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Water quality assessment: A baseline study of Canal de Pasacao in Pasacao Camarines Sur

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Abstract

This study used a quantitative descriptive design to evaluate the baseline water quality of the Canal De Pasacao River in Pasacao, Camarines Sur, and to identify environmental pressures across upstream (Barangay Quitang), midstream (Odicon), and downstream (Sta. Rosa Del Norte) stations. Water samples were analyzed for physical, chemical, and microbiological parameters through in situ measurements and accredited laboratory testing, following DENR-EMB Water Quality Monitoring Manual guidelines. Results were interpreted using DAO 2016-08 standards. Findings revealed that temperature, total suspended solids, salinity, pH, dissolved oxygen, color, and fecal coliform levels complied with standards. Phosphate and nitrate levels were above guideline values, indicating nutrient enrichment. Biochemical oxygen demand failed at the midstream station, while chloride concentrations rose markedly downstream. Contributing factors include domestic discharges, agricultural runoff, livestock activities, and Increasing human settlement along riverbanks. Based on these results, the river aligns with Class C classification under DAO 2016-08 suitable for fisheries, irrigation, and secondary contact recreation, but not for direct human consumption. These findings underscore the need for strengthened waste management systems, routine water quality surveillance, and community-driven conservation strategies to protect the ecological integrity of the Canal De Pasacao River.

Keywords: water quality assessment, physico-chemical parameters, biological parameters, DAO 2016-08, river classification

Water quality assessment: A baseline study of Canal de Pasacao in Pasacao Camarines Sur

1. Introduction

Water is a fundamental natural resource that sustains life on Earth. About 71 percent of the Earth's surface is water-covered and only 2.5% of Earth's water is freshwater – the amount needed for life to survive (United States Geological Survey, 2019). Water plays an essential role in both natural ecosystems and human development. It is not only a basic need but also a central pillar of economic and environmental sustainability. The use of water varies according to geographic, economic, and demographic conditions. Agriculture accounts for approximately 70% of global freshwater withdrawals, followed by industry (20%) and domestic use with 10% (Food and Agriculture Organization, 2022). Water quality degradation remains a critical global concern, driven largely by inadequate waste management and increasing human activities. Globally, according to United Nations Educational, Scientific and Cultural Organization (UNESCO) World Water Assessment Programme (2017), a significant proportion of wastewater is released into the environment without proper treatment estimated at over 80% resulting in the contamination of rivers, lakes, and coastal waters. This widespread discharge of untreated wastewater contributes to the deterioration of water quality, posing serious risks to human health, aquatic ecosystems, and sustainable water resource management.

Urbanization and industrialization contribute significantly to the reduction of water quality and quantity. Urbanization is another significant challenge that exacerbates water quality issues. It is anticipated that over twothirds of the global population will reside in urban areas soon, leading to heightened pollution from wastewater, industrial effluents, and other anthropogenic activities (Kim & Kim, 2022, as cited in Machona et al., 2025). Poor agricultural practices, such as the excessive use of fertilizers and pesticides, further degrade water quality (Khatri & Tyagi, 2015, as cited in Machona et al., 2025). Pollution has also degraded the quality of freshwater ecosystems, with many rivers and lakes near urban centers considered biologically dead (Rola et al., 2015a). The Philippines faces a significant national water threat between 2015 and 2025, characterized by severe water shortages, pollution, and management issues. Major cities, especially in the Luzon region and Metro Manila, are expected to experience some form of water shortage by 2025 due to rapid urbanization, rising demand, and climate change impacts such as erratic rainfall patterns and more frequent droughts (Rola et al., 2015b).

Canal de Pasacao, situated in Barangay Quitang, Odicon, and Sta. Rosa Del Norte, Pasacao, Camarines Sur, is a vital resource supporting local livelihoods and daily needs. It serves domestic purposes such as cleaning and laundry, irrigates agricultural crops, and provides food and income through fisheries. Beyond its utility, the canal plays a key role in the local economy and family sustenance, functioning as an essential freshwater ecosystem that supports diverse life forms. They play an essential role in regulating the water cycle, which involves the movement of water between the atmosphere, land, and oceans. Rivers collect rainwater and surface runoff, which are then transported to other parts of the world, replenishing groundwater reserves and sustaining wetlands, lakes, and other aquatic habitats. Moreover, rivers support the growth of vegetation and provide essential nutrients to terrestrial ecosystems, which in turn provide habitats for a diverse range of species (Tong, 2023).

Assessment of prevailing conditions provides essential data to guide policymakers and stakeholders in formulating community-level interventions for water resource protection, thereby advancing the sustainable management of freshwater systems in rural Filipino communities. It further reinforces the implementation of the Clean Water Act of 2004 (Republic Act No. 9275). Additionally, it aligns with global mandates under the Sustainable Development Goals: SDG 6 on ensuring sustainable water management and sanitation; SDG 13 on climate action; and SDG 15 regarding terrestrial ecosystem conservation and land degradation control. Given the escalating impact of pollution on inland waters and biodiversity, regular water quality evaluation is imperative to safeguard ecological integrity and support all forms of life.

Objective of the Study - Generally, the study aims to assess the water quality of the Canal de Pasacao in Barangay Quitang, Odicon, and Sta. Rosa Del Norte in Pasacao, Camarines Sur. Specifically, the objective of the study are:

- To create a detailed map of the key features and characteristics of the Canal de Pasacao.
- To determine the physicochemical and Biological Parameters of the Canal de Pasacao, specifically - Physical Parameter: Temperature, Total Suspended Solids (TSS), Color, and Salinity, Chemical Parameter: Hydrogen Ion Concentration (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Phosphate, Chloride, and Nitrate as NO –N, and Biological Parameter: Fecal Coliform.
- To classify the Canal de Pasacao based on the DENR Administrative Order 2016-08.
- To propose a strategic plan for the conservation and management of Canal de Pasacao.

2. Methodology

This section describes the detailed research approach used to conduct the study and fulfill its objectives. It covers research method, area of the study, sampling station, and data gathering procedure from upstream, midstream, and downstream of the Canal de Pasacao.

Research Method - This study adopts Department of Environment and Natural Resources Administrative Order (DAO) 2016-08 as the primary regulatory basis for water quality assessment. It outlines national standards for physico-chemical and biological parameters, as well as uniform effluent limits for all wastewater sources. These guidelines were used to evaluate whether Canal de Pasacao meets environmental quality criteria and complies with the Clean Water Act. To assess the river's overall condition, composite sampling was performed to get representative samples for laboratory analysis. Composite sampling involved collecting multiple samples of water over a specific period and location, then mixing them to obtain a single, representative sample. The composite sample obtained provided an average representation of the quality of the water over the sampling period (Boqu, 2023).

