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Water Quality Assessment of the Balu and Turag Rivers: A Case Study in Bangladesh

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ABSTRACT

Water pollution creates substantial adverse effects on ecological balance and agricultural productivity together with major public health risks for the Balu and Turag Rivers in Bangladesh. The study examines physical-chemical elements of pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, arsenic, iron, chlorides, nitrates, and phosphates against both national DoE and international WHO standards. The study obtained surface water samples from predetermined areas around industrial emission sites and urban sewage points and agricultural drainage areas. Fatigued by extensive contamination both the Balu River and Turag River overwhelmingly exceeded national and international standards with arsenic (6 mg/L), iron (0.67 mg/L) and COD (75 mg/L) concentrations in the Balu River and arsenic (11 mg/L), nitrates (12 mg/L) and phosphates (1.76 mg/L) in the Turag River. Industrial wastewater along with agricultural irrigation waste and raw domestic sewage combined to create pollution in the water bodies. The environmental well-being needs swift implementation of enhanced pollution controls that encompass modern wastewater facilities and tightened industrial management and eco-friendly farming systems. Monitoring activities should operate continually under DoE and WHO guidelines to maintain sustainable ecological well-being and human health preservation.

1. Introduction

Industrial and agricultural development works as a fundamental force that shapes both economic systems and social growth according to Kudesia [1]. Environmental degradation and pollution now endanger water which remains essential for survival of humans along with animals, plants, and all organisms [2]. The biological requirement for water extends to pull life quality together since rivers, lakes, and streams work as homes for different organisms. Human societies base their way of living on the delicate state of their ecosystems which directly depends on the condition of water resources. The natural equilibrium of water ecosystem functions and species becomes unbalanced when pollutants enter the water system, which results in diseases, habitat destruction, and land quality degradation [3].

Multiple contemporary research papers illustrate that water pollution creates parallel problems involving water shortage along with its diminishing quality. Industrial development, together with urban growth as well as technological improvements, have increased water source pollution to dangerous levels that peril the worldwide water quality [4]. The natural aquatic environment hosts three types of pollutants between inorganic compounds, organic substances, and biological agents.

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Heavy metals constitute extremely toxic pollutants that affect aquatic systems at their smallest concentrations, but biodegradable organic compounds result in dissolved oxygen depletion through decomposition leading to damage of aquatic ecosystems and fish mortality [5].

Life in aquatic environments depends on water conditions that include proper pH balance, correct temperature levels, and sufficient dissolved oxygen (DO). The proper balance of pH serves as a prerequisite to execute two main chemical functions, including sewage coagulation and cyanide ions regulation [6]. Temperature changes occurring in rivers because of seasonal variations and industrial pollutants from geographical locations undermine the wellbeing of aquatic creatures [7]. The presence of chlorides at lower than 250 mg/L concentrations does not cause harm but their elevated levels point to organic pollution according to Nahar [6]. Aquatic organisms need dissolved oxygen levels above 5–6 ppm to survive along with most fish species in the area. A water quality standard of good status occurs when DO levels measure at 6.5 mg/L [8].

Water contamination through industrial waste streams continues to be among the most urgent environmental issues because it contains toxic metals along with pesticides. The water quality deteriorates significantly when industries release their effluents from chemical and pharmaceutical and food processing facilities [9]. Organic and industrial agricultural operations introduce several long-lasting pollutants because they frequently implement comprehensive usage of chemical products including pesticides, herbicides, insecticides, and fertilizers that cannot degrade naturally. The level of contaminants remains low but creates substantial ecological dangers because these materials prove toxic and ecologically dangerous and potentially cause cancer [10].

The main structure of food production through irrigated agriculture relies on accessible water resources that maintain appropriate quality levels. Good-quality water availability and numerous available water sources throughout history led to the common disregard of water quality issues. The rising water consumption levels alongside excessive usage forced farmers to switch to less desirable water resources, which makes irrigation more challenging [11]. The composition of irrigation water becomes vital based on geological conditions and climatic factors since it affects both agrarian soil vitality and crop productivity together with nutritional elements. The gardening and growth of plants together with soil health get compromised by inadequate irrigation water both from surface water and groundwater sources because of toxicity factors, nutrient deficiencies, and changes in nutrient availability [12].

The main purpose behind this research is to examine Balu and Turag Rivers' water quality by evaluating their pH content against regulatory and advisory body water quality benchmarks. A complete evaluation of standards set by DoE along with EQS and WHO enables this analysis to determine river suitability for fisheries, drinking water, irrigation, and domestic purposes. The study evaluates river water quality by comparing it to established standards to determine the present state of water quality together with its health implications.

