Research Article

Estimating Pollution Load and Assimilative Capacity of Labangan River, Zamboanga Del Sur, Philippines

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Abstract

The study estimates the state of the river's water quality and its capacity to assimilate pollutants without adverse environmental impacts. Water quality monitoring was conducted at key sampling stations, revealing significant exceedances in key parameters such as total suspended solids (TSS), phosphates, and fecal coliform. These pollutants predominantly originate from domestic, agricultural, and industrial activities within the watershed. The results indicate that the assimilative capacity of the Labangan River has been compromised, particularly for organic pollutants, nutrients, and microbial contaminants. Contributing factors include urbanization, inadequate wastewater management, and surface runoff. The study employs computational models to quantify pollution loads and evaluates them against the river's assimilative capacity, providing a comprehensive analysis of pollution sources and their impacts on water quality. The findings underline the need for integrated water resource management strategies, improved wastewater treatment systems, and stricter enforcement of environmental regulations to restore and preserve the river's ecological integrity. This study serves as a vital reference for policymakers and stakeholders in designing sustainable interventions to protect and manage the Labangan River effectively.

Keywords: *Pollution Load, Assimilative Capacity, Labangan River, Computational*

Introduction

The Zamboanga Peninsula, or Region 9, is home to an intricate river network that plays a vital role in sustaining the region's ecological balance, agriculture, and local economies. Major rivers such as the Dipolog River, Sindangan River, Zamboanga River, and Labangan River provide essential resources, including freshwater for domestic use, irrigation for farmlands, and habitats for diverse aquatic species. Among these, the Labangan River stands out due to its perennial nature and significant role in connecting upland tributaries to the coastal ecosystem of Pagadian Bay. Based on the latest data from EMB Region IX, the river has an average width of 60 meters under normal conditions and maintains a consistent flow throughout the year. However, during the rainy season, it frequently overflows due to runoff from various tributaries. Spanning 17 barangays, on which covered by Municipalities of Labangan, Tukuran, Ramon Magsaysay, and others, the river supports a total population of 18,606, providing critical resources for agricultural irrigation, fisheries, and domestic needs. Furthermore, its average discharge rate of 21.94 cubic meters per second underscores its substantial hydrological importance, necessitating focused research to understand and manage its pollution load and assimilative capacity effectively.

In 1999, the river was classified by DENR Region IX as Class A for its upstream segments and Class B from the midstream to its mouth. According to these classifications, Class A waters are suitable for use as Public Water Supply Class II, requiring conventional treatments like coagulation, sedimentation, filtration, and disinfection to comply with the Philippine National Standards for Drinking Water (PNSDW). Meanwhile, Class B waters, designated as Recreational Water Class I, are intended for activities involving primary contact, such as bathing and swimming.

The river is primarily utilized for irrigation, serving as the main water source for two farmers' associations: the Division A Sandata Irrigation Association and the Division B Muschrist Association. The NIA Dam within the Labangan River System supplies irrigation to approximately 2,800 hectares of prime rice fields. In addition to its agricultural applications, the river is widely used for domestic activities such as bathing, laundry, and occasionally drinking, particularly from open wells. The extraction of sand and gravel is also prevalent among various sections of the river.

However, the increasing urbanization and industrialization in the areas surrounding the river have raised concerns about potential contamination, posing risks to both human health and aquatic ecosystems, as observed in the Philippines (Regmi, 2017) and in other countries (Balan et al., 2020; Ouyang et al., 2006). Pollutants such as heavy metals, nutrients, and organic compounds can significantly degrade the water quality of the Patalon River, reducing its capacity to support local biodiversity and provide safe drinking water. Heavy metals are particularly concerning due to their toxicity and ability to bioaccumulate in the food chain, leading to risks for aquatic organisms and humans through both direct and indirect exposure, such as neurological damage and other physiological impairments (Bernales et al., 2022), organ damage and increased cancer risk (Sia Su et al., 2009), reproductive and developmental issues (Pandey & Madhuri, 2014), and disruption of metabolic processes (Sanone et al., 2020). The river's assimilative capacity is critical in mitigating these effects, as it determines the extent to which pollutants can be absorbed and neutralized without harming the environment (Darmian & Schmalz, 2024; Leandri, 2008; Hashemi Monfared et al., 2017).

This study aims to evaluate the latest water analysis data from EMB Region IX and pollution load and assimilative capacity of the Labangan River, focusing on the concentrations of primary parameters and their potential sources. The hypothesis posits that the river's assimilative capacity has diminished due to increased pollution loads from surrounding activities. By assessing the current state of the river's water quality, this research will provide valuable insights into the ecological health of the Labangan River and inform future management strategies to protect this essential water resource.

Material and methods

Study Site

The research assessed the levels of pollution of the Labangan River Watershed, an extremely essential hydrological system covering a catchment area of 48,515.95 hectares. The catchment area refers to the area draining a river's system, through which all precipitation is gathered and channeled to a particular location, such as the exit of a reservoir, the mouth of a bay, and points along a stream channel. The proposed research area, the Labangan River Watershed, geographically covers seven (7) municipalities, namely Dumalinao, Labangan, Lakewood, Midsalip, Tigbao, Tukuran, and Sominot, and one (1) city, Pagadian City.

