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Ambient Water Analysis of Cagayan de Oro River, Philippines

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ABSTRACT

Cagayan de Oro River is one of the rivers that drain the northern central region of Mindanao, and urbanization has given rise to problems with its ambient water quality. A cross-sectional, correlational study was carried out to assess the physicochemical parameters and total coliform count of the river and evaluate it against applicable national standards. Spectrophotometric analyses showed that mercury (Hg) and nitrate (NO3-) concentrations were below the maximum limit. The amounts of dissolved oxygen (DO) and total dissolved solids (TDS) across the sampling spots were also observed to be acceptable. Except for samples taken upstream, pH and water temperature readings were within the recommended range. Phosphate (PO4-3) concentrations and total coliform counts had significantly exceeded allowable limits. TDS was positively correlated with both water temperature and PO4-3 concentration, while an increase in pH is associated with decreasing water temperature. Spatial variation in DO and TDS was not observed in this study; however, water temperature from upstream was relatively lower and more alkaline. The study has established that Cagayan de Oro River is not fully compliant with the national water quality guidelines for Class A water bodies. This finding points to the fact that the river has been vulnerable to both natural and human-related threats.

Keywords: River water quality, physicochemical parameters, total coliform, spatial variation, spectrophotometric analysis

INTRODUCTION

Rivers have played an important role in human history and have been extensively used by people over time. Consequently, rivers have been significantly impacted by human activity, leaving few or none in their pristine condition. Ever-rising global population, extensive deforestation, urbanization, hydrological change, and inefficient water usage have all contributed to a significant decline in river water quality. Moreover, the reckless discharge of industrial effluents and other point and non-point sources of pollution have left rivers near metropolitan areas in a more vulnerable state (Adeosun, 2019).

Tropical rivers are more exposed to intense rains and other factors contributing to eutrophication due to warmer water temperatures. These attributes coupled with improper land use, such as the conversion of forests to built-up areas, lead to higher nutrient flux and lower dissolved oxygen concentration, which could disrupt nutrient cycling (Bello et al., 2017).

The Cagayan de Oro River is one of the rivers that drain the northern central region of Mindanao. The river's headwaters are located in the Kalatungan Mountain Range of Bukidnon Province. Taking in tributaries along the way, the water travels roughly 90 kilometers through the municipalities of Talakag, Baungon, and Libona until it discharges into Macajalar Bay, Misamis Oriental. It is estimated that 1,521 square kilometers are drained by the river. About 80% of the river basin is situated in the province of Bukidnon, and the remaining 20% covers areas within Iligan City and Cagayan de Oro City. The four main tributaries of the Cagayan de Oro River are the Kalawaig, Tagite, Bubunaoan, and Tumalaong Rivers ("Cagayan River," 2022). Cagayan de Oro River has been acknowledged as a Class a freshwater body and designated as a Water Quality Management Area by virtue of DENR Administrative Order No. 2013-18.

Forest Foundation Philippines (2022) reported that urbanization has given rise to problems with water sustainability in the Cagayan de Oro River Basin. The specific concerns include pollution (e.g., sewage), rising water demand (e.g., for agriculture), groundwater depletion, quarrying, and changes in land use.

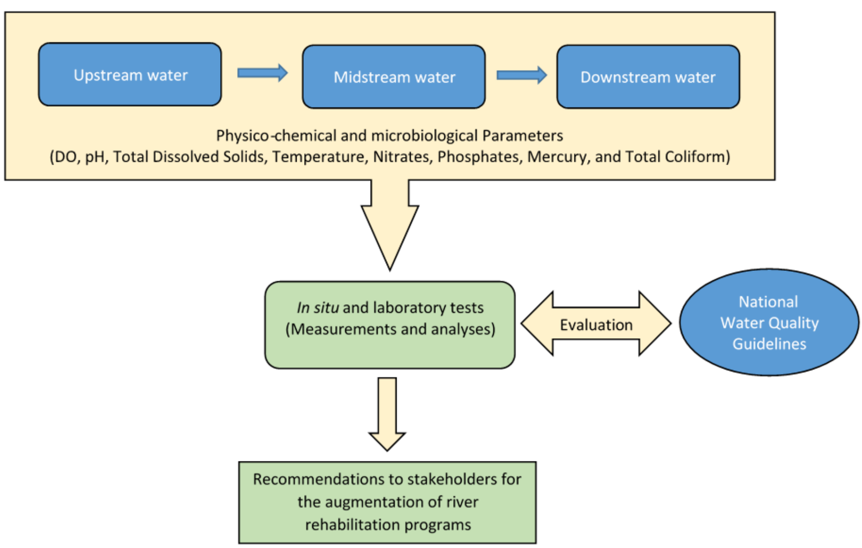
Both artificial and natural causes of river water deterioration differ spatially because they strongly depend on the various human activities that take place in specific locations. Due to the complexity of the natural and anthropogenic impacts, it is essential to have a fundamental understanding of how the physicochemical and microbiological properties of water change over time and space in order to assess its quality. Analysis of fluctuations in water quality has revealed that they are strongly influenced by DO, coliforms, and temperature among others (Nguyen & Nhien, 2020).

