



American Journal of Environment and Climate (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 3 ISSUE 2 (2024)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Water Quality Assessment of Sarangani Bay: Basis for Sustainable Coastal Management

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Article Information

Received: May 24, 2024

Accepted: June 26, 2024

Published: June 28, 2024

Keywords

Coastal Water, Sustainable Management, Water Quality

ABSTRACT

Marine ecosystems are vital for both wildlife and human populations, but their benefits depend on the quality of the water. The study aimed to assess the quality of water in Sarangani Bay for sustainable management. The study employed a descriptive research design to evaluate the quality of water covering General Santos City's major industrialized coastal regions and Barangays. Various factors such as physical, chemical, and biological parameters, which include dissolved oxygen, total suspended solids, nitrate, phosphate, fecal and total coliforms, pH, and temperature, are considered. The research findings reveal that the covered areas had organic pollution, and human activities like tourism, industry, restaurants, agro-industries, commercial establishments, and residential areas caused the variations in values. As a result, the study suggests that the two management zones, SU2 and MU2, responsible for regulation, should intensify their efforts to monitor the concerned areas. They may also consider organizing capacity-building activities through the LGU, reviewing policies on coastal resources, and enforcing environmental policies to improve the situation.

INTRODUCTION

Marine water bodies are crucial for various species and human populations, but their benefits depend on water quality. Coastal activities like infrastructure development harm the environment (Rowan, 2011; Ghosh & Datta, 2012; Hall, 2001). Every day, we discharge two million tons of waste into water bodies globally (UN WWAP 2003). 1,500 cubic meters of wastewater are produced annually, six times more than all rivers combined (UN WWAP 2003). Open defecation by 1.2 billion people harms the quality of water bodies and poses a significant risk to human health. In Southern Asia, 63% of rural people practice open defecation (UNICEF, WHO, 2008). Water is incredibly vital, second only to air, in sustaining life on Earth. However, its importance lies not just in its availability but also in its quality and quantity across different sources. Surface water, covering 70% of the Earth's surface in various forms, is particularly significant. Despite its abundance, concerns about water quality persist globally, with many water bodies showing signs of contamination and degradation (Abinotami *et al.*, 2023). The lack of strong environmental regulations means that swift and coordinated efforts are urgently needed from both federal and state authorities to address these issues and protect our environment (Oke *et al.*, 2024).

The Philippines is surrounded by water, which means that there is a diverse range of aquatic organisms in its waters. However, with human settlements popping up in coastal areas, the water quality has been affected by human activities. The Sarangani Bay Area in southern Mindanao is known for its rich aquatic life. Unfortunately, there has been rapid industrial, urban, and infrastructural growth along the coast of Sarangani Province and General Santos City in recent years. This development

has increased the population, which puts more pressure on services, infrastructure, and the coastal environment. Many people in this area rely on fishing as their primary source of income. Fishing, aquaculture, eco-tourism, and coastal food transit contribute millions of pesos annually to the local economy (Quin *et al.*, 2014). Sarangani Bay benefits five barangays as the tuna industry center. It has beautiful southern beaches and a growing economy. However, environmental issues like pollution, weak law enforcement, and resource exploitation confront the place. The mangroves, coral reefs, and near-shore fish populations are affected by environmental deterioration and the coastal water quality is worsening due to urbanization and industrialization.

The Protected Area Management Board (PAMB) operates under the regulations outlined in RA 11038, also known as the ENIPAS Act of 2018. The PAMB works alongside government units (LGUs), people's organizations, and the academic community. The Sarangani Bay Water Quality Management Area (SB-WQMA) was designated according to DENR's Department Administrative Order No. 2009-12. This order established the governing board and designated the area, which includes parts of the City of General Santos and the Municipalities of Maasim, Alabel, Malapatan, and Glan in Sarangani Province, as well as General Santos City in the province of South Cotabato (Emperua *et al.*, 2018).

The water quality in the bay typically meets the standards set by DENR for Class SB and Class SC waters. However, monitoring has revealed instances where certain parameters exceeded acceptable limits. Specifically, 'pollution hotspots' have been pinpointed, particularly near tributary mouths and along the coastlines (Ragsag, 2020). This might be owing to the bay's oceanographic

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features, which show that organic contaminants are flushing out at a relatively slow rate, which means that whatever wastes are released into it are likely to remain along the coastline or concentrated in small regions. Because it's designated as a protected seascape, the water quality in the SBPS should meet the standards for coastal/marine water class SA. As a result, only a limited amount of discharge, together with other beneficial uses, should be permitted in the bay.

In General Santos City, one of its major industrialized coastal regions is Barangay Tumbler, where most fishing industries and developments are found. According to the water quality standards outlined in DENR Administrative Order 2016-08 (DAO 2016-08), the water in this area falls under the classification of Coastal/Marine Water Class SC. This classification is attributed to the area's characteristics and its designation as a heavy-industrial coastal zone. Several manufacturing enterprises and establishments along the shore dump effluents into the bay. The effluent standard establishes the maximum number of pollutants that can be discharged from various sources, and the effluent regulations for new industrial point sources are more restrictive than those for existing sources.

