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Correlation of Riparian Population Size and Selected DENR Class C Water Quality Indicators at Pampanga River Monitoring Stations, 2020

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ABSTRACT: This study examined the relationship between riparian population size and selected DENR Class C water quality indicators in Pampanga River monitoring stations in 2020. A quantitative descriptive-correlational design was used, utilizing secondary data from PSA and DENR-EMB. Parameters analysed included dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), pH, fecal coliform, nitrate, phosphate, and chloride.
Spearman's rank correlation showed a negative relationship between population and DO ($\rho = -0.625$), and positive relationships with BOD ($\rho = 0.60$) and fecal coliform ($\rho = 0.625$). TSS showed a weak negative relationship ($\rho = -0.20$). Results indicate that higher population levels are associated with poorer water quality.

KEYWORDS: Riparian population, water quality, Pampanga River, DENR Class C, Spearman correlation, environmental management

I. INTRODUCTION

1.1 Background of the Study

Rivers are dynamic ecosystems that play a vital role in supporting human life, agriculture, fisheries, and ecological balance. Globally, billions of people rely on river systems for freshwater supply and livelihood activities, particularly in densely populated and low-lying regions. However, river ecosystems are increasingly affected by human activities such as improper waste disposal, agricultural runoff, and domestic and industrial wastewater discharge.

Studies have shown that population growth and increasing human settlements contribute to the degradation of water quality in river systems. According to Liyanage and Yamada (2017), areas with higher population density tend to experience greater environmental stress, resulting in declining water quality conditions compared to less populated regions. This suggests that population pressure may be associated with increased pollution loading in freshwater systems.

In the Philippines, the Pampanga River is one of the most important river systems in Central Luzon. It supports agriculture, fisheries, and domestic water use across several provinces. However, due to rapid urbanization and increasing human settlement along its banks, the river has become vulnerable to pollution from domestic wastewater, agricultural runoff, and other anthropogenic sources. Previous environmental assessments have identified sections of the Pampanga River as experiencing deteriorating water quality conditions, highlighting the need for continuous monitoring and evaluation.

To address water quality concerns, the Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB) conducts regular monitoring of river systems based on Class C water quality standards under DAO 2016-08. These standards serve as a basis for assessing river suitability for fisheries, irrigation, and recreational purposes.

In this context, this study examines the relationship between riparian population size and selected DENR Class C water quality indicators in the Pampanga River for the year 2020. Using PSA population data and DENR water quality monitoring results, the study aims to determine whether population size shows an observable association with river water quality conditions. The findings may provide useful baseline information for environmental planning and river management strategies.

1.2 Statement of the Problem

This study aims to examine the relationship between riparian population size and DENR Class C water quality indicators of the Pampanga River in 2020. Specifically, it seeks to answer the following:

1. What is the estimated riparian population for each monitoring station based on nearby barangays?
2. What are the 2020 water quality conditions of selected Pampanga River stations in terms of DO, BOD, TSS, pH, fecal coliform, nitrate, phosphate, and chloride?
3. Which monitoring stations comply or do not comply with DENR Class C standards under DAO 2016-08?

4. Is there a relationship between riparian population size and selected water quality parameters (DO, BOD, TSS, and fecal coliform)?
5. Which stations show relatively higher environmental pressure based on population and water quality conditions?

1.3 Hypothesis of the Study

Null Hypothesis (H_0): There is no relationship between riparian population size and selected water quality indicators at Pampanga River monitoring stations.

Alternative Hypothesis (H_1): There is a relationship between riparian population size and selected water quality indicators at Pampanga River monitoring stations.

1.4 Significance of the Study

The results of this study will provide essential information on the relationship between population size and water quality classification.

Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB) and Local Government Units (LGUs) – by examining the relationship between population size and water quality classification, this study provides a vital foundation for refining environmental policies, land-use planning, and wastewater management systems. Ultimately, these findings will empower regulatory agencies to better monitor river conditions, pinpoint critical areas requiring immediate intervention, and strengthen the enforcement of environmental laws to effectively mitigate pollution.

Future Researcher – this study will serve as a reference for future research related to water quality classification, population studies, and environmental management. It may also contribute to the development of more advanced studies and methodologies in the field.

Educators and Students – the study will provide useful learning material that can enhance knowledge and awareness about environmental issues, particularly the impact of the human population on water resources. It may also encourage students to participate in environmental protection activities.

1.5 Scope and Limitation

This study focuses on the relationship between riparian population size and DENR Class C water quality indicators of the Pampanga River using 2020 data. It is limited to five monitoring stations identified in DENR monitoring reports.