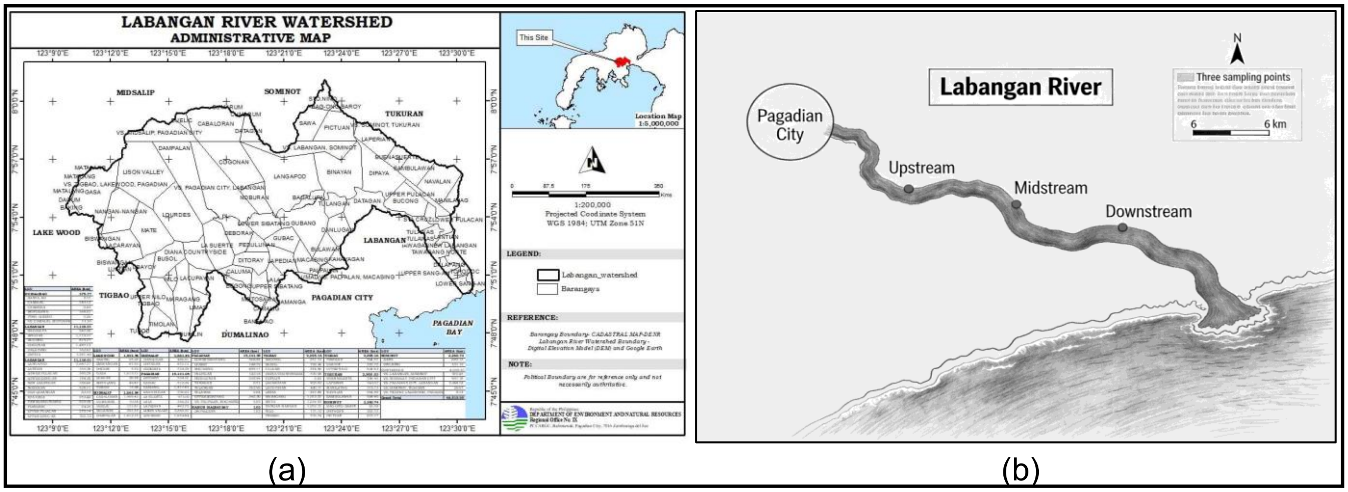

Figure 1. Map of the study: (a) Labangan River watershed map; (b) sampling stations

Most of the municipalities within the watershed shown in Figure 1(a) are situated in a sloping area ranging from 18% to 30% (rolling to hilly) with an area coverage of 14,144.08 ha and a sloping area ranging above 50% (mountainous) area of 14,125.12 ha. Labangan River has its main headwaters from Mt. Kulabog of Lakewood, Mt. Timolan in Tigbao, and Mt. Pinukis of Pagadian, with a total of twelve (12) sub-watersheds. A total of 4,751 streams with a corresponding total stream length of 1,025.84 km with a major stream length of 80.20 kilometers will drain into the main river named Labangan River.

Sampling References

The ambient water quality monitoring, conducted in sampling areas illustrated in Figure 1 (b), served as the basis for establishing existing pollution loads and the assimilative capacity of the Labangan River in accordance with DENR Administrative Order (DAO) No. 2016-08, as amended by DAO No. 2021-19. It focused on key parameters required for computing pollution loading and evaluating compliance with the National Water Quality Guidelines (WQG), namely biochemical oxygen demand (BOD), chloride, color, dissolved oxygen, fecal coliform, pH, phosphate, temperature, and total suspended solids, using water quality data provided by DENR–Environmental Management Bureau Region IX. Updated WQG values for the principal physico-chemical parameters, including the revised criteria for fecal coliform and phosphate, for each classification of surface water (AA, A, B, C, and D for freshwater, and SA, SB, SC, and SD for marine and coastal waters). These guideline values are applied in this study as reference thresholds to identify exceedances, compute pollution loads, and assess the assimilative capacity of each river segment relative to the new limits for fecal coliform and phosphate set under DAO 2021-19.

Data Gathering Procedure

Water quality assessment followed DENR–EMB monitoring and laboratory procedures, and input data for pollution-load computation were compiled from national statistics and sectoral agencies, including PSA, DOH, DENR–EMB, relevant LGUs, NAMRIA, DENR–FMB, DA, NIA, NSWMC, BAI, and BFAR. Pollution load was defined as the mass of pollutants from these sources that can affect the receiving water body and was computed using the sectoral methods and default parameters prescribed in EMB Memorandum Circular No. 2020-25 on total pollution load estimates and assimilative capacity. Standard environmental engineering references were consulted only to support equation checking and unit conversions, while the final Total Pollution Load (TPL) for each pollutant was obtained by summing the loads from all major sectors: domestic sewage, industrial and commercial wastewater, non-point surface runoff, solid waste, backyard livestock and poultry, and fisheries.

Computation for Pollution Load

Pollution load for this study was estimated using the standard methods prescribed in Environmental Management Bureau (EMB) Memorandum Circular No. 2020-25, “Guidelines on the Total Pollution Load Estimates for Freshwater Bodies in Relation to its Assimilative Capacity.” The circular defines the procedures and default parameters for computing waste loads and pollution loads from all major source sectors, including Household Domestic Waste Load and Pollution Load (HDWL, HDPL), Industrial/Commercial Waste Load and Pollution Load (ICWL, ICPL), Surface Runoff Pollution Load (SROPL), Solid-Waste BOD Loading (SWBOD), Backyard Livestock and Poultry Waste Load and Pollution Load (BLPWL, BLPEL), and Fisheries BOD Loading (FBOD), which together form the Total Pollution Load (TPL) of the watershed. In this research, pollution loads from these sectors, TPL, and the assimilative capacity of the receiving water body were all computed strictly following EMB MC 2020-25; detailed equations and unit-load tables are therefore omitted here and may be consulted directly in the circular.