The researcher's objective is to evaluate and assess the quality of water at three designated stations within the Sarangani Bay Water Quality Management Area. These stations are located in the Commercial Residential, Industrial, and Tourism Zones of General Santos City. The purpose of this evaluation is to provide the public and government agencies with practical and accessible

information regarding water quality. The tuna industry, which is a significant contributor to General Santos City's economy, stands to benefit from this assessment. The use of indices will be employed to effectively communicate changes in water quality to various stakeholders, including policymakers, the public, and the water quality management team.

LITERATURE REVIEW

This study is based on Niklas Luhmann's "Environment in the System" theory, which suggests that the environment is an essential aspect of every individual system. According to this theory, each system represents its distinct entity within the broader framework of the environment. This theory further stresses that the environment exists as something defined as a result of observations of a given system. Wherein the environment is merely a product of a system's internal operations (Mattheis, 2012).

The theoretical premise of maintaining ecological systems through monitoring and mitigating measures for coastal improvement is deemed necessary for the protection of aquatic biodiversity. Coastal management is a multifactorial measure ensuring that the quality of marine communities is protected amidst coastal industrialization and the influx of anthropogenic coastal activities. Designing coastal management plans must always reflect the conceptual, theoretical, and actual scenario, and all aspects must be consolidated upon consideration. This study will promulgate current standards and situations within targeted sites to provide the basis for coastal management plans.

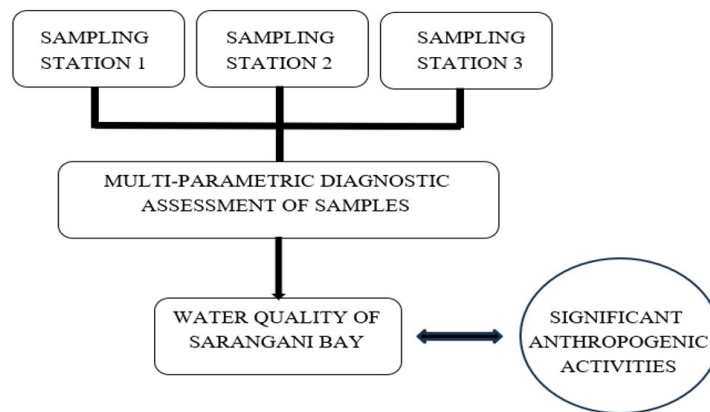


Figure 1: Schematic Diagram of the Study showing the Interplay Variables

The water in Sarangani Bay was threatened due to a variety of factors, ranging from land-based to water-based activities. The problems causing pollution in the bay stem from inadequate solid waste management systems, which struggle to cope with the large amount of trash produced. This leads to garbage being disposed of in coastal waters and rivers due to a lack of proper dump sites. Additionally, ineffective sewage treatment systems contribute to pollution in coastal waterways, groundwater, and river water, as soil permeability allows contaminants to seep through and septic tanks to overflow.

Objectives of the Study

The current study assessed the water quality at three designated stations within the Sarangani Bay Water Quality Management Area. These stations are strategically located in the Commercial Residential, Industrial, and Tourism Zones of General Santos City. The primary goal of this assessment is to translate complex water quality data into accessible and practical information for the benefit of the public and government agencies. Specifically, this study sought to

- (1) Determine the status of the water quality of

Sarangani Bay in terms of the physical, chemical, and biological parameters;

(2) Determine if there is a significant difference in the water quality across months in terms of physical, chemical, and biological characteristics;

(3) Determine the status of the various anthropogenic activities along Sarangani Bay; and

(4) Determine which anthropogenic activities greatly impacted the water quality in select sampling sites.

MATERIALS AND METHODS

Research Design

The study utilized a descriptive research design. It was deemed fit to describe the water quality in select stations using different parameters and identifying anthropogenic activities around the said sites.

Research Setting

In terms of its location on the map, Sarangani Bay is a vast coastal indentation positioned between latitudes 5°33'25" and 6°6'15" N and longitudes 124°22'45" and 125°19'45" E (refer to Figure 2-9). It includes the six coastal municipalities (Alabel, Malapatan, Glan, Maasim, Kiamba, and Maitum) in Sarangani Province, as well as General Santos City, a highly urbanized city in South Cotabato. Sarangani Bay has an area of 449.22 square kilometers north. The length of the coastline from Pinol

in Maitum to Tinaca Point in Glan is approximately 240 km. The bay's average depth is around 350 meters, and its deepest section plunges to over 800 meters. It extends outwards into the Celebes Sea in the southern part of the Philippines. The Sarangani Bay Protected Seascape (SBPS), which comes in as the second largest Marine Protected Area in the country, is home to rich marine biodiversity, especially in terms of fishery resources. The SBPS was declared a protected area under Presidential Proclamation No. 756 (March 5, 1996), with an original area of 215,950 hectares that was later expanded to 218,639.54 hectares (LEPDENR 12 2015). On June 22, 2018, Republic Act 11038, known as the Expanded National Integrated Protected Area System (ENIPAS), finally established SBPS as a national protected area with an area of 210,887.69 hectares. Rapid biological and hydrological assessments were conducted on the marine waters of Sarangani Bay located along the coastal waters of (a) Barangay Bawing, General Santos City; (b) Barangay Tumbler, General Santos City; and Barangay Dadiangas West, General Santos City. A total of three (3) sampling locations were established with their corresponding GPS coordinates, as shown in Table 5, to be recorded during the time of sampling. These were carried out for three (3) consecutive months with one (1) day of sampling per month from May to July 2023. Figure 3 shows the map of the sampling stations.

