WATER QUALITY ASSESSMENT OF BUTUANON RIVER IN CEBU CITY: FECAL INDICATOR BACTERIA AND PHYSICOCHEMICAL PROPERTIES

S.M. Macawile[1], S.J. Sumalpong[1], D. Reyes[1] , C.N.M.E. Siojo[1], J. Bustamante[1*]

[1]University of Cebu-Banilad.

[*]Corresponding Author's Email: jesonbustamante@gmail.com

Article History: Received April 13, 2025; Revised June 04, 2025; Accepted July 16, 2025

ABSTRACT: Cebu's Butuanon River is under investigation as potential water source by the Department of Environment and Natural Resources [DENR], together with the Environmental Management Bureau of Region 7 [EMB 7], but declining water quality poses risks to human and animal health. This study investigates its fecal indicator bacteria [FIB], specifically fecal and total coliforms, and physicochemical properties within Cebu City's borders. Utilizing analytical cross-sectional design and purposive sampling, researchers collected samples from upstream (Pulang-Bato), midstream (Bacayan Bridge-Biofence), and downstream (Talamban Bridge-Sitio Tintay) for laboratory testing. FIB levels were determined using the Multiple Tube Fermentation Technique (MPN/100 mL), while Biochemical Oxygen Demand [BOD] was determined using the 5-day BOD test, Dissolved Oxygen [DO] using Azide Modification, and Total Suspended Solids [TSS] with Gravimetric Analysis. Data were treated using mean, standard deviation, SPSS version 29 for statistical analysis. Findings revealed lower fecal coliform levels in the upstream, with increasing levels in the midstream and downstream, whereas, total coliforms are constant among the three sampling sites. Physicochemical properties failed to meet the Class C water quality criteria set by the DAO 2016-08, indicating significant microbial pollution. No significant differences were found in mean FIB, BOD, DO, and TSS levels among sites, but a significant relationship existed between water quality and FIB levels, indicating the need for interventions to improve the river's water quality.

***KEYWORDS**: Public Health, Contamination, Wastewater, Industrial, Residential*

1.0 INTRODUCTION

Butuanon River is a 23-km long water with an area comprising 62.5 square kilometers running through some parts of Mandaue and Cebu City. The Butuanon River's condition was deteriorating, according to the Department of Environmental and Natural Resources Central Visayas research as revealed by abnormally high levels of biochemical oxygen demand and coliform compared to previous years. The state of Butuanon River is under significant stress due to the rising human population, urban expansion, and economic endeavors. According to the Environmental Management Bureau of Region 7, sixty commercial or industrial establishments dump wastewater into the Butuanon, fifty-three of which are in Mandaue City and seven in Cebu City. Other factors including pathogenic microorganisms, chemical pollutants, and contaminants from urbanization were highlighted [1]. The combined impact of these factors adversely affects both ecological systems and human health, rendering contaminated rivers unfit for human use and unsustainable for plant and animal life.

The contamination of river water poses significant health risks to humans through various pathways such as drinking water, consumption of contaminated food from the river's food chain, and background exposure for those living near pollutant sources. The presence of fecal coliform across various sites along the river further emphasizes the widespread nature of this issue, indicating that multiple points in the water system are affected. The following conditions can be acquired in water with elevated fecal coliform counts: hepatitis, gastroenteritis, dysentery, typhoid fever, and ear infections. Diarrheal illnesses are expected to kill 1.8 million people worldwide each year, the majority of whom are children from underdeveloped countries [2]. Fecal pollution has the potential to impact human health and the environment due to the release of pathogens, antibiotic-resistant organisms, high nutritional loads, and the emission of toxic gasses. The study implies that understanding how individuals perceive and respond to the quality of river water is essential for effective environmental management and public health initiatives. Ensuring sustainable access to sufficient quantities of water with acceptable quality is essential for supporting human well-being, socioeconomic development, and environmental conservation, as well as mitigating pollution and water-related disasters [3].

A study conducted states that the Butuanon River is not a suitable site for water sources for humans, plants, and animals due to its physicochemical components [4]. Aside from this, the water quality of the Butuanon River has worsened due to the rampant improper disposal of waste and incorrect use of river water. Untreated wastewater from factories is dumped directly or indirectly into rivers, producing surface water contamination [5]. Municipal solid waste and industrial effluents have both had a significant impact on the water quality of rivers in Bangladesh over the last several decades [6-8]. In a different study conducted, the usage of coliform as an indicator in assessing the waters of Buhisan, Bulacao, and Lahug rivers was utilized [9]. Another study conducted assessed the bacteriological quality of water in the Matutinao River since this is one of the spots where canyoneering activity is done [10]. In general, the presence of fecal-indicator bacteria in river water samples indicates fecal pollution of this freshwater resource, boosting the probability of dangerous microorganisms in the water and posing a concern to public health.