Area of the Study - The Municipality of Pasacao is a coastal municipality situated on the northwest coast of Camarines Sur, facing Ragay Gulf. It lies at coordinates 13°30'52" N, 123°2'36" E, and is known for its diverse coastal ecosystems, fishing communities, and river systems that drain toward the sea. Its geographical location makes the municipality's waterways highly significant for local livelihoods, transportation, and biodiversity. Specifically, the study was conducted at Canal de Pasacao, covering Barangays Quitang, Odicon, and Sta. Rosa Del Norte, Pasacao, Camarines Sur.

Sampling Station - The sampling stations (Figure 1) were selected at three river sections: upstream, midstream, and downstream. Water samples were collected to assess water quality parameters. The sites are located at: 13°33′04″N, 123°03′10″E (upstream, 13.0 m / 42.7 ft above sea level); 13°31′49″N, 123°03′06″E (midstream, 60.6 m / 198.8 ft above sea level); and 13°31′08″N, 123°02′51″E (downstream, 8.8 m / 28.9 ft above sea level). Canal de Pasacao runs near residential areas and is lined with abundant vegetation. The upstream station in Barangay Quitang has lush riverbanks and nearby houses; the river is used for swimming and as a crossing path for animals such as carabaos. The midstream station in Barangay Odicon features shallow water with visible pebbles, a temporary spillway, and a bridge under construction for the new highway; residents also use this area for fishing. The downstream station in Barangay Sta. Rosa Del Norte has mangroves and dense vegetation, surrounded by municipal buildings and the central business district, and serves as a crossing point via rafts.

Data Gathering Procedure - The study utilized geo-spatial mapping to identify and document the features and characteristics of Canal de Pasacao from upstream to midstream using Goggle Earth Pro, Locus Map, Geocam, and Manifold Software. It also followed water quality guidelines for primary parameters outlined in DAO 2016-08 to analyze the water quality of Canal de Pasacao. Parameters include temperature, total suspended solids, color, pH, dissolved oxygen, biochemical oxygen demand, phosphate, chloride, nitrate as NO -N, and fecal coliform. Salinity, not included in the given primary parameters, was included as a parameter to measure saltwater intrusion in the Canal de Pasacao, due to its proximity to the sea.

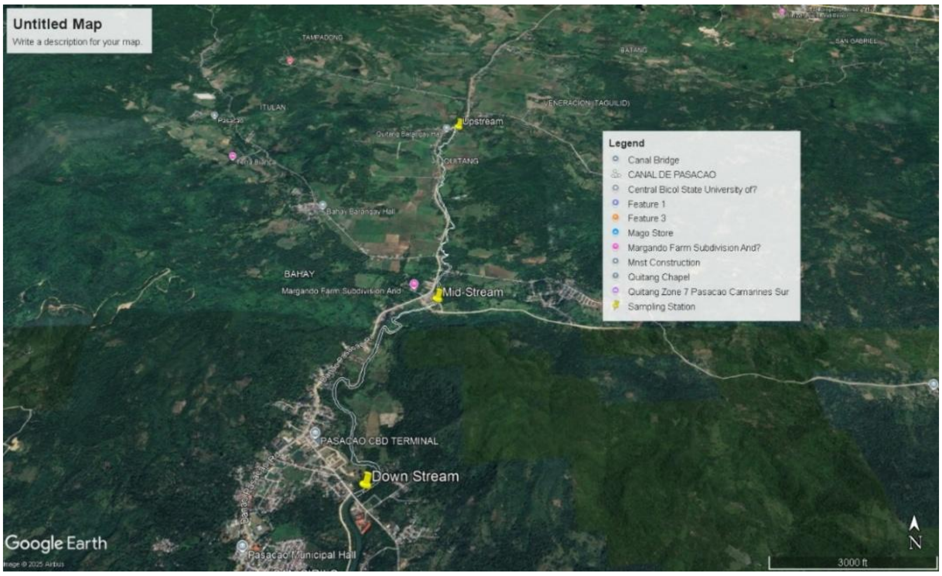

Figure 1. Locations of sampling stations in Canal de Pasacao

Geo-Spatial Mapping

- **Google Earth Pro**. It was used to locate the river and trace its course from upstream to midstream using its drawing tools.
- **Locus Map Application**. It was used by recording GPS tracks along the river to capture its course, elevation changes, and distances.
- **Geocam Application**. It was used by taking geo-tagged photos and videos of the river.
- **Manifold Software**. Collected GPS tracks and geo-tagged images were imported into Manifold to be combined, edited, and visualized as spatial data.

Physico-chemical and Biological Parameters

- **Temperature (°C)**. Temperature was measured in situ at each sampling station by submerging the probe 5–10 cm below the surface and allowing the reading to stabilize for 30 seconds.
- **Color (TCU)**. Water color was assessed through laboratory analysis rather than the naked eye method to obtain precise numerical data. Water samples were collected in clean containers, stored in a cooler box, and brought to the Environmental Health Laboratory Services Cooperative (Naga Branch) for analysis.
- **Salinity (ppt)**. Salinity was determined in situ using a calibrated handheld salinometer. The probe was rinsed with a small amount of the same water sample to remove residues that may affect the reading, and the reading was recorded once it stabilizes.
- **Total Suspended Solids (TSS) (mg/L)**. Water samples were collected in clean containers, stored in a cooler box, and brought to the Bicolandia Environmental Testing and Consultancy Services for analysis.
- **Hydrogen Ion Concentration (pH)**. It was measured by rinsing the meter's probe with clean water,

dipping it into the water sample, waiting for the reading to settle, then reading and recording the pH value.

- **Dissolved Oxygen (DO)**. DO was measured in situ using a calibrated dissolved oxygen meter. The sensor was submerged 1 to 1.5 inches below the water surface, ensuring minimal disturbance, and the reading was recorded once it stabilizes.
- **Biochemical Oxygen Demand (BOD)**. Water samples were collected in clean containers, stored in a cooler box, and brought to the Bicolandia Environmental Testing and Consultancy Services for analysis.
- **Phosphate ($PO4^3$-P)**. Water samples were collected in clean containers, stored in a cooler box, and brought to the Regional Soil Laboratory under the Department of Agriculture–Regional Field Office 5 Integrated Laboratories Division for analysis.
- **Chloride (Cl-)**. Water samples were collected in clean containers, stored in a cooler box, and brought to the Environmental–Health Laboratory Services Cooperative Naga Branch for analysis.
- **Nitrates (NO -N)**. Water samples were collected in clean containers, stored in a cooler box, and brought to the Regional Soil Laboratory under the Department of Agriculture–Regional Field Office 5 Integrated Laboratories Division for analysis.
- **Fecal Coliform (MPN/100 mL)**. Water samples was collected in a sterilized plastic bottle, sealed, stored in a cooler box, and brought to the Metropolitan Naga Water District (MNWD) in Naga City for analysis.

