants that could interfere with the analysis (De, 2005; Ellis *et al.*, 1946; Rahman *et al.*, 2016).

Once cleaned, a small portion of the fish muscle is carefully weighed and subjected to a drying procedure. This can be achieved either by placing the sample in a 100°C oven overnight or by using a microwave oven for rapid drying (EQS, 1997). After drying, the muscle portion undergoes further treatment on a hot plate until smoking ceases. It is then placed in a furnace set at 525°C for a specified duration to obtain ash that is free from carbon. Although the ash may contain carbon particles, they are effectively removed by wetting the ash with water and adding a precise amount of nitric acid (HNO_3) (Faisal *et al.*, 2004; FAO/WHO, 1984). The treated sample is then dried again on a hot plate before being returned to the furnace for additional processing.

Through this meticulous procedure, the fish sample is transformed into a suitable form for heavy metal analysis, ensuring accurate and reliable results. This methodical approach enables researchers to comprehensively assess the heavy metal content in fish samples, contributing valuable insights into environmental contamination and potential health risks associated with consuming contaminated fish (Forti *et al.*, 2011).

- **Digestion of sample**

In the process of sample digestion, a precise methodology is employed to ensure the accurate preparation of samples for laboratory analysis. Initially, a measured quantity of the sample, typically 10 grams, is placed in an open beaker. Subsequently, 10 ml of freshly prepared nitric acid is added to the beaker, and the mixture is covered with a watch glass to contain the initial reaction, allowing it to subside over approximately one hour (Garcia-Leston *et al.*, 2010). Following this, the beaker is carefully placed on a hot plate, and the temperature is gradually increased to 160°C. The contents are then gently boiled for approximately two hours to reduce the volume to a range between 2-5 ml, ensuring optimal concentration for subsequent analysis. After cooling, the digested sample is transferred to 50 ml volumetric flasks and diluted to the mark with distilled or deionized water.

This meticulous procedure ensures the thorough digestion of the sample and the preparation of a homogeneous solution suitable for laboratory analysis. The digested fish sample is then stored in plastic bottles to preserve its integrity until further analysis is conducted, allowing for accurate assessment of its composition and potential contaminants (Hadiuzzaman *et al.*, 2006).

- **Data processing and analysis**

Following the culmination of data collection, a meticulous process of data processing and analysis was initiated. Initially, all gathered data points were carefully compiled, tabulated, and organized for systematic analysis. Utilizing statistical tools, including univariate techniques such as mean, median, and mode, the data underwent comprehensive analysis to identify key variables and trends.

Statistical analysis of the chemical analysis data from water samples was conducted using a scientific calculator, ensuring accuracy and precision in the calculations (Ideriah *et al.*, 2012; Islam *et al.*, 2014). Subsequently, the collected data were coded and entered into Microsoft Office Excel 2016 software for further analysis and presentation (Islam *et al.*, 2015).

Incorporating various statistical methods, the data were analyzed to uncover patterns, correlations, and insights relevant to the study objectives. Moreover, advanced statis-tical tools facilitated the interpretation of complex datasets, aiding in the identification of significant findings (Islam *et al.*, 2012).

The analyzed data were then synthesized and presented in a comprehensive manner, utilizing visual aids such as maps, tables, and graphs to enhance clarity and comprehension. This facilitated the effective communication of research findings, enabling stakeholders to gain valuable insights from the study outcomes. Ultimately, the culmination of these efforts resulted in a detailed report, encapsulating the key findings and implications of the research (Islam *et al.*, 2010). The process of sample digestion, a precise methodology is employed to ensure the.