2. Methodology

2.1 Study Area

As a Shitalakshya tributary the Balu River stretches 44 kilometers across Bangladesh from 23°49′51″N, 90°29′11″E to its junction point. The river passes through both Beel Belai as well as Dhaka before joining the Shitalakshya at Demra. The Balu River requires strategic sampling to determine pH value and turbidity as well as pollution levels since these parameters directly influence its ecological stability.

(a) (b)

Figure 1. Study Area (a) Balu River and (b) Turag River

The Turag River at 23°46′N, 90°20′E begins its course as an upper tributary of Buriganga from Bangshi River before flowing through Gazipur then reaches Dhaka. The Turag River remains accessible to boat traffic yet continues to face high levels of contamination alongside neglected industrial operations and progressive water sedimentation. Monitoring operations in this river assess pollution alongside sediment levels to help support conservation activities. The hydrological system heavily relies on these rivers thus comprehensive monitoring is needed to execute effective ecological management practices over the long term.

2.2 Sampling Procedure

There was a use of 2000 ml plastic bottles for water quality analysis as sampling containers. Washing and rinsing procedures with distilled water and 1–2 ml of 2% industrial-grade HCl served to remove any possible contamination from sampling bottles before collection. River water rinsed the bottles before their use for water sampling began.

The sampling process included detailed care to prevent aeration since it protected the dissolved gases and other water quality elements from changes. Important identification labels along with secure seals were added to each bottle to avoid contamination and mixture mistakes. The team performed sampling following a systematic pattern which maintained a 100-meter distance range between points at the river.

The laboratory received the collected samples which went through controlled transportation to maintain their quality before degradation happened. All samples followed standardized preservation methods before they could undergo laboratory-based physical and chemical analysis. The implemented procedure enabled researchers to obtain trustworthy data essential for water quality evaluations in the examined rivers.

The collection took place at set points 100 meters apart on both rivers so ten total points existed throughout each river. Sampling sites for the study were chosen with great precision in locations that were closest to industrial discharge points as well as urban wastewater outlets and regions with intensive agricultural practices. The team consistently obtained water samples down to 30cm depth beneath the water surface because surface areas show enhanced pollution from runoff and industrial waste. The selected depth of water samples guarantees proper representation of damaging substances which impact human and environmental wellbeing.

2.3 Detailed Reference to Standards Used

Water quality results were evaluated using specific national standards set by the Bangladesh Department of Environment (DoE, Environment Conservation Rules 1997) and international guidelines provided by the World Health Organization (WHO Guidelines for Drinking-Water Quality). These standards ensure that the analysis accurately assesses the suitability of river water for drinking, domestic use, fisheries, and agricultural irrigation, facilitating precise comparisons and actionable management interventions.

2.4 Water Quality Analysis Procedures

2.4.1 pH Measurement

A pH meter received calibration from buffer solution together with distilled water. The water solution required a clean 100 ml plastic beaker which received 50 ml of test water subsequently the pH probe entered for a minimum immersion period of five minutes. Every recording process included a pH reading while the probe received clearance using distilled water or buffer solution between each measurement to prevent inaccuracy.

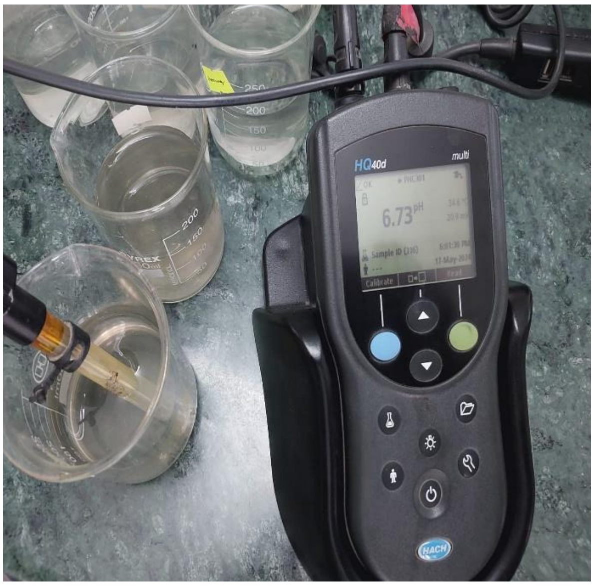

Figure 2 pH test

2.4.2 Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

The conductivity-TDS meter electrode received cleaning with distilled water prior to its usage. A verification check of the cell constant operated on the conductivity meter took place. The water sample measurement stopped at 20 ml in a 50 ml cylinder so the electrode could rest in the solution for ten seconds or more to measure TDS, TSS and EC levels. The testing device received complete rinses among individual measurements to stop contamination between tests.

2.4.3 Biochemical Oxygen Demand (BOD)

The BOD testing evaluated how much oxygen it takes for dissolved organic substance decomposition at 20°C over a five-day period. Research personnel performed sufficient dilution of water specimens before placing them into BOD bottles. The laboratory tested initial dissolved oxygen content in bottles from one set before adding them to incubate another set. An analysis of final dissolved oxygen (D2) took place five days later. Scientists derived the BOD measurement from the subtraction (D1–D2) thus providing data regarding the organic pollution intensity of the evaluated sample.