Data Analysis **-** The results of water testing parameters, such as temperature, total suspended solids (TSS), color, salinity, hydrogen ion concentration (pH), dissolved oxygen (DO), biochemical oxygen demand (BOD), phosphate, chloride, nitrate as NO -N, and fecal coliform, were analyzed with the water quality standard set by Department of Environment and Natural Resources-Environmental Management Bureau (DENR-EMB) in DAO 2016-08. Hence, the Canal de Pasacao was classified based on the set guidelines for each Classes (AA, A, B, C, and D) according to its intended use.

3. Results and Discussion

This section presents the map in Figure 2, key features and characteristics of Canal de Pasacao, its physico-chemical and biological parameters, water body classification and usage per DAO 2016-08, and the strategic plan for the river’s conservation and management.

3.1 Key Features and Characteristics of the Canal de Pasacao

Key Features **-** The Canal de Pasacao originates from the forested slopes of Mount Bernacci, an important watershed between Libmanan and Pasacao. From its headwaters, the river flows through Barangay Quitang, Bahay, and Sta. Rosa Del Norte covers an estimated length of 4.83 kilometers based on Google Earth measurements. The depth of the Canal de Pasacao cannot be described by only one fixed value because it is connected to the Ragay Gulf. As a result, tidal movements affect the water level, causing the depth to change over time. In tidal rivers and canals, tidal waves propagate upstream from the river mouth, producing alternating high and low water levels that directly change river stage and depth (Lu et al., 2015; Talke et al., 2021). The magnitude of these depth variations depends on tidal range, river discharge, and channel geometry, causing water levels in coastal waterways to fluctuate throughout the tidal cycle (Zhang et al., 2020; Mihel et al., 2024).

Its channel averages about 12.04 meters in width. The riverbed is composed mainly of sand, silt, and gravel materials that naturally undergo continuous erosion and deposition that shapes river form over time. This pattern of morphological variability aligns with broader findings from global remote-sensing analyses. Using Landsat records and the Global Rivers Widths from Landsat (GLOW) dataset (1984–2020), Feng et al. (2022) estimated cross-sectional widths for more than a billion river segments worldwide and found that a substantial portion of rivers exhibit significant temporal trends in channel width. Specifically, while 85% of river reaches showed relatively low width variability (interquartile range < 150 m), 37% exhibited statistically significant trends in width over the 36 years, a proportion that increased to 46% in human-regulated rivers. This suggests that both natural drivers (e.g., climate and hydrology) and human influences (e.g., landuse changes and infrastructure) play measurable roles in altering channel dimensions over time. Ultimately, the Canal de Pasacao drains toward its endpoint at the Ragay Gulf.

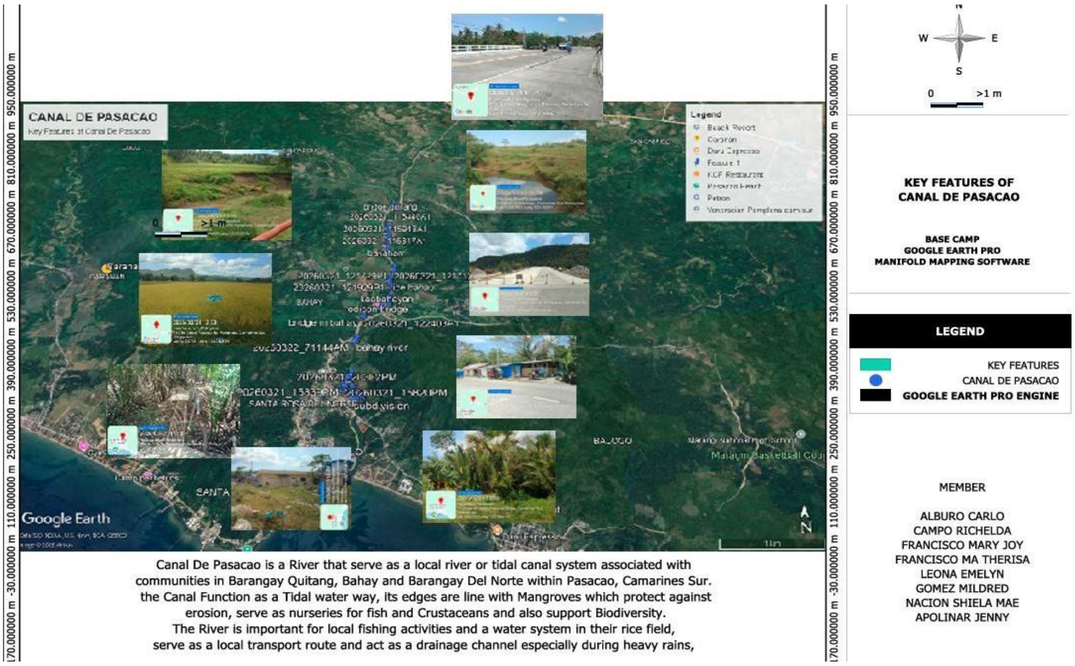

Figure 2. Key features of Canal de Pasacao

Characteristics - Canal de Pasacao is one of the principal drainage systems of Pasacao, Camarines Sur, and forms an essential component of the municipality's coastal upland hydrological network. According to the Pasacao Comprehensive Land Use Plan (CLUP), the river drains from the hilly interior terrain toward Ragay Gulf, following the common pattern of short, steep watersheds typical of the municipality's physiographic structure. This topographic setting results in rapid runoff response during rainfall events and contributes to the downstream transport of freshwater, sediments, and organic matter into the coastal zone. Biological inventory conducted in the area by documented diverse macro invertebrate assemblages within the local mangrove ecosystem, demonstrating the ecological connectivity between the river's freshwater inputs and the coastal habitat's biological productivity (Luna et al., 2020).

Physico-chemical and Biological Water Quality Parameters of Canal de Pasacao - Using established water quality standards, the profile of Canal de Pasacao was assessed based on data collected from upstream, midstream, and downstream stations (Table 1). Analysis covered key physico-chemical and biological parameters specified in DAO 2016-08. According to the Department of Environment and Natural Resources-Environmental Management Bureau (2016), these are the required minimum water quality parameters for monitoring for each water body, including temperature, total suspended solids, color, pH, dissolved oxygen, biochemical oxygen demand, phosphate, chloride, nitrate, and fecal coliform. Salinity was also tested to evaluate saltwater intrusion, given the Canal de Pasacao's proximity to the sea.