FRAMEWORK

Various sections of a river are differentially exposed to physical, chemical, and biological factors. These variations could reflect the impact of natural and anthropogenic events in and around these sections. The status of a river's ambient water quality can be estimated by means of regular testing on-site and further analysis of the samples in the laboratory. Data can then be evaluated against national guidelines to enable stakeholders to formulate sound programs aimed at rehabilitating the river ecosystem (Figure 1).

Figure 1

Model for regular analysis of the Cagayan de Oro River ambient water quality



OBJECTIVES OF THE STUDY

This study investigated the ambient water quality of the Cagayan de Oro River by assessing its physicochemical properties and coliform count. The measurements were also evaluated against the applicable standards set by the Department of Environment and Natural Resources (DENR). The difference between the variables with respect to spatial considerations and the association between and among these variables were also determined.

RELATED LITERATURE

Physicochemical Factors. Physical and chemical factors including pH, total solids, total dissolved solids, total suspended solids, dissolved oxygen, biological oxygen demand, chemical oxygen demand, and hardness are of particular importance in water quality studies because they have a direct or indirect impact on the incidence, transit, and speciation of heavy metals (Kumar, 2019).

Temperature affects the toxicity of chemicals, pH, density, electrical conductivity, solubility of gases (like oxygen), and other contaminants. In addition, temperature regulates the cycles of nutrients, the decomposition of organic matter, and primary production. In general, warmer temperatures encourage photosynthesis and microbial metabolic activity and have an influence on the growth and functionality of biotic communities (Bonacina et al., 2022).

Nitrogen and Phosphorus. Excessive nitrogen (N) and phosphorus (P) inputs are the main cause of eutrophication. The presence of these nutrients in the river depends on the ecological and geological features of the surrounding area. However, it is well recognized that human activities raise river P and N levels and that larger nutrient imports speed up eutrophication. These human-related factors include household sewage, industrial wastewater, and urban stormwater runoff. These factors would also explain why the TP and TN levels were higher in rivers running through urban areas than in rivers flowing along rural areas (Zhang et al., 2015).

Nitrates and phosphates in rivers can also be attributed to the heavy use of fertilizers and farmland leaching, as well as contamination by human or animal waste. Most experts agree that phosphorus is the primary factor contributing to water eutrophication. Phosphorus can build up in sediments after entering an aquatic environment, but not all sediment phosphorus types contribute to eutrophication. Indeed, specific phosphorus forms may be released from the sediment into the water column depending on the physicochemical characteristics of the environment such as pH, temperature, dissolved oxygen, and salinity. The amount of phosphorus and nitrogen in river flows is greatly increased by soil erosion and leaching brought on by prolonged periods of high rainfall, as well as by interactions between water and sediments. (Soro et al., 2021).

Eutrophication. Eutrophication is the excessive autotrophic growth brought on by nutrient enrichment. Increased autotrophic biomass, changes in species composition, declines in biodiversity, the potential generation of algal toxins, oxygen depletion, and the emergence of undesirable taste and odor in water are only a few of the adverse ecological and economic implications of eutrophication. Several nutrient sources contribute to anthropogenic nutrient loading, and most of them have to do with how waste is disposed of and how land is used and managed such as agricultural land use management techniques and effluents. Numerous geochemical and biological factors also play a role in the availability of certain nutrients. The global nitrogen and phosphorus cycles have grown by factors of around 1 and 4, respectively, as a result of anthropogenic alterations (Griffin, 2017).