Result and Discussion

Nature and Magnitude of Pollution Based on Water Quality Monitoring Results

The Environmental Management Bureau 9 does not conduct monitoring for nitrate as NO3-N in the Labangan River as the laboratory analysis for the said parameter is not available at the time of gathering in the EMB 9 laboratory unit in Zamboanga del Sur.

As stipulated in EMB Memorandum Circular No. 2020-25 re Guidelines on the Total Pollution Load Estimates for Freshwater Bodies in Relation to its Assimilative Capacity, waterbodies that exceed water quality guideline values for BOD, COD, nitr ates as NO3-N, phosphate, fecal coliform and TSS are considered as polluted. Table 8 shows the nature and magnitude of pollution in the Labangan River based on the ambient water quality characteristics provided by EMB 9 based on its monitoring of the river in 2023.

It was summarized in Table 1 that the water quality data collected from the Labangan River across three stations reflect varying levels of pollution, with each station exhibiting different contamination profiles. Station 1, located at the mouth of the river approximately 3 km from the Labangan Bridge in Old Labangan, recorded a total suspended solids (TSS) concentration of 79 mg/L, phosphate at 0.180 mg/L, and fecal coliform levels of 34,874 MPN/100 mL, indicating significant contamination. Station 2, positioned midstream near Labangan Bridge (downstream), showed slightly higher TSS at 83 mg/L and phosphate at 0.188 mg/L, with a notable decrease in fecal coliform to 15,031 MPN/100 mL, suggesting some natural dilution of pollutants. Station 3, upstream at the NIA Siphon in Sta. Cruz, exhibited the highest TSS level at 84 mg/L, phosphate at 0.190 mg/L, and fecal coliform at 18,875 MPN/100 mL, which implies moderate pollution presence even in the upper reaches of the river.

The presence of pollutants like Total Suspended Solids (TSS), phosphates, and fecal coliform in the Labangan River poses significant environmental, ecological, and public health risks. High TSS reduces water clarity, harms aquatic habitats, and can alter river flow and increase flooding. Phosphates, often from agricultural runoff and sewage, lead to eutrophication, causing harmful algal blooms that deplete oxygen and block sunlight, threatening aquatic life. Fecal coliform indicates contamination by harmful pathogens, posing health risks to humans. Together, these pollutants degrade biodiversity, disrupt ecosystem functions, and threaten the livelihoods of communities dependent on the river for fishing, agriculture, and drinking water.

Table 1. Nature and Magnitude of Pollution of Labangan River

Class	Station	GPS Coordinates Longitude, Latitude	Parameters (mg/L; MPN/100 mL)
B	1	123°30'32.46" E, 7°50'10.23'' N	TSS – 79 mg/L Phosphate – 0.180 mg/L Fecal Coliform – 34,874 MPN/100 mL
B	2	123°30'6.65" E, 7°51'25.40'' N	TSS – 83 mg/L Phosphate – 0.188 mg/L Fecal Coliform – 15,031 MPN/100 mL
A	3	7°54'19.61'' N, 123°26'57.95" E	TSS – 84 mg/L Phosphate – 0.190 mg/L Fecal Coliform – 18,875 MPN/100 mL

Computation of Pollution Load

a. Domestic

The computation of household domestic pollution load (HDPL) depends directly on the total population in the contributing area because the Household Domestic Waste Load (HDWL) is calculated as the product of the number of persons, the per-capita sewage flow, and the assumed pollution unit load for each parameter. Using the population figures in Table 2, the combined 40,860 residents of Labangan (33,349) and Tukuran (7,511) are first converted to wastewater volume with the standard sewage flow of 50 gal/cap/day prescribed under PD 856, and then multiplied by the pollution unit load assumptions from EMB Memorandum Circular No. 2020-25 (e.g., 200 mg/L for BOD, 5.6 mg/L for phosphate, 195 mg/L for TSS, and 10,000–1,000,000 MPN/100 mL for fecal coliform). This yields the gross HDWL in kg/day (or MPN/day for fecal coliform), which represents the potential domestic pollutant mass generated by the population before any treatment. The HDPL is then obtained by applying the treatment-efficiency factors for wastewater treatment plants, septic tanks, and direct discharges from Table 4, so that a larger population or a higher proportion of residents without effective treatment will translate into greater residual pollution load entering the Labangan River.

Table 2. Population Distribution by Municipality under Study

Municipality	Population
Labangan	33, 349
Tukuran	7, 511
Total	40, 860

Table 3 presents the computed Household/Domestic Pollution Load (HDPL) for each priority parameter generated by the 40,860 residents of Labangan and Tukuran, after accounting for sewage flow, pollution unit loads, and treatment efficiencies for WWTPs, septic tanks, and direct discharges. BOD and COD have the highest mass loads among the physico-chemical parameters, with total HDPL values of approximately 930.96 kg/day and 2,364.6 kg/day, respectively, indicating that oxygen-demanding substances from household wastewater are the dominant contributors to organic pollution pressure on the Labangan River. TSS also constitutes a substantial load at about 907.69 kg/day, suggesting that solids from domestic sources can significantly increase turbidity and sedimentation in the receiving water.