Table 1
Results of Physico-chemical and Biological parameters

Physicochemical and Biological Parameters w/Units	Stations					
	Upstream	Remarks	Midstream	Remarks	Downstream	Remarks
Temperature (℃)	27.1	Passed	27.1	Passed	26.9	Passed
Total Suspended Solids (mg/L)	10.2	Passed	13.8	Passed	7.2	Passed
Color (TCU)	22	Passed	25	Passed	18	Passed
Salinity (ppt)	0%	Passed	0%	Passed	0%	Passed
Hydrogen Ion Concentration (pH)	7.4	Alkaline	7.8	Alkaline	7.5	Alkaline
Dissolved Oxygen (mg/L)	5.3	Passed	5.7	Passed	5.8	Passed
Biochemical Oxygen Demand (mg/L)	4.2	Passed	7.4	Failed	5.1	Passed
Phosphate (ppm)	2.12	Failed	1.65	Failed	3.43	Failed
Chloride (mg/L)	151	Passed	153	Passed	5,172	Failed
Nitrate as NO -N (ppm)	38.85	Failed	36.75	Failed	35.70	Failed
Fecal Coliform	4.6	Passed	2.6	Passed	4.6	Passed

Note. Passed parameters met the standard limit set by DAO 2016-08; Failed parameters exceeded the standard limit; and Alkaline indicates an alkaline condition and is within the standard limit.

Passed Water Quality Parameters - Several physico-chemical and biological parameters consistently met standards. Temperature was 27.1°C upstream, 27.1°C midstream, and 26.9°C downstream. Total Suspended Solids measured 10.2 mg/L upstream, 13.8 mg/L midstream, and 7.2 mg/L downstream. Color recorded 22 TCU upstream, 25 TCU midstream, and 18 TCU downstream; salinity remained 0 ppt at all stations. pH ranged 7.4 upstream, 7.8 midstream, and 7.5 downstream, indicating alkaline conditions. Dissolved Oxygen was 5.3 mg/L upstream, 5.7 mg/L midstream, and 5.8 mg/L downstream. Fecal coliform complied at 4.6 MPN/100 mL upstream, 2.6 MPN/100 mL midstream, and 4.6 MPN/100 mL downstream. Biochemical Oxygen Demand passed 4.2 mg/L upstream and 5.1 mg/L downstream; Chloride was compliant 151 mg/L upstream and 153 mg/L midstream.

Temperature (°C). The higher temperatures recorded upstream and midstream are likely influenced by the state of the riparian vegetation and the exposure to sunlight during sampling. This observation is supported by the principle discussed by Itua et al. (2024) that riparian vegetation's change impacts the temperature of water bodies. When water bodies are exposed to more direct solar radiation particularly when riparian vegetation that shadows a water body is eliminated, temperature differences become more pronounced. In contrast, the low temperature of the downstream water can be attributed to mangrove trees. In the study by Al-Huqail et al. (2024), linear regression analysis across various clusters demonstrated a consistent negative relationship between Normalized Difference Vegetation Index (NDVI) increases (indicative of greater mangrove density) and Land Surface Temperature (LST) decreases. The variation in slope values among different clusters, ranging from −4.03 in Cluster 14 to −44.1 in Cluster 30, highlights that the cooling effect of mangroves can be more pronounced in certain areas. The intercept values, which represent the estimated LST when NDVI is zero, varied significantly from 29.8°C in Cluster 14 to 49.3°C in Cluster 30, indicating baseline temperature differences across the study area. These findings emphasize the critical role of mangrove coverage in moderating local climate conditions, potentially influenced by geographical and environmental factors specific to each cluster. Therefore, in relation to river water temperatures, they imply that water cools as land surface temperature decreases.

Total Suspended Solids (TSS) (mg/L). The amount of TSS concentration in upstream area can be significantly influenced by land transportation infrastructure, specifically highway bridges or roads over the river. For instance, road-deposited sediments (RDS), composed of natural sediments such as soil material, leaf litter, atmospheric particles, and anthropogenic sediments produced by the deterioration of vehicle components, combustion products accumulated on the surface (Beckwith et al., 1986, as cited in Haynes et al., 2020). Consequently, contaminants in RDS can be transported in stormwater runoff to other ecologically sensitive locations (Goonetilleke et al., 2017, as cited in Haynes et al., 2020). Notably, the highest concentrations of total suspended solids at midstream may be attributed to the ongoing bridge construction at the site. Previous studies have shown that construction works lead to relatively high levels of suspended solids in streams because of the wash-off of construction sites that release into runoff, as well as the generation of flying dust during the construction period (Gavrić et al., 2019; Kong et al., 2021, as Cited in Pang & Guan, 2024). In the case of suspended solids, construction works as anthropogenic activities can alter the concentrations of suspended solids in streams primarily through land cover change and urban runoff (Dufresne et al., 2020; Rodrigues et al., 2018, as cited in Pang & Guan, 2024). Subsequently, the recorded lower concentration of TSS in the downstream can be attributed to the reduced flow velocity by allowing sediments to settle. As stated by Clearwater Industries, Inc. (2022), suspended solids are influenced by the speed and direction of a flowing fluid (flow velocity). When the force of water is slight, particles settle (United States Environmental Protection Agency, 2025) at the bottom of the water. Significantly, as observed in the study by Lins et al. (2024), the lowest concentrations of TSS were observed near the mouth of the estuary during the high tide stage. The sediment accumulated in the water column begins to flocculate as the current velocity decreases, leading to the formation of clusters of TSS.

Color (TCU). Color concentration in the upstream and midstream can be influenced by the decomposition of plants trapped in debris, such as submerged branches. Wilson (2019) noted that decomposition of plants affects color because tannins and dissolved organic carbon, which are byproducts of the degradation of plants and other organisms, usually impart a brown to black color to water. In comparison, the midstream area has more trapped plants undergoing decomposition, which explains its higher color concentration relative to the upstream station. Conversely, the lower color concentration downstream can be attributed to mangrove filtration. The unique root structures of mangrove trees form a dense physical barrier that slows the flow of water running off the land through the forest. This slow movement of water allows contaminants suspended in the water, such as heavy metals, excess nutrients, debris, and sediment to settle out or get trapped by the roots, filtered from the water column. By trapping sediment and suspended solids, this filtration process reduces turbidity, often causing the water to change from a murky brown or gray to a clearer, more translucent state. Mangrove forests can filter out 8090% of nitrates, phosphates, and suspended solids in water flowing through them (Hammond, 2022). Therefore, the mangrove forest in the downstream acts as a natural filter that trap suspended sediments and organic matter, such as decaying plants from the upstream and midstream stations, resulting in clearer color of water.