Figure 3 Biochemical Oxygen Demand (BOD) test.

2.4.4 Chemical Oxygen Demand (COD)

The COD measurement involved adding excessive dichromate to the solution followed by ferroin indicator assessment of unabsorbed dichromate. For testing accuracy a blank sample was added to the testing process. The COD measurement presented results using the quantity of oxygen found in mg per liter.

2.4.5 Nitrate (NO_2^- and NO_3^-)

The analysis of nitrates involved a colorimetric method utilizing a yellow color derivative between nitrate and brucine which can be measured at 410 nm wavelength. The method supported measurement range from 0.1 to 2.0 mg/l. The analysis method prevented oxidizing/reducing agents from interfering through the use of sodium arsenide and sulphanilic acid together with appropriate sample preparation protocols for controlling organic matter effects.

2.4.6 Chlorides

Silver nitrate titration allowed chloride content determination while the method resulted in white silver chloride precipitate formation. A reddish-brown silver chromate precipitate formation served as the endpoint indicator when using potassium chromate during the analysis.

2.4.7 Alkalinity

The clean beaker received 100 ml of the sample then the addition of several drops of phenolphthalein indicator followed. The experiment required titration with 0.02 N H_2SO_4 solution until the solution became colorless through the phenolphthalein endpoint. The endpoint identification for total alkalinity required methyl orange indicator followed by a process of light orange color development through titration. A calculation of alkalinity as calcium carbonate ($CaCO_3$) required the determination of used acid volume.

2.4.8 Hardness

The analysts used buffer solution for pH adjustment to 10 when working with 100 ml samples for complex stabilization. After Eriochrome Black T indicator was added the solution changed color to wine-red. The solution obtained blue appearance after receiving 0.01 M EDTA causing the titration to reach its endpoint. The measurement units for hardness appeared as mg/L $CaCO_3$. The testing procedure for calcium hardness included the utilization of murexide indicator with a matching titration process.

2.4.9 Arsenic

The analysis method for arsenic measurement began with a 50 ml water sample digestion through HNO_3 and H_2SO_4 treatment to eliminate organic content. The potassium iodide (KI) and stannous chloride mixture reduced arsenic to trivalent form before the analysis took place. Laboratory analysis of the water sample occurred either through the colorimetric method or through Atomic Absorption Spectroscopy (AAS). The analyses of the results through calibration standards provided µg/L measurements of arsenic concentration.

2.4.10 Iron

Analysis of Iron materials involved the phenanthroline method as the detection technique. The 50 ml water sample received HCl acidification for dissolving iron precipitates before addition of hydroxylamine hydrochloride reduced ferric iron (Fe^{3+}) into ferrous iron (Fe^{2+}). An orange-red complex between Fe^{2+} and the orthophenanthroline reagent formed when reagent was included into the reaction. The spectrophotometer measured the color intensity at 510 nm for a color analysis resulting in mg/L results which were reported after using blank controls for accuracy testing.

3. Results and discussion

The water quality of the Balu and Turag Rivers reflects varying degrees of compliance with national and international standards, offering insights into pollution levels, probable causes, and required interventions.

Table 1: Comparison of the test result with the standard values for different water quality parameters.

Parameter	Balu River	Turag River	DoE Standard (2001) [13]	Fisheries Standard [14]	Domestic Standard [15]	Drinking Standard [16]	Irrigation Standard [12]	WHO Standard [17]

pH	6.73	6.85	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5	6.5–8.5
EC (μS/cm)	2100	1080	1200	No limit	No limit	1500	3000	1500
TDS (mg/L)	1095	564	1000	1500	No limit	1000	2000	1000
TSS (mg/L)	6	17	50	50	50	10	50	10
DO (mg/L)	6	5.6	6	5	6	5	No specific limit	5
BOD (mg/L)	3.8	2.6	6	3	No limit	6	No specific limit	3
COD (mg/L)	75	36	200	No limit	No limit	200	No specific limit	50
Alkalinity (mg/L)	211	77	200–500	No limit	No limit	No specific limit	600	No specific limit
Hardness (mg/L as $CaCO_3$)	165	40	200	No limit	300	500	200	500
Arsenic (mg/L)	6	11	0.05	No limit	0.01	0.01	No specific limit	0.01
Iron (mg/L)	0.67	0.34	1.0	No limit	1.0	0.3	No specific limit	0.3
Chlorides (mg/L)	50	55	150–600	No limit	250	600	400	250
Nitrate (NO_3^-) (mg/L)	10.3	12.0	10	No limit	45	50	30	50
Phosphate (PO_4^{3-}) (mg/L)	2.54	1.76	6	0.2	No specific limit	0.1	2.0	0.1