- **Statistical analysis of data**

For the statistical analysis of the data, Microsoft Excel 2016 software was utilized, providing a robust platform for thorough examination. The collected data underwent meticulous scrutiny, with statistical tests and procedures applied to extract meaningful insights (Islam *et al.*, 2012). Utilizing Excel's analytical features, the data were organized, processed, and analyzed to uncover underlying patterns, trends, and relationships (Ahmed *et al.*, 2009). The findings of the study were methodically presented through charts and tabular forms, facilitating clear visualization and interpretation of the results. Through comprehensive tabulation and compilation, the data were structured in a manner conducive to rigorous statistical analysis. Various statistical techniques were applied to assess the significance of the findings and draw meaningful conclusions (Alam *et al.*, 2003; Alam *et al.*, 2007).

The utilization of MS Excel 2016 enabled researchers to conduct a comprehensive statistical examination, ensuring accuracy and reliability in the interpretation of the collected data. By subjecting the data to rigorous analysis, researchers could effectively evaluate hypotheses, identify trends, and derive valuable insights pertinent to the re-search objectives (Alam *et al.*, 2007). Ultimately, the statistical analysis conducted using Excel contributed to the robustness and credibility of the study, allowing for the dissemination of accurate and informative findings (Ahmed *et al.*, 2009).

3. Results and Discussion

An overview of the analysis results and findings regarding the water quality parameters and heavy metal concentrations in both water and fish from the Kirtankhola River is presented below. The physicochemical parameters of the river water, derived from the analysis, are summarized in Table 1. Water samples were collected from three designated sampling points along the river, labeled S1, S2, and S3, while fish samples were procured using a similar approach (Abida & Harikrishna 2008; Ahmed *et al.*, 2012; Alam *et al.*, 2007).

Table 1: Physicochemical Parameters of water samples of Kirtankhola River

Parameters	**Kirtankhola river**			
	S_1	**S_2**	**S_3**	**Mean±SD**
Temperature (°C)	25.50	24.70	25.70	25.23±0.46
Transparency (cm)	32	31	34	32.33±1.53
pH	7.6	7.45	7.65	7.57±0.10
TDS (mg/L)	205	217	220	214±7.94
EC (µS/cm)	355	352	348	351.67±3.51
DO (mg/L)	3.50	3.70	3.20	3.47±0.25
BOD (mg/L)	4	3.6	4.2	3.9±0.31
Alkalinity (mg/L)	97	105	108	103.3±5.69

3.1. The physicochemical parameters of water Sample

The physicochemical parameters of water from the Kirtankhola River were evaluated across three sampling sites. The color of the water ranged from colorless to grey-blueish grey, meeting WHO standards for fish and irrigation purposes. Odor, another significant parameter, was assessed as tolerable across all sampling points. According to WHO guidelines, water should be odorless. The summarized findings, along with other physicochemical parameters, are detailed in Table 2 for references (Bolger *et al.*, 2000; Chapman, 1996; EQS, 1997; Tuhin *et al.*, 2024; Islam *et al.*, 2021). The analysis of water quality parameters in the Kirtankhola River revealed several key findings (Figure 2). Firstly, the mean temperature across the three sampling points ranged from 24.7°C to 25.5°C, meeting various international standards for aquatic life and household activities. The temperature showed seasonal variations, with higher values recorded in summer and lower values in winter, which can impact oxygen solubility and metabolic activities of aquatic organisms (Abida & Harikrishna, 2008; Afirn *et al.*, 2014). Secondly, transparency levels ranged from 31 cm to 34 cm, slightly below the WHO standard of 40 cm. However, the transparency was within the acceptable range for fish culture, indicating a suitable environment for aquatic life. Seasonal variations in transparency were observed, with higher values in winter and summer due to decreased runoff and floodwaters (Alam *et al.*, 2003, 2007). Thirdly, pH levels ranged from slightly acidic to alkaline, with values ranging from 7.45 to 7.65 across the sampling points. These values fell within the acceptable range for diverse uses such as irrigation and domestic purposes. However, fluctuations in pH can impact the concentrations of other substances in water, potentially affecting aquatic organisms (Ahmed *et al.*, 2009, 2010).