Salinity (ppt). A collective 0 ppt of salinity across all stations can be attributed to the precipitation, specifically rainfall, as one of the main sources of the river. Rain replenishes freshwater in rivers, while all the salts and minerals from rivers are transported to the ocean (National Oceanic and Atmospheric Administration, 2024).

Hydrogen Ion Concentration (pH). The hydrogen ion concentration at the upstream, midstream, and downstream station may be attributed to the geological composition of the riverbed at that location, particularly the presence of pebbles that are often composed of carbonate minerals. According to the United States Geological Survey (2018), landscape in an area containing rocks such as limestone, the runoff picks up chemicals such as calcium carbonate ($CaCO3$), which raises the pH and alkalinity of the water. This natural process mirrors observations in controlled environments; as Yabao (2023) explains, in aquarium management, pebbles are specifically chosen to influence water chemistry because the sediment or stones within the aquarium water can rapidly alter its chemical composition, particularly its pH. This occurs as minerals dissolve slowly in water, releasing compounds. Critically, all of the objects that elevate the pH are calcareous ions, calcium, carbonates, and bicarbonates. The alkalinization results from the dissolution of ions contained in these stones, which increase and maintain alkalinity.

Dissolved Oxygen (DO) (mg/L). The lower dissolved oxygen (DO) concentration measured In the upstream reach (5.3 mg/L) can be attributed to reduced flow velocity and limited turbulence, which restrict atmospheric reaeration and promote oxygen consumption within the water column. This causal relationship is supported by Metcalf and Eddy (2018), who demonstrated that slow-moving waters enhance organic matter accumulation and microbial decomposition, thereby increasing biochemical oxygen demand and reducing available dissolved oxygen. Their findings validate that constrained hydrodynamic conditions intensify oxygen utilization during organic matter breakdown, which explains the comparatively lower DO observed at the upstream station. The higher dissolved oxygen (DO) concentration observed in the midstream reach can be attributed to enhanced flow velocity and turbulence, which promote more efficient atmospheric reaeration and oxygen exchange. This causal relationship is supported by the findings of Allan and Castillo (2019), who demonstrated that increased hydrodynamic activity in river channels significantly elevates dissolved oxygen levels by intensifying water–air interactions. Their results validate that improved physical mixing and associated biological activity in midstream environments explain the higher DO recorded at this station compared to the upstream reach. The elevated dissolved oxygen (DO) level measured at the downstream site can be attributed to its status as the station with the lowest recorded temperature. Based on the recorded hourly dissolved-oxygen concentration and water temperature of Passaic River below Pompton River at Two Bridges, N. J. between January and December 2017, it shows that the concentration of dissolved oxygen in surface water is affected by temperature. As noted by the United States Geological Survey (2018), 'cold water can hold more dissolved oxygen than warm water. Their results validate the inverse relationship between water temperature and oxygen solubility, which explains why the highest DO reading was observed at the coolest, downstream station.

Fecal Coliform (MPN/100 ml). The fecal coliform results indicate contamination across upstream, midstream, and downstream stations. This may be attributed to direct discharge from domestic toilets and livestock enclosures situated near the river, which introduce waste materials directly into the water body. This is supported by Department of Environment and Natural Resources (2019), which state that fecal coliform are bacteria associated with fecal material from humans and other animals. They enter bodies of water from sources such as direct defecation or sewage overflow. While such sources are present along Canal de Pasacao, the recorded values remained within acceptable limits, which can be explained by the influence of environmental conditions on bacterial survival and transport. According to Fletcher et al. (2024), fecal coliforms are mesophilic organisms whose growth is strongly influenced by temperature and pH. In this study, the water temperature ranged from 26.9°C to 27.1°C, and pH levels were slightly alkaline (7.4–7.8) at all sites. Although these temperatures are within the range where bacteria can survive, the prevailing alkaline conditions likely restricted their proliferation. Solic and Krstulovic (1992) and Jamieson et al. (2002), as cited in Fletcher et al. (2024), noted that fecal coliforms persist longest under near-neutral conditions (pH 6–7); deviations above this range reduce bacterial counts by approximately 30% per pH unit increase. The slightly alkaline environment observed here likely suppressed bacterial growth, contributing to the low concentrations recorded. Furthermore, rainfall intensity plays a critical role in the transport of fecal matter into waterways. Heasley et al. (2021) identified rainfall as the most significant driver of contamination, appearing in 74% of predictive water quality models. During sampling, rainfall was minimal and light in intensity. This limited surface runoff and reduced the washing of waste materials from riverbanks and nearby livestock areas into the water body. Consequently, despite the presence of domestic toilets and livestock rearing along the riverbank at upstream and downstream and near at midstream area, the low volume of runoff prevented significant transport of contaminants.

Biochemical Oxygen Demand (BOD) (mg/L): Upstream and Downstream. The lowest concentration of biochemical oxygen demand (BOD) in the upstream can be attributed to the riparian vegetation. Their root systems are deep and bind soil to stabilize banks and prevent soil erosion that can wash into the water as sediment. The riparian vegetation filters nutrients and pollutants mechanically and biologically from the runoff to improve water quality before it enters the water body (Kinhal, 2025). Likewise, as shown in the study of Jiang et al. (2024), an increase in aquatic plant coverage could directly absorb excess nutrients (e.g., nitrogen and phosphorus). Reducing nitrogen and phosphorus is crucial for alleviating eutrophication, the principal driver of algal blooms and oxygen depletion that can lead to hypoxia or anoxia and severely impact freshwater biodiversity (Zamparas & Zacharias, 2014; Breitburg et al., 2009; as cited in Songkun et al., 2025). The BOD concentration in downstream is primarily attributed to domestic wastewater. Domestic wastewater usually consists of used washing water, food waste, and other daily activities except toilets, which contain various pollutants, both organic and inorganic (de Zeeuw and Drechsel, 2015, as cited in Ro'in & Dahalan, 2024). When a domestic wastewater discharge is untreated, the presence of hazardous substances such as ammonia can trigger the phenomenon of eutrophication (Akinnawo, 2023, as cited in Ro'in & Dahalan, 2024), where algae growth becomes uncontrolled and disrupts the balance of the aquatic ecosystem (Dubey and Dutta, 2020, as cited in Ro'in & Dahalan, 2024).