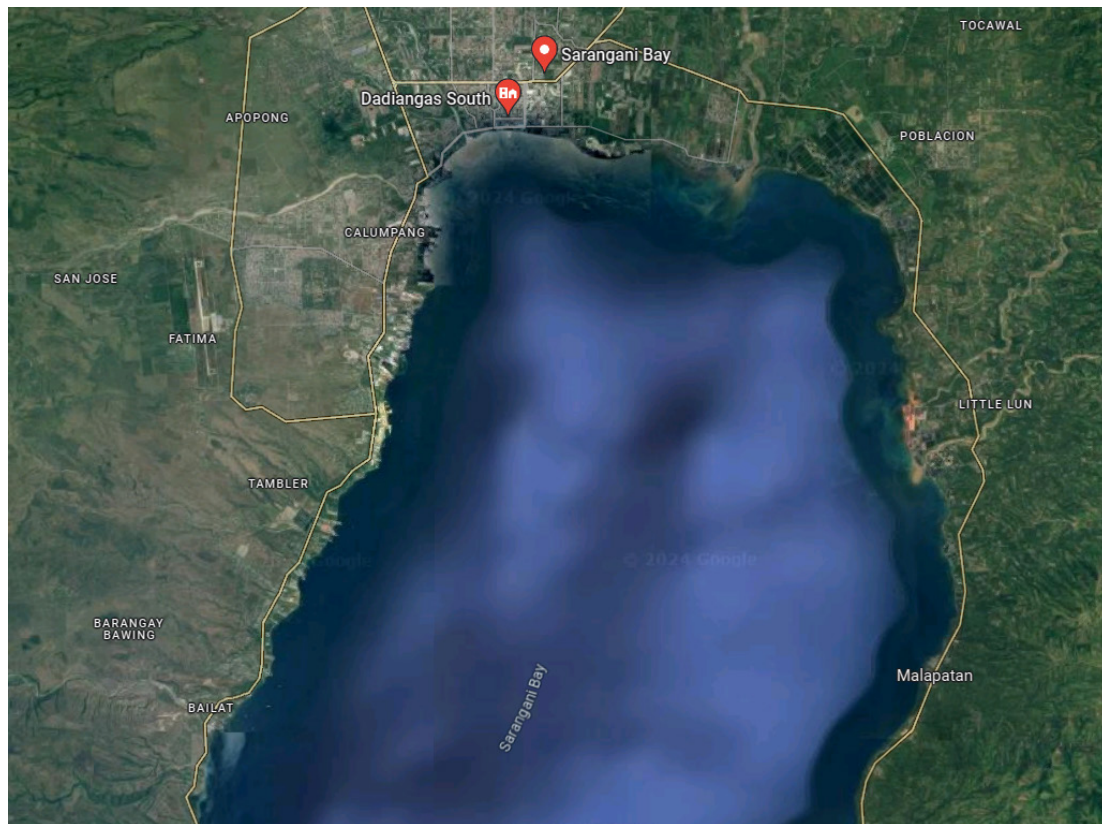


Figure 2: Map showing the Sampling Stations

Source: [https://www.google.com/maps/place/Sarangani Bay](https://www.google.com/maps/place/Sarangani+Bay)

Table 1: Summary of the Locations and Descriptions of the Three Sampling Stations

Sampling Station	Area	Geographic Location	Area Description
SW #1	London Beach Resort Barangay Bawing, General Santos City	5°58'40.04"N 125° 6'53.08"E Distance from the shoreline: 50 meters	Tourist Beach Resorts with Hotel, Restaurants, Function Rooms & Cottages
SW #2	General Santos Fish Port Complex, Barangay Tambler, General Santos City	6° 6'9.33"N 125°10'9.59"E Distance from the shoreline: 50 meters	Heavy Industrial Zone where industrial plants like Tuna Canning and seafood Processing Plant, Wharves and Ports, Fish Markets, Ice Plants, and Cold Storage are located
SW #3	Silway River Estuary, Silway, Barangay Dadiangas West, Gen. Santos City	6° 3'9.88"N 125° 9'5.76"E Distance from the shoreline: 50 meters	Densely Populated Residential Area with Commercial Establishments

Sampling Station 1 (SW#1)

Barangay Bawing was one of the nine coastal barangays in General Santos City. This barangay was bounded on the north by Barangay Tambler, on the east by Sarangani Bay, on the west by the Municipality of Maasim, and on the south by the Siguel River. This is where the London Beach Resort was located at Purok Darussalam. London Beach Resort is bounded on the east by Marchael Sea Ventures Corporation with Ice Plant, Shipyard, and Port; on the north by the National Highway, on the west by Sea Oil Petroleum Depot; and the south by Sarangani Bay. London Beach is approximately 23 kilometers from the city center and 8 kilometers from the General Santos Fish Port Complex.