3.1 pH

The measured pH levels of Balu River at 6.73 and Turag River at 6.85 fulfill the DoE, WHO, and other standard criteria between 6.5–8.5 thus making them suitable for aquatic life while supporting irrigation needs and drinking purposes. Water acidity at a minimal level occurs through decomposition of organic matter as well as industrial releases and acid precipitation. Sustainable ecosystems depend upon keeping pH values balanced because such changes threaten aquatic life and lead to water machinery destruction and harm human health through skin issues and stomach problems. The regular monitoring of industrial effluents with strengthened control measures needs implementation for achieving proper pH levels.

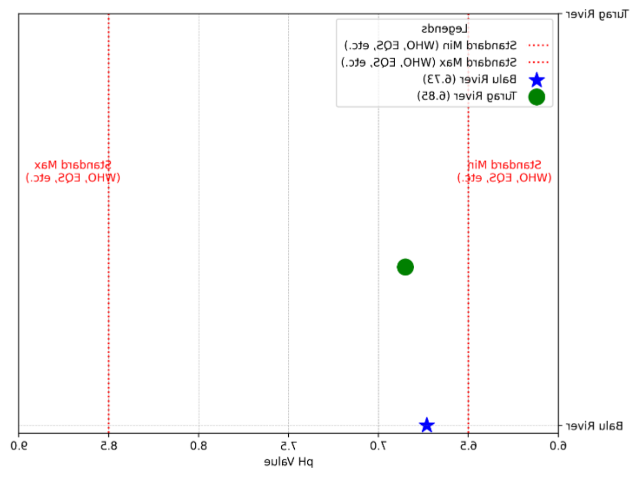

Figure 4 Comparison of pH test result with standard values.

3.2 Electrical Conductivity (EC)

The water quality of the Balu River exceeds the maximum values set by DoE (1200 µS/cm) and WHO (1500 µS/cm) due to its high EC reading of 2100 µS/cm yet Turag River persists within acceptable limits at 1080 µS/cm. The high levels of EC in Balu River water show elevated dissolved ion concentrations that may come from agricultural runoff as well as industrial waste and urban waste discharge sources. Soil salinity caused by high EC levels deteriorates agricultural production and decreases water water quality suitable for human consumption. Several remediation measures should be adopted such as managing fertilizer usage in agricultural areas and establishment of wastewater treatment facilities and industrial emission control.

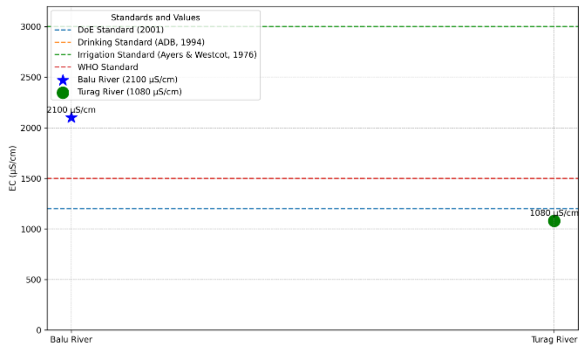

Figure 5 Comparison of EC test result with standard values.

3.3 Total Dissolved Solids (TDS)

Tests show that the TDS levels in the Balu River (1095 mg/L exceed both DoE and WHO standards of 1000 mg/L but Turag River TDS levels (564 mg/L) meet accepted standards. High TDS values in the Balu River may develop through wastewater from domestic settlements combined with agricultural drainage water and natural soil leaching. High TDS concentration in water leads to objectionable taste in drinking water and causes problems with irrigation equipment scaling and harms aquatic life in the ecosystem. To resolve this problem the water infrastructure must strengthen sewage collection systems while restricting pollutant releases and establishing modern water purification systems which maintain regulatory standards.

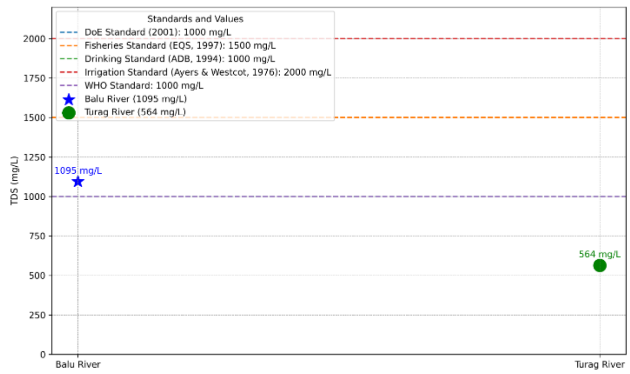

Figure 6 Comparison of TDS test result with standard values.