Population data are estimated using nearby barangays as proxies for each monitoring station due to the absence of direct station-based population data. Secondary data are obtained from the Philippine Statistics Authority (PSA) and DENR-EMB.

Water quality parameters are evaluated based on DENR Administrative Order 2016-08 standards. The study uses a correlational design and does not establish causality between variables. The findings are limited to 2020 data and do not account for seasonal variations or long-term trends.

1.6 Conceptual Framework

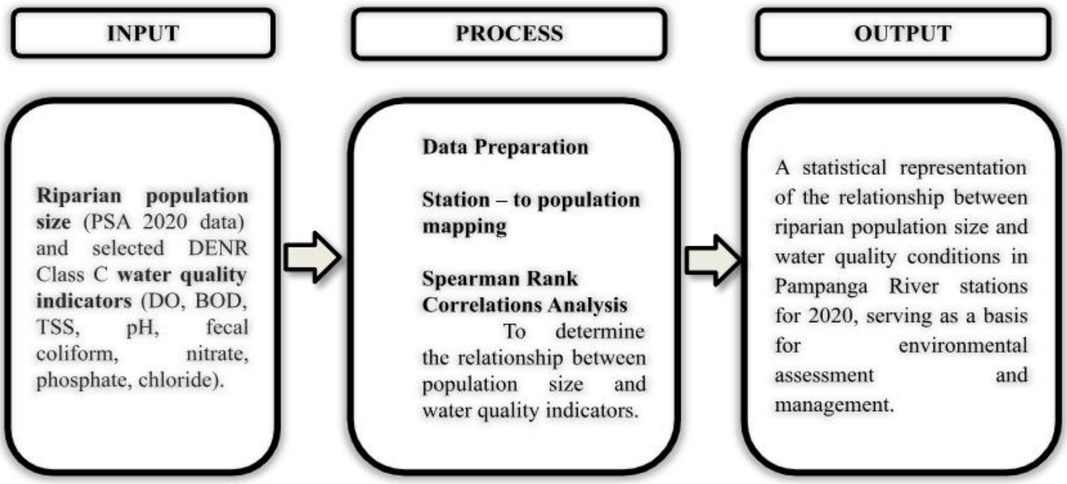

Fig. 1

Figure 1 shows the IPO model illustrating the relationship between riparian population size and selected DENR water quality indicators in 2020.

River Communities – the results of this study will raise awareness about the effects of increasing population size on water pollution. It encourages the public to adopt proper waste-disposal practices and to participate in community efforts to protect river systems.

The Input includes riparian population size from 2020 PSA data as the independent variable and selected DENR Class C water quality indicators (DO, BOD, TSS, pH, fecal coliform, nitrate, phosphate, and chloride) as dependent variables.

The Process involves data cleaning, mapping population data to monitoring stations, and applying Spearman correlation analysis to determine the strength and direction of the relationship between population size and water quality.

The Output presents the statistical results, providing a clear assessment of how riparian population size influences the ecological condition of the Pampanga River in 2020, serving as a basis for environmental management and planning.

1.7 Definition of Terms

Biochemical Oxygen Demand (BOD) – A measure of organic pollution in water.
Chloride – Indicator of wastewater or saline contamination.
Class C Water – DENR classification for fisheries, irrigation, and recreation use.
Dissolved Oxygen (DO) – Amount of oxygen dissolved in water (mg/L).
Fecal Coliform – Indicator of fecal contamination in water.
Nitrate – A nutrient commonly found in fertilizers and sewage.
pH – Measure of acidity or alkalinity of water.
Phosphate – Nutrient contributing to algal growth and oxygen depletion.
Riparian Population – Population of nearby barangays used as a proxy for each monitoring station.
Spearman Correlation – A statistical method measuring the strength and direction of the relationship between two variables.
Total Suspended Solids (TSS) – Particles suspended in water measured by filtration.

II. REVIEW OF RELATED LITERATURE

The review of related literature presents key findings on the relationship between population and river water quality, with emphasis on the Pampanga River.

Rivers are vital freshwater systems that support agriculture, fisheries, ecosystems, and human settlements (Yu et al., 2022). However, declining water quality leads to biodiversity loss and increased risks of waterborne diseases such as cholera and dysentery (Namara et al., 2022; Du et al., 2022). In Central Luzon, the Pampanga River remains essential for livelihoods, but growing human activities have contributed to contamination, particularly fecal pollution near residential and agricultural areas (Cortez et al., 2023).