Sampling Station 2 (SW#2)

The General Santos Fish Port Complex (GSFPC) spanned 32 hectares and was situated in Barangay Tambler, General Santos City. GSFPC was situated along the coast of Sarangani Bay. It's located approximately 15 kilometers south of downtown, near the fish port complex, and ranks as one of the largest fish ports in the Philippines, second only to the Navotas Fish Port Complex in Metro Manila. There are numerous support facilities in the vicinity of the fish port complex, which include:

1. Cold Storage buildings as Refrigeration facilities that cater to small-scale tuna processors and rentable cold storage rooms for fishery and seafood products.
2. Harbor facilities that include six (6) wharves and harbor basins that can accommodate huge capacity domestic and international fishing boats and refrigerated vessels.
3. Market facilities, which include four (4) Fish Market Hall Buildings, Warehouse, Food Court, Fishing Supplies Stores, Fresh Frozen Tuna Store, Administration Buildings, Fish Market Extension, Comfort Rooms,

Mezzanine Offices, Locker

- Rooms, Reefer Container Vans, and Commercial Banks.
- 4. Process Buildings as co-locators like Sta.Cruz Tuna Processing Plant, Citra Mina Tuna Canning Factory, PhilBest Canning Cold Storage & Ice Plant Corporation Fishport, and Ocean Deli Packing Plant

Sampling Station 3 (SW#3)

The collection of seawater samples was done at sampling station 3 at the mouth of the Silway River and Sarangani Bay near the coast of Purok San Juan and Silway in Barangay Dadiangas West. This coastal area of Silway was considered the most densely populated area of downtown Gensan, where many residential houses are situated. Also, many commercial buildings were established in Silway, Dadiangas West.

For the Silway River, this body of water was classified as a Class C category under DENR Administrative Order No. 34 for river water classification. The river is about 20 kilometers long, with its upstream starting at Tupi South Cotabato, the midstream portion in Polomolok, South Cotabato, and the downstream portion that ends at the estuary of the river in Purok San Juan, Sulway in Barangay Dadiangas West, General Santos City. Silway River was designated as a Water Quality Management Area (WQMA) in 2010 with DENR-AO No. 2010-10. DENR-EMB personnel, along with representatives from the Multi-Sectoral Group, conducted regular water sampling.

Sampling Procedure

This study was carried out by a Chemical Engineer who studied Environmental Planning and Management together with a sampling aide who was a Marine Biology Graduate. Samples sent to the laboratory were analyzed by Chemists who worked in an Accredited Laboratory following the qualifications set in the Clean Water Act criteria for technical personnel to work on water quality

analyses. The researcher was accompanied together with marine biologists and boat drivers for coastal navigation and a private laboratory for the analyses of different parameters involved in the study. Surface/subsurface water samples were collected using a standard 4-liter Niskin Sampling Bottle or Sampling Thief Jar. Physico-chemical parameters measured included temperature, dissolved oxygen (DO), hydrogen potential (pH), total suspended solids (TSS), nitrate, phosphate, and biological parameters such as presence and levels of Fecal Coliform and Total coliform (FC). pH and Temperature were measured in situ (in the field) using calibrated multi-parameter tester digital probes. Samplings were done through the grab sampling method at the surface and through composite samples taken from the top, middle, and bottom levels of seawater. These were sent to a DENR-Accredited Laboratory for analysis specifically to Ostrea Mineral Laboratories, Inc. (OMLI).

For physico-chemical parameters, the composite sampling which is obtained by combining portions of multiple grab samples or by mixing equal water volumes collected at a regular time interval, was utilized. The collection of water samples was accomplished by selecting representative sampling points in the water supply system and observing aseptic techniques during sampling to prevent contamination of the sample being collected, The sampling bottle was kept closed until it was filled; the cap should not be put on dirty surfaces while taking the sample, and filling the bottle immediately after opening, leaving ample air space (about 2.5 cm from the mouth) to allow mixing; the sample was held in containers maintained at 4 °C to 6 °C during transport; and samples should be properly labeled and adequately described.

Research Instruments

A set of three (3) 1-liter bottles was prepared before the collection of water samples, each assigned to each

sampling point. A calibrated multi-parameter tester and digital probes were prepared before in-situ analyses. A laboratory-grade insulated box was prepared with ice cubes inside for holding and transporting water samples. Other materials that were prepared for sample collection are 1-gallon plastic bottles, 1-liter glass, 500 ml wide-mouthed plastic bottles, water-proof markers for labeling water samples, geotagging equipment for geographical location of sampling points, and a digital camera for photo documentation.

