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Fecal coliform distribution and its implication to coastal water quality: A case study of Tibungco Bay, Davao City, Philippines

Jason Ben Romano Paragamac [1,2*], Jasper Morala Maglinab [2], Marjorie Tocmo Rebuyon [2]

[1] *University of the Philippines Los Banos, Laguna, Philippines*
[2] *Professional Schools, University of Mindanao, Matina Campus, Davao City, Philippines*

Abstract

Urbanization greatly influences water quality on a spatial and temporal scale. Water bodies, especially coastal waters, experience various threats from intensive industrial and economic development. These results in diminishing marine ecosystems' water quality and productivity and pose a risk to human health and the environment. This study employs descriptive and quantitative research design aimed to quantify the coliform distribution across Tibungco Bay. Key Informant Interviews (KII) were conducted to formulate the problem, and a solution tree and logical framework analysis were created. Nine (9) sampling stations were sampled and analyzed for coliform concentration. Results show that majority of the sampling sites were above the threshold values. Eight (8) of the sampling stations examined were non-attainment areas that were contaminated with coliform bacteria. These areas are considered unsafe for direct contact and are unfit for recreational activities. The Analysis of Variance (ANOVA) shows that coliform did not differ significantly among sampling sites based on the computed f value of 1.234 and p-value of 4.321 tested at 0.05 level of significance. Majority of sampling sites exceeded the threshold values and are non-attainment areas. Insufficiency of household infrastructure concerning sewage is considered as a significant factor in the escalation of fecal concentration.

Keywords: Water Quality, Fecal Coliform, Tibungco Bay, Davao City, Philippines

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* Corresponding author. *E-mail address:* jrparagamac@up.edu.ph

1. Introduction

Water is a natural resource that enables life to flourish. The presence of water pollution-is linked to various sources such as urbanization, manufacturing or chemical industries and agriculture (Avigliano and Schenone, 2015) which causes severe environmental problems, especially in water quality (Ren, Cui, and Sun, 2014), which includes untreated wastewater (Bayram et al., 2012). The decline in water quality is a global challenge as it accounts for over 3.4 million deaths worldwide through unsafe water consumption. Reduction in water quality also leads to an increase in human health risk, which is escalated by population growth and poverty (Xue et al.,2018). Coastal seas have been focal points of human settlements over the years (Lotze, 2006). A study has shown that population and economic development drive water pollution (Juma et al., 2014). Water contamination results from unhygienic communities and poor household practices (Gizachew et al., 2020), which pose negative health effects resulting in increased morbidity and mortality (Wang and Yang, 2016). Bacterial contamination limits water bodies' ability to provide a commercial and recreational function (Kelsy et al., 2004). The presence of fecal coliform is an indication of water quality degradation. The increased presence of fecal coliform can be attributed to the increased point and non-point sources of pollution, which is magnified by humans' presence (Webster et al.,2004). The investigation of water quality is important in order to determine if the water at Tibungco Bay is suitable for recreation, commercial, or irrigation and to reduce the risk of health-related cases brought by the utilization of unsafe water resources.

2. Aims and objectives

The study aims to examine the coastal water quality of Tinungoc Bay. This involved sampling in various sampling sites at different sampling depths to characterize the fecal coliform distribution. This is to determine the suitability and conformance of the Bay to the national standards of coastal water bodies based on its current waterbody classification. Specifically, this study will answer the following objectives:

- To investigate the fecal coliform distribution along Tibungco bay
- To identify the attainment areas
- To determine non-attainment areas
- To explore the significant differences in fecal concentration along with different sampling sites
- To develop a problem and solution tree analysis as well as a logical framework analysis

2.1. Hypothesis

The following hypothesis was tested at a 0.05 significance level: There is no significant difference in fecal coliform concentration between and among sampling stations.

3. Research method

3.1. Research design

A descriptive and quantitative research design was employed in this study to describe and quantify the fecal coliform distribution along Tibungco Bay. Descriptive design was used to describe the existing condition of the study site to explain various variables (Paragamac et al.,2020). On the other hand, the quantitative tries to quantify the level of coliform concentration at various sites to analyze the patterns in a numeric term by collecting various samples of objects being studied (Paragamac and Bonghanoy, 2019). This was achieved through the collection of water samples across different sampling sites and depths. The area of the coastal Bay was measured in kilometers to establish the three sampling sites. This ensured that there was an equal distance between each of the three sampling sites. Each of the three main sampling sites were then further divided into three sampling sites which measured 5m, 10m, and 15m, from the shoreline. Thus, a total of nine (9) sampling sites were established across Tibungco Bay. The study is limited to the sampling and analysis of fecal coliform distribution across Tibungco Bay. The study is also limited to the sampling equipment used at the sample collection of deeper strata. Moreover, the costs of laboratory analysis limit the researcher to collect the number of samples.