Population growth and urbanization are identified as major drivers of river pollution. Expanding settlements increase domestic wastewater discharge, solid waste, and septic leakage, while urban runoff carries pollutants into rivers (Cookson et al., 2024). Studies show that inadequate sanitation infrastructure intensifies nutrient loading, algal blooms, and microbial contamination (Caballero and Navarro, 2021; Onifade et al., 2025). Higher population density is consistently associated with increased biochemical oxygen demand (BOD) and reduced dissolved oxygen (DO), indicating organic pollution stress (Liyanage and Yamada, 2017), while local findings confirm rising fecal contamination due to sewage and land-use changes (Macawile et al., 2025).

Water quality is assessed using parameters such as DO, BOD, total suspended solids (TSS), fecal coliform, pH, nitrate, phosphate, and chloride (Spellman, 2016). These are regulated in the Philippines under the Clean Water Act of 2004 (Congress of the Philippines, 2004) and DENR Administrative Order 2016-08 (DENR, 2016), which classify rivers like the Pampanga River as Class C waters. Despite these standards, maintaining compliance remains challenging in urbanizing areas due to insufficient wastewater systems and increasing pollution loads (Caballero and Navarro, 2021; Velasco et al., 2025).

Related studies consistently show that higher population density leads to increased BOD, lower DO, and elevated fecal coliform levels due to organic waste and inadequate sanitation (Liyanage and Yamada, 2017; Stajkowski et al., 2020; Xiaoyue et al., 2020). However, a key gap remains in directly linking population size with station-based water quality data. This study addresses that gap by analysing 2020 DENR data alongside population estimates to determine relationships between population pressure and indicators such as DO, BOD, TSS, and fecal coliform, contributing to improved river management in the Pampanga River basin.

III. METHODOLOGY

3.1 Research Design

This study uses a quantitative descriptive-correlational design, a non-experimental approach that examines relationships between variables without manipulation (Creswell, 2014). As explained by Creswell (2014), the descriptive phase summarizes key characteristics—such as riparian population and water quality—while the correlational phase determines the strength and direction of their relationship in a natural setting. This design is suitable for environmental studies where variables cannot be controlled.

3.2 Study Area

The study was conducted along selected monitoring stations of the Pampanga River classified as Class C inland waters based on the 2020 DENR monitoring report.

The Pampanga River is one of the major river systems in Central Luzon, supporting agriculture, fisheries, settlements, and floodplain communities. Five monitoring stations were included in the study.

3.3 Data Sources

3.3.1 Water Quality Data

Water quality data were obtained from the official records of the Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB). These data served as the basis for evaluating river conditions.

The following parameters were used in the analysis:

1. Dissolved Oxygen (DO)
2. Biochemical Oxygen Demand (BOD)
3. Total Suspended Solids (TSS)
4. pH
5. Fecal Coliform

6 Nitrate (as NO_3-N)
7 Phosphate (as PO_4-P)
8 Chloride

Compliance was assessed using DENR Administrative Order No. 2016-08 (Water Quality Guidelines).

3.3.2 Population Data

Population data for 2020 were obtained from the Philippine Statistics Authority (PSA).

The population assigned to each monitoring station was based on the nearest one or two riparian barangays adjacent to its location.

3.4 Monitoring Stations

Table 1. Pampanga River Monitoring Stations

Station	Monitoring Station	Municipality
1	Expressway Bridge, Brgy. San Juan	Apalit, Pampanga
2	Sulipan Bridge, Brgy. Sulipan	Apalit, Pampanga
3	Calumpit Bridge, Brgy. Gatbuca	Calumpit, Bulacan
4	Paulino Residence Sitio Kanukay, Brgy. San Vicente / Brgy. Santa Lucia	Macabebe, Pampanga / Calumpit, Bulacan
5	Villa Lourdes Sitio Bitas, Brgy. Batasan / Brgy. Candelaria,	Macabebe, Pampanga

Philippine Statistics Authority, Census (2021)

3.5 Population Assignment Procedure

Since monitoring stations are not official census units, nearby riparian barangays were used as proxies for population to represent local anthropogenic pressure.

The procedure followed:

1 Identify the monitoring station location from the DENR records
2 Identify the nearest one to two riparian barangays
3 Obtain 2020 population data from PSA
4 Sum barangay populations to represent station-level riparian population

3.6 Data Cleaning and Preparation

The DENR dataset indicated that no sampling was conducted during the second quarter due to COVID-19 restrictions. Therefore, second-quarter entries were treated as missing values (N/A) and excluded from computation.