Data Gathering Procedure

A standard 4-liter Niskin bottle or a sampling thief jar was used to collect surface and subsurface water profiles. Color, temperature, dissolved oxygen (D.O.), hydrogen potential (pH), total suspended solids (TSS), nitrate, phosphate, and biological factors such as the presence and amounts of fecal coliform bacteria and total coliform were among the physical-chemical and biological parameters examined. The calibrated multi-parameter tester digital probes were used to measure them in situ (in the field). A total of three (3) sampling locations were established, each with its GPS coordinates that were recorded during the sampling process.

Methods of Data Analysis

Most of the data that was gathered in situ was analyzed, while other parameters were sent to a private laboratory for analysis. The findings were evaluated against the marine water quality standards outlined in DENR Administrative Order No. 2016-08 and DENR Administrative Order No. 2021-19, which updated the Water Quality Guidelines (WQG) and General Effluent (GES) Standards for selected parameters. Shown in Table 2 are the updated Water Quality Guidelines for Primary and Secondary Parameters. Table 3 presents the waterbody classification and usage of marine waters.

Table 2: Water Quality Guidelines for Primary and Secondary Parameters

Parameter	Unit	Waterbody Classification			
		SA	SB	SC	SD
Dissolved Oxygen (DO), Minimum	mg/L	6	6	5	2
Fecal Coliform	MPN/100 mL	20	100	200	400
Nitrate As No3-N	mg/L	10	10	10	15
Ph, Range		7.0 - 8.5	7.0 - 8.5	6.5 - 8.5	6.0 - 9.0
Phosphate	mg/L	0.1	0.2	0.2	0.4
Temperature	°C	26 - 30	26 - 30	25 - 31	25 – 32
Total Suspended Solids	mg/L	25	50	80	110
Oil And Grease	mg/L	1	2	3	5

Source: DENR-EMB's DAO 2016-08

Table 3: Water Body Classification and Usage of Marine Waters

Classification	Intended Beneficial Use
Class SA	1. Fishery Water Class II – Waters suitable for commercial propagation of shellfish and intended as spawning areas for milkfish (<i>Chanos chanos</i>) and similar species.

	2. Tourist Zones – For ecotourism and recreational activities
	3. Recreational Water Class I – Intended for primary contact recreation (bathing, swimming, skin diving, etc.)
Class SB	1. Fishery Water Class II – Waters suitable for commercial propagation of shellfish and intended as spawning areas for milkfish (<i>Chanos chanos</i>) and similar species.
	2. Tourist Zones – For ecotourism and recreational activities
	3. Recreational Water Class I – Intended for primary contact recreation (bathing, swimming, skin diving, etc.)
Class SC	1. Fishery Water Class III – For the propagation and growth of fish and other aquatic resources and intended for commercial and sustenance fishing.
	2. Recreational Water Class II – For boating, fishing, or similar activities
	3. Marshy and/or mangrove areas declared as fish and wildlife sanctuaries.
Class SD	Navigable waters

Source: DENR-EMB's DAO 2016-08

Based on DENR Department Administrative Order No. 2016-08, the waterbody of Sarangani Bay was under Classes SB and SC. This classification included water bodies that are Recreational Water Class I, Tourism Zone, Fishery Water Class II, Recreational Water Class II, Fishery Class III, and marshy and/or mangrove areas declared as fish and wildlife sanctuaries, respectively. Tables 2 and 3 show the water quality standards of the different parameters used in this study based on DENR Administrative Order No. 2016-08. In this particular study, the stations where sampling was carried out were

under Class SB and SC; hence, the values that were obtained were compared with the standards indicated in Table 4 and Table 5.

Statistical Technique. The study employed the Analysis of Variance (ANOVA) a statistical technique used to check if the means of two or more groups are significantly different from each other (Kaufman, 2014). ANOVA checks the impact of one or more factors by comparing the means of different samples to validate the results, especially the determination of the significant difference across stations and months.

Table 4: DENR Coastal/ Marine Water Quality Standards for Class SB

Parameter	Unit	Standard
Temperature	°C	26-30
Oil and Grease	mg/L	2
pH (range)		7.0-8.5
Dissolved Oxygen (Minimum)	mg/L	6
Fecal Coliform	MPN/100mL	100
Total Suspended Solids	mg/L	50
Phosphate	mg/L	0.2
Nitrate as NO ₃ -N	mg/L	10

Source: DENR-EMB's DAO 2016-08

Table 5: DENR Coastal/ Marine Water Quality Standards for Class SC

Parameter	Unit	Standard
Temperature	°C	25-31
Oil and Grease	mg/L	3
pH (range)		6.5 -8.5
Dissolved Oxygen (Minimum)	mg/L	5
Fecal Coliform	MPN/100mL	200
Total Suspended Solids	mg/L	80
Phosphate	mg/L	0.2
Nitrate as NO ₃ -N	mg/L	10

Source: DENR-EMB's DAO 2016-08

RESULTS AND DISCUSSION

Objective 1. To Determine the Status of the Water Quality of Sarangani Bay in Terms of the Physical, Chemical, and Biological Parameters