Eutrophication is a worldwide problem that gravely threatens the ecological quality of surface water. Nutrient enrichment has been identified as one of the key stresses on aquatic biota in streams and rivers where intense periphyton growth negatively affects physicochemical surface water quality by causing large diel fluctuations in oxygen concentrations and pH (Gerke et al., 2020).

Mining and Contamination of Rivers. Artisanal and small-scale gold mining (ASGM) contributes up to 37% of all anthropogenic Hg emissions globally and yearly emits 1,400 tons of Hg into the air, soil, and water. Liquid elemental Hg is used in the ASGM process to remove gold from sediments. Hg is released into the atmosphere or dumped directly into soil and water as mining waste. Hg is utilized in this method despite its negative health effects because it is easy to use, inexpensive to procure, and produces a high rate of gold recovery (Gerson et al., 2018).

ASGM is also the predominant type of mining in Northern Mindanao, where most miners pan for gold along the riverbeds of the entire river system. Other mining locations use drift mining or tunnel and ball mills with tailing ponds in the processing of gold ores. The Iponan River System suffered environmental harm as a result of the gold panning practice such as very high concentrations of total suspended solids and sediment load deposition. Additionally, cyanide pollution and the formation of sinkholes are two additional significant effects of drift mining along the Bigaan River. A group of small-scale miners in Barangay Gango, Libona have been urged by the provincial government of Bukidnon to provide the necessary documentation for the designation of the area's 58 hectares as "Minahan ng Bayan" and the facilitation of the operation of the mining association organized in Bukidnon (Canencia et al., 2015).

Coliforms. Total coliforms (TC) and Ecoli are both considered to be indicator organisms. While the presence of TC may point to the existence of additional disease-causing organisms in the water source, the presence of Ecoli indicates recent human or animal fecal pollution (Potgieter et al., 2020).

Fecal Indicator Bacteria (FIB) are microorganisms typically measured by many water quality monitoring systems. These FIBs, which are commensal organisms, are chosen because they are frequently found in both human and animal feces. Thus, pathogens may be thriving in the water if they are present. The bacteria *Enterobacter, Klebsiella, Citrobacter*, and *E*. coli make up the coliform group of the FIB and are used all over the world as markers of fecal contamination in surface waters. When bacteria associated with feces are present as well as enteric pathogens, high levels of fecal coliforms are typically utilized as indicators. Pathogenic fecal protozoa and bacteria can spread and infect a variety of aquatic habitats, including lakes, rivers, creeks, and seas (Díaz-Gavidia et al., 2022).

METHODOLOGY

Study Area. The study was carried out in three different sites along a 32,590-meter stretch of the Cagayan de Oro River traversing from the boundary of Talakag, Bukidnon, and Cagayan de Oro City, Misamis Oriental to Barangay Carmen, Cagayan de Oro City (Figure 2). The area has an average annual maximum temperature of 32°C and an average annual minimum temperature of 22°C. The average amount of annual precipitation is 67.14 inches with July and March being the wettest and driest months, respectively.

Although this section of the river runs along an open area (i.e., no forest cover), vegetation along the bank's ranges from light to moderate. This section of the river can easily be access by motor vehicle and by foot. Human settlements are very sparse along riparian zones from the sampling spot designated as Upstream. Human activities include bathing, fishing, washing, and occasional commercial rafting.

Upstream (8°17’21.27”N; 124°35’10.72”E) is situated at an altitude of 143 masl and about 17,738 meters away from Midstream (8°23’20.68”N; 124°36’47.22”E), which has an elevation of 42 masl. Approximately 14,852 m further downhill is the third sampling spot, Downstream (8°28’32.16”N; 124°38’23.77”E), which has an elevation of 1 masl.

Figure 2

Physicochemical Parameters. Dissolved oxygen (DO), potential of hydrogen (pH), water temperature, and total dissolved solids (TDS) of the water from each of the sampling spots were measured in situ using handheld electronic meters following the specified procedure in the manual. The average of the three readings for each parameter per site was reported as the final value.