Annual representative values were computed using available data from the first, third, and fourth quarters.

Arithmetic Mean for Regular Parameters

Used for: Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), pH, nitrate, phosphate, and chloride.

Equation 1:

$$x = \frac{x_1 + x_2 + x_3}{3}$$

Where:
x_1= 1st Quarter value
x_2= 3rd Quarter value
x_3= 4th Quarter value

Geometric Mean

Used because fecal coliform data are typically log-distributed.

Equation 2:

$$GM = (x_1 \cdot x_2 \cdot x_3)^{1/3}$$

Where:
x_1, x_2, and x_3 are sampled quarterly fecal coliform values.

3.7 Water Quality Compliance Assessment

Table 2. DENR Class C Water Quality Guidelines under DAO 2016-08.

Parameter	Units	Water Body Classification
		Class C
BOD	mg/L	≤ 7
Chloride	mg/L	≤ 350
Dissolved Oxygen (Minimum)	mg/L	≥ 5
Fecal Coliform	MPN/100 ml	≤ 200
Nitrate	mg/L	≤ 7
pH (Range)		6.5- 9.0
Phosphate	mg/L	≤ 0.5
Temperature	C	25 - 31
Total Suspended Solids	mg/L	≤ 80

Source: *DENR-EMB Monitoring Reports; Standards based on DENR Administrative Order No. 2016-08, Section 6.0 (Water Quality Guidelines), Table 3.*

3.8 Statistical Analysis

3.8.1 Descriptive Statistics

Descriptive statistics were used to summarize population size and water quality conditions per station. According to Kaur, Stoltzfus, and Yellapu (2018), descriptive statistics provide a simplified representation of data through measures such as mean and distribution.

This allowed for a clear comparison of water quality conditions and population levels across monitoring stations.

3.8.2 Correlational Analysis

Spearman's Rank Correlation Coefficient was used to determine the relationship between riparian population size and selected water quality indicators. This non-parametric test was selected due to the small sample size (n = 5) and the ordinal nature of ranked environmental data. It is appropriate for assessing monotonic relationships without assuming a normal distribution of variables. According to Spearman (1904), this correlation measures the strength and direction of a monotonic relationship based on ranked values. These procedure follows standard statistical conventions to ensure accurate computation of correlation values.

The analysis is conducted using the following Equation 3:

$$\rho = \frac{6\sum d_i^2}{n(n^2-1)}$$

Where:

ρ = Spearman's rank coefficient

d_i = difference between paired ranks

n = number of stations

3.8.3 Variable Pairs Tested

Correlation was computed between the riparian population and:

1. Population vs DO
2. Population vs BOD
3. Population vs TSS
4. Population vs Fecal Coliform

3.8.4 Interpretation of Correlation Strength

Table 3. Interpretation of Spearman's Rank Correlation Coefficient (ρ)

Spearman Value (+ or -)	Interpretation
0.00 – 0.19	Very Weak
0.20 – 0.39	Weak
0.40 – 0.59	Moderate
0.60 – 0.79	Strong
0.80 – 1.00	Very Strong

Source: *Sugiyono (2010)*

3.9 Scope and Limitations of Method

1. The study is limited to five monitoring stations and may not represent the full spatial condition of the Pampanga River.
2. Population values are proxy estimates based on nearby barangays rather than direct riparian population counts.
3. The analysis is limited to 2020 data only and does not include seasonal or multi-year trends.
4. The study identifies statistical relationships only and does not establish causality.
5. External factors such as industrial discharge, agricultural runoff, and hydrological variability were not separately analysed.

IV. RESULTS AND DICUSSION

4.1 Population Profile of Monitoring Stations

The population data was collected from the riparian barangays immediately adjacent to each designated monitoring station.

Table 4.1 Population Distribution by Monitoring Station

Stations	Population Size 2020
1. Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	8,861
2. Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	11,693
3. Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	6,384
4. Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	5,741
5. Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	7,480

Source: *Philippine Statistics Authority, Census (2020)*

Table 4.1 shows variation in population distribution across the monitoring stations. Station 2 recorded the highest population, while Station 4 recorded the lowest. This variation reflects differences in settlement density along the river system.

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4.2 Water Quality Condition of Pampanga River Stations

Table 4.2 Mean Values of Selected Class C Water Quality Parameters Across Pampanga River Monitoring Stations

In general, upstream and midstream stations show relatively higher population exposure compared to selected downstream areas. This spatial variation is important in interpreting possible anthropogenic influence on water quality conditions.