Table 6 provides a summary of the water conditions in Sarangani Bay at specific stations over three months; For month one, station 1, which was at London Beach Resort in Barangay Bawing, General Santos City, had values for all the parameters (temperature, pH, color, dissolved oxygen, total suspended solids, oil and grease, nitrate, phosphate, fecal coliform, and total coliform) within the standard of Class SB, which is intended for fish propagation, spawning, swimming, and recreation. On the other hand, SW2, which was at the General Santos

Fish Port Complex, obtained values that were within the standard of Class SC, which was for propagation and sustenance fishing as well as boating. The weather, which was rainy during the time of sampling, may have contributed to this condition since rainwater can tend to dilute marine water. As for SW3, however, fecal coliform and total coliform values were way beyond the standard (240 and 920 MPN/100 mL, respectively). This may be caused by the location of the station, which is near the mouth of the Silway River, which carries the major water flow. Aside from this, the area is also near human settlements, and wastewater from the household drains into the nearby water body.

Table 6: Summary Status of the Water Quality in Select Stations of Sarangani Bay

Parameter	Month 1 (May 28, 2023)			Month 2 (June 29, 2023)			Month 3 July 31, 2023)		
	SW1 BB "Class SB" (London Beach)	SW2 BT "Class SC" (Fish Port)	SW3 BD "Class SC" (Silway)	SW1 BB "Class SB" (London Beach)	SW2 BT "Class SC" (Fish Port)	SW3 BD "Class SC" (Silway)	SW1 BB "Class SB" (London Beach)	SW2 BT "Class SC" (Fish Port)	SW3 BD "Class SC" (Silway)
Temperature	25	25	26	25	25	25	25	25	25
Ph	8.1	8	8	8.2	7.8	8.2	8.2	8.2	8.2
Color (cu)	<5	<5	<5	<5	<5	<5	<5	<5	<5
DO (mg/L)	7	<6	6	7	2*	7	7	6	8
TSS (mg/L)	<1	<1	<1	<1	<1	<1	9	6	39
O/G (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nitrate (mg/L)	<0.10	<0.10	<0.10	0.03	0.01	0.01	0.01	0.01	0.13
Phosphate (mg/L)	0.038	0.018	0.044	0.04	0.88*	0.06	<0.007	<0.007	0.139
Fecal Coliform MPN/100 ml	<1.8	<1.8	240*	350*	240*	790*	9.3	490*	9200*
Total Coliform MPN/100 ml	<1.8	<1.8	920*	1600*	920*	1300*	38	790*	1600*

On the second month of sampling, SW1 (London Beach) showed normal results for temperature, pH, color, DO, TSS, oil and grease, nitrate, and phosphate but not for fecal and total coliform values. These last two parameters were way beyond the standard (350 and 1600 MPN/100 mL, respectively). As a water body intended for bathing and swimming, these values do not meet the requirements under the SB classification. SW2 showed a low value for DO that was below the standard (2 mg/L) at the time of sampling. This may have been due to the warm temperature on the surface, which tends to dissipate dissolved oxygen. The phosphate level (0.88 mg/L) went a little above the standard of 0.5 mg/L. This value may have been caused by the phosphates from soaps and detergents that drained into the body. Also, effluent with human excreta, animal blood, and viscera has traces of

phosphorous flowing into the drainage line. The Fish Port Complex has been observed to have wastewater with blood and viscera from fish, such as tuna and other species. This is due to the presence of numerous processing plants in the area. Although the wastewater goes through treatment facilities, traces of phosphates can still be present in the effluent. These contaminants come from cleaning compounds, like soaps and detergents, which are used to clean utensils, tables, and equipment in the processing plants. These washings are then mixed with industrial effluents from various factories in the Fish Port Complex. The outflow of this effluent may have contributed to the slight increase in the seawater's phosphate level during the second month of sampling. If left untreated, excess phosphates can be harmful to aquatic plants and cause eutrophication in the long run.

Eutrophication is a natural process that occurs as bodies of water, like bays, age. It happens when nutrients are abundant in the water, leading to rapid plant growth. It is the overabundance of nutrients in a body of water that results in harmful algal blooms, fish kills, and in some cases ecosystem collapse. It is a process driven by the enrichment of water by nutrients, particularly compounds of nitrogen and/or phosphorus, leading to increased growth, primary production, and biomass of algae;

changes in the balance of nutrients causing changes to the balance of organisms; and water quality degradation (NOAA, 2007; UNEP, 2015). However, these plants decay faster than they can be broken down. This dead plant matter accumulates and fills the bed of the bay, making it shallower together with sediments. Table 7 indicates the list of industries that were generating wastewater for the Wastewater Treatment Plants of the General Santos Fish Port Complex.