Table 3. Calculated Household/Domestic Pollution Load (HDPL) per Pollutant

Pollutant	No. of Persons	SF (Lcpd)	PUL (mg/L), MPN/100ml	HDWL kg/day MPN/ day	HDPL 1	HDPL 2	HDPL 3	Total HDPL kg/day, MPN/ day
					wWTP	Septic Tank	Direct Dischrage	
BOD	40,860	189.25	200	1,546.551	299.66	498.29	133.03	930.96
COD	40,860	189.25	508	3,928.240	761.14	1265.68	337.83	2364.6
Phosphate	40,860	189.25	5.6	43.303	8.390	13.95	3.724	26.07
NO_3-N	40,860	189.25	35	270.646	52.44	87.20	23.276	162.92
TSS	40,860	189.25	195	1,507.887	292.17	485.84	129.68	907.69
Fecal Coliform	40,860	189.25	1x10E+6	7.73276E+13	1.498E+13	2.49E+13	6.65E+13	4.65E+13

In contrast, nutrient loads from domestic sources are much lower in magnitude, with phosphate at only 26.07 kg/day and nitrate as NO_3–N at 162.92 kg/day, implying that, under the applied pollution-unit-load assumptions, eutrophication risk from household discharges alone may be less critical than organic and solids loading. However, the bacterial component is extremely large: the fecal coliform HDPL is on the order of 10^{13} MPN/day (≈4.65×10^{13} MPN/day after considering treatment), highlighting a substantial potential for microbiological contamination if effluent is not adequately treated or if excreta management is poor. Overall, the table shows that domestic wastewater is a major source of organic matter, suspended solids, and fecal contamination in the Labangan River system, and it underscores the need to strengthen household sanitation, improve on-site treatment performance, and reduce direct discharges to protect the river's assimilative capacity.

Figure 3 (a) illustrates the relative contribution of each parameter to the total household domestic pollution load (HDPL). Chemical Oxygen Demand (COD) accounts for the largest share at 54%, indicating that the bulk of the load from domestic sources is associated with oxidizable organic and inorganic matter that exerts a strong oxygen demand on the river. Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) each contribute 21%, showing that degradable organic matter and particulate material are also significant components of the household waste stream and can further reduce dissolved oxygen levels and increase turbidity. In contrast, nitrate as NO_3–N (4%) and phosphate (0%) represent only a small fraction of the calculated HDPL, suggesting that, based on the applied pollution unit loads, nutrient inputs from domestic sources are relatively minor compared with organic and solid loads. Overall, the figure highlights that management efforts aimed at improving the Labangan River's assimilative capacity should prioritize reducing COD, BOD, and TSS from household wastewater, while nutrient control may be a secondary concern under the present loading assumptions.