Despite their importance for public health, however, not much research has been done on the persistence, transfer, and proliferation of these pathogens and their corresponding indicator organisms, such as fecal indicator bacteria (FIB) like Escherichia coli and fecal coliforms, in humid tropical systems like those found in Southeast Asia or the tropical regions of Africa [11]. Even though the Butuanon River is the first Water Quality Management Area (WQMA)in Region 7, nothing is known regarding its exact FIB levels in some areas of Cebu City corresponding indicator organisms. In coordination with the Cebu City Environment and Natural Resources Office (CCENRO), chose total coliforms and fecal coliforms as the bacterial indicators to be quantified to provide data essential to evaluating the state of the river. Results from this study will then be utilized to provide research-based data to inform risk assessment and propose targeted interventions.

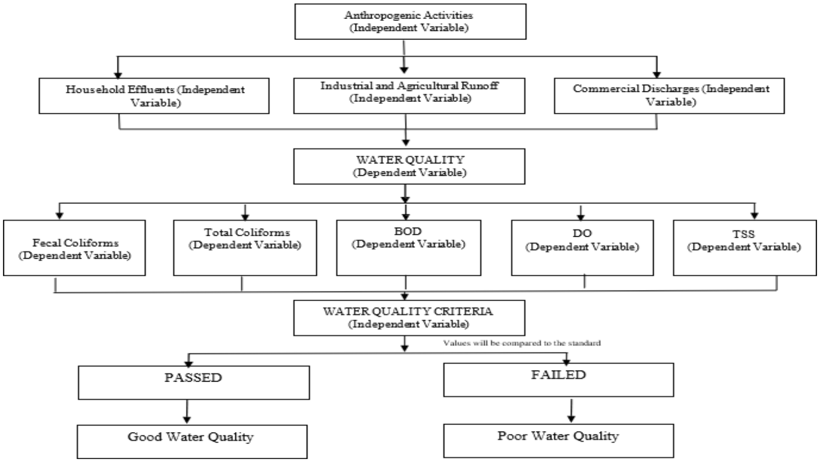

Figure 1: Conceptual Framework

Figure 1 illustrates the independent and dependent variables used in this investigation. The Butuanon River's water quality was assessed using the following parameters: biochemical oxygen demand [BOD], dissolved oxygen [DO], total suspended solids [TSS], thermotolerant (fecal) coliform [FC], and total coliform [TC]. Another independent variable, the water quality criteria, which include the Department of Environment and Natural Resources Administrative Order 2016-08, is utilized to assess if the measured parameters passed or failed. If the values met the required threshold levels, they passed; otherwise, they failed. This study is anchored to the Germ theory by Charles Chapin. Charles Chapin states that Germ Theory indicates that many pathological conditions are caused by the presence in the body of certain micro-organisms. According to Fracastoro, germs spread through populations through direct or indirect contact between individuals, making people sick. However, in the 16th century, Fracastoro's ideas were disregarded by other physicians [12]. The transition to acceptance of the Germ Theory during the 19th century provided a solid mechanistic grounding to the study of disease patterns [13]. Koch's insights paved the way for further understanding of infectious agents, as demonstrated when he successfully cultured Bacillus anthracis, leading to the identification of numerous pathogenic bacteria [14]. This method, introduced by Robert Koch, revolutionized pathogen identification and provided strong support for the germ theory of diseases [15].

The study aimed to conduct a thorough assessment of the water quality in Butuanon River, with a focus on the parameters needed by the Cebu City Environment and Natural Resources Office (CCENRO) to provide baseline data for their independent water quality monitoring. The study addressed the following specific aims:

1. The levels of total coliforms and fecal coliforms in Butuanon River were assessed at key sampling sites (upstream in Barangay Pulang-Bato, midstream at Bacayan Bridge-Biofence, and downstream at Talamban Bridge-Sitio Tintay) to gauge the extent of microbial pollution and determine which area had the highest levels of biological pollution.
2. The microbial quality of water was classified as either passed or failed based on established standards.
3. Total Suspended Solids [TSS], Biochemical Oxygen Demand [BOD], and Dissolved Oxygen [DO] were measured to understand the river's overall health and its ability to support aquatic life. This analysis also helped identify possible sources of pollution.