Station	DO	BOD	TSS	pH	Fecal Coliform	Nitrate	Phosphate	Chloride
1	2.95	10.00	53.00	8.25	21714.20987	0.66	0.23	18.67
2	2.90	14.67	74.67	8.26	51805.98312	0.69	0.26	16.00
3	2.94	12.67	84.67	8.25	33376.16716	0.67	0.28	321.00
4	3.25	7.00	61.00	7.71	21000	0.59	0.24	217.67
5	2.95	11	60.33	7.68	21000	0.67	0.25	237.33

***Source**: Department of Environment and Natural Resources - EMB (2020)*

Table 4.2 presents the mean values of selected Class C water quality parameters across the five monitoring stations based on Department of Environment and Natural Resources standards.

Dissolved oxygen (DO) values range from 2.90 to 3.25 mg/L, consistently below the Class C requirement. The uniformly low DO indicates system-wide oxygen depletion, which may reflect widespread organic loading, consistent with findings of Liyanage and Yamada (2017) on population-related oxygen reduction in river systems.

Biochemical oxygen demand (BOD) ranges from 7.00 to 14.67 mg/L, showing spatial variation in organic pollution levels. The higher BOD observed at Station 2 suggests localized organic loading, also consistent with population-driven increases in oxygen demand reported in similar studies.

Total suspended solids (TSS) range from 53.00 to 84.67 mg/L, with no consistent spatial trend, suggesting that sediment transport, runoff, and erosion processes may have greater influence than population distribution. The pH values remain within the acceptable Class C range (7.68–8.26), indicating stable alkaline conditions across all stations.

Fecal coliform levels are extremely high (21,000–51,805 MPN/100 mL), significantly exceeding standards. This indicates widespread microbial contamination, commonly associated with untreated domestic wastewater discharge in populated areas (Onifade et al., 2025). Nitrate and phosphate show minimal variation across stations, while chloride exhibits spatial differences, suggesting combined influences of natural processes and anthropogenic inputs.

4.3 Compliance with DENR Class C Standards

- Compliant - the station meets the required water quality standards
- Non-compliant - the station does not meet the standards
- Borderline - the station occasionally exceeds the standard but is not consistently non-compliant

Table 4.3 Compliance Status of Water Quality Parameters per Monitoring Station

Sta. No.	DO	BOD	TSS	pH	Fecal Coliform	Compliance
1	Non-Compliant	Non-Compliant	Compliant	Compliant	Non-Compliant	Non-Compliant
2	Non-Compliant	Non-Compliant	Compliant	Compliant	Non-Compliant	Non-Compliant
3	Non-Compliant	Non-Compliant	Non-Compliant	Compliant	Non-Compliant	Non-Compliant
4	Non-Compliant	Borderline	Compliant	Compliant	Non-Compliant	Borderline
5	Non-Compliant	Non-Compliant	Compliant	Compliant	Non-Compliant	Non-Compliant

All monitoring stations fail to meet the Department of Environment and Natural Resources (DENR) Class C water quality standards, particularly in dissolved oxygen (DO) and fecal coliform, which are key indicators of aquatic health.

Low DO levels indicate insufficient oxygen for aquatic life, while extremely high fecal coliform counts reflect widespread microbial contamination. Although some stations show partial compliance in pH and total suspended solids (TSS), these are not enough to offset the overall decline in water quality.

Station 4 shows relatively better performance in biochemical oxygen demand (BOD), but it still fails to comply with critical parameters, especially DO and fecal coliform. Overall, none of the stations meet the required standards, indicating general impairment of the Pampanga River system.

4.4 Correlation Analysis Between Population and Water Quality

Spearman's rank correlation was used to determine the relationship between riparian population size and selected water quality parameters.

Given the small sample size (n = 5), the results are interpreted as indicative associations rather than definitive statistical conclusions.

4.4.1 Population

Stations were ranked according to population size.

Table 4.4.1 Population Rank (X)

Station	Population	Rank (X)
1	8,861	4
2	11,693	5
3	6,384	2
4	5,741	1
5	7,480	3

4.4.2 Population Vs Dissolved Oxygen (DO)

Table 4.4.2 Dissolved Oxygen Values and Rank

Station	DO (mg/L)	Rank (Y)
1	2.95	3.5
2	2.90	1
3	2.94	2
4	3.25	5
5	2.95	3.5

Spearman correlation results were derived from ranked data, with tied values handled using averaged ranks as described in the methodology.