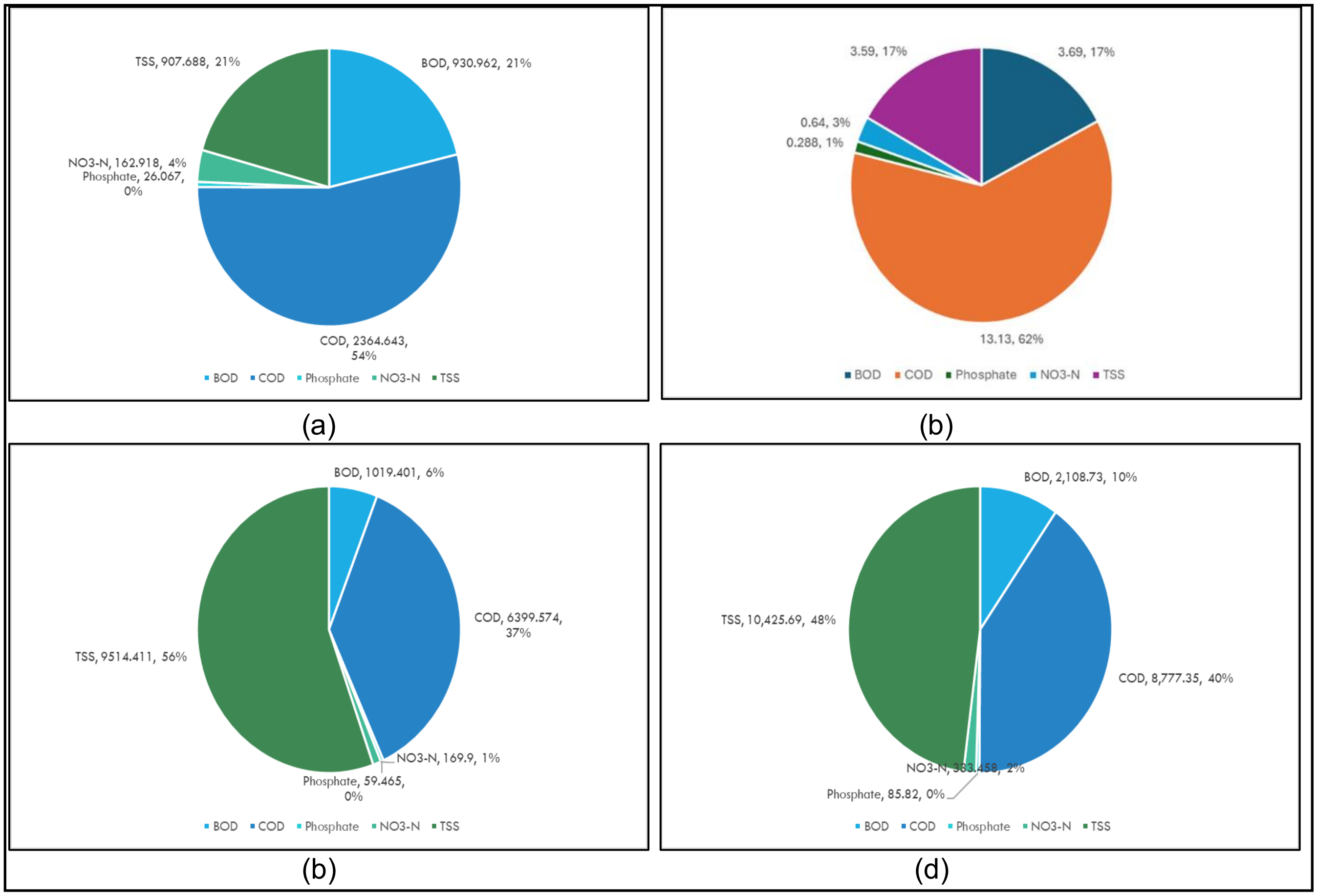

Figure 3. Pie chart of distribution by pollutants for : (a) HDPL, (b) ICPL, (c) SROPL, (d) TPL

b. Industrial / Commercial

Industrial and commercial facilities can contribute significantly to the pollution of surface waters through various discharge mainly wastewater.

Regulated establishments under the Wastewater Charge System provided by the Environmental Management Bureau (EMB) Region IX in the barangays of the Municipalities of Labangan, Tukuran, and Ramon Magsaysay that are within the Labangan Watershed. The list shows the establishments with Wastewater Discharge Permit (WDP) issued since 2020 and some of the permits are already expired as to date.

Table 4. Total ICPL per Pollutant Generated by Industrial/Commercial Establishments

Pollutant	**ICPL 1**	**ICPL 2**	**Total ICPL kg/day, MPN/day**
BOD	3.20	-	3.690
COD	8.14	3.76971	13.130
Phosphate	0.09	0.18828	0.288
NO3-N	0.56	-	0.640
TSS	3.12	-	3.590
Fecal Coliform	160,230,000,000	-	1.84253E+11

Table 4 summarizes the Industrial/Commercial Pollution Load (ICPL) by parameter, combining discharges from two groups of establishments (ICPL 1 and ICPL 2). COD has the highest total ICPL at approximately 13.13 kg/day, followed by BOD (3.69 kg/day) and TSS (3.59 kg/day), indicating that organic matter and suspended solids are the dominant industrial/commercial pollutants, consistent with effluents from food processing, service, and small manufacturing facilities. Nutrient loads are comparatively low, with phosphate at about 0.29 kg/day and nitrate as NO_3–N at 0.64 kg/day, suggesting that, under current operations, industrial and commercial sources are not major drivers of nutrient enrichment relative to organic and solid loads. Fecal coliform, however, reaches an estimated 1.84×10^{11} MPN/day, implying that even limited sanitary wastewater discharges from commercial facilities can pose a microbiological risk if not adequately treated

Figure 3 (b), which presents the ICPL distribution by pollutant, reinforces this pattern by showing COD as the dominant fraction of industrial/commercial load, with notable shares of BOD and TSS and much smaller percentages for nitrate and phosphate. This distribution implies that control strategies for the industrial/commercial sector should prioritize improving pre-treatment of high-strength organic wastewater and solid removal (e.g., grease traps, settling, or biological treatment), while continuing to monitor nutrients and fecal contamination to ensure they remain within acceptable levels. When combined with the domestic load analysis, these results help clarify the relative importance of industrial/commercial inputs in the overall pollution budget and guide targeted interventions for enhancing the assimilative capacity of the Labangan River.

c. Surface Runoff

The estimation of surface runoff pollution load for the Labangan River watershed combined land-use information, runoff coefficients, and local rainfall data to quantify non-point source contributions. shows that the 48,515.96 ha watershed is dominated by production and protection forest/plantation areas, with most land uses (agricultural, brushland, grassland, plantation, and production) assigned a runoff coefficient $C = 0.41$, protection and forest areas assigned $C = 0.25$, and residential areas assigned $C = 0.50$. Using the upper limits of these coefficients to represent a worst-case scenario, 64.7% of the surface area was represented by $C = 0.41$, 32.92% by $C = 0.25$, and 1.61% by $C = 0.50$. Combining these proportions with the effective watershed area of 14,038.74 ha yielded a composite runoff area $CA = 4{,}992.457$ ha. The monthly average rainfall for Labangan and Tukuran, derived from 2011–2020 data, was 67.35 mm/month, corresponding to an average rainfall intensity of 0.094 mm/h. Applying the Rational Method $Q = 0.0028CiA$ with the composite C, A, and rainfall intensity produced an estimated surface runoff discharge of 1.314 m³/s for the watershed.

This discharge was then combined with surface-runoff pollution unit loads (PUL_{so}) to compute the Surface Runoff Pollution Load (SROPL) for each parameter (Table 19). The resulting loads indicate that total suspended solids (TSS) and chemical oxygen demand (COD) dominate the non-point source contributions, with SROPL values of 9,514.411 kg/day and 6,399.574 kg/day, respectively, reflecting the strong influence of eroded soil, organic debris, and oxidizable material mobilized from agricultural, grassland, and production forest areas during rainfall events. Biochemical oxygen demand (BOD) is also substantial at 1,019.401 kg/day, demonstrating that runoff carries enough degradable organic matter to exert a noticeable oxygen demand on the river. In contrast, nutrient loads from surface runoff are comparatively smaller, with nitrate as NO_3–N and phosphate contributing 169.900 kg/day and 59.465

kg/day, respectively, while fecal coliform from diffuse sources is estimated at 6.80×10^5 MPN per 100 mL equivalent.