3.4 Total Suspended Solids (TSS)

The TSS concentrations in the Balu River at 6 mg/L and Turag River at 17 mg/L fall under acceptable standards for domestic and aquatic life however the Turag River approaches its upper permissible threshold. Turbidity in the Turag River originatess mainly from industrial waste dumping and urbanization patterns as well as runoff from built-up areas and agricultural operations. The Turag River reveals high levels of pollution because Dhaka's densely populated area releases both untreated wastewater and agricultural land soil erosion from its vicinity. Water quality becomes worse when Total Suspended Solids are above their recommended levels since this creates unclear water that hinders water treatment and raises the possibility of waterborne disease transmission. Rising solids in water systems limit aquatic life survival because they block light from reaching below and reduce available oxygen. Providing centered wastewater treatment alongside regulating urban runoff and controlling agricultural runoff must be accompanied by public pollution prevention education. Continuous monitoring in addition to sustainable practices deployment will successfully minimize human health and aquatic ecosystem dangers originating from TSS contamination.

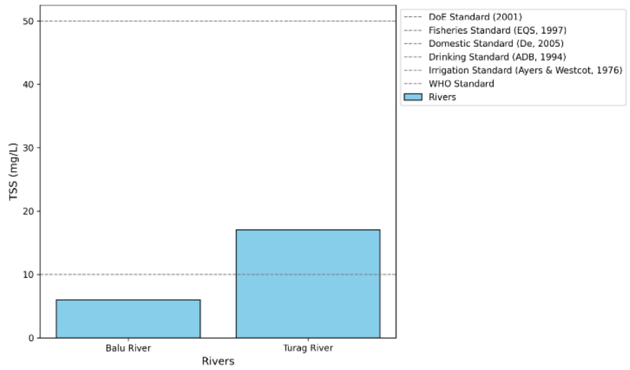

Figure 7 Comparison of TSS test result with standard values.

3.5 Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD)

Monitoring results from Balu (6 mg/L) and Turag (5.6 mg/L) rivers prove acceptable since both measured above the baseline standard of at least ≥ 5 mg/L. The features in the Turag River showed signs of moderate organic pollution since its Biological Oxygen Demand measures (Balu: 3.8 mg/L; Turag: 2.6 mg/L) approached the fisheries standard (≤ 3 mg/L). Waters with high BOD values contain more organic compounds mainly because of untreated sewage together with agricultural runoff. The environment becomes oxygen depleted when such conditions occur leading to injury or death of aquatic organisms. Community members should increase their awareness of sound waste disposal practices while enhancing sewage treatment plants and implementing eco-friendly agricultural practices.

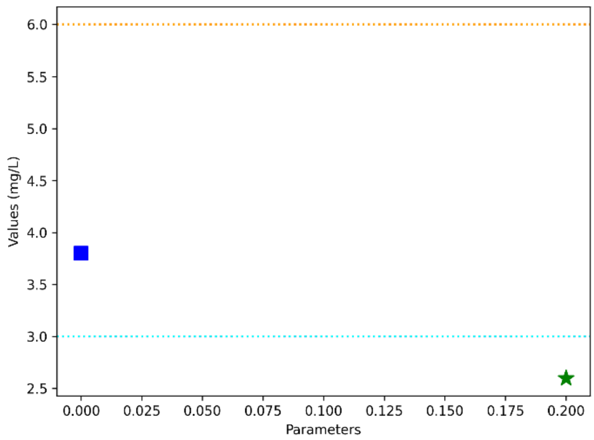

Figure 8 Comparison of BOD test result with standard values.

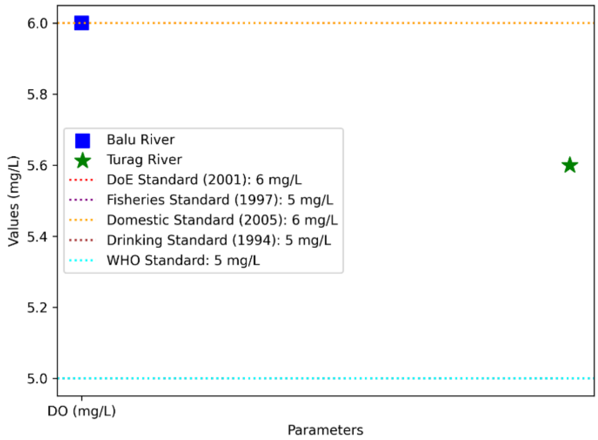

Figure 9 Comparison of DO test result with standard values.