3.2. The study sites

Davao City is a highly urbanized city that lies 7.1907° N, 125.4553° E. The city has various industrial, commercial, residential, and institutional activities. The estimated population is 1.82 million people based on the 2020 census (National Economic Development Authority, 2021). The sampling sites are located in Tibungco Bay located at 7.1907° N, 125.4553° E. The Bay is surrounded by industrial plants, harbors, container yards, and informal settlements. The growing industrial activities and informal settlements along the bay area are examined in this study to determine their significant impact on the coastal environment.

3.3. Sample collection and analysis

Samples of water from the sampling sites were collected using composite sampling techniques. This technique is applied by collecting a water sample from different sampling depths with equal volume and mixed to obtain a representative sample from each of the sampling sites established. All samples collected from the study site were stored in a 500 ml container and were submitted to Davao Analytical Laboratories in Bangkal, Davao City, Philippines, to undergo a fecal coliform test.

3.4. Statistical data analysis

Statistical analysis was employed to analyze data using One-Way Analysis of Variance (ANOVA), and means were compared to determine the significant difference among different sampling stations at a 0.05 confidence interval. Data from Key Informant Interviews (KII) was tabulated and analyzed to generate the problem tree and solution tree analysis as well as develop a logical framework.

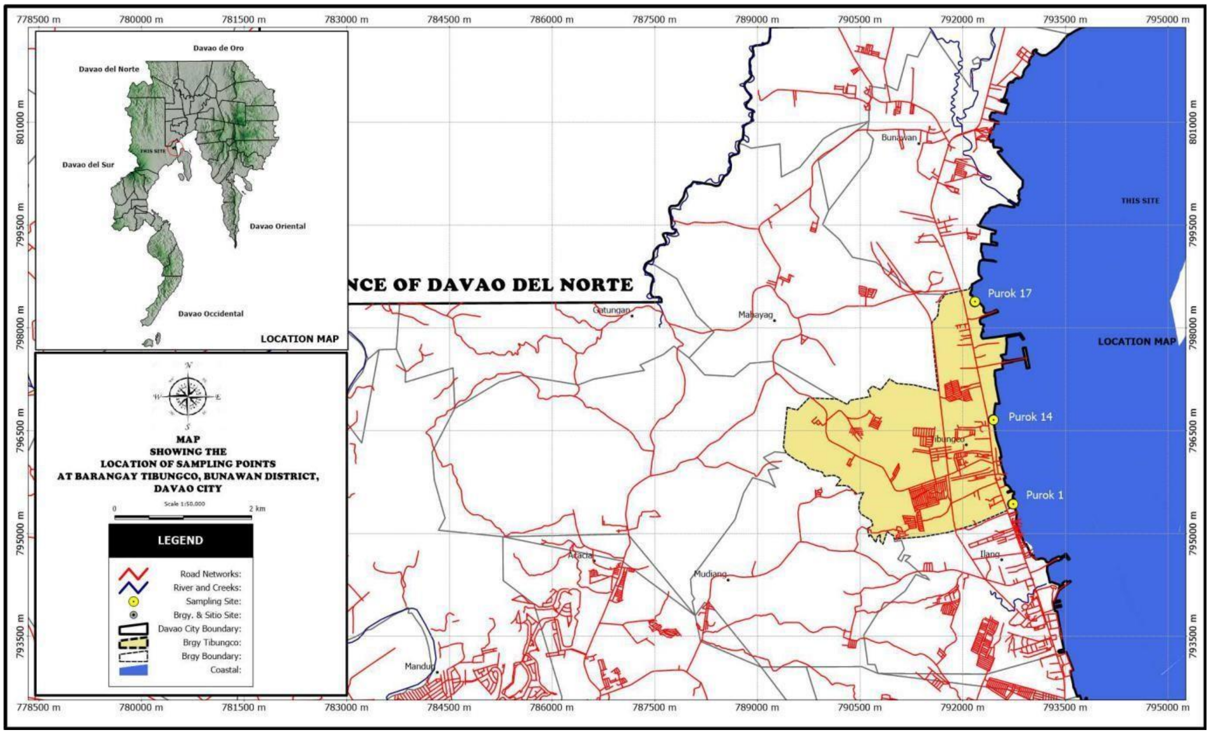

Figure 2. Map Showing the Location of Sampling Sites

4. Results and discussions

4.1. Coliform concentration

Table 1 shows the analysis of nine (9) water samples collected from three (3) sampling sites at 5m, 10m, and 15m sampling depth across the Tibungco bay. In Site 1, the highest recorded concentration of fecal coliform was found in 10m depth with 1,600 MPN/ 100 ml followed by 5m depth with 920 mg/L. The lowest concentration was observed at 15m depth with 280 mg/L. The high concentration of fecal coliform along the different sites of Tibungco bay can be attributed to the presence of informal settlements along the bay area. Untreated sewage from settlements has a high impact on coastal ecosystems and contributed to the decline in an area's recreation value (Chen and Liu, 2017).

For site 2, 10m, and 5m sampling depth had the highest coliform concentration with 1,600 MPN/ 100 ml for both, and the lowest recorded fecal concentration was observed in 15 m depth with a concentration value of 61 MPN/ 100 ml. The results can be attributed to its distance from the surface levels where most of the fecal coliform are more concentrated in the 5- and 10-meters sampling depth.

Table 1. Fecal coliform concentration in different sampling sites

Sampling Site	Sampling Depth (m)	Concentration	Threshold Value (DAO 2016-08)
1	5	920	
	10	1,600	
	15	280	
2	5	1,600	
	10	1,600	100 MPN/
	15	61	
3	5	1,600	
	10	920	
	15	1,600	