Chloride (mg/L): Upstream and Midstream. The upstream and midstream area shows no salt contained in the water and are far from seawater. Chloride ions are the most common ion in water environments. According to Cao Y. et al. (2020), the sources of chloride ions in water are as follows: chlorine ($ClO2$), which sterilizes; water flows through chloride containing strata; water sources are polluted by domestic sewage or industrial wastewater in coastal areas; a large amount of seawater enters the water sources due to backwater caused by high tides.

Failed Water Quality Parameters - Several parameters exceeded standard limits across stations. Phosphate failed at all sites: 2.12 ppm upstream, 1.65 ppm midstream, and 3.43 ppm downstream. Nitrate as NO_3-N also exceeded limits, measuring 38.85 ppm, 36.75 ppm, and 35.70 ppm, respectively. Additionally, BOD was high at 7.4 mg/L midstream, while chloride reached an excessive 5,172 mg/L at downstream.

Phosphate (ppm). High phosphate concentrations across upstream, midstream, and downstream stations are primarily attributed to domestic wastewater discharge, with levels varying based on household proximity and density relative to sampling points. The reduction in production costs since the 1960s has led to the widespread use of mineral phosphate in everyday industrial products (agri-food, matches, metallurgy, detergents in the form of polyphosphates in laundry). The use of polyphosphates in laundry has led to a very large increase in the amount of phosphorus in domestic wastewater. Thus, recent and massive introductions of phosphorus into the environment, erosion of cultivated land (diffuse sources), and increased domestic wastewater (point sources) are contributing to the rapid increase in phosphorus concentrations in aquatic environments (Nemery, 2025). Specifically, upstream exhibited the second-highest levels due to households situated in proximity to the water source; midstream showed the lowest concentrations due to a temporary spillway positioned between households and the sampling area; and downstream recorded the highest levels due to greater household density along the sampling area. This pattern aligns with hydrodynamic modeling findings of Carr et al. (2020), where flow period spillway operations impact the distribution of nutrients as increased epilimnion flow velocities route the incoming water through the surface of the reservoir and reduce mixing. This reduces reservoir concentrations but can lead to increased outflow phosphorus (P) concentrations, validating midstream minima and downstream maxima.

Nitrate as NO3-N (mg/L). According to Shukla and Saxena (2018), Nitrate nitrogen (NO3-N) is derived from fertilizers, septic tanks, landfills, as well as other agricultural and industrial activities. However, agricultural practices augment NO3-N levels by applying soluble fertilizers, but bovine urine and faeces, septic tanks, livestock mortality burial pits, and silage pits also contribute to enrichment of the N-load (Bougouin et al., 2022; Rowarth and Coles, 2024). Moreover, fertilizers undergo nitrification and are converted to NO3-N, which is easily transported as a solute through the hydrological cycle. Any surplus nitrate in the soil profile can then be leached into groundwater, or discharged to rivers through surface or subsurface pathways (Sigtryggsson et al., 2020), with excessive concentrations being recognised globally as a risk to both human health and the environment (Stewart and Aitchison-Earl, 2020).

Biochemical Oxygen Demand (BOD) (mg/L): Midstream. The presence of decaying organic matter can be attributed to the highest BOD concentration recorded in the midstream. As noted by the Water Science School (2018), decaying organic matter serves as a food source for aerobic bacteria and other microorganisms present in the water. As these organisms decompose the organic matter, they consume dissolved oxygen to carry out the metabolic processes required to break it down. Therefore, the greater the amount of organic waste introduced into a water body, the more oxygen is demanded by the decomposer community, leading to a higher measured BOD.

Chloride (mg/L): Downstream. The highest concentration of chloride recorded in downstream can be attributed to seawater intrusion, as saline water moves into freshwater aquifers. Studies confirm that the seawater intrusion in Laizhou bay coastal zone leads to elevated chloride levels due to this mixing (Wang et al., 2019). Additionally, land-based pollutants accumulate as water flows downstream, with groundwater withdrawal and sea level rise exacerbating the buildup from sources like agriculture and runoff (Anderson & Al-Thani, 2016). This cumulative effect, including chloride threshold to identify the onset of seawater intrusion, peaks near the coast in river systems (Fidelibus et al., 2025). Salinity measurements indicated no saltwater intrusion at any station, while laboratory chloride analysis revealed no intrusion upstream and midstream, but confirmed its presence downstream. This discrepancy between onsite and laboratory results arises from methodological differences. Salinometers measure total dissolved ions via electrical conductivity; readings may remain low due to freshwater dilution or interference from non-marine salts, potentially masking marine chloride inputs. In contrast, potentiometric analysis specifically detects chloride ions, a stable and reliable tracer unaffected by biological or chemical processes. This method also minimizes errors from field conditions such as temperature fluctuations, water turbidity, or changes during transport. Variations in detection limits, sampling timing, or localized intrusion patterns may further contribute to these differing outcomes.

3.2 Freshwater Body Classification of Canal de Pasacao

Based on a simulated water quality assessment using the DAO 2016-08, which categorizes water bodies into classes such as AA, A, B, C, and D based on its own different intended beneficial uses, the result of the physico-chemical and biological parameters shows that most of the primary parameters such as the temperature, color, hydrogen ion (pH), Dissolved Oxygen (DO), Total Suspended Solids (TSS) and salinity met water quality standard for Class C freshwater body. Classifying the river based on its parameters allows people to determine its intended beneficial uses such as limited water class II recreational purposes, suitable for fisheries and supports aquatic life to reproduce and survive, industrial and agricultural supply such as irrigation and drainage despite of its moderate levels of pollution, specifically, high concentration of nutrients such as Nitrate and Phosphate, high chloride in downstream, BOD issues in midstream, and fecal coliform impacted by anthropogenic activities that led to nutrient enrichment and microbial contamination.

3.3 Plan for Conservation and Management of the River

The Canal de Pasacao is a crucial resource for various beneficial uses for the community and connected areas, making it essential to implement a strategic plan for an effective management and conservation of the river, ensuring sustainable use and ecological health in compliance to various Philippine environmental laws, together with all stakeholders and policy makers, specifically in coordination with the Local Government Unit (LGU) and other agencies to enforce and follow regulations which is crucial to ensure the effectiveness of continuous improvement of the river’s water quality and ensuring the safety of all kind.

The findings of this study indicate that the integration of a Communication, Education, and Public Awareness (CEPA) strategy is essential for the community stewardship, policy compliance and contribute to a long-term improvement of the river’s water quality and ecosystem condition. It allows people to understand environmental issues, specifically in accordance to the river’s water quality, and allows each individual to support, participate, and take an action. Previous studies support this approach, showing that sustained CEPA programs can lead to significant improvements in environmental awareness and positive behavioral change within local communities. For instance, long-term evaluations of CEPA initiatives in the Philippines documented increased awareness of conservation laws and improved attitudes toward resource protection, which translated into greater community cooperation in conservation efforts (Van der Ploeg et al., 2018).