Statement of Null Hypotheses

From the statement of the problem presented above, the following hypothesis is formulated:

H01: There is no significant relationship between the water quality of the Butuanon River and its fecal indicator bacteria, specifically, total coliform and fecal coliform.

H02: There are no significant differences in the levels of total coliform in the three different sampling sites.

H03: There are no significant differences in the levels of fecal coliform in the three different sampling sites.

H04: There are no significant differences in the levels of BOD, DO, and TSS among the three sampling sites (upstream, midstream, and downstream) of the Butuanon River.

2.0 METHODOLOGY

2.1 Research Design

The researchers used the Analytical Cross-Sectional Study Method as their quantitative research design in gathering data regarding the levels of Fecal Indicator Bacteria [FIB], specifically, total coliforms and fecal coliforms. Quantification for Dissolved Oxygen [DO], Biochemical Oxygen Demand [BOD], and Total Suspended Solids [TSS] were also utilized in correlation with the parameters needed by CCENRO for their independent monitoring. Setia cited that this research design is also used and proven to be beneficial in establishing plans and assessing public health concerns [16].

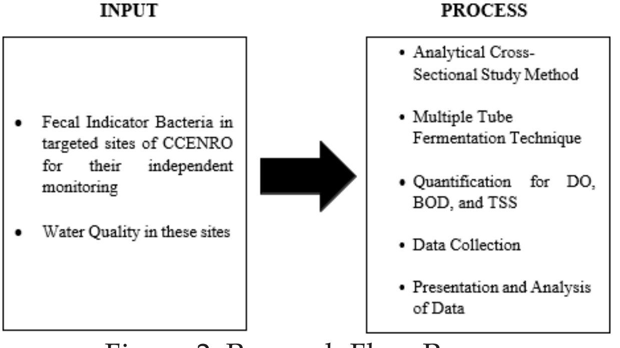

Figure 2: Research Flow Process

2.2 Research Environment

The testing was conducted by the F.A.S.T. Laboratories-Cebu, M.C. Briones St. Highway, Brgy. Guizo, Mandaue City, 6014 Cebu. The researchers chose to conduct the water quality testing at the aforementioned laboratory since it is equipped with the instruments needed and has government accreditation to perform water testing. The water samples were specifically collected in three different locations, upstream, midstream, and downstream. The upstream location identified by the CCENRO was in Barangay Pulang-Bato (10°24'02.7"N 123°54'06.7" E), Midstream: Bacayan Bridge-Bio fence (10°22'47.3"N 123°55'14.8" E), and Downstream: Talamban Bridge- Sitio Tintay (10°22'29.8"N 123°55'15.4").

2.3 Research Subjects

This study utilized a purposive sampling technique. In coordination with the Cebu City Natural Resources and Environment Office [CCENRO], the researchers collected water samples from the sampling sites identified by CCENRO for their independent water quality monitoring. These sampling sites include upstream (Pulang-Bato), midstream (Bacayan Bridge-Biofence), and downstream (Talamban Bridge-Sitio Tintay). The water samples are then delivered to a DENR-accredited third-party laboratory, the F.A.S.T. Laboratories, for analysis. In testing for fecal indicator bacteria [FIB], specifically total and fecal coliforms, the third-party laboratory used a multiple tube fermentation technique, where results are expressed in MPN/100 mL. For the analysis of the physicochemical properties, the 5-day BOD test was used for the biochemical oxygen demand, azide modification for the dissolved oxygen, and gravimetric analysis for the total suspended solids. While purposive sampling is justified due to the collaboration with CCENRO and their identification of key sampling locations based on environmental relevance and ongoing monitoring programs, the lack of randomization and small sample size pose limitations to the study. With only one sample collected per site ($n = 3$ in total), the data may not fully represent the variability of water quality conditions over time or within each site. This limits the generalizability of the findings, as the results may be affected by site-specific anomalies or transient environmental factors, especially during the rainy season when water characteristics can rapidly change. Future studies may benefit from increasing the sample size and incorporating random or stratified sampling methods to enhance the reliability and representativeness of the data.