Table 5. Calculated Surface Runoff Pollution Load (SROPL) per Pollutant

Pollutant	Q	PULSO Average concentration mg/L, MPN/100 mL	SROPL kg/day, MPN/100 mL
BOD	1.314	9	1,019.401
COD	1.314	56.5	6,399.574
Phosphate	1.314	0.525	59.465
NO_3-N	1.314	1.5	169.900
TSS	1.314	84	9,514.411
Fecal Coliform	1.314	6000	679,600.800

Overall, Table 19 shows that, under average rainfall conditions, surface runoff is a significant source of TSS, COD, and BOD to the Labangan River, and therefore any strategy to protect the river's assimilative capacity must address erosion control and land-management practices in the watershed in addition to point-source controls.

Figure 3 (c) shows the relative contribution of each pollutant to the total surface runoff pollution load entering the Labangan River. TSS represents the largest share at about 56% (9,514.411 kg/day), indicating that sediment and particulate matter mobilized from the watershed are the dominant non-point source stressors. COD makes up roughly 37% (6,399.574 kg/day), while BOD contributes around 6% (1,019.401 kg/day), confirming that oxidizable organic material is also a major component of runoff. Nitrate as NO_3–N and phosphate account for only about 1% and a negligible fraction of the total load, respectively, suggesting that nutrient inputs from surface runoff are comparatively minor under the current conditions.

d. Solid Waste for BOD

Table 6 summarizes the estimated solid-waste–related biochemical oxygen demand (BOD) loads generated by the municipalities of Tukuran and Labangan. Using the assumed BOD content of solid waste (SWBOD = 0.01576 kg BOD/kg waste) and an average per-capita solid waste generation rate of 0.40 kg/person/day, each resident contributes a small but quantifiable BOD load through municipal solid waste. For Tukuran, with 7,511 inhabitants, this corresponds to about 24.858 kg/day of generated solid waste and an associated BOD load of 0.21 kg/day. Labangan, with a larger population of 33,349, generates approximately 129.818 kg/day of solid waste and 0.247 kg/day of BOD. When combined for the entire population of 40,860 people, the total BOD load attributable to solid waste reaches 154.677 kg/day. This indicates that improperly managed solid waste can be a non-negligible source of oxygen-demanding pollution in the Labangan River system, even though the per-person contribution is relatively small.

Table 6. Calculated Solid Waste Pollution Load (SW) for BOD

Municipality`	No. of persons*	BODsw kg BOD	GSW kg	Generated Solid Waste (PCG) kg/day
Tukuran	7,511	0.01576	0.21	24.858
Labangan	33,349	0.01576	0.247	129.818
	40,860		BOD	154.677

e. Backyard Livestock and Poultry

In this study, the pollution load from backyard livestock and poultry was not calculated as the Department of Agriculture in Region IX did not provide the data necessary for the computation.

f. Fisheries

In this study, the pollution load from the fishery sector was not calculated since the Bureau of Fisheries and Aquatic Resources in Region IX currently do not have data on the area of fish pen and/or fish cage in the Municipalities of Labangan and Tukuran, Zamboanga del Sur.

g. Total Pollution Load

Figure 3 (d) summarizes the Total Pollution Load (TPL) of the Labangan River by showing how each parameter contributes to the combined load from all identified sources. The TPL for each pollutant was computed as the sum of the loads from household/domestic sources (HDPL), industrial/commercial discharges (ICPL), surface runoff (SROPL), solid waste (SWBOD for BOD), base-load and future-load components (BLPPL and FBOD), such that, for example, $TPL_{BOD} = \sum$BOD loads from all contributory sectors. The pie chart indicates that total suspended solids (TSS) account for the largest fraction of the TPL at about 48% (10,425.69 kg/day), followed by COD at 40% (8,777.35 kg/day) and BOD at 10% (2,108.73 kg/day). Nitrate as NO_3–N and phosphate contribute only small shares, roughly 2% (383.458 kg/day) and less than 1% (85.82 kg/day), respectively.

These results show that, overall, suspended solids are the dominant pollutant in the Labangan River system, consistent with the earlier finding that surface runoff is a major source of TSS due to erosion and sediment transport from agricultural and production lands. Organic pollutants, represented by COD and BOD, form the second most important group, reflecting substantial inputs of degradable and oxidizable material from domestic wastewater, industrial/commercial effluents, and solid waste. Although not explicitly shown in the figure, the study also found that high fecal coliform loads enter the river, with households and commercial establishments identified as the primary contributors. Taken together, Figure 6 indicate that management strategies should prioritize reducing suspended solids and organic loads—through erosion control, improved wastewater treatment, and better solid-waste management—while simultaneously addressing fecal contamination to protect public health and maintain the river's assimilative capacity.