3.6 Chemical Oxygen Demand (COD)

The COD measurements from the Balu River reached 75 mg/L while the Turag River showed 36 mg/L which appears acceptable according to the DoE standard (≤ 200 mg/L) although they surpass the WHO recommendation (≤ 50 mg/L). Heavy COD levels in water indicate major chemical pollution from industrial effluents together with urban runoff deposits. If COD concentration levels increase in water they deteriorate quality standards making the water unfit for usage by humans and aquatic organisms. The Balu River shows COD values of 75 mg/L while the Turag River measures 36 mg/L yet both exceed the WHO standard limitation of ≤ 50 mg/L. Mitigation efforts should actively involve intensified environmental regulation enforcement and waste treatment compliance with reductions of untreated industrial waste pouring into rivers.

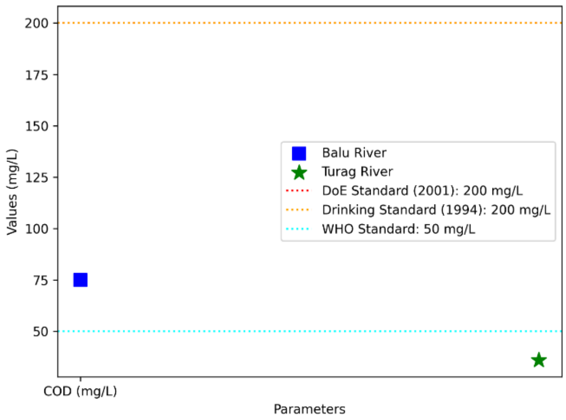

Figure 10 Comparison of COD test result with standard values.

3.7 Alkalinity and Hardness

The Balu River maintains alkalinity at 211 mg/L while Turag River shows 77 mg/L which matches the defined acceptable range of 200–500 mg/L. The proper range of alkalinity creates a protection system which maintains water stability needed by aquatic ecosystems. The lower alkalinity of Turag River water makes it more vulnerable to pH variations because of its composition. Drinking and irrigation requirements are met since the water's hardness levels in Balu River (165 mg/L) and Turag River (40 mg/L) show that it is neither soft nor excessively hard. The measured salts of calcium and magnesium show low amounts of contamination.

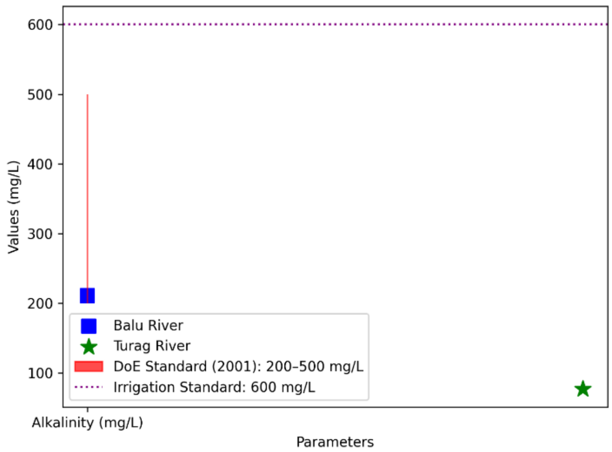

Figure 11 Comparison of Alkalinity test result with standard values.

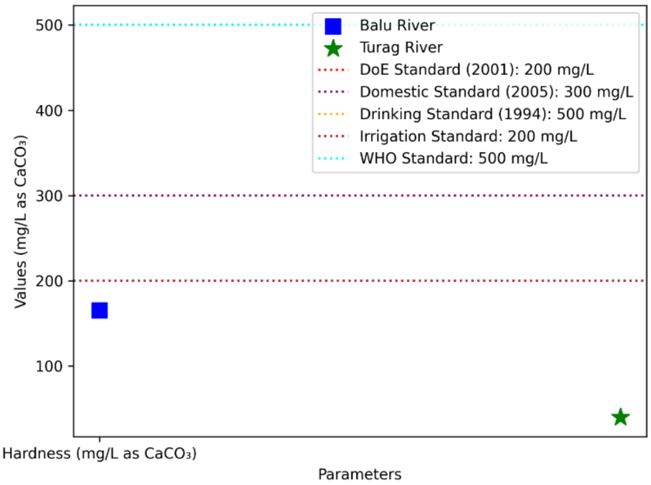

Figure 12 Comparison of Hardness test result with standard values.

3.8 Arsenic

The excessive concentration of arsenic in the Balu River reaches 6 mg/L while the Turag River contains 11 mg/L surpassing all allowable thresholds (≤ 0.05 mg/L) which threatens public health. Arsenic contamination emerges primarily because of industrial wastewater releases and urban runoff and natural sediment leaching processes. Health problems triggered by prolonged arsenic exposure will develop into fatal cancers coupled with cardiovascular diseases and neurological disorders. The implementation of arsenic removal plants with necessary monitoring of industrial discharges together with public education about arsenic contamination must start right now.