Similarly, community-based CEPA programs were found to enhance public participation in environmental rehabilitation activities by strengthening local ownership and responsibility (Alaman et al., 2021). Observed environmental pressures on the river, such as improper waste disposal and degradation of riparian areas, highlight the role of human behavior as a major contributing factor to declining river conditions. CEPA directly addresses these issues by improving public understanding of the ecological and health significance of the river and encouraging responsible practices by educating the community, stakeholders, and future stewards (shown in Table 2) that will increase community engagement and responsibility toward watershed protection. This plan involves enabling public awareness through seminars led by the policy makers which addresses the issues such as the risks and or impacts of the water quality to their health and to the ecosystem, enlightening further the community about the Philippine Clean Water Act of 2004 (Republic Act 9275) which aims to protect the water bodies in the Philippines from pollution primarily from land-based sources such as industrial, agricultural, and domestic wastes.

Moreover, the application of Republic Act 6969, also known as the Toxic Substances and Hazardous and Nuclear Wastes Control Act which aims to restrict or regulate the distribution of use and disposal of chemical substances, are expected to be implemented as it risks human health and the river's water quality. Implementing of the Ecological Solid Waste Management Act of 2000 (Republic Act 9003), which aims a systematic, comprehensive, and ecological solid waste management program that shall ensure the protection of both public and environmental health. Furthermore, a regular water quality monitoring wherein detecting any changes is crucial in preventing any potential risks or diseases by a long-term solutions (Table 3) in protecting both biotic and abiotic organisms. This includes an effective implementation of various activities like river clean-up drive, waste trap, and green embankment such as vetiver and water trees in each Barangays (Quitang, Odicon, Canal-Bahay, and Sta. Rosa Del Norte) which will improve the water quality of the river as it will reduce solid waste, filter agricultural runoff, control erosion, and enhance the levels of each water parameters.

Table 2
Proposal for Enhancing Public Awareness on River Restoration

Communication, Education, and Public Awareness (CEPA)					
Barangay	Environmental Pressure	Topics to be Discussed	Timefrrame	Responsible People Involved	Budget
Quitang	Urbanization and land conversion, agricultural runoff, sand and gravel mining, and industrial and domestic pollution	1. Clean Water Act (RA 9275) 2. Ecological Solid Waste Management Act (RA 9003) 3. Toxic Substances & Hazardous & Nuclear Waste Act (RA 6969) 4. Agricultural & industrial impact 5. Sanitation & human waste 6. Livestock manure management 7. Environmental & health risks	June 6, 2026	Local Government Unit (LGU), DENR representatives, Barangay Officials, and Barangay Health Workers (BHW)	Php 13,000
Odicon			June 20, 2026		Php 10,000
Canal-Bahay			July 4, 2026		Php 12,000
Sta. Rosa, Del Norte			July 18, 2026		Php 15,000
				Total Budget	Php 50,000

Table 3
Proposal for Regular Water Quality Monitoring

Regular Water Quality Management					
Activities	Target Area/Beneficiaries	Timeframe	Responsible People Involved	Budget	Expected Outcome
Installation of water traps	Barangays Quitang, Odicon, Canal-Bahay, and Sta. Rosa del Norte	1 month	Local Government Unit (LGU) and Barangay Officials	Php 25,000	Reduction in floating plastics and debris, easier waste collection.
Conduct regular clean-up Drive	Barangays Quitang, Odicon, Canal-Bahay, and Sta. Roda del Norte	Twice a month	Local Government Unit (LGU), Barangay Officials, Youth Councils, and Community/Volunteers	Php 18,000	Decrease in waste volume and restoration of river's natural water flow.
Establish green embankment (vetiver and water trees)	Barangays Quitang, Odicon, Canal-Bahay, and Sta. Roda del Norte	1 month	Local Government Unit (LGU), Barangay Officials, and Community/Volunteers	Php 35,000	No bank Collapses during heavy rain.
Maintenance of planted areas	Barangays Quitang, Odicon, Canal-Bahay, and Sta. Roda del Norte	Twice a year	Local Government Unit (LGU), Barangay Officials, and Volunteers	Php 13,000	Shaded green corridor that provides natural cooling and flood protection.
			Total Budget	Php 91,000	

In addition to this, the implementation of sustainable practices and livelihood activities is essential in promoting environmental protection while enhancing community income generation (Table 4). This includes conducting training workshops on composting and organic farming aimed at improving waste management and ensuring food sustainability, as well as the provision of livelihood training on the production of eco-products derived from recyclable material. Furthermore, the establishment of a livelihood center serves as a dedicated space for residents to create, display, and sell their finished products, thereby strengthening local entrepreneurship and supporting continuous community-based economic development. Partnering with local buyers and securing formal agreements also guarantees a steady market, ensuring long-term income stability while encouraging the consistent reduction and reuse of waste materials within the community. This includes policies and regulatory enforcement activities (shown in Table 5) which aim to improve waste management and protect the river's water quality by installing color-coded waste bins to promote proper segregation, conducting regular inspections to ensure compliance among households and establishments, and requiring the use of labeled containers for hazardous wastes such as used oil and chemicals. Strict enforcement of penalties and coordination with local authorities further ensures adherence to environmental laws, effectively minimizing pollution and safeguarding the Canal de Pasacao's ecosystem and water quality against further degradation.

Table 4

Proposal for Sustainable Practices and Livelihood

Sustainable Practices and Livelihood					
Activities	Target Area/Beneficiaries	Timeframe	Responsible People Involved	Budget	Expected Outcome
Conduct training workshops on composting and organic farming	Farmers and household heads from Brgy. Quitang, Odicon, and Sta. Rosa del Norte	1 month	Barangay agricultural coordinator (BAC) and 2 Trained farmers as co-facilitators	Php 18,000	At least 80% establish composting; waste reduced by 15% in 3 months.
Conduct livelihood training on making eco-products from recyclable wastes	Women, youth, and seniors from the 3 Brgy, Quitang, Odicon, and Sta. Rosa de Norte	1 month	Barangay Environment Officer (BEO) and local eco-entrepreneur partner	Php 19,000	Each participant produces at least 10 marketable eco-products (eco-bags, coin purses, organizers) upon training completion
Establish a livelihood center where residents can make eco-products, display and sell finished products	Housewives, unemployed and youth along with brgy. Quitang, Odicon, and Sta. Rosa del Norte	2-3 months	Barangay Captains of Quitang, Odicon, and Sta. Rosa del Norte and Barangay Council Committee on Livelihood	Php 20,000	Functional livelihood center operating 3 days weekly, with a minimum of 15 active members
Partner with local buyers to ensure the recyclable products are sold	Local sari-sari store owners, public market vendors, barangay hall offices, and nearby municipal tourism office	3 months (ongoing Memorandum of Agreement (MOA) signing)	Barangay Treasurer, 1 designated Marketing Representative from barangay Quitang, Odicon, and Sta. Rosa del Norte	Php 12,000	At least 3 signed MOAs with local buyers; monthly income of ₱5,000–8,000 for the livelihood group within 2 months of operation
			Total Budget	Php 69,000	