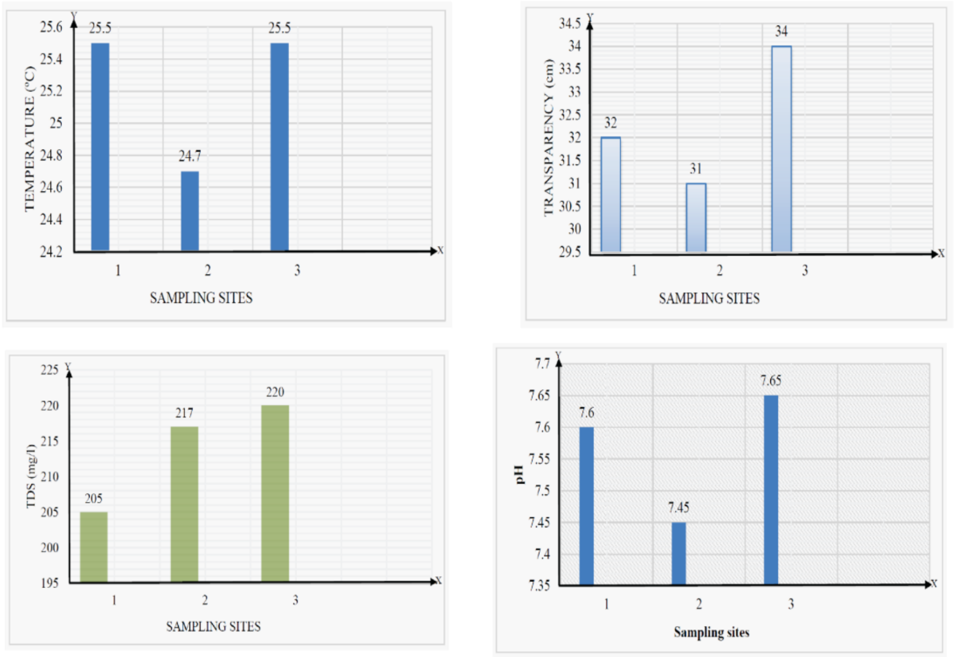


Figure 2: Physical Parameters of water samples (Temp, Trans, TDS, pH)

The investigated TDS level of three sampling points of the Kirtankhola River were 205, 217, 220 mg/L respectively (Figure 3). TDS mainly indicates the presence of various kinds ofminerals like ammonia, nitrate, phosphate, alkalis, some acids, sulphates, and metallicions, etc., which comprised both colloidal and dissolved solids in water. TDS levels were within acceptable limits, indicating low pollution levels but increasing trends over time.Elevated TDS levels can impact taste, hardness, and water corrosiveness (Abida & Harikrishna, 2008; Ahmed *et al.*, 2009; Alam *et al.*, 2007; Islam *et al.*, 2020). Overall, the results suggest that the Kirtankhola River provides a conducive environment for aquatic life, with temperature, transparency, and pH levels within acceptable limits. However, continued monitoring and management are essential to ensure the long-term health and sustainability of the river ecosystem (Ahmed *et al.*, 2007; Alam *et al.*, 2009). The analysis of physicochemical parameters in the

Kirtankhola River provided valuable insights into water quality and its suitability for various uses. Electrical conductivity (EC) values were observed to be 355, 352, and 348 µS/cm at the three sampling points, with the lowest value recorded at site 3 and the highest at site 1. Fluctuations in EC values across sampling points and seasons were noted, reflecting variations in overall ionic species in the water. High EC values have the potential to affect seed germination and crop yields (Afrin *et al.*, 2014; Bakri *et al.*, 2014). Dissolved oxygen (DO) levels ranged from 3.50 to 3.70 mg/L across the sampling points, with higher values observed in winter and lower values in the monsoon, and intermediate values in the summer season. However, DO levels were below standard limits, primarily due to pollution from municipal sewage, industrial effluents, and agricultural activities, posing risks to aquatic life and fish culture (Chaerun *et al.*, 2004; Daily Star, 2004; Tuhin *et al.*, 2024; Hanif *et al.*, 2020). Biochemical Oxygen Demand (BOD) values varied among the sampling points,with values of 4.0, 3.6, and 4.2 mg/L recorded. These values indicated moderate pollution levels, influenced by industrial and domestic wastewater discharge. While BOD levels were near standard limits, high values can lead to the depletion of dissolved oxygen, impacting aquatic ecosystems (Ellis *et al.*, 1946; Faisal *et al.*, 2004). Alkalinity values ranged from 97 to 108 mg/L across the sampling points, with the lowest value observed at site 1 and the highest at site 3. Alkalinity levels were within permissible limits, primarily influenced by CO_2. Increasing trends in alkalinity suggest potential changes in water quality over time (De, 2005; FAO/WHO, 1984).