Table 7: Name of Establishments and Facilities Operating inside the Fish Port Complex

Name of Establishment/ Industry	Address	Wastewater Treatment Type
1. Sta. Cruz Seafoods, Inc.	Lot 20, Agro Industrial Area, PFDA General Santos Fish Port Complex, Barangay Tambler, General Santos City	Water Treatment Facility
2. Citra Mina Canning Corporation	Lot 5 Agro-Industrial Area, PFDA General Santos Fish Port Complex, Barangay Tambler, General Santos City	Water Treatment Facility
3. Philbest Canning Cold Storage & Ice Plant Corporation – Fishport (Igloo Storage Complex Corporation - Fishport)	Agro Industrial Area, PFDA- General Santos Fish Port Complex, Barangay Tambler, General Santos City	Water Treatment Facility
4. Ocean Deli Packing Corporation	Lot 19, Fish Port Complex, Tambler, General Santos City	Water Treatment Facility
5. Fish Market Buildings 1,2,3 & 4	Seafront, Fish Port Complex, Tambler, General Santos City	Water Treatment Facility
6. Cold Storage & Refrigerated Buildings	Beside Fish Market 3 & Market 4, Fish Port Complex, GSC	Drainage System going to WTF

SW 3 (Dadiangas West-Silway River Estuary), on the other hand, showed normal results for temperature, pH, color, DO, TSS, oil and grease, nitrate, and phosphate but not for fecal and total coliform values. These last two parameters were way beyond the standard (90 and 1300 MPN/100 ml), respectively. The Barangay Dadiangas West was observed to be congested with commercial establishments in the downtown area, while the coastal portion fronting Sarangani Bay was dense with residential dwellers.

Table 8: Population of Barangay Dadiangas West

Census date	Population	Growth rate
1990 May 1	–	–
1995 Sept. 1	17,570	–
2000 May 1	16,196	-1.73%
2007 Aug 1	18,253	1.66%
2010 May 1	15,202	-6.44%
2015 Aug. 1	13,827	-1.79%
2020 May 1	13,090	-1.15%

Source: <https://sp.gensantos.gov.ph/barangays/barangay-dadiangas-west/>

On the third month of sampling, July 29, 2023, it can be gleaned from the table that station 1 still had values within standards, and that includes fecal and total coliform (9.3

and 38 MPN/100 mL, respectively). These are low values that are within the assimilative capacity of the water body. As for station 2, the rest of the parameters obtained normal values except again for fecal and total coliform (490 and 790 MPN/100mL, respectively).

Meanwhile, station 3 had even higher values for fecal and total coliform at 9200 and 1600 MPN. 100mL. The increase in such values may be attributed to the presence of fecal matter from human settlements, as effluents from the household are conveyed through storm drainages and into the outfalls and emptied into the water body. Station 3 is near the Silway River and releases the major water flow, which may have in turn carried as runoff some fecal matter and other bacteria from the upstream part of the Silway River.

Objective 2. To Determine If There is a Significant Difference in the Water Quality Across Months in Terms of Physical, Chemical, and Biological Characteristics

The results of the test on significant differences across months for class SC values are presented in Table 9. Based on the table, it can be observed that there is no significant difference across months in terms of temperature. The p-values in the table are all greater than alpha at 0.05, which means that the assumed hypotheses in the current study are all accepted.

Table 9: Test of Significant difference by parameters for Class SC values across months

Hypothesis	Level of Significance	P-value	F-value	Result
H ₀ : There is no significant difference in the Temperature across different Months	0.05	0.4219	1.00	No significant difference
H ₀ : There is no significant difference in the pH across different Months	0.05	0.3554	1.24	No significant difference
H ₀ : There is no significant difference in the DO across different Months	0.05	0.5529	0.66	No significant difference
H ₀ : There is no significant difference in the TSS across different Months	0.05	0.1534	2.60	No significant difference
H ₀ : There is no significant difference in the Nitrate across different Months	0.05	0.1128	3.21	No significant difference
H ₀ : There is no significant difference in the Phosphate across different Months	0.05	0.5610	0.64	No significant difference
H ₀ : There is no significant difference in the Fecal across different Months	0.05	0.4244	0.99	No significant difference
H ₀ : There is no significant difference in the Coliform across different Months	0.05	0.2056	2.08	No significant difference

Legend: Level of Significance: < = .05

This suggested that temperature conditions within the three months are relatively the same. The same applies to pH, as indicated by the p-value of 0.3554, which is greater than alpha. The same goes for dissolved oxygen (DO), despite having a low value only for the second station in the second month of sampling. The p-value, which is 0.5529, is also greater than the alpha set at 0.05. More or less, then, the conditions are the same throughout the sampling period.

The p-value for TSS is also greater than alpha, indicating no significant difference in the conditions across the three months implying the similarity in conditions in terms of TSS. The distribution of nitrate and phosphate is also similar across months as indicated by the p-value which is higher than alpha despite having a slightly higher value in the second station of the second month. As for fecal and

total coliform whose values suggest organic pollution, their distribution is more or less similar across months. Overall, the occurrence of organic pollution is detected across the three-month sampling period.