Table 4.4.3 Spearman Rank Computation (Population vs DO)

Station	Rank (X)	Rank (Y)	d_i = X-Y	d_i^2
1	4	3.5	0.5	0.25
2	5	1	4	16
3	2	2	0	0
4	1	5	-4	16
5	3	3.5	-0.5	0.25

Given:
$\sum d_i = 32.5$
n = 5
$n^2 = 25$

$$\rho = \frac{6\,(32.5)}{5(25-1)}$$

ρ = - 0.625 (Strong Negative Relationship)

The result indicates that higher population levels are associated with lower dissolved oxygen concentrations. This suggests that increased human activity may contribute to oxygen depletion through organic loading and reduced water quality conditions.

4.4.3 Population Vs Biochemical Oxygen Demand (BOD)

Table 4.4.4 Biochemical Oxygen Demand Values and Rank

Station	BOD (mg/L)	Rank (Y)
1	10.00	2
2	14.67	5
3	12.67	4
4	7.00	1
5	11.00	3

Table 4.4.5 Spearman Rank Computation (Population vs BOD)

Station	Rank (X)	Rank (Y)	d_i = X-Y	d_i^2
1	4	2	2	4
2	5	5	0	0
3	2	4	-2	4
4	1	1	0	0
5	3	3	0	0

Given:
$\sum d_i = 8$
n = 5
$n^2 = 25$

$$\rho = \frac{6\,(32.5)}{5(25-1)}$$

ρ = 0.60 (Strong Positive Relationship)

The positive relationship suggests that stations with higher surrounding populations tend to exhibit higher organic pollution levels. This may reflect increased domestic wastewater contribution in densely populated areas.

4.4.4 Population Vs Total Suspended Solids (TSS)

Table 4.4.6 Total Suspended Solids Values and Rank

Station	TSS (mg/L)	Rank (Y)
1	53.00	1
2	74.67	4
3	84.67	5
4	61.00	3
5	60.33	2

Table 4.4.7 Spearman Rank Computation (Population vs TSS)

Station	Rank (X)	Rank (Y)	d_i = X-Y	d_i^2
1	4	1	3	9
2	5	4	1	1
3	2	5	-3	9
4	1	3	-2	4
5	3	2	1	1

Given:
$\sum d_i = 24$
n = 5
$n^2 = 25$

$$\rho = \frac{6\ (24)}{5(25-1)}$$

ρ = - 0.20 (Weak Negative Relationship)

The weak relationship indicates minimal association between population and suspended solids. This suggests that TSS is likely influenced by other factors, such as erosion, rainfall, and river flow dynamics, rather than by population alone.

4.4.5 Population Vs Fecal Coliform

Table 4.4.8 Fecal Coliform Values and Rank

Station	Fecal Coliform (MPN/100ml)	Rank (Y)
1	21714.20987	3
2	51805.98312	5
3	33376.16716	4
4	21000	1.5
5	21000	1.5

Spearman correlation results were derived from ranked data, with tied values handled using averaged ranks as described in the methodology.

Table 4.4.9 Spearman Rank Computation (Population vs Fecal Coliform)

Station	Rank (X)	Rank (Y)	d_i = X-Y	d_i^2
1	4	3	1	1
2	5	5	0	0
3	2	4	-2	4
4	1	1.5	-0.5	0.25
5	3	1.5	1.5	2.25

Given:
$\sum d_i = 7.5$
n = 5
$n^2 = 25$

$$\rho = \frac{6\ (7.5)}{5(25-1)}$$

ρ = 0.625 (Strong Positive Relationship)

The result suggests that higher population areas are associated with higher microbial contamination levels. This is consistent with the expected influence of domestic wastewater discharge and an inadequate sanitation system

4.5 Spearman Correlation Between Population and Selected Water Quality Parameters

Table 4.5 Spearman Correlation Between Population and Selected Water Quality Parameters

Variable Pair	Spearman (ρ)	Direction
Population vs DO	-0.625	Negative Strong Correlation
Population vs BOD	0.60	Positive Strong Correlation
Population vs TSS	-0.2	Negative Weak Correlation
Population vs Fecal Coliform	0.625	Positive Strong Correlation

The findings indicate that the population has a range of interactions with several water quality parameters; TSS has a weak relationship, whereas DO, BOD, and fecal coliform show stronger relationships. The results indicate that population size shows stronger associations with DO, BOD, and fecal coliform, while its relationship with TSS is weak. However, given the limited number of stations, these results should be interpreted cautiously as indicative patterns rather than definitive relationships.