Sample Collection. The first batch of water samples was collected from the three sampling spots on November 14, 2022, and followed by the second batch on December 9, 2022. There were four sets of samples that were taken for each sampling batch, that is, one set for each analysis that was performed namely:

nitrate; phosphate; mercury; and coliform. Nine 1-L polyethylene bottles were filled up with water samples from every sampling spot, three bottles each for nitrate, phosphate, and mercury analysis. Three 120-ml sterilized capped glass bottles were used to contain water samples for the coliform count.

The polyethylene bottles were initially rinsed with river water downstream from the exact spot where the samples were collected, then recapped. The bottles were then submerged to about 1 ft. before removing the cap to allow it to be filled up without any air pockets. The bottles were then tightly sealed and placed in a chest filled with ice that was maintained at a temperature not to exceed 4°C.

The glass bottles were uncapped underwater at a depth of approximately 1 ft. with the mouth facing against the current. Enough water was quickly poured off until it was at the level of the bottle's shoulder. The cap was then replaced carefully, and the bottles were immediately set down inside a cooler with the temperature regulated not to go higher than 4°C.

Nitrate and Phosphate Analysis. The concentration of nitrate was determined using US EPA 352.1 Colorimetric Brucine test method while that of phosphate was through 4500-P D. Stannous Chloride Method.

Mercury. The samples were read using Cold Vapor Atomic Absorption Spectroscopy to measure the quantities of mercury.

Total Coliform. Multiple Tube Fermentation Technique was employed to estimate the most probable number (MPN) of coliforms. The presumptive detection was carried out using single-strength Lauryl Sulfate Tryptose Broth incubated at 35°C for 24 hours. The confirmatory test used Brilliant Green Lactose Bile Broth incubated at 35°C for 24 hours.

Data Analysis. The statistical treatment of data was performed using IBM Statistical Product and Service Solutions Version 26 (SPSS 26). The Kruskal-Wallis test was used to determine if there is a significant difference among the samples taken from the three sampling spots. The Wilcoxon signed-rank test allowed for the comparison of the sample values with the standards provided under DENR Administrative Order No. 2016-08. The relationships between variables were then assessed employing Spearman's rank correlation coefficient.

RESULTS AND DISCUSSION

In Table 1 data shows that Mercury (Hg) and nitrate (NO3-) concentrations of all the samples taken from the three sampling spots did not exceed the maximum values provided by DENR A0 2016-08, thus considered to be compliant with the national standards.

Table 1

Measurements of Water Quality Parameters Along with National Standard Values

PARAMETER	UPSTREAM		MIDSTREAM		DOWNSTREAM		DENR AO 2016-08
	1st sampling	2nd sampling	1st sampling	2nd sampling	1st sampling	2nd sampling	
Mercury (HG)	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	0.001 mg/L
	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	
	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L	
Nitrate (NO_3^-)	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	0.1 mg/L	0.15 mg/L	7 mg/mL
	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	0.1 mg/L	0.15 mg/L	
	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	< 0.02 mg/L	0.1 mg/L	0.15 mg/L	
Phosphate (PO_4^{-3})	0.05 mg/L	0.05 mg/L	0.04 mg/L	0.04 mg/L	0.05 mg/L	0.06 mg/L	0.025 mg/mL^
	0.05 mg/L	0.04 mg/L	0.04 mg/L	0.04 mg/L	0.05 mg/L	0.05 mg/L	
	0.05 mg/L	0.05 mg/L	0.03 mg/L	0.04 mg/L	0.05 mg/L	0.05 mg/L	
Total Coliform	> 16,000 MPN/mL	3,500 MPN/mL	> 16,000 MPN/mL	3,500 MPN/mL	> 16,000 MPN/mL	> 16,000 MPN/mL	3,000 MPN/100 mL^^
	16,000 MPN/mL	2,400 MPN/mL	> 16,000 MPN/mL	9,200 MPN/mL	> 16,000 MPN/mL	> 16,000 MPN/mL	
	16,000 MPN/mL	5,400 MPN/mL	9,200 MPN/mL	3,500 MPN/mL	> 16,000 MPN/mL	> 16,000 MPN/mL	
DO	7.9 mg/L	21.70 mg/L	7.86 mg/L	8.57 mg/L	6.68 mg/L	8.67 mg/L	5 mg/L
pH	9.8	8.98	8.0	8.95	8.07	8.77	6.5 – 8.5
Temperature	23.7 °C	24.63 °C	25.53 °C	27.17 °C	27.27 °C	27.97 °C	26 – 30 °C
TDS	64.3	62.33	62	68.67	64	72	Not included as a parameter