2.4 Inclusion and Exclusion Criteria

All water samples were collected in the mid-depth section and are grossly fit for the study of water quality. Wastewater, such as river water obtained from the Butuanon River in the three locations (upstream, midstream, and downstream) was included in this study. Water testing was done by F.A.S.T laboratories, a DENR- accredited laboratory. Secondary parameters for water quality assessment set by DAO 2016-08 were excluded during the testing of all water samples. Also, the water quality from the dry season is not tested in this study.

2.5 Research Instruments

The Multiple Tube Fermentation Technique, 5-day BOD test, Gravimetry, and Azide Modification were utilized in this investigation by the accredited third- party laboratory, F.A.S.T. Laboratories-Cebu. These were used as quantitative tools that directly quantified total coliform, fecal coliform levels, total suspended solids, dissolved oxygen, and biochemical oxygen demand to further allow assessment of the potential risks present along the area of Butuanon River. The findings were instrumental in making informed decisions regarding the data gathering and rehabilitation of the area. Water samples (3L and 450mL) were collected from three sites: Pulang-Bato (10°24'02.7"N 123°54'06.7"E), Bacayan Bridge-Bio fence (10°22'47.3"N 123°55'14.8"E), and Talamban Bridge-Sitio Tintay (10°22'29.8"N 123°55'15.4"E). Samples were placed in screw-cap bottles with tin foil. The Multiple Tube Fermentation Technique involved Lauryl Tryptose Broth for the presumptive test, with gas formation indicating positive results after 24 hours. Positive samples were inoculated in Brilliant Green Lactose Bile Broth (BGLB) and Escherichia coli Broth (EC) for confirmation. For completed tests, Eosin-Methylene Blue (EMB) agar, Lauryl Tryptose Broth, and nutrient agar slants were used. Gram-staining was performed on gas-producing colonies, and microbial concentration was reported as the Most Probable Number (MPN). Total Suspended Solids (TSS) utilized he gravimetric method. Samples were filtered through glass fiber filters, dried in an oven, and weighed to determine solid concentrations. Dissolved Oxygen (DO) was measured using Winkler's Azide Modification. Oxygen reacted with Mn^{2+} under basic conditions, forming a brown precipitate, which was dissolved in acid. Liberated iodine was titrated with sodium thiosulfate, with a starch indicator marking the endpoint. Sodium azide was used to eliminate nitrite interference. Biochemical Oxygen Demand (BOD) was determined by incubating water samples in dilution water containing inorganic nutrients and a pH buffer for five days. Initial and final DO levels were measured, and oxygen consumption was calculated to assess organic matter decomposition.

2.6 Research Procedures

The research paper underwent a University of Cebu Research Ethics Committee [UCAREC] review for ethical clearance and approval. Following F.A.S.T. Laboratories-Cebu protocols, water samples were collected from upstream, midstream, and downstream locations. Sterile screw-cap bottles with tin foil were submerged one foot below the surface, with the bottle mouth facing upstream. Each sample was labeled with location, date, time, and collector's initials, then transported within six hours to F.A.S.T. Laboratories under <10°C storage conditions using an ice chest. The Multiple Tube Fermentation Technique was used to detect fecal and total coliforms. In the Presumptive Stage, water samples were inoculated into lauryl tryptose broth and monitored for gas formation at 24 and 48 hours. Positive samples proceeded to the Confirmatory Stage, where they were transferred to Brilliant Green Lactose Bile Broth (BGLB) and Escherichia coli Broth (EC) for further incubation, with gas production confirming contamination. In the Completed Stage, samples were streaked on Eosin Methylene Blue (EMB) agar and incubated. Colonies were then transferred to nutrient agar slants and fermentation tubes for further incubation, and Gram-staining confirmed the presence of coliform bacteria. Most Probable Number (MPN) results were compared to Department of Environment and Natural Resources (DENR) standards (Administrative Order 2016-08) to classify water quality as passed or failed. Bacterial levels were analyzed to determine the most contaminated site. Used materials were disposed of per standard laboratory protocols, and work areas were disinfected to prevent cross-contamination. The 5-Day Biochemical Oxygen Demand (BOD) Test involved collecting 3L of water samples, preparing dilution water, and incubating BOD bottles at 20°C for five days. For Dissolved Oxygen (DO) Analysis, the Azide Modification method was used, where manganous sulfate, potassium iodide, and sodium azide were added to the sample, forming a precipitate that was acidified with sulfuric acid; iodine was then titrated with phenylarsine oxide using a starch indicator. The Gravimetric Method was applied for Total Suspended Solids (TSS) by filtering water samples through pre- weighed glass fiber pads, drying them at 105°C, and weighing for TSS concentration. If total volatile solids were analyzed, samples were further incinerated at 550°C in a muffle furnace, cooled, and reweighed.