4.6 Discussion of Key Findings

The results suggest that riparian population size shows a consistent statistical association with variations in selected water quality indicators in the Pampanga River.

Stations with higher population exposure tend to exhibit lower dissolved oxygen levels and higher biochemical oxygen demand and fecal coliform concentrations. This pattern may reflect increased organic and microbial loading from domestic wastewater and human activities.

Among the parameters analyzed, DO, BOD, and fecal coliform show relatively stronger associations with population compared to TSS. This indicates that organic and microbial pollution may be more sensitive to population pressure than suspended sediment conditions.

However, it is important to emphasize that population is only one of several influencing factors. Other possible contributors include agricultural runoff, industrial discharge, rainfall variability, and natural hydrological processes. These factors were not individually quantified in this study and may also affect observed water quality conditions.

Therefore, the findings should be interpreted as statistical associations rather than causal relationships.

4.7 Implications for River Management

The findings highlight the importance of strengthening wastewater management, particularly in densely populated riparian areas.

Improved sanitation infrastructure and proper wastewater treatment may help reduce organic and microbial pollution in the river system.

Continuous monitoring by DENR-EMB remains essential for tracking water quality trends and identifying critical pollution hotspots. Expanding monitoring coverage may also improve spatial understanding of river conditions.

Local government units are encouraged to support community-based environmental initiatives such as waste segregation programs, river clean-up activities, and public awareness campaigns.

Integrated watershed management involving both government agencies and local communities is necessary to support the sustainable improvement of the Pampanga River water quality.

V. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of the Findings

This study examined the relationship between riparian population size and selected water quality indicators in the Pampanga River using 2020 PSA population data and DENR-EMB monitoring results. The parameters analyzed included dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), pH, fecal coliform, nitrate, phosphate, and chloride.

Results show that water quality conditions vary across the five monitoring stations. Dissolved oxygen levels were consistently below the DENR Class C standard in all stations, indicating limited oxygen availability in the river system. Fecal coliform levels were extremely high across all stations, suggesting widespread microbial contamination. Elevated BOD levels were also observed in most stations, indicating the presence of organic pollution.

Other parameters such as pH, nitrate, and phosphate generally remained within acceptable ranges, with only minor variations among stations. Total suspended solids showed moderate variation but did not follow a clear spatial pattern.

Correlation analysis revealed that higher population sizes were associated with lower dissolved oxygen levels and higher BOD and fecal coliform levels. This suggests an observable association between population pressure and indicators of organic and microbial pollution. However, TSS showed a weak relationship with population size, suggesting it may be influenced more by environmental and hydrological factors than by population alone. Future studies may apply regression analysis to better model the predictive relationship.

5.2 Conclusions

Based on the findings of the study, the following conclusions are drawn:

1. The Pampanga River monitoring stations exhibit varying water quality conditions based on selected DENR Class C parameters.
2. Dissolved oxygen and fecal coliform levels consistently failed to meet Class C standards across all stations.
3. Stations with higher riparian population sizes tend to show less favorable water quality conditions in terms of DO, BOD, and fecal coliform.
4. The results suggest a possible association between population size and increased organic and microbial pollution in the river system.
5. Total suspended solids show a weak association with population size, indicating that other environmental factors likely have a greater influence on this parameter.
6. The findings indicate that population pressure may be one of several factors influencing water quality in the Pampanga River, but not the sole determinant.

5.3 Recommendations

Based on the results and conclusions of the study, the following recommendations are proposed:

1. **Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB)** continuous monitoring of Pampanga River water quality should be strengthened, especially in densely populated riparian areas.
2. **Local government units and communities** should improve proper waste disposal and sanitation practices to help reduce river pollution. Environmental awareness programs and river clean-up activities should be encouraged among nearby communities.
3. **Future studies** should include more monitoring stations and multi-year data for a more comprehensive assessment of water quality trends. Additional factors such as agricultural runoff, land use, and industrial activities should also be investigated in future research.

Limitation of the Study

In summary, while the study provides insights into the relationship between population pressure and water quality in the Pampanga River, the small sample size (n = 5) limits statistical generalization of the results.