In sampling site 3, 5m, and 15m sampling depth sites recorded the greatest amount of fecal coliform, while site10 had the least amount recorded with 1600 MPN/ 100 ml and 920 MPN/ 100 ml, respectively. The increasing water pollution and contamination in an environment that humans inhabit can potentially affect their health by increasing the transmission and rates of different infectious diseases. In fact, according to (Tong et al.,2016), diarrheal and gastrointestinal infections are among the significant concerns in underdeveloped countries, especially where financial resources are limited, and there is a lack of proper water and sanitation facilities.

4.2. Attainment and non-attainment areas

The attainment and non-attainment areas signify the conformance and non-conformance of any sampling station being examined as compared to the set threshold limits in terms of concentrations. The attainment areas are those areas that conform with the national guideless for water quality in accordance with its stated beneficial uses. Moreover, the non-attainment areas are non-compliant based on the set guidelines concerning its current water quality classifications and beneficial use. Based on the results of the analyses of the samples collected from different sampling sites and sampling depths. It shows that eight (8) of the sampling sites analyzed for fecal coliform were not attained based on the DENR Administrative Order No. 2016-08 guidelines for Seawater of Class B waterbodies (SB) water bodies set at 100 MPN/ ml of fecal coliform concentrations. Moreover, only one (1) site was attained or within the set threshold values among the sampled sampling sites. Improper sewage facilities from residential areas informally settling along the shorelines have significantly affected the quality of coastal waters along the Tibungco Bay. This has led to some areas become non-attained or compliant to the minimum threshold set for class SB waters. The increased anthropogenic activities have significantly influenced massive pollution along with coastal environments (Wang et al.,2020). Furthermore, industrial activities like seaports and other facilities such as container yards, cement plants, and petroleum berthing facilities around the surrounding environment also caused environmental pollution (Tri et al.,2019).

4.3. Significance of the difference

Table 2 shows the results of the analysis of samples collected in Tibungco Bay using Analysis of Variance (ANOVA). It shows that fecal coliform distribution across different sampling sites did not differ significantly based on the computed f value of 1.5804 and p-value of 0.2809, which was higher at 0.05 level of significance. The distribution of fecal coliform along the coastal Bay is attributed to the existing settlement and industrial development patterns along the shoreline. Considering that informal settlers entirely inhabit the Bay without proper sewerage treatment facilities, it has further added to widespread of fecal contamination. According to Hong et al. (2010), the coliform concentration is influenced by the surrounding land use pattern and the occurrence of stormwater runoff that added to the decline of water quality, making water bodies unsuitable for their particular uses.