2.7 Treatment of Data

Data were presented in tabular form, showing the mean and standard deviation of fecal indicator bacteria (FIB), biochemical oxygen demand (BOD), dissolved oxygen (DO), and total suspended solids (TSS). Hypotheses were tested at a 0.05 significance level using SPSS version 29. The Mann-Whitney U Test assessed differences in thermotolerant (fecal) and total coliform levels (MPN/100 mL), while One-way ANOVA determined significant differences among physicochemical properties (mg/L). Normality was checked using the Shapiro-Wilk test ($p > 0.05$), variance equality was assessed with Levene’s test ($p > 0.05$), and the

Brown-Forsythe test further examined differences in mg/L levels. The Butuanon River's water quality was classified as passed or failed based on DAO 2016-08, identifying locations with persistent fecal contamination.

3.0 RESULTS AND DISCUSSION

This assessment is carried out by comparing the measured value of a water quality parameter to the Philippine water quality requirements. This chapter is divided into three parts. The first part is intended for microbiological analysis, interpretation, and discussion. The second part is solely for the microbiological classification of the Butuanon River, and the third part indicates the physicochemical properties analysis, interpretation, and discussion.

3.1 Microbiological Analysis

Table 1: Mean levels of fecal coliforms and total coliforms (in MPN/100 mL)

Parameters	Upstream	Midstream	Downstream	Mean	SD
Thermotolerant (Fecal) coliforms	5.4×10^4	1.6×10^6	1.6×10^6	1.1×10^6	7.3×10^5
Total coliforms	1.6×10^6	1.6×10^6	1.6×10^6	1.6×10^6	0

As shown in Table 1, the mean level of total coliforms (in MPN/100 mL) is higher than that of fecal coliforms (in MPN/100 mL) across the sampling locations in Butuanon River. Thermotolerant (Fecal) and total coliform counts were consistently high at all three sampling locations, indicating significant microbial pollution. These levels exceeded the Class C Water Quality Criteria of DAO 2016-08. Total coliform levels were uniform upstream to downstream, while Thermotolerant (Fecal) Coliform is highest in concentration in the midstream (Bacayan Bridge-Biofence) and downstream (Barangay Talamban-Sitio Tintay) locations indicating a high probability for microbial pollution. However, results across the three sampling locations for total coliforms were identical, signifying why the standard deviation for total coliforms is 0. The consistency of the results appear unlikely due to the natural environment that is more likely subject for variability. To ensure the robustness of these results, it is highly encouraged for future studies to collect more than one sample for each parameter and sampling site, and to consider seasonal changes that may affect the water quality of the Butuanon River.

Table 2: Mann-Whitney U test results of the difference between the mean levels of fecal coliforms and total coliforms (in MPN/100 mL)

Test statistic	Standard Error	p-value	Interpretation
6.000	1.500	0.700	There was no significant difference between the two groups.

As shown in Table 2, the Mann-Whitney U test results indicate that there was no significant difference in the distribution of fecal coliforms and total coliforms, thus accepting the first null hypothesis. This suggests that there's no sufficient evidence that the average MPN/100 mL is different between the two parameters. Mann-Whitney U Test was also used to make a comparison of results between the two independent groups (fecal coliforms and total coliforms). Also, this non-parametric counterpart was chosen over ANOVA, a parametric test, for its robustness in analyzing data that may not meet the assumptions for normal distribution. This is also suitable for a smaller sample size and results that are ordinal or skewed, which is common in environmental studies involving microbial counts.

Table 3: Mean levels of total coliforms (in MPN/100 mL) by sampling location

Parameters	Upstream	Midstream	Downstream
Total coliforms	1.6×10^6	1.6×10^6	1.6×10^6

Table 3 indicates that the mean levels of total coliforms (in MPN/100 mL) are the same across the three sampling locations. This suggests no variation in the presence of total coliforms regardless of the sampling location, thus, accepting the second null hypothesis. However, total coliforms from the three sampling sites exceeded the Class C water body classification of the Department of Environment and Natural

Resources [DENR] Administrative Order 2016-08, where the threshold level is 5000 MPN/100 mL, thus, failing to fulfill regulation. This also points to a system-wide source of contamination, potentially due to continuous upstream inputs or multiple sources of pollution. Additionally, Mann-Whitney U Test, in comparison to fecal coliforms, was conducted to ensure that the consistency of results was unlikely due to random chance.