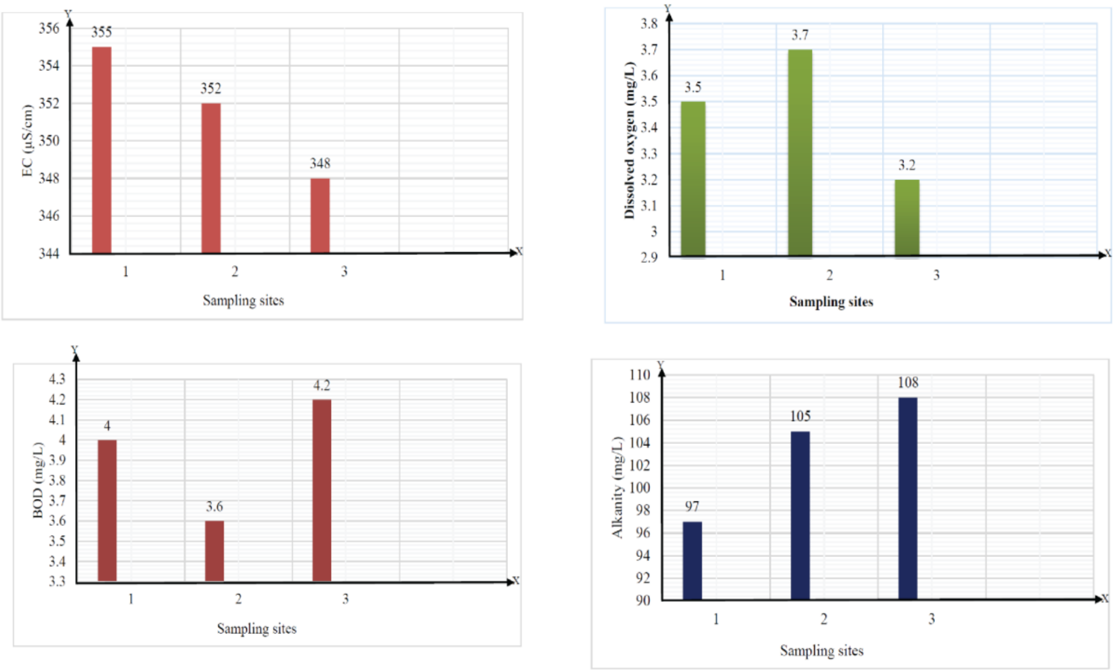


Figure 3: Physical Parameters of water samples (Temp, Trans, TDS, pH)

Overall, while some parameters met standard requirements, others indicated moderate pollution levels, highlighting the importance of continued monitoring and management to ensure the long term health of the Kirtankhola River ecosystem (Forti *et al.*, 2011; Hadiuzzaman *et al.*, 2006; Islam *et al.*, 2014).

3.2. Heavy Metals in Water Sample

The heavy metal concentrations in water samples collected from the Kirtankhola River in the Barishal region have been meticulously analyzed, revealing important insights into potential environmental concerns. At Sampling Site 2, elevated concentrations of Lead (Pb), Chromium (Cr), Cadmium (Cd), and Nickel (Ni) were observed, indicating a localized source of contamination or higher anthropogenic activities in that area (Figure 4). The concentration of Lead exceeded the WHO standard value of 0.02 ppm, likely due to the discharge of industrial effluents into the river. Elevated Lead levels can lead to adverse health effects such as anemia, kidney diseases, and nervous disorders (Garcia-Leston *et al.*, 2010).