Note: ^. Updated Water Quality Guidelines for Class A Water Body under DENR AO-2021-19. ^^. The value is set as the maximum allowable limit under Class A Water Body Effluent Standards (DENR AO 2016-08). Phosphate (PO_4^{-3}) concentration is significantly higher than the national standard at $p < .01$. Measurement Unit for Mercury (Hg), Nitrate (NO_3^-), Phosphate (PO_4^{-3}), DO, and TDS = mg/L. Measurement Unit for Total Coliform = MPN/100 mL

It can be seen, however, that NO3- concentrations from downstream were higher than those from upstream and midstream. Quantities of phosphate (PO4-3) across the sampling spots, on the other hand, were significantly higher than the maximum value under the applicable guideline (DENR AO-2021-19). The mean total coliform exceeded the maximum allowable count, reaching more than five-fold higher in the downstream samples. The dissolved oxygen (DO) concentrations in the three sampling spots were well above the minimum standard. Water from upstream had a higher average pH than the acceptable range, making it too alkaline (pH 9.39). Although the waters from midstream and downstream fell within the standard range, they were still strongly leaning toward the alkaline scale with pH of 8.48 and 8.42, respectively. Both midstream and downstream waters were compliant, whereas upstream water was cooler than the standard temperature range. The range of typical values for total dissolved solids (TDS) in rivers varied greatly among the available literature. However, using the standard provided by Lehigh University Environmental Initiative, the TDS from the three sampling spots had measurements below the range for rivers, which is 100 – 20,000 mg/L.

Drawing comparisons from the study of Zoleta (2015) in the same sampling spots, it can be observed that NO3- concentrations were uniformly measured at 0 mg/L. The concentration limit of NO3- is 10 mg/L set by DENR AO 1990-34, which was the applicable water quality criteria during that time. It also revealed an even higher total coliform count, which was about 32 times more, considering the lowest measurements (76,667 MPN/100 mL & 2400 MPN/100 mL), compared to the present study. The average pH, DO, and water temperatures were 7.34 & 8.76, 10.33 mg/L & 10.23 mg/L, and 24.6 °C & 26.5 °C, corresponding to the study of Zoleta and that of the present study. Phosphate (PO4-) concentrations were also found to be compliant with DENR AO 1990-34. Although there have been some agricultural activities within the vicinity of the sampling spots with a considerable number of residential and commercial settlements downstream, Cagayan de Oro River remains to be compliant with the national guidelines for NO3-. This was the case despite the samples being obtained during rainy months.

Nitrogen pollution can be buffered in freshwater ecosystems through its conversion in the sediments, water columns, and biota. Shallow lakes or rivers are biogeochemical hotspots because of their close terrestrial-aquatic connection. Denitrification can eliminate more than half of the nitrogen influxes in these environments, making it an essential step for preventing eutrophication (Klein et al., 2017).

Phosphate is a nutrient that enters rivers from a variety of sources, including animal and human waste, phosphate-rich rocks, laundry waste, boiler water treatment, and agricultural operations, including fertilizer residues. In addition to domestic sewage, organic phosphates are predominantly produced by biological processes. Additionally, phosphorus can be found in bottom sediments and biological sludge in both their precipitated inorganic and combined forms. Algal blooms (eutrophication), which lower the amount of dissolved oxygen in the water and interfere with the normal water cycle, are brought on by phosphorus increase in rivers and lakes. In general, phosphate is not harmful to people or animals unless it is present in exceptionally high doses (Alauddin & Yadav, 2012).

The total coliform group of bacteria is everywhere. These bacteria are generally harmless and can be found in the soil and vegetation throughout our environment. Total coliform bacteria, specifically *E.coli*, are frequently regarded as a sign that a water supply may be contaminated with something more serious. Numerous factors might lead to bacterial contamination. These factors include surface runoff carrying animal feces, especially from animal farms, or other places where animal waste is dumped or stacked. Human waste can also be a cause of bacterial contamination, most commonly in malfunctioning onsite wastewater systems like household septic tanks, laterals, mounds systems, or lagoons. Remains of dead animals are other causes of contamination as well as floodwaters, which can have high bacterial counts (University of Nebraska-Lincoln Institute of Agriculture and Natural Resources, 2021).