Table 4: Mean levels of fecal coliforms (in MPN/100 mL) by sampling location

Parameters	Upstream	Midstream	Downstream
Thermotolerant (Fecal) coliforms	5.4×10^4	1.6×10^6	1.6×10^6

As presented in Table 4, the presence of fecal coliforms upstream is lower on average compared to midstream and downstream (in MPN/100 mL), indicating a significant difference, thus rejecting the third null hypothesis. Whereas, the mean levels of fecal coliforms in midstream and downstream are the same. However, according to the Department of Environment and Natural Resources [DENR] Administrative Order 2016-08, the threshold level of thermotolerant (fecal) coliform is 200 MPN/100 mL, which all sampling sites failed to meet. Moreover, the standard deviation from Table 1 ensures the variability of the data given, supporting the robustness of this analysis.

3.2 Microbiological Classification of Butuanon River

Table 5: Comparison between the of Absolute Growth Index of Test Microorganisms in Mung Bean Agar and Trypticase Soy Agar

Sampling Sites	Unit of measurement	Thermotolerant (fecal) coliforms	Total coliforms	Interpretation
Pulang-Bato	MPN/100 mL	5.4×10^4	$>1.6 \times 10^6$	**FAILED**
Bacayan-Biofence	MPN/100 mL	$>1.6 \times 10^6$	$>1.6 \times 10^6$	**FAILED**
Talambam Sitio Tintay	MPN/100 mL	$>1.6 \times 10^6$	$>1.6 \times 10^6$	**FAILED**

Standards (Class C Water Quality Criteria from DAO 2016-08)	MPN/100 mL	200 (DAO 08)	5000 (DAO 08)

Table 5 demonstrates how the Butuanon River sampling sites are classified according to accepted standards. Pulangbato's fecal coliform had a value of 5.4×10^4 MPN/100 mL, which is above the threshold level, failing. Bacayan and Talamban sites have values above the standard (>$1.6\text{x}10^6$), which also indicates failure. Furthermore, total coliform levels at all three sampling sites exceeded the Class C criterion (>$1.6\text{x}10^6$), thus, failing it. These findings are contextualized by a comparison to other Cebu City rivers such as Buhisan, Bulacao, and Lahug. The University of the Philippines Cebu conducted a study on the water quality of these rivers, using fecal and total coliform as markers. The researchers discovered that all three rivers had high coliform counts, with fecal coliform levels exceeding the acceptable limit of 400 Most Probable Number (MPN) per 100 milliliters. Buhisan River had fecal coliform counts as high as 7.8×10^{12} MPN/100 mL, while Bulacao and Lahug rivers also showed abnormal levels.Further analysis by the Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB 7) in 2022 reported alarmingly high fecal coliform levels in several Cebu City rivers. The report indicated that Butuanon River had fecal coliform counts reaching 5 million MPN/100 mL, Bulacao River at 3 million MPN/100 mL, and Lahug River at 24,000 MPN/100 mL. These levels significantly exceed the acceptable limit of 400 MPN/100 mL for Class C water bodies.

3.3 Physiochemical Properties Analysis

Table 6: Physicochemical Properties Classification of Butuanon River based on DAO 2016-08

Barangays	BOD	Interpretation	αDO	Interpretation	TSS	Interpretation
Pulang-bato	Less than 1**	FAILED	7.5	FAILED	8	PASSED
Bacayan-Biofence	119	FAILED	1.2	FAILED	86	FAILED
Talamban Sitio Tintay	57	FAILED	0.6	FAILED	28	PASSED
Standards (Class C Water Reference	7		5 (DAO 2016-08)		<80 (DAO 2016-08)	

Indicated in Table 6, the biochemical oxygen demand in the Barangay Pulang-bato location was determined to be less than 1 mg/L. The barangay of Bacayan is at 119 mg/L, while the barangay of Talamban revealed a value of 57 mg/L. Dissolved oxygen (DO) levels fluctuate throughout three places, with 7.5 mg/L in Pulang-bato, 1.2 mg/L in Bacayan, and 0.6 mg/L in Talamban. The results for BOD and DO may be deficient. Analysis proceeded despite non-conformance to sample requirements for holding time of the Dissolved Oxygen (not done on-site) and Biochemical Oxygen Demand (with airspace). Total suspended solids (TSS) levels were low at the upstream location, at 8 mg/L. This is due to the clarity of the water sample at that site. Barangay Bacayan has the greatest amounts, at 86 mg/L, due to effluents from the domestic sector flowing down the river channel. With a TSS of 28 mg/L, Barangay Talamban values are lower than midstream. Biochemical oxygen demand [BOD], due to its high levels, failed to meet the standards set by the Department of Environment and Natural Resources Administrative Order 2016-08. Dissolved oxygen [DO] levels across the three locations are found to be outside the laboratory's PAB accreditation. In terms of total suspended solids [TSS], only the Barangay Pulang-bato and Barangay Talamban met the standards and therefore, passed.