Table 2. Results of the One-Way Analysis of Variance (ANOVA)

Source of Variation	F-value	P-Value
Between Groups	1.580	0.281*

** Not significant*

4.4. Problem and solution tree analysis

The risk of fecal coliform (E. Coli) concentration present along the coastal environment predominantly occupied by informal settlements without proper sanitation is summarized in (Figure 2). Problem tree analysis was formulated using the Key Informant Interview (KII) results. This was based on the residents' responses during the conduct of the KII. It shows that the core reasons for the increased fecal coliform count along the bay area are linked to informal settlements and the unhygienic community practices that lack solid waste management and proper sewage treatment and disposal along with various households. Studies have indicated that high levels of environmental contamination are often associated with improper management of human excreta, which are prevalent in informal settlements in urban areas, particularly in developing countries (Opisa et al., 2012). During the interview, it was also revealed that the presence of settlement in the area might pose harm and contribute to various health-related issues if not addressed carefully. Studies have shown that poor infrastructural maintenance at the household levels exacerbated microbial water pollution (Abia et al., 2017) and was considered detrimental to public health and over well-being (Ishii and Sadowsky, 2008).

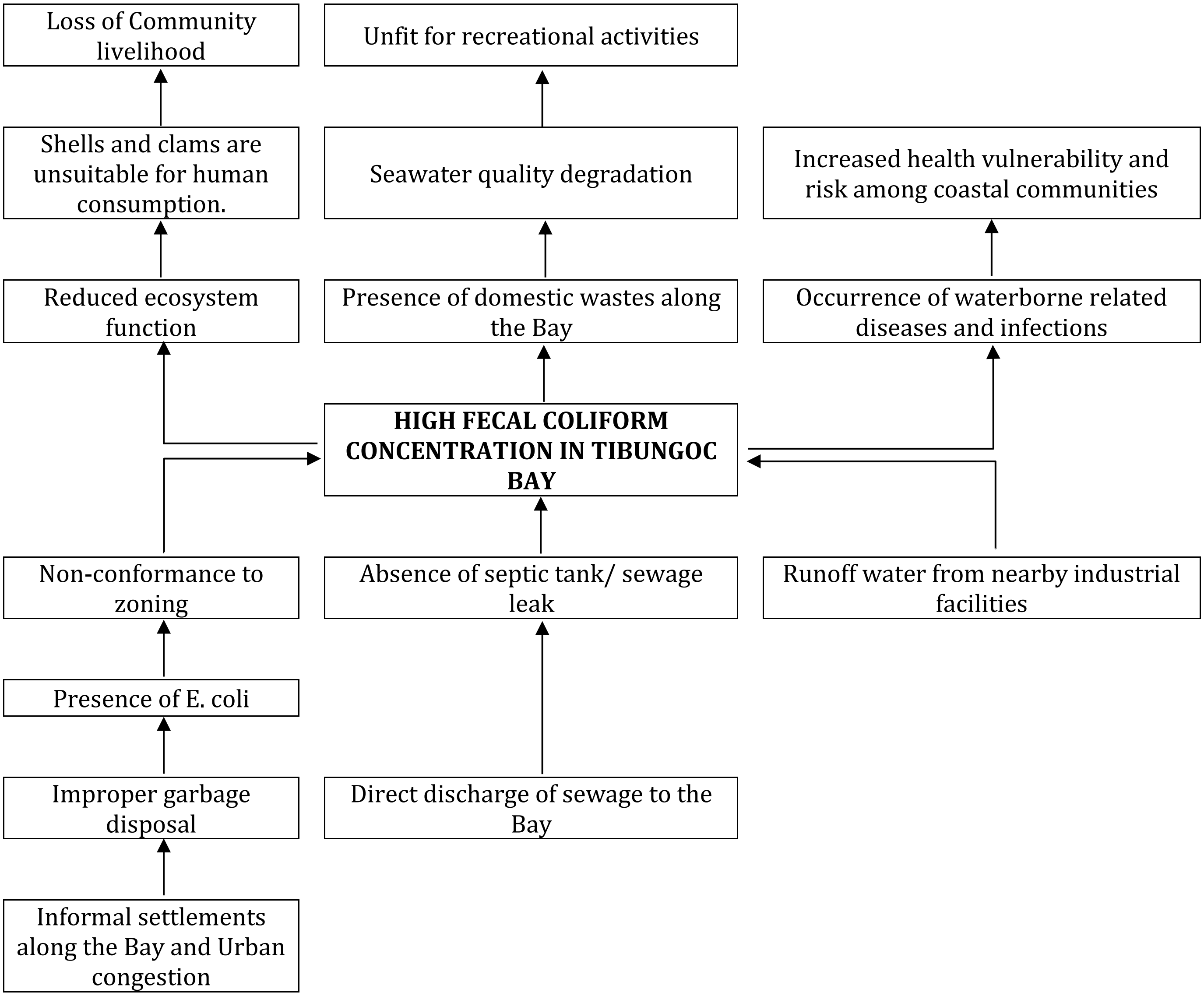

Figure 2. Problem tree analysis

Presented in Figure 3 are the recommended solutions to further improve the water quality along the coastal area of Barangay Tibungco, anchored on the generate problem tree analysis results. Further, this presents the implications of improved water quality or reduced fecal concentrations related to economic, environmental, and social aspects. Infrastructure development at the household level has been an important tool in improving the coastal water quality involving proper wastewater treatment, which significantly improved water conditions. Studies have shown that planning and implementing proper wastewater treatment have significantly improved water quality and qualifies for other beneficial uses (Hmaoda et al., 2004). Intensive education campaigns concerning water quality improvement should be incorporated in the local planning and urban development and engage in investments to the water system to improve water quality (McGarvey et al., 2008).