Table 2: Heavy Metals in water samples of Kirtankhola River

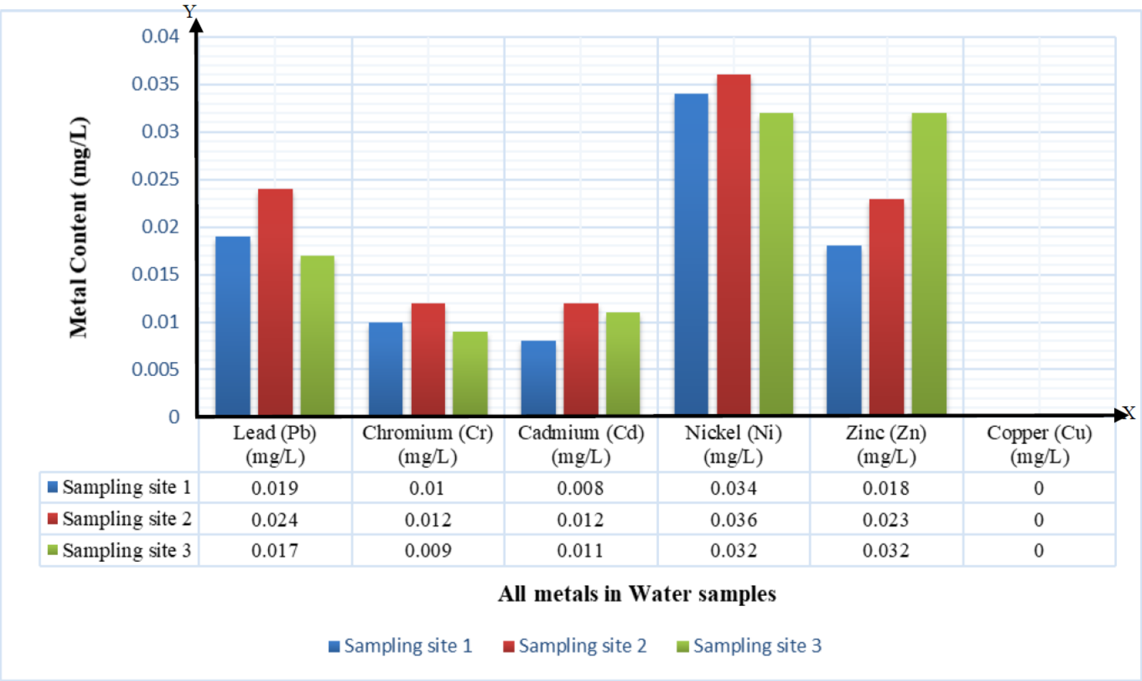
Parameter	**Kirtankhola river (mg/L)**			
	S_1	**S_2**	**S_3**	**Mean±SD**
Pb	0.019	0.024	0.017	0.02±0.004
Cr	0.010	0.012	0.009	0.01±0.002
Cd	0.008	0.012	0.011	0.01±0.002
Ni	0.034	0.036	0.032	0.034±0.002
Zn	0.018	0.023	0.032	0.02±0.007
Cu	0	0	0	0±0

Chromium concentrations varied across sampling sites, with the highest concentration recorded at Sampling Site 2. The presence of tannery and textile effluents may contribute to the alteration of water quality in the Kirtankhola River (Afrin *et al*., 2014). Although the concentration of Cadmium exceeded the standard value for drinking water, it remained within acceptable limits for aquaculture. However, fluctuations in Cadmium concentrations were noted between rainy and dry seasons, indicating potential seasonal variations influenced by environmental factors (Ahmed *et al*., 2010).