Table 7: Mean levels of BOD, DO, and TSS (in mg/L)

Parameters	Upstream	Midstream	Downstream	Mean	SD
BOD	1	119	57	59.0	48.19
DO	7.5	1.2	0.6	3.1	3.12
TSS	8	86	28	40.7	33.08

As indicated in Table 7, Butuanon River contains an average of 59.0 mg/L BOD (SD = 48.19 mg/L). Compared to the presence of DO and TSS levels (in mg/L), this is the highest of the three parameters. According to Class C water body guidelines, biochemical oxygen demand [BOD] should not exceed 7 mg/L; thus, 59.0 mg/L is significantly too high. The standard specifies dissolved oxygen concentrations of 5 mg/L. Butuanon River has an average of 3.12 mg/L, which is lower than the standard. Total suspended solids, on the other hand, had an average of 33.08 mg/L, which is less than the threshold level of 65 mg/L.

Table 8: Analysis of Variance of the Mean levels of BOD, DO, and TSS (in mg/L)

Source of Variation	SS	df	MS	F	p-value	Interpretation
Between Groups	4872.18	2	2436.09	1.422	.312	There was no significant difference across the three parameters.
Within Groups	10279.89	6	1713.31			
Total	15152.06	8				

Table 8 shows that at 0.05 level of significance, there was no significant difference in the mean levels of BOD, DO, and TSS (in mg/L) across the sampling sites in Butuanon River, $F(2, 8) = 1.422$, $p > 0.05$, thus accepting the fourth null hypothesis. This implies that the water quality in terms of these parameters is rather consistent across the study sites. This suggests that pollution sources affecting these parameters have a similar impact along the river. These findings are consistent with Picardal and Marababol's (2012) investigation, which found that water samples had low levels of dissolved oxygen [DO], high biochemical oxygen demand [BOD], and high chemical oxygen demand [COD], all of which were over the DENR A.O.'s normal limits. 34 (1990). The Butuanon River's water quality has deteriorated as a result of widespread inappropriate disposal of waste and incorrect usage of river water, both of which have contributed significantly to the river's pollution.

Table 9: Brown-Forsythe for the levels of BOD, DO, and TSS (in mg/L)

Test statistic	df1	df2	p-value	Interpretation
1.422	2	3.562	.352	There was no significant difference across the three parameters.

Brown-Forsythe robust test indicated that there was no significant difference in the mean levels of mg/L of BOD, DO, and TSS in Butuanon River (Table 9).

4.0 CONCLUSION

The Findings of this study revealed that the water quality of Butuanon River in Cebu City Locations still failed to meet the criteria set by the Department of Environment and Natural Resources for Class C water bodies due to its levels that are higher than the said standard thus, is not fit for human use and cannot support a variety of plants and aquatic animals. Thermotolerant (Fecal) Coliform is highest in concentration in the midstream (Bacayan Bridge-Biofence) and downstream (Barangay Talamban-Sitio Tintay) locations indicating a high probability of microbial pollution. There were no variations in the presence of total coliforms regardless of the location. Uncontrolled disposal of wastes from the industrial and commercial sectors was mainly responsible for the river's current polluted status. There was no significant difference at 0.05 between the mean levels in MPN/100 mL of fecal and total coliforms. The concentration of coliform bacteria is variable under the changing aquatic environment. Biochemical oxygen demand [BOD] averages 59 mg/L, which exceeds the 7 mg/L standard. High BOD levels are typically associated with large amounts of organic pollution caused by sewage, industrial runoff, or household runoff. These settings provide an ideal environment for coliform bacteria to thrive. Total suspended solids and dissolved oxygen levels were lower than the established requirements. There were no significant differences in the mean levels of fecal and total coliform, while biochemical oxygen demand [BOD], dissolved oxygen [DO], and total suspended solids [TSS] did not differ significantly between sample locations. The river's status is determined using the obtained results,determining the impact of measures required to improve the water quality of the river.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare and are in agreement with the contents of the manuscript.