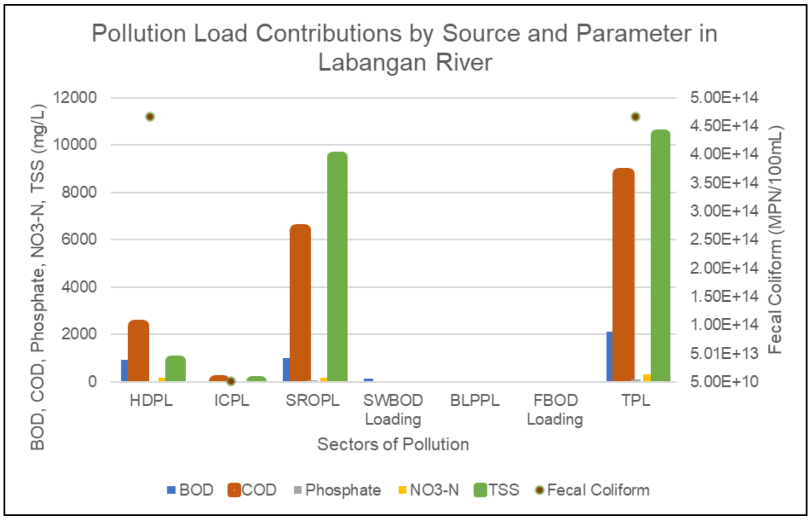

Figure 7. Graphical representation of sectoral pollution contribution

Consistent with the earlier discussion, Figure 7 shows that surface runoff (SROPL) produces the highest TSS and substantial COD and BOD loads, confirming that erosion and wash-off from the watershed are the dominant non-point sources of suspended solids and organic material. Household/domestic sources (HDPL) also exhibit notable BOD, COD, and TSS bars and the highest fecal-coliform marker, reflecting the large loads contributed by septic-tank effluent and direct discharges identified in Table 10 and indicating that domestic wastewater is a major contributor to both organic pollution and microbiological contamination. Industrial/commercial sources (ICPL), while smaller in magnitude than households and runoff, still add measurable COD and TSS. The SWBOD bar, though much smaller than other sectors, demonstrates that mismanaged solid waste contributes additional BOD. At the far right, the TPL group aggregates all sectors and clearly shows that, when combined, TSS and COD dominate the total load, with BOD as a significant secondary pollutant and fecal coliform remaining at very high levels. This integrated picture underscores the need for a mixed management strategy: reducing erosion and runoff, improving household and commercial wastewater treatment—particularly septic-tank performance and elimination of direct discharges—and strengthening solid-waste handling to protect the Labangan River's assimilative capacity.

Analysis

a. Compute the Assimilative Capacity

Table 7 compares the river's computed assimilative capacity (CAC) with the Total Pollution Load (TPL) and shows that the Labangan River is already overloaded for several key pollutants. For BOD, the CAC is 2,029.54 kg/day while the TPL is 2,108.73 kg/day, indicating that the river can no longer safely assimilate additional organic matter without further depleting dissolved oxygen. Phosphate is even more critical: a CAC of only 16.91 kg/day is exceeded by a TPL of 85.82 kg/day, pointing to strong eutrophication pressure and a high risk of algal blooms. Fecal coliform shows the most severe exceedance, with a CAC of 1.728×10^4 MPN/day versus an enormous TPL of about 4.66×10^{14} MPN/day, confirming heavy microbial contamination from domestic and commercial sources and serious public-health risks for any use of untreated river water.

By contrast, the computed TPLs for NO_3–N (333.46 kg/day) and TSS (10,425.69 kg/day) remain below their respective CAC values (4,735.58 and 33,825.60 kg/day), suggesting that, on a purely mass-balance basis, there is still apparent capacity for these parameters. However, this margin is likely overstated because the load estimates cover only 28.94% of the watershed, and surface runoff—already identified as the dominant source of TSS—was not fully captured. This is consistent with EMB-IX 2023 monitoring, which reported exceedances of guideline values for TSS, phosphate, and fecal coliform at several stations. Overall, the table indicates that the river has effectively lost its assimilative capacity for BOD, phosphate, and fecal coliform, underscoring the need to reduce domestic and commercial wastewater discharges, better manage nutrients and detergents, and strengthen watershed controls before further degradation of ecological quality and human health occurs.

Table 7. Computed Assimilative Capacity vs. Total Pollution Load

Pollutant	Q_t	C_a (Based on Class A) mg/L	C_f	CAC kg/day, MPN/100 mL	TPL kg/day, MPN/100 mL	TPL vs CAC	Remarks
BOD	676,512	3	0.001	2,029.54	2,108.73	TPL > CAC	AAC has been exceeded
Phosphate	676,512	0.025	0.001	16.91	85.82	TPL > CAC	AAC has been exceeded
NO_3-N	676,512	7	0.001	4,735.58	333.46	TPL < CAC	AAC has not been exceeded
TSS	676,512	50	0.001	33,825.60	10,425.69	TPL < CAC	AAC has not been exceeded
Fecal Coliform	345,600	50	0.001	17,280.00	4.66E+14	TPL > CAC	AAC has been exceeded

b. Proposed Pollution Reduction Target

The quantity of pollutants must be reduced to attain a certain level of improvement in the water quality of the river. For practical assessment, the water quality target (WQT) is based on the computed assimilative capacity (CAC). The WQT should be at least equal to or less than the CAC. The table below shows the recommended pollution reduction of the pollution load for BOD, phosphates, and fecal coliform.