The pH of freshwater ecosystems can vary significantly over the course of a day and season. Water's pH is initially determined by alkalinity, but as carbon dioxide is added or removed, the pH changes from that starting point. The chemical process shifts with the addition of carbon dioxide, resulting in the formation of carbonic acid and hydrogen ions as well as a drop in pH. The removal of carbon dioxide changes the direction of the reaction, resulting in the loss of hydrogen ions and an increase in pH. Alkalinity, which tends to buffer or lessen the impact of variations in carbon dioxide concentrations, and the amount of carbon dioxide introduced or removed determine how much pH varies. Carbon dioxide is continuously produced by all organisms as a byproduct of respiration. During the photosynthetic process, algae and other aquatic plants take carbon dioxide from the water during the day. Whether there is a net addition or removal of carbon dioxide, and thus whether pH rises or lowers, depends on the relative rates of respiration and photosynthesis that occur in the water body (Tucker & D'Abramo, 2008).

As of the time of writing, the researcher was not able to come across a published study that specifically measured the mercury concentration of the ambient waters of the Cagayan de Oro River. There is a felt need to incorporate such analysis in this study, stemming from the fact that there are mining activities in the areas where the Cagayan de Oro River and its tributaries traverse. Nevertheless, the observed levels of mercury in the samplings spots were below the national limit prescribed by the Department of Environment and Natural Resources (DENR). One reason for the finding could be that these artisanal miners do not extensively use mercury in their methods, or they have understood the need and practiced the procedure to properly dispose of the mercury. It could also be that, currently, artisanal mining is not as widespread as once thought along the Cagayan de Oro River due to an effective crackdown by government authorities against unauthorized mining and the realization that practice is not as profitable as believed.

Significant amounts of heavy metals have been introduced into bodies of freshwater because of industrialization and related anthropogenic activities. Mercury (Hg) discharges have been decreased because of regulatory actions in some regions of the world, although widespread historic contamination still exists.

Additionally, freshwater ecosystems now contain novel metal inputs because of the creation and use of new products (Brand et al., 2020).

Changes in water temperature and DO content in the river system are influenced by the type of land use in the river catchment. Future development along with climate change may damage tropical rivers and the aquatic natural system. Compared to the conversion of forest to agriculture, the conversion of forest to built-up area causes an increase in water temperature and a drop in the DO content. Increased water temperature and lower DO could cause higher nutrient flux, which in turn affects nutrient cycling (Bello et al., 2017).

Fluctuations in DO are crucial information for determining whether the water quality is good or not. DO has an important role in how pollutants migrate through the environment and undergo delicate ecological changes. Nitrogen for instance is converted from nitrate to nitrite as the oxygen is withdrawn when the oxygen content in a system decreases (as the system becomes anaerobic). Bacteria begin to use the oxygen bound in nitrate at this point. These processes are of utmost relevance because reduced species of nitrogen frequently contaminate water (Liqoarobby et al., 2021).

In Table 2, Spearman's correlation coefficients show that water temperature and pH had a negative correlation, rs (16) = -.48, p < .05. On the other hand, there was a positive correlation between water temperature and TDS, rs (16) = .60, p < .01 as well as TDS and PO4-3, rs (16) = .54, p < .05.

It was also observed that there was no significant relationship between DO and any other parameter used in the study.