Nickel concentrations ranged from 0.004 to 0.007 mg/L, as reported in previous studies, suggesting a gradual increase in heavy metal levels over time (Forti *et al*., 2011; Islam *et al*., 2020; Rahman *et al*., 2016). Zinc exhibited the highest concentration at Sampling Site 3 but remained within the WHO standard value of 3 mg/L. Despite exceeding the previous study's results, the Zinc concentration did not surpass the standard level (FAO/WHO, 1984; Islam *et al*., 2020, 2021). Copper was not detected at any sampling site, possibly due to natural processes, dilution effects, or methodological sensitivities. However, the absence of Copper indicates a lower risk of contamination in the sampled areas compared to the WHO standard value of 0.1 mg/L (FAO/WHO, 1984). Continuous monitoring and assessment of heavy metal pollution are essential to mitigate risks to aquatic organisms and human health. Effective management strategies are necessary to protect the environment and communities surrounding the Kirtankhola River. Further research and monitoring efforts will provide valuable insights into the sources, pathways, and impacts of heavy metal contamination in this vital water body. Copper was not detected at any sampling site, possibly due to natural processes, dilution effects, or methodological sensitivities. However, the absence of Copper indicates a lower risk of contamination in the sampled areas compared to the WHO standard value of 0.1 mg/L.

3.2. Heavy Metals concentration in Fish species

The accumulation of heavy metals in fish species residing in the Kirtankhola River reflects the pollution levels in their aquatic environment and can vary significantly among different species. Metal accumulation in fish is intricately linked to environmental pollution levels (Chapman, 1996), with higher concentrations in areas with increased pollution leading to increased uptake and accumulation by fish. The concentrations of heavy metals in various fish species, including Tenualosa ilisha, Otolithoides pama, and Polynemus paradiseus, collected from the Kirtankhola River, have been meticulously analyzed and are summarized in Table 3. It provides valuable insights into the extent of heavy metal contamination in different fish species inhabiting the river.



	Lead (Pb) (mg/L)	Chromium (Cr) (mg/L)	Cadmium (Cd) (mg/L)	Nickel (Ni) (mg/L)	Zinc (Zn) (mg/L)	Copper (Cu) (mg/L)
🟦 Sampling site 1	0.019	0.01	0.008	0.034	0.018	0
🟥 Sampling site 2	0.024	0.012	0.012	0.036	0.023	0
🟩 Sampling site 3	0.017	0.009	0.011	0.032	0.032	0

Figure 4: All Metals in water samples

Table 3: Heavy Metals in Fish Species

Fish Species	Parameter	Average value (mg/kg)
Ilish *Tenualosa ilisha*	Lead (Pb)	0.22
	Cadmium (Cd)	0.17
	Chromium (Cr)	0.19
	Copper (Cu)	0
	Nickel (Ni)	0.31
	Zinc (Zn)	0.49
Poa *Otolithoides pama*	Lead (Pb)	0.25
	Cadmium (Cd)	0.21
	Chromium (Cr)	0.17
	Copper (Cu)	0
	Nickel (Ni)	0.25
	Zinc (Zn)	0.58
Ramsos *Polynemus paradiseus*	Lead (Pb)	0.27
	Cadmium (Cd)	0.23
	Chromium (Cr)	0.22
	Copper (Cu)	0
	Nickel (Ni)	0.29
	Zinc (Zn)	0.48

The results reveal varying concentrations of heavy metals across different fish species, reflecting differences in their habitat preferences, feeding behaviors, and metabolic processes. Species such as Tenualosa ilisha, Otolithoides pama, and Polynemus paradiseus may exhibit distinct patterns of metal accumulation influenced by factors such as trophic level, habitat utilization, and physiological characteristics. Moreover, the concentrations of heavy metals in fish are influenced not only by environmental factors but also by biological factors such as age, size, and reproductive status. Older and larger fish tend to accumulate higher concentrations of heavy metals due to longer exposure periods and greater bioaccumulation potential.