Table 8. Percent Reduction of TPL

Pollutant	CAC kg/day, MPN/100 mL	TP kg/day, MPN/100 mL L	%Reduction of TPL
BOD	2,029.54	2,108.73	≥3.76%
Phosphates	16.91	85.82	≥80.30%
Fecal Coliform	17,280.00	4.66E+14	>100%

Table 8 summarizes the minimum percentage reductions in Total Pollution Load (TPL) needed for the Labangan River to meet its assimilative capacity for the most critical pollutants. For BOD, the current load of 2,108.73 kg/day slightly exceeds the CAC of 2,029.54 kg/day, so a reduction of at least 3.76% in BOD inputs from households, commercial establishments, and runoff would be sufficient to bring the river back within its allowable limit. Phosphates require a far more stringent response: with a CAC of only

16.91 kg/day and a TPL of 85.82 kg/day, the load must be cut by at least 80.30%, implying strong control of detergent-rich domestic wastewater, septic effluent, and surface runoff. For fecal coliform, the TPL of about 4.66×10^{14} MPN/100 mL exceeds the CAC of 17,280 MPN/100 mL by several orders of magnitude, so the table notes that a reduction of more than 100% relative to the present load is effectively required—meaning that existing discharges must be almost entirely eliminated through comprehensive sanitation upgrades, sewerage improvements, and strict control of direct wastewater releases to approach Class A microbial standards.

Conclusion

The assessment of pollution load and assimilative capacity shows that the Labangan River is already overloaded with key pollutants and has effectively lost its ability to safely receive additional BOD, phosphate, and fecal coliform inputs. Domestic wastewater is the dominant source of organic matter, suspended solids, and fecal contamination, as reflected in the very high household pollution loads for BOD, COD, TSS, and fecal coliform, with septic-tank effluent and direct discharges playing a particularly critical role. Surface runoff from the largely agricultural and production-forest watershed further contributes substantial TSS, COD, and BOD, making suspended solids the major pollutant by mass in the Total Pollution Load, followed by organic pollutants, while industrial/commercial sources and solid-waste-related BOD add smaller but non-negligible loads. Sanchez et al. (2020) similarly identified domestic sewage as the primary source of organic and microbiological pollution in the Sapangdaku River in Cebu, Philippines, while Pratama et al. (2020) reported that domestic wastewater dominated BOD, COD, suspended solids, and coliform contamination in the Code River in Yogyakarta, Indonesia. When these sectoral contributions are combined, the resulting TPL exceeds the river's computed assimilative capacity for BOD and phosphate and surpasses fecal coliform limits by several orders of magnitude, in agreement with EMB IX monitoring data that already report frequent exceedances of TSS, phosphate, and fecal coliform guidelines.

These findings indicate that the current water quality status of the Labangan River poses serious risks to aquatic ecosystems and to communities relying on the river for domestic use, agriculture, and fisheries, and they define clear quantitative targets for remediation. To bring TPL within the river's assimilative capacity, BOD loads must be reduced by at least 3.76%, phosphate by about 80.30%, and fecal coliform by more than 100% relative to present levels which essentially requiring near-elimination of untreated sanitary discharges. Priority interventions therefore include upgrading and properly maintaining septic systems, eliminating direct household and commercial wastewater discharges, implementing effective industrial pretreatment, strengthening solid-waste management, and adopting watershed-scale erosion and runoff controls to curb TSS, COD, and BOD from non-point sources. Achieving these reductions will not only restore part of the river's assimilative capacity but also provide a practical framework for future water-quality improvement programs and regulatory enforcement within the Labangan watershed.

Recommendation

To address the exceedance of the Labangan River's assimilative capacity for organic pollutants, phosphates, and fecal coliform, wastewater management must be strengthened as a first priority. The LGUs of Labangan and Tukuran should upgrade on-site sanitation by promoting improved septic tanks and, where feasible, low-cost advanced options such as anaerobic baffled reactors or constructed wetlands for households and commercial establishments. Regular desludging should be mandated through local ordinances, with accredited haulers and designated septage treatment facilities, and compliance with effluent standards must be strictly monitored and enforced. In parallel, LGUs should enhance solid-waste management by improving segregation, collection, recyclingTo address the exceedance of the Labangan River's assimilative capacity for BOD, phosphates, and fecal coliform, wastewater management in Labangan and Tukuran must be strengthened. LGUs should upgrade on-site sanitation by improving septic tank designs and, where feasible, introducing low-cost advanced options such as anaerobic baffled reactors or constructed wetlands for households and commercial establishments. Regular desludging should be mandated through local ordinances, with accredited haulers and proper septage treatment facilities, and compliance with effluent standards strictly monitored and enforced. Although this study did not quantify agricultural pollution loads, much of the watershed is agricultural or plantation land, so the Department of Agriculture should promote slow-release fertilizers and integrated nutrient management, establish vegetated buffer strips along waterways, and implement soil- and water-conservation measures and controlled irrigation to reduce erosive, nutrient-laden runoff.

Solid waste management also needs to be enhanced by strengthening waste segregation, collection, recycling, and disposal systems to prevent litter and leachate from reaching the river, while institutionalizing regular riverbank cleanups and supporting community-led initiatives. The DENR–EMB should expand the frequency and spatial coverage of water-quality monitoring, develop simple early-warning mechanisms for water-quality deterioration, and feed results back to LGUs and stakeholders to guide timely interventions. At the same time, LGUs, NGAs, schools, and civil society organizations should conduct sustained information and education campaigns on sanitation, septic-tank maintenance, and waste management, and organize community-based riverwatch groups to foster local stewardship. At the policy level, DENR and partner agencies must reinforce enforcement of existing water-quality and wastewater regulations and formulate an integrated Labangan watershed management plan that aligns land-use planning, agricultural support, and infrastructure with pollution-reduction targets. Finally, degraded riparian zones and wetlands should be rehabilitated with native vegetation to stabilize banks, reduce erosion, and provide natural polishing of sediments, nutrients, and pathogens. Implemented together, these measures can reduce pollution loads, begin to restore the river's assimilative capacity, and improve the health and resilience of the Labangan River and its watershed.

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