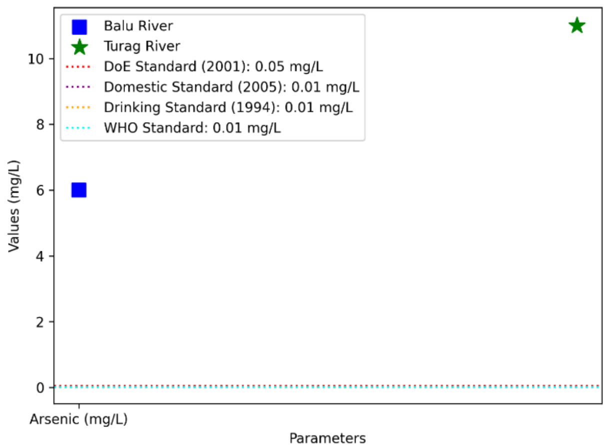

Figure 13 Comparison of Arsenic test result with standard values.

3.9 Iron

The Balu river contains iron at 0.67 mg/L together with Turag river at 0.34 mg/L due to DoE standards permitting up to 1.0 mg/L of iron but WHO drinking water standards limit iron at 0.3 mg/L. Human health depends on iron in small quantities but excessive iron results in material staining and changes water taste in addition to plumbing fixture discoloration. Contamination from industrial waste and water pipe corrosion leads to the presence of iron in water sources. To combat iron contamination the water industry develops filtration methods along with implementing materials that resist corrosion in pipelines.

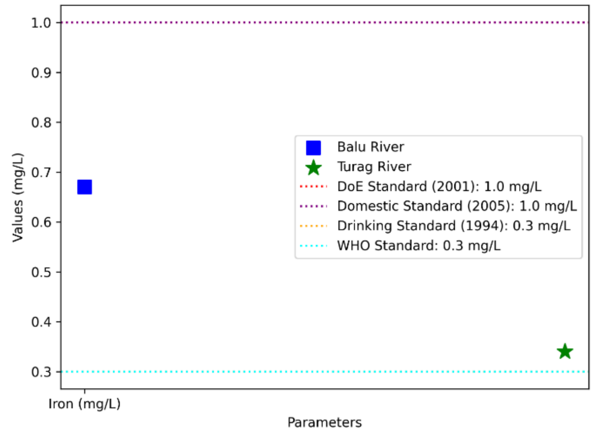

Figure 14 Comparison of Iron test result with standard values.

3.10 Chlorides

The Chloride levels measured in the Balu River at 50 mg/L and Turag River at 55 mg/L remain inside permissible limits (150–600 mg/L) showing minimal intrusion of salt. Both rivers remain unaffected by seawaters and industrial waste carrying chloride salt contaminants.

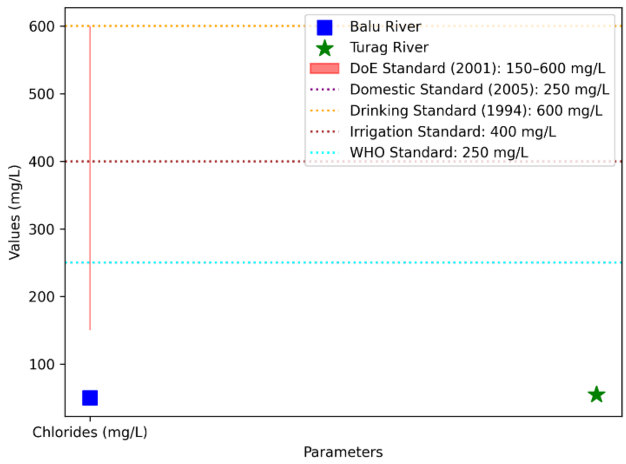

Figure 15 Comparison of TDS test result with standard values.

3.11 Nitrate and Phosphate

Testing shows the Balu River contains 10.3 mg/L nitrates while the Turag River has 12 mg/L nitrates which exceed the DoE maximum (≤ 10 mg/L) although they fall below other permissible limits (≤ 50 mg/L). The accumulation of high nitrate content at 10.3 mg/L and 12 mg/L in river water stems from farming practices and sewage waste along with urban runoffwater which creates a double threat for infant health and oxygen pollution in the water. The phosphate content in Balu River water at 2.54 mg/L and Turag River water at 1.76 mg/L surpasses both fisheries and WHO phosphate concentration standards of ≤ 0.2 mg/L which promotes algal blooms and nutrient enrichment of water ecosystems. The necessary solutions for improving water quality consist of supporting environmentally sustainable farming approaches and better wastewater treatment methods together with controls for agricultural fertilizer usage close to water sources.