ACKNOWLEDGMENTS

This study would not have been possible without the assistance and support of these individuals, who inspired the creation of this thesis. Sincere gratitude to the following: Dr. Jeson Bustamante, Ms. Chloe Naty Marie Eugenie A. Siojo, Cebu City Environment and Natural Resources Office [CCENRO], especially Engineer Myka Marie Llanos and the Water Testing Team, and the Barangays, the Research Team, and to the Almighty God.

5.0 REFERENCES

[1] Sanchez JM, Caturza RR, Picardal M, Librinca J, Armada R, Pineda H, et al. Water management practices and environmental attitudes of riparian communities in Sapangdaku River. Biosaintifika. 2022;14:147–59. doi:10.15294/biosaintifika.v14i2.36185

[2] *Ahs J, Tao W, Löfgren J, Forsberg B. Diarrheal diseases in low- and middle-income countries: incidence, prevention and management. Open Infect Dis J. 2010;4:113–24. doi:10.2174/1874279301004010113*

[3] Lu Y, Nakicenovic N, Visbeck M, Stevance A-S. Policy: Five priorities for the UN Sustainable Development Goals. Nature. 2015. Available from: https://go.nature.com/3U8gHKH

[4] Picardal J, Marababol M. Impacts of waste disposal practices and water utilization of riverside dwellers on physicochemical and microbiological properties of Butuanon River, Central Visayas. CNU J Higher Educ. 2012;Special Issue:78–100. Available from: https://bit.ly/3wg6ILx

[5] Whitehead P, Bussi G, Hossain MA, Dolk M, Das P, Comber S, et al. Restoring water quality in the polluted Turag–Tongi–Balu river system,

Dhaka: modelling nutrient and total coliform intervention strategies. Sci Total Environ. 2018;631–2:223–32. Available from: https://bit.ly/3TmRL1C

[6] Hasan MK, Shahriar A, Jim KU. Water pollution in Bangladesh and its impact on public health. Heliyon. 2019;5(8):e02145. doi:10.1016/j.heliyon.2019.e02145

[7] Islam MS, Tusher TR, Mustafa M, Mahmud S. Effects of solid waste and industrial effluents on water quality of Turag River at Konabari Industrial Area, Gazipur, Bangladesh. *J Environ Sci Nat Resour*. 2012;5(2):2. doi:10.3329/jesnr.v5i2.14817

[8] Uddin MJ, Jeong Y-K. Urban river pollution in Bangladesh during last 40 years: potential public health and ecological risk, present policy, and future prospects toward smart water management. *Heliyon*. 2021;7(2):e06107. Available from: https://bit.ly/49LCu1r

[9] Bensig E, Flores MJ, Maglangit F. Assessment of the water quality of Buhisan, Bulacao and Lahug Rivers, Cebu, Philippines using fecal and total coliform as indicators. *Curr World Environ*. 2014;9:570–6. Available from: https://bit.ly/3wm78jc

[10] Bureros KJC, Layos JJC, Dueñas KJ. Bacteriological water analysis of Matutinao River in Badian, Cebu. *Palawan Scientist*. 2022;14(2):1–8. Available from: https://bit.ly/4dhlTok

[11] Rochelle-Newall E, Nguyen TMH, Le TPQ, Sengtaheuanghoung O, Ribolzi O. A short review of fecal indicator bacteria in tropical aquatic ecosystems: knowledge gaps and future directions. *Front Microbiol*. 2015;6:308. doi:10.3389/fmicb.2015.00308

[12] Miller C. *Human biology – excerpts for BBIO 053*. Thompson Rivers University; 2020. Available from: https://pressbooks.bccampus.ca/humanbiology053/

[13] Kagle J. *Microbiology for the health sciences*. Mansfield (PA): LibreTexts; 2020. Available from: https://bio.libretexts.org/Bookshelves/Microbiology

[14] Berche P. Louis Pasteur: from crystals of life to vaccination. *Clin Microbiol Infect*. 2012;18(5):1–6. doi:10.1111/j.1469-0691.2012.03945.x

[15] Lakhtakia R. The legacy of Robert Koch. *Sultan Qaboos Univ Med J*. 2014;14(1):37–41. doi:10.12816/0003334

[16] Setia MS. Methodology series module 3: cross-sectional studies. Indian J Dermatol. 2016;61(3):261–4. doi:10.4103/0019-5154.182410