Table 5

Proposal for Policy and Regulatory Enforcement

Policy and Regulatory Enforcement					
Activities	Target Area/Beneficiaries	Timeframe	Responsible People Involved	Budget	Expected Outcome
Install eco-friendly signages detailing proper waste disposal, penalties, and river use guidelines.	Areas along Canal de Pasacao in Barangays Quitang, Odicon, Canal-Bahay and Sta. Rosa del Norte with more houses/establishments	1-2 months (implementation) and continuous maintenance thereafter	Local Government Unit (LGU) Personnel, Barangay Officials and Youth Councils	Php 15,000	Increased awareness among the residents along the Canal de Pasacao
Installation of shared color-coded waste bins	Areas along Canal de Pasacao jn Barangays Quitang, Odicon, Canal-Bahay and Sta. Rosa del Norte with more houses and establishments	1-2 months	Barangay Officials	Php 15,000	Improved waste segregation and reduced improper waste disposal
Require every household and establishments a separate bin with proper labeled containers for used oil, solvents, and chemical waste.	Households and establishments located along Canal de Pasacao in Barangays Quitang, Odicon, Canal-Bahay and Sta. Rosa del Norte	1 month (implementation) and continuous monitoring	Barangay Officials	–	Reduced hazardous wastes discharge into the Canal De Pasacao

Conduct a scheduled waste inspection on houses and establishments for proper waste segregation.	Households and establishments located along Canal de Pasacao in Barangays Quitang, Odicon, Canal-Bahay and Sta. Rosa Del Norte	2 times/month	Assigned Environmental Enforcement Unit and Barangay Tanod	–	Ensures residents and businesses' compliance with the environmental law and reduced improper waste disposal
Imposition of penalties and sanctions for violating RA 9003 and RA 6969	Households and establishments located along Canal de Pasacao in Barangays Quitang, Odicon, Canal-Bahay and Sta. Rosa del Norte	Continuous, upon detection of violations	Assigned Environmental Enforcement Unit and Barangay Tanod	–	Increased compliance with environmental laws
Coordinate with LGU for regular collection and a designated dropoff point for hazardous waste	Pasacao, Camarines Sur	1-2 months and continuous operation	Department of Environment and Natural Resources (DENR), LGU Officials and Barangay Officials	–	Proper collection and management of hazardous wastes
			Total Budget	Php 30,000	

Overall, the proposed strategic plan for the conservation and management of Canal de Pasacao emphasizes the importance of a collaborative and sustainable approach in protecting the river's water quality and ecological condition. Through the implementation of communication and public awareness campaigns, regular water quality monitoring and restoration activities, eco-friendly practices and livelihood programs, and policy and regulatory enforcement, the identified environmental issues affecting the canal may be effectively addressed. The combined efforts of the community, local government units, and environmental management bodies are essential in achieving the Sustainable Development Goals (SDGs) and ensuring long-term protection and sustainable use of Canal de Pasacao for present and future generations. Furthermore, the proposed plan serves as a useful guide for future conservation efforts, helping to maintain the river as an important resource for the residents and surrounding ecosystems of Pasacao, Camarines Sur.

4. Conclusion and Recommendation

Conclusion - The study concludes that the Canal de Pasacao is classified as a Class C freshwater body, suitable for fisheries, irrigation, and limited recreation (e.g., boating, fishing). However, it is unsuitable for drinking water supply and primary contact recreation due to microbial contamination and nutrient loading. It indicates that while the river remains ecologically functional, its water quality is under stress from human activities. Without timely intervention, its ecological integrity and capacity to support local households and livelihoods may further decline. Maintaining and improving its water quality is essential for environmental sustainability and public welfare.

Recommendation - Maintaining and improving water quality of Canal de Pasacao, the following actions are recommended:

- LGU must strictly enforce existing waste management policies to reduce improper disposal of household and agricultural waste, enforcing Republic Act 9275, Republic Act 6969, and Republic Act 9003.
- LGU and barangay officials can establish buffer zones and vegetative strips (e.g., vetiver, water trees) along the canal to minimize agricultural runoff and implement green embankments.
- LGU and environmental agencies are recommended to institutionalize regular water quality monitoring (field and laboratory) to detect contamination and seawater intrusion.
- LGU, barangay health workers, and school heads could launch public awareness campaigns (Communication, Education, and Public Awareness programs) to educate residents on pollution consequences and sustainable practices.
- LGU, Non-Governmental Organizations, academe, and community leaders may consider establishing a multi-stakeholder river management council aligned with the Sustainable Development Goals (SDGs).

- The Bachelor of Science in Environmental Science program at Central Bicol State University of Agriculture – Pasacao Campus may adopt this plan as an extension program.

Implications for Practitioners – The findings emphasize the need for immediate action from environmental managers, agricultural officers, health officials, and local planners. Exceedances in phosphate, nitrate, and bacterial levels demand stricter monitoring and enhanced waste management. Practitioners must promote controlled fertilizer application and proper livestock waste disposal to reduce nutrient loading. Public health officers should disseminate safety advisories, while planners are urged to integrate river conservation into development plans, adhering to DAO 2016-08 and the Clean Water Act.

Implications for the Community – Results highlight the importance of collective responsibility and awareness. Residents should adopt safety measures such as boiling or filtering water prior to use. Barangay officials must lead clean-up initiatives and strictly enforce anti-dumping ordinances. Farmers and fisherfolk are encouraged to practice sustainable methods to protect their livelihood resources. Schools and youth groups should spearhead environmental campaigns to foster stewardship and active protection of the river.

Implications for Academic Institutions and Future Researchers – This study provides baseline data valuable for environmental science curricula and future research. As sampling was limited to October 2025, longitudinal and seasonal studies are recommended to capture variations over time. Institutions may expand research into biodiversity and socio-economic impacts, while policy researchers can utilize these findings to formulate evidence-based guidelines linking science and governance in water management.

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