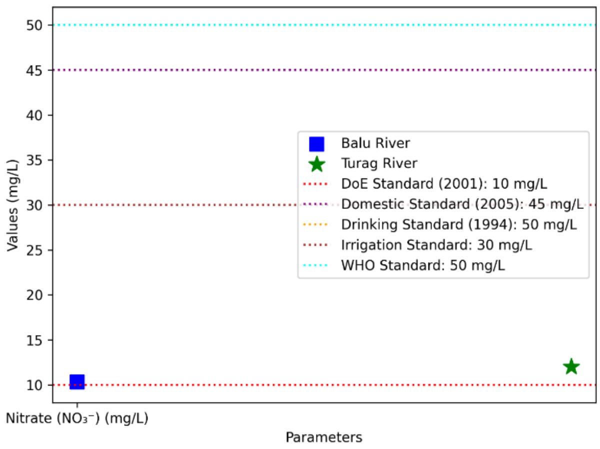

Figure 16 Comparison of Nitrate test result with standard values.

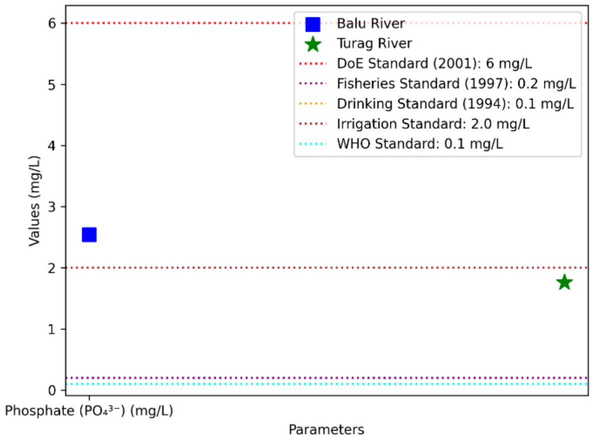

Figure 17 Comparison of Phosphate test result with standard values.

Detailed analysis of water quality parameters revealed significant variations between the Balu and Turag Rivers, highlighting alarming pollution levels with considerable ecological, health, and agricultural implications.

- **Balu River**: The Balu River exhibited severe contamination with arsenic levels at 6 mg/L, dramatically exceeding both national and international limits, posing substantial health risks including cancer, cardiovascular diseases, and neurological disorders. Iron concentrations of 0.67 mg/L and chemical oxygen demand (COD) levels of 75 mg/L also exceeded permissible limits, indicating severe industrial and urban wastewater pollution. Additionally, elevated electrical conductivity (EC) at 2100 µS/cm and high total dissolved solids (TDS) levels of 1095 mg/L pointed to extensive contamination from agricultural runoff and untreated urban sewage.

- **Turag River**: The Turag River also presented substantial contamination, particularly with arsenic reaching a critical level of 11 mg/L. Nitrate concentrations at 12 mg/L and phosphate levels at 1.76 mg/L surpassed safe drinking water standards, driven primarily by agricultural fertilizer runoff and untreated urban wastewater discharge. Although the pollution levels were relatively lower than the Balu River, the continued presence of these contaminants poses ongoing significant threats to human health, biodiversity, and agricultural productivity.

In-depth analysis traced the primary pollutants to persistent sources, including industrial effluents containing heavy metals, urban sewage rich in organic pollutants, and runoff from intensive agricultural practices laden with nitrates and phosphates. These contaminants collectively threaten aquatic biodiversity, significantly impacting species survival and ecosystem resilience, while also presenting serious risks to human health through direct exposure and indirect agricultural contamination.

4. Conclusions

The study delivers extensive details about Balu and Turag Rivers water quality by assessing their ecological state and their achievement of both national and international water quality requirements. The assessment reveals that both water bodies have diverse pollution levels since some test parameters including pH and electric conductivity and total dissolved solids coupled with heavy metal concentrations surpass accepted standards. The Balu River shows elevated contamination characteristics because it suffers from excessive arsenic along with elevated iron concentrations and chemical oxygen demand (COD) pollution that primarily results from industrial activity and urban runoff impacts. Industrial discharges together with sedimentation and organic pollution continue to present substantial challenges for the Turag River even though its pollution levels remain lower than those of the Balu River.

Harmful substances at elevated concentrations of arsenic and nitrates in the two rivers create dangerous risks for human wellness together with aquatic ecosystems and agricultural production systems. The polluting substances come from multiple human-made activities such as industrial wastewater discharges along with agricultural drainage water as well as municipal sewage. These research results demonstrate that an urgent long-term solution must be implemented for enhancing water quality conditions in these rivers. To tackle the water pollution problem we need improved wastewater treatment methods together with stronger management of agricultural and industrial drainage as well as increased population-wide engagement in pollution control efforts.

In conclusion, the Balu and Turag Rivers serve as critical water resources for both ecological stability and human welfare. The rivers require immediate actions to manage pollution sources besides strengthening water quality monitoring and environmental regulations because their current viability for domestic and agricultural and industrial purposes must be safeguarded. Ameliorated conservation practices will enable these rivers to recover to better health levels which ultimately secures long-term benefits to surrounding communities and ecosystems.

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