Table 2

Spearman Correlation Coefficients among Physico-chemical Parameters

	Dissolved Oxygen	Water Temperature	Potential of Hydrogen	Total Dissolved Solids
Dissolved Oxygen (DO)				
Water Temperature (°C)	0.005			
The potential of Hydrogen (pH)	0.358	-.482*		
Total Dissolved Solids (TDS)	0.133	.603**	0.138	
Phosphate (PO_4^{-3})	0.035	0.358	0.408	.540*

Note: **. p < .01 (2-tailed); *. p < .05 (2-tailed); N = 18.

electrical conductivity, solubility of gases (like oxygen), and other contaminants. In addition, temperature regulates cycles of nutrients, decomposition of organic matter, and primary production. In general, warmer temperatures encourage photosynthesis and microbial metabolic activity and have an impact on the growth and functionality of biotic communities (Bonacina et al., 2022). Moreover, the main nutrients and minerals appeared to be unaffected by temperature (Scrine et al., 2017). At higher temperatures, both growth rates and oxygen needed for metabolism increase. Oxygen shortages also occur when water temperatures rise because oxygen solubility in water is inversely related to temperature (Dallas & Ross-Gillespie, 2015). However, this case was not observed in this study. Other aspects might have played a role in this seeming lack of association between temperature and DO like aquatic organisms where photosynthesis and respiration may influence DO concentration and the amount of organic matter in the water that gets to be decomposed by microorganisms would cause a decrease in DO. Moreover, the kind of land use and riparian vegetation have an impact on the amount of DO independent of temperature.

The temperature of the water and the biomass of organisms in the water and sediment have an impact on respiration rates. The intensity of sunlight and plant biomass, among other factors, primarily affects photosynthetic rates. Underwater photosynthesis typically outpaces respiration during the day, causing pH to rise as carbon dioxide is drawn out of the water. The pH of the water decreases during the night as respiring organisms add carbon dioxide to the atmosphere after the sun sets in the late afternoon and photosynthesis slows and eventually ceases. Daily respiration and photosynthesis are roughly equal in most aquatic settings, and the pH will typically stay within an acceptable range for most species. However, when algae or macrophytes grow or multiply quickly, more carbon dioxide is extracted by photosynthesis each day than what is generated by respiration each night. As a result, pH may increase excessively during the afternoon and may continue to climb through the night (Tucker & D'Abramo, 2008).

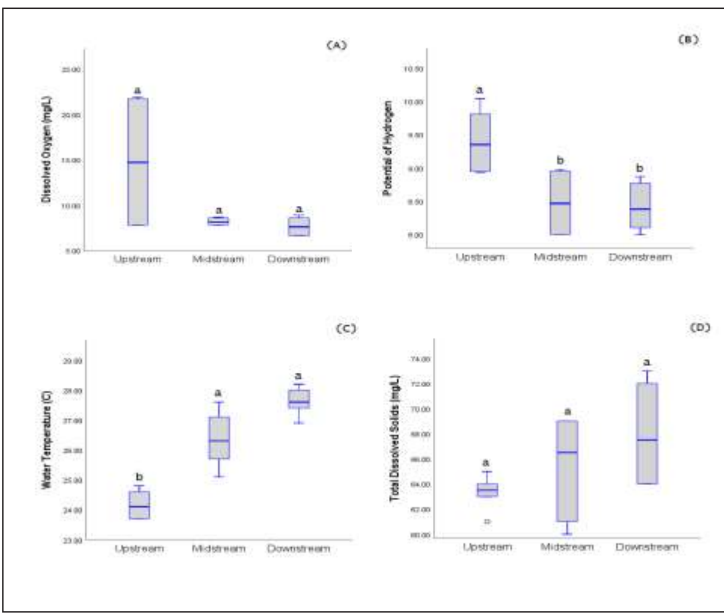
Many water bodies affected by hypoxia may have also been exposed to prolonged warming, and habitats with low oxygen levels can also contain high levels of CO2 and are characterized by subsequent pH declines. Thus, heat that reduces oxygen availability in aquatic habitats could simultaneously accelerate basal metabolism, oxygen consumption, and pH reduction (Griffith & Gobler, 2020).

Solids in water bodies naturally occur, which may have an impact on the water quality and aquatic biota. Anthropogenic influences may result in increased concentrations of solids, leading to physical changes such as decreased light penetration, temperature changes, and aggradation; chemical changes such as the release of contaminants including heavy metals, pesticides, and nutrients, other than DO depletion; and biological changes like biota death because of physical and chemical disruptions (Cunha et al., 2010).

Kruskall-Wallis Test revealed that the distribution of DO was the same for upstream, midstream, and downstream with mean rank scores of 11.50, 9.58, and 7.42 respectively.