Objective 3. To Determine the Status of the Various Anthropogenic Activities along Sarangani Bay

The anthropogenic activities along Sarangani Bay near the sampling sites were coastal tourism such as beach resorts and hotels, oil depots, restaurants, agro-industrial activities like fish markets and deliveries, shipyards, ice plants, tuna and seafood processing plants, commercial establishments, and residential areas. Two management zones regulate these activities to protect these areas, the strict protection zone for coral reefs and other ecosystem protection, and multiple-use zones for recreational and

Table 10: Anthropogenic activities along Sarangani Bay near the sampling sites- Beach resorts, Hotel and Restaurants

Beach Resorts	Hotel & Restaurant	Location(GSC)
Lion's Beach Resort		Dadiangas South
	The Port Food Court	Fish Port Complex Tambler
	Fisherman's Village Restaurant	Fish Port Complex Tambler
Tropicana Beach Resort	Tropicana Beach Resort	Tambler
Maharlika Beach Resort		Tambler
Dolores Beach Resort		Tambler
Rajah Beach Resort		Tambler
Labo Beach		Bawing
Passionist Beach		Bawing
London Beach Resort	London Beach Resort	Bawing
Watergran Resort	Watergran Resort	Bawing
Reina Virginia Beach Resort	Reina Virginia Resort	Bawing

Table 11: Anthropogenic activities along Sarangani Bay near the Sampling Sites- Oil Depots

Oil Petroleum Depot	Location
Phoenix Petroleum Terminal	Tambler
Chevron Oil Depot	Tambler
Petron Oil Depot	Tambler
SEAOIL Petroleum Terminal-Gensan Oil Depot	Bawing
YBS Green Oil Depot	Bawing

Table 12: Anthropogenic activities along Sarangani Bay near the sampling sites in General Santos City- Industrial Plant/ Factories

Industrial Plants/ Factories	Location
Cargill Oil Mill Philippines, Inc.	Tambler
General Santos Fish Port Complex	Tambler
Philbest Canning Corp.	Tambler
General Tuna Canning Corp.	Tambler
Century Pacific Agricultural Ventures, Inc.	Tambler
Celebes Canning Corporation	Tambler
Citra Mina Seafood Processing Plant	Tambler
Seatrade Canning Corporation	Tambler
RD Tuna Ventures, Inc.	Calumpang
RR Manufacturing Corp.	Tambler
Alliance Food International Corp.	Tambler
Genpack Corporation	Tambler
Ten Point Corporation	Labangal

fish farming purposes. Eight (8) commercial beach resorts were established along the beachfront of Sarangani Bay in Barangays Bawing and Tambler, and one (1) public beach resort downtown is located at Barangay Dadiangas South, about 400 meters from sampling station 3 as shown in Table 10, 11, and 12.

Objective 4. To Determine Which Anthropogenic Activities Greatly Impacted the Water Quality in Select Sampling Sites

Based on the presence of organic pollution in the bay, this condition, which was the same for all the stations belonging to three (3) different barangays over three months, may be attributed to all the aforementioned activities: beach resorts and hotels, oil depots, restaurants, fish markets, seaports, shipyards, ice plants, tuna and seafood processing plants, oil mills, commercial establishments, and residential areas.

CONCLUSIONS

Based on the findings of the study, it has been concluded that the water quality of Sarangani Bay in certain stations was within the established standards in terms of the physicochemical parameters that were covered. However, it was observed that there was the presence

of organic pollution throughout the three months in the sampled areas, indicating a consistent trend. The human activities that may have caused this condition were the establishments present in the area, such as fish markets, beach resorts and hotels, shipyards, seaports, tuna canning and seafood processing plants, ice plants, coconut oil mills, and residential areas. In this case, it seems that the guidelines for the two management zones may not have been fully implemented in the areas affected by human activities. It is necessary to increase efforts to maintain the classification of the water quality, to ensure the well-being of both the population and the marine ecosystems.

Acknowledgments

The researcher would like to extend her sincere gratitude to Dr. Alice G. Comahig, Dr. Mariano M. Lerin, and Dr. Edzen A. Espina for their invaluable feedback and insightful recommendations during the review process of my thesis manuscript. Their expertise and constructive criticism have greatly contributed to the refinement of my research.

Special thanks are also due to Dr. Judy Marie R. Zoleta, for her guidance and support throughout the preparation of my thesis. Additionally, the researcher is also grateful to Ma'am Riza Joy C. Cañas for her encouragement and motivation, which inspired me to persevere and complete my manuscript. I am truly appreciative of their mentorship and encouragement.

The researcher would like to acknowledge also Mr. Jomarlds Ramoga for his dedication, hard work, and enthusiasm as my marine water sampler. His assistance in collecting samples in the waters of Sarangani Bay has been invaluable to the success of my research. His patience and commitment are commendable, and grateful for his contribution to this endeavor.

Finally, I am indebted to my family, especially my mother Teresita, son Elijah Nikk Chloe, siblings Jessica and Tito Jojo, and friends whose unwavering support and encouragement have been my source of inspiration throughout this journey. Furthermore, the researcher is also thankful to Ms. Farrida Simpal for encouraging me to pursue further education in environmental management, which has been instrumental in enhancing my skills as an environmental consultant.

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