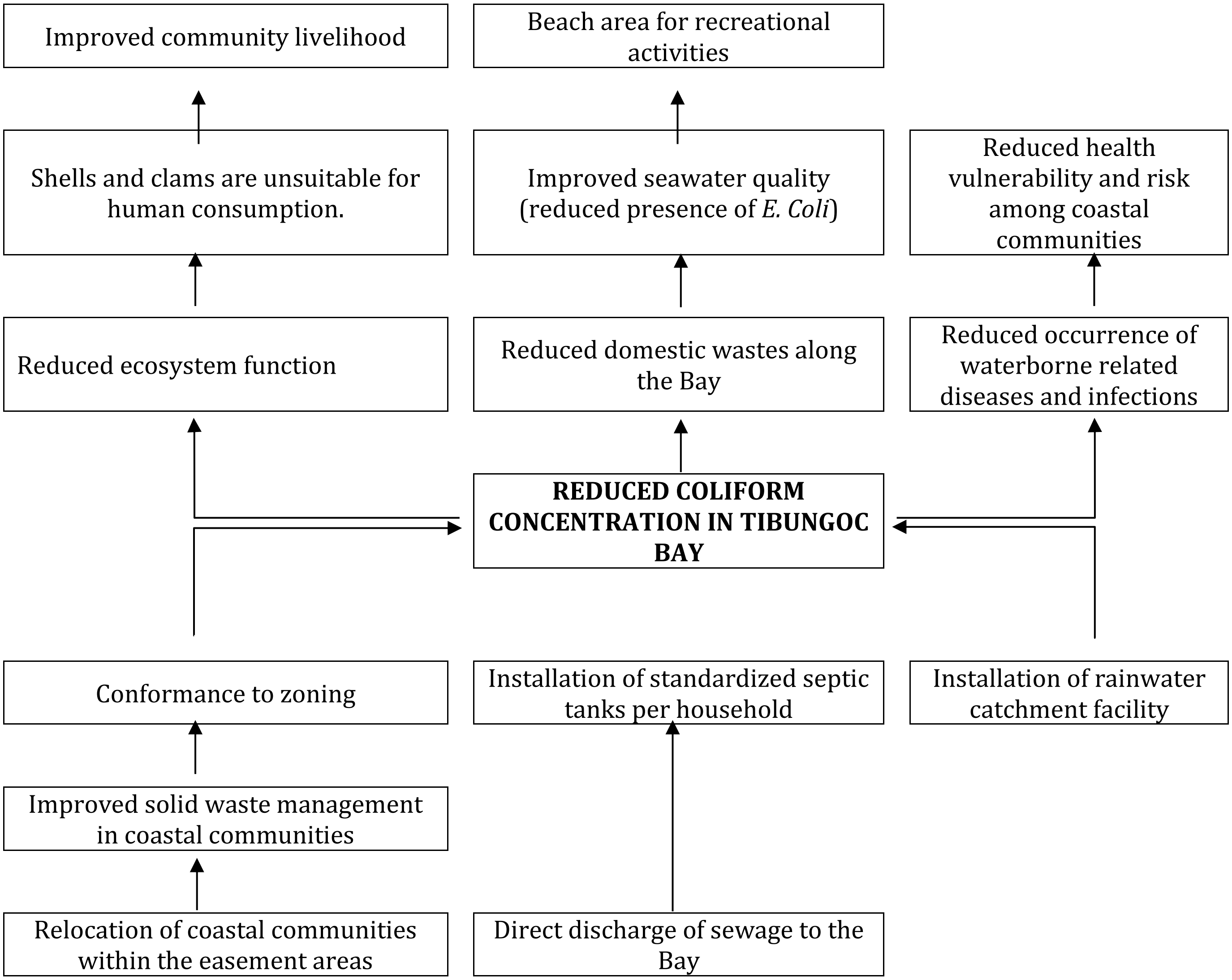

Figure 3. Solution tree analysis

4.5. Logical framework analysis

The logical framework is formulated based on the problem's findings and recommendations and solution tree analysis. It presents the key factors, indicators, means of verification, and assumptions concerning water quality improvement or reduced fecal coliform concentration along with the coastal environment of Tibungco Bay.

Moreover, to achieve the goal, series of activities and deliverables with the appropriate course of action was formulated. These activities are expected to generate sufficient data, which will be significant in attaining the expected outcomes.

Lastly, the multi-stakeholder participation and the local government units' commitment to come up with concrete plans, programs, and strategies will ensure the improvement of the quality of the environment, economic prosperity, and the highest quality of life. Community involvement an eliciting social perception, and utilizing local knowledge is relevant in planning and implementing water quality initiatives. According to Okumah and Yeboah (2009), understanding the community's perception must be carefully reviewed and incorporated into various action plans and programs to advance the understanding of the root causes of the problem and develop various interventions in solving the problem.

Table 3. Logical framework analysis

Logical Framework	Project Summary	Indicator	Means of Verification	Risks / Assumptions
Goal	Improved water quality of Tibungco Bay	Reduced E. coli concentration	Seawater quality analysis report	N/A
Outcomes/ Objectives	Conformance of households to appropriate sanitation practices	A number of sanitation facilities were installed.	Geotagged photos of sanitation facilities installed.	All households have sanitation facilities.
	Survey results were utilized to determine social and infrastructure needs.	Number of social and infrastructure needs	List of social and infrastructure needs	Lack of funds to finance the implementation of social and infrastructure needs
Outputs/Deliverables	At least 80% of the residents along Tibungco Bay are surveyed.	Number of survey questionnaires accomplished.	Filled up questionnaires	Some questionnaires were not completely filled out.