Figure 3

Box and Whisker Plot of Kruskall-Wallis Test on the Distribution of DO, pH, Water Temperature, and TDS Across Sampling Spots Upstream, Midstream, and Downstream



Note: Significant at the $p < .05$ level

There was a significant difference in pH across the sampling spots with values upstream being shown to be higher when compared pairwise with both midstream and upstream (mean rank scores of 14.83 for upstream, 7.42 for midstream, and 6.25 for downstream). The water temperature upstream was lower compared to that of midstream and downstream with mean rank scores of 3.50, 10.17, and 14.83 respectively. There was no significant difference in the distribution of TDS across the sampling spots with mean rank scores of 6.50 for upstream, 9.50 for midstream, and 12.50 for downstream.

The elevation of the sampling spot upstream could be largely responsible for the significantly lower temperature compared to the other two sampling spots. The density of riparian vegetation that was observed upstream might also have contributed to this temperature difference.

The higher pH that was recorded upstream could be due to a lesser amount of dissolved CO2 and the presence of more CO3-2 ions. Photosynthetic microorganisms could account for the removal of CO2, and the lower rate of microbial decomposition of organic materials in the water would reduce CO2 release. These two events would result in an increased water pH. The loading of CO3-2 into the water upstream as it carves along limestone cliffs may contribute to this alkalinity as well. High atmospheric CO2, which contributes to the acidity of precipitation along the midstream and downstream sections, could also be responsible for this pH difference. Wastewater discharge, which increases along with an increase in human settlement and activities, is another consideration for lower pH values. The practice of washing clothes using detergents and other soap-based products in the upstream area might also explain the elevated pH in the samples.

It was found in the study of Bello et al. (2017) that the water temperature and DO concentration of a section of a river may vary irrespective of changes in the climate. These parameters could be related to the state of the river channel, vegetation, hydrology, physical characteristics of the river, solar radiation, and rate of flow. Compared to the upstream segment of the river, the middle and downstream have a stronger resistance to climate change. This case is largely due to the contribution from the tributaries that discharge into the main river, which mostly connects at the midstream and the downstream sections.

It was initially assumed that water samples taken downstream would have a higher concentration of TDS because water bodies closer to human activities could be impacted significantly in terms of both inorganic and organic substance load. This assumption is not supported by the data obtained in this study.

The above results for DO and pH were in stark contrast to the study of Zoleta in 2015 that found a significant difference in the distribution of the former and no significant difference in the latter across stations.

CONCLUSIONS

Mercury and nitrate concentrations of the Cagayan de Oro River are below the maximum threshold indicated in the national water quality guidelines for Class A water bodies (DENR AO 2016-08). Meanwhile, phosphate and total coliforms are significantly higher than the established values under DENR AO-2021-19 and DENR AO 2016-08, respectively. All the sampling spots have dissolved oxygen levels above the minimum national standards. The water upstream is more alkaline than the recommended pH range and at the same time cooler than the lowest temperature set by DENR AO 2016-08.

Among the physicochemical parameters that were tested, water temperature was found to be significantly correlated with pH (-) and TDS (+). On the other hand, TDS is also positively correlated with phosphate. DO and TDS are observed to be equally distributed across the sampling spots, whereas upstream waters are cooler and have a higher pH compared to those in the midstream and downstream.

The physical, chemical, and biological characteristics of a water body are all related to its water quality, which is a measure of all hydrological parameters. Thus, physicochemical, and microbiological analyses that may reflect the biotic and abiotic status of aquatic ecosystems are vital components of a process that will assess the overall ambient water quality.

RECOMMENDATIONS

High-frequency monitoring is necessary to adequately capture the episodic nature of the physicochemical and microbiological parameters of the Cagayan de Oro River. Furthermore, it is crucial to consider both the type of data being gathered and the frequency of data collection. It is also important to evaluate catchments over longer periods to adequately assess the range of catchment nutrient flux behaviors and develop and implement the best mitigation strategies.

A more extensive assessment would provide a better picture of the ambient water quality of the river considering that the general conditions (both geogenic and anthropogenic) of the watershed, characteristics of the riparian zone, the physical and chemical features of the soil, and the slope of the land can all affect fluctuations in the water quality. Evaluating the local land use management can also give researchers a glimpse into the extent of water quality deterioration.

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