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APPENDICES

SUMMARY REPORT OF WATER QUALITY MONITORING DATA						
SUBMITTED BY THE REGIONAL OFFICES						
CY 2020						
Region	**Physical Parameter**	**Stn. No.**	**Stn. ID**	**I**	**III**	**IV**
Pampanga River						
Classification: Class C						
III	**Temperature (^{O}C)**	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	27.30	30.20	26.99
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	27.50	30.70	26.96
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	26.23	30.28	26.68
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	27.80	30.78	26.80
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	28.00	30.60	27.10
	Color (TCU)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	15	30	20
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	15	30	20
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	15	40	20
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	20	30	20
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	25	40	20
	TSS (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	23	47	89
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	85	36	103
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	63	37	154
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	16	23	144
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	23	29	129

	Chemical Parameter	**Stn. No.**	**Stn. ID**	**I**	**III**	**IV**
	Disolved Oxygen (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	3.60	2.14	3.12
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	3.32	1.72	3.65
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	2.39	2.26	4.16
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	3.87	1.78	4.11
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	3.17	2.12	3.57
	Biochemical Oxygen Demand (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	13	13	4
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	12	16	16
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	7	12	19
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	6	9	6
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	8	4	21
	pH Level	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	7.81	8.82	8.13
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	7.80	8.74	8.25
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	7.39	8.88	8.49
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	7.56	7.24	8.33
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	7.60	7.12	8.32
	Nitrates or NO_3-N (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	0.936	0.771	0.285
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	0.971	0.742	0.350
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	1.080	0.559	0.384
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	0.851	0.567	0.343
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	1.073	0.528	0.416
	Phospate or PO_4-P (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	0.147	0.250	0.285
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	0.264	0.175	0.350
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	0.224	0.223	0.384
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	0.153	0.231	0.343
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	0.163	0.170	0.416
	Cl- (mg/L)	**1**	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	29	15	12
		2	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	17	15	16
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	923	16	24
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	606	20	27
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	682	19	11
	Biological Parameter	**Stn. No.**	**Stn. ID**	**I**	**III**	**IV**
		1	Expressway Bridge: Brgy. San Juan, Apalit, Pampanga	54,000	24,000	7,900

	Fecal Coliform (MPN/100mL)	**2**	Sulipan Bridge: Brgy. Sulipan, Apalit, Pampanga	160,000	110,000	7,900
		3	Calumpit Bridge: Brgy. Gatbuca, Calumpit, Bulacan	110,000	26,000	13,000
		4	Paulino Residence Sitio Kanukay, San Vicente, Macabebe, Pampanga; Brgy. Santa Lucia, Calumpit, Bulacan	54,000	35,000	4,900
		5	Villa Lourdes Sitio Bitas, Brgy. Batasan; Brgy. Candelaria, Macabebe, Pampanga	54,000	35,000	4,900

Total Population by Province, City, Municipality, and Barangay: as of May 1, 2020

Province, City, Municipality, and Barangay	. **Population**
PAMPANGA	**2,437,709**
APALIT	**117,160**
Balucuc	10,867
Calantipe	3,998
Cansinala	7,856
Capalangan	7,394
Colgante	8,307
Paligui	3,925
Sampaloc	13,408
San Juan (Pob.)	8,861
San Vicente	23,686
Sucad	7,775
Sulipan	11,693
Tabuyuc (Santo Rosario)	9,390
MACABEBE	**78,151**
Batasan	4,450
Caduang Tete	7,104
Candelaria	3,030
Castuli	1,081
Consuelo	2,669
Dalayap	2,668
Mataguiti	1,118
San Esteban	6,553
San Francisco	2,024
San Gabriel (Pob.)	4,025
San Isidro	2,412
San Jose	3,984
San Juan	2,827
San Rafael	3,592
San Roque	4,127

San Vicente	3,281
Santa Cruz (Pob.)	442
Santa Lutgarda	1,098
Santa Maria	5,128
Santa Rita (Pob.)	3,603
Santo Niño	2,625
Santo Rosario (Pob.)	2,561
Saplad David	1,239
Tacasan	2,453
Telacsan	4,057
CALUMPIT	**118,471**
Balite	5,016
Balungao	5,720
Buguion	3,841
Bulusan	2,603
Calizon	2,221
Calumpang	3,517
Caniogan	4,510
Corazon	2,175
Frances	6,129
Gatbuca	6,384
Gugo	1,960
Iba Este	4,161
Iba O'Este	14,085
Longos	4,265
Meysulao	4,280
Meyto	2,925
Palimbang	1,684
Panducot	1,752
Pio Cruzcosa	4,663
Poblacion	1,785
Pungo	9,528
San Jose	5,661
San Marcos	2,671
San Miguel	6,005
Santa Lucia	2,460
Santo Niño	2,544
Sapang Bayan	3,140
Sergio Bayan	1,727
Sucol	1,059