	At least 80% of the household attend the IEC activity.	Number of IEC materials distributed.	List of household attendees received IEC materials.	Low participation and translation of learning in the community.
Activities	Conduct demographic survey on households living along the bay area	Demographic data of households living along the bay area	Records on file in the barangay	Sufficient data on the demographic profile of households along the bay area.
	Conduct of IEC seminar-lecture among households concerning E.coli. concentrations in seawater	Number of IEC seminar lectures conducted	IEC seminar lecture attendance sheet	Increased level of perception and awareness relative to the E.coli. concentration

5. Conclusion

The study results show that most of the sampling stations examined for fecal coliform concentration are above the class SB coastal waters threshold values. Moreover, results indicated that water quality along Tibungco Bay is not suitable for recreation and bathing purposes due to its high concentration of fecal contamination. Due to the non-attainment of most of the sampling sites, this might cause skin irritation, infections, and other health-related issues. The statistical analysis confirms that fecal coliform distribution among sampling points did not differ significantly based on the computed F and P-value tested at a 95% confidence interval. Integrated planning and multi-stakeholder participation are considered relevant in developing critical water quality improvement strategies along with urban centers in a developing country.

6. Recommendation

This study recommends strengthening the water quality management initiatives to improve the water quality along Tibungco Bay. Also, the implementation of easement for waterbodies and relocation of informal settlements along the Tibungco Bay is recommended to protect the integrity and sustain ecosystem services. Include the Tibungco Bay as one of the water quality management areas and rehabilitate the coastal area to conform to the guidelines for class SB waterbodies.

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