The findings underscore the importance of monitoring heavy metal levels in fish populations as a vital component of ecosystem health assessment and fisheries management (Garcia-Leston *et al.*, 2010; Ideriah *et al.*, 2012; Islam *et al.*, 2020). Elevated concentrations of heavy metals in fish can pose significant risks to human health through the consumption of contaminated seafood. Thus, effective measures to mitigate heavy metal pollution in aquatic ecosystems are essential to safeguard both environmental and public health. Continued research and monitoring efforts are necessary to better understand the dynamics of heavy metal accumulation in fish and its implications for ecosystem integrity and human well-being (Figure 5).

The analysis of heavy metal concentrations in fish species inhabiting the Kirtankhola River sheds light on the extent of metal pollution in this aquatic ecosystem (Ahmed *et al.*, 2009, 2010, 2012). Lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), and zinc (Zn) were among the heavy metals investigated, with notable findings regarding their presence and levels in different fish species.

Lead concentrations ranged from 0.22 mg/kg to 0.27 mg/kg, with the highest value observed in Ramsos fish. These concentrations exceeded the WHO standard value of 0.3 mg/kg, indicating elevated lead contamination in the river water and subsequent bioaccumulation in fish. Lead exposure poses serious health risks, including neurotoxicity and nephrotoxicity, highlighting the importance of mitigating lead pollution in aquatic environments (Bolger *et al.*, 2000; Chaerun *et al.*, 2004; EQS, 1997).

Cadmium levels varied from 0.17 mg/kg to 0.23 mg/kg, with Ramsos fish exhibiting the highest concentration. Although below the WHO standard value of 0.5 mg/kg, these findings underscore the potential chronic toxicity of cadmium, necessitating ongoing monitoring and pollution control measures (Bolger *et al.*, 2000; Chaerun *et al.*, 2004; EQS, 1997; Tuhin *et al.*, 2024; Islam *et al.*, 2021).

Chromium concentrations ranged from 0.17 mg/kg to 0.22 mg/kg, within the WHO standard value of 1 mg/kg. While chromium typically does not accumulate significantly in fish, its presence underscores the need for continued environmental vigilance to prevent potential health hazards (Chaerun *et al.*, 2004; EQS, 1997; Hanif *et al.*, 2020; Islam *et al.*, 2020).

Copper levels were undetectable in the fish samples, indicating minimal contamination and adherence to the WHO standard value of 10 mg/kg. However, studies have shown that excessive copper intake can lead to adverse health effects, emphasizing the importance of maintaining low copper levels in aquatic ecosystems (Bolger *et al.*, 2000; Chaerun *et al.*, 2004; EQS, 1997; Hanif *et al.*, 2020).

Nickel concentrations ranged from 0.25 mg/kg to 0.31 mg/kg, remaining below the WHO standard value of 10 mg/kg. Although within acceptable limits, nickel exposure can still pose health risks, necessitating ongoing monitoring to prevent accumulation over time (Bolger *et al.*, 2000; Chaerun *et al.*, 2004; EQS, 1997; Hanif *et al.*, 2020).

Zinc concentrations varied from 0.48 mg/kg to 0.58 mg/kg, well below the WHO standard value of 30 mg/kg. While zinc is relatively harmless, chronic exposure can affect reproductive physiology in fish and potentially lead to health issues in humans (Bolger *et al.*, 2000; EQS, 1997; Islam *et al.*, 2021; Rahman *et al.*, 2016).

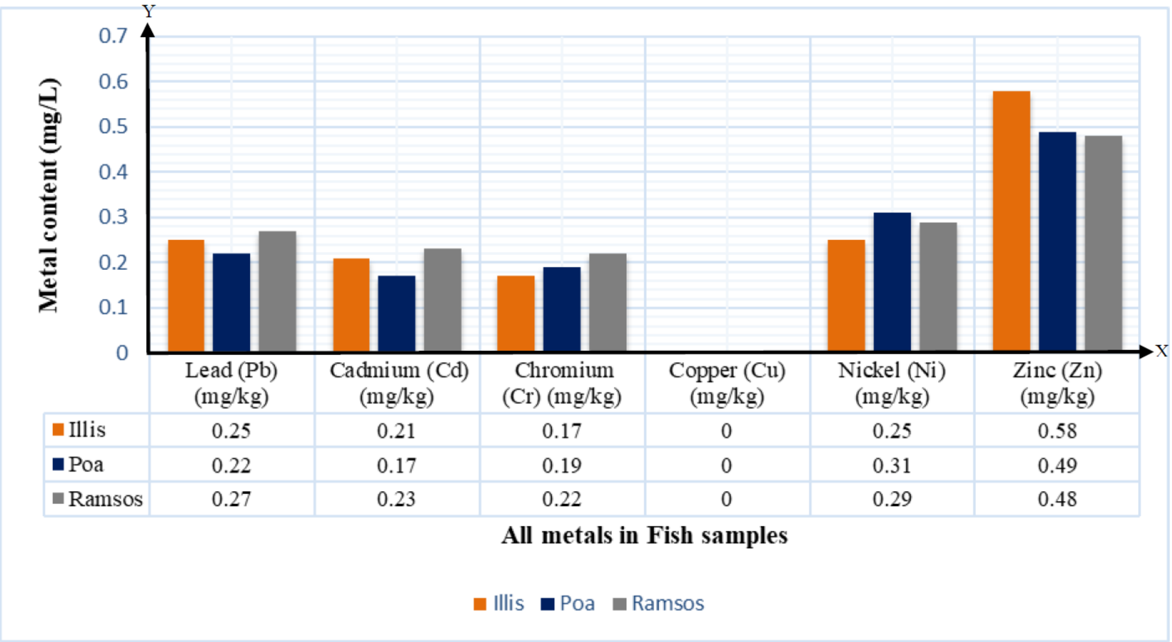


Figure 5: All Metals in Fish Species

Overall, the findings indicate that heavy metal contamination in the Kirtankhola River poses risks to both aquatic ecosystems and human health. Continued monitoring and pollution control efforts are essential to safeguarding the integrity of the environment and ensuring the safety of fish for human consumption (Hadiuzzaman *et al.*, 2006; Islam *et al.*, 2012, 2015, 2021; Hanif *et al.*, 2020).

Conclusion

The study has undertaken a comprehensive assessment of the pollution status of the Kirtankhola River in Barishal district, Bangladesh, with a specific focus on water quality and metal accumulation in available fish in that river. Through the collection and analysis of water samples from three sites along the river, as well as direct sampling of three fish species, various parameters were evaluated including color, odor, temperature, pH, dissolved oxygen, biological oxygen demand, total suspended solids, electrical conductivity, and alkalinity. The findings of this study have revealed a concerning presence of heavy metals in both the river water and sediment, indicating potential contamination and posing risks to aquatic ecosystems and human health. However, it is noteworthy that the concentrations of metals in the fish species studied were found to be below permissible limits according to FAO/WHO guidelines. This suggests that fish consumption from the Kirtankhola River may not pose significant immediate health risks to local communities. Despite this somewhat reassuring finding, it is imperative to underscore the importance of ongoing monitoring and management of river water quality to prevent further contamination and safeguard public health. Strict regulations, increased awareness among the population regarding water safety, and the implementation of effective monitoring systems are essential steps towards ensuring the sustainability of water resources in the region. In light of the study's findings, there is an urgent need for the formulation and implementation of comprehensive management strategies to address water pollution not only in the Kirtankhola River but also in other water bodies across Bangladesh. By adopting proactive measures such as stringent regulations, robust monitoring systems, and targeted public awareness campaigns, it is possible to mitigate the risks associated with contaminated water sources and secure access to safe and clean water for present and future generations. This study contributes to the growing body of knowledge on water quality assessment and pollution management in Bangladesh, and it is hoped that its findings will inform evidence-based policy-making and action towards the protection and preservation of water resources for the benefit of all stakeholders.

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