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Rehabilitation Program of Lambiki River: A Proposed Aeration Design and Sustainable River Management Plan in Brgy. Sta. Teresa 2nd, Lubao, Pampanga

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Abstract:

The Environmental Management Bureau (EMB) in the Philippines has identified 14 rivers needing water quality monitoring and potential rehabilitation. This research focuses on creating a program to restore the Lambiki River in Brgy. Sta. Teresa 2nd, Lubao, Pampanga, through sustainable water management. Objectives include evaluating water quality parameters like Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Dissolved Oxygen (DO); testing a prototype aeration system; identifying causes of water quality deterioration; and devising a river management strategy. Using quantitative methodologies and mixed methods, the study conducted water laboratory tests and an Interpretative Phenomenological Approach (IPA). Initial water quality did not meet standards set by DAO 2021-19 for fisheries but improved after implementing the prototype aeration system for three and seven days. Findings pointed to overpopulation and community practices as key factors in water quality decline. The river management plan developed emphasizes community involvement, environmental education, and innovative strategies, highlighting the importance of engaging communities, raising environmental awareness, and employing sustainable methods to address water pollution and foster growth.

Keywords **— Lambiki River, Aeration, Rehabilitation, Water Quality, Program, Sustainable Management, Community Participation, Environmental Awareness, Parameter.**

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I. INTRODUCTION

The significance of river restoration for environmental protection and long-term sustainability has been thoroughly documented. River rehabilitation aims to restore damaged or contaminated rivers to a healthy state, thereby enhancing their ecological functions and biodiversity. This involves strategies such as enhancing water quality, reintroducing species, reinforcing riverbanks, and implementing aeration to boost dissolved oxygen levels [1].

The primary goal of river rehabilitation is to improve water quality and ensure its sustainable use for future generations. Rivers play an important role in maintaining ecosystem balance, supporting communities, and conserving natural heritage. Effective riverwater rehabilitation requires integrating sustainable practices and regulations into water management plans [1].

The impact of industrialization, agriculture, and urbanization on pollution and environmental degradation, especially in essential water sources like rivers, has been serious. This degradation

compromises long-term societal progress and has significant adverse effects on human health. Globally, approximately 80% of wastewater from industries and cities is released into the environment without treatment, posing a threat to human health and ecosystems [3]. This issue is particularly common in developing countries, such as the Philippines, where the lack of proper sanitation and wastewater treatment facilities amplifies the problem.

Rivers in the Philippines are mainly affected by agriculture, households, and industry [3]. The Department of Environment and Natural Resources (DENR) initiated the "Sagip Ilog Program" in 2002, identifying 14 rivers with poor water quality that require ongoing monitoring and rehabilitation efforts. Pollution in these rivers is released from both point-source and non-point-source pollution, including industrial effluents, municipal sewage, agricultural runoff, urban stormwater, and untreated human waste [4]. Consequently, polluted river water exhibits unpleasant odors, reduced transparency, and elevated pollutant levels.

Bioremediation, using live organisms such as bacteria, fungi, plants, and microorganisms, is a sustainable and eco-friendly technique for removing or neutralizing toxins from contaminated environments [5]–[8]. The main contributors to river pollution include untreated solid waste, sewage, and runoff from commercial and agricultural activities, leading to the presence of physical, chemical, and microbial contaminants [9]–[10]. Many of the nation's rivers are severely polluted, raising concerns about their viability [11].

The legal framework for water resource management in the Philippines comprises the Water Code of the Philippines (Presidential Decree No. 1067) and the Philippine Clean Water Act of 2004 (Republic Act No. 9275). These laws govern the management and conservation of the country's water resources, emphasizing pollution control measures and sustainable water quality management [12]–[19]. The Sustainable Development Goals (SDGs), particularly SDG 6.3, seek to enhance water quality through pollution reduction and increased safe reuse and recycling to a global extent. The Philippines has been actively working towards achieving these targets, with notable progress in wastewater treatment and community engagement in water management efforts [20]–[27].

Efforts to improve water quality in river systems involve monitoring various parameters, including physical, chemical, and biological aspects. Proper sampling and analysis techniques are important for accurate water quality assessments [28]–[29]. Rehabilitation programs in the Philippines, such as the Pasig River Rehabilitation Program, focus on non-structural approaches, including community involvement and strict enforcement of environmental regulations [30].

An alternative non-structural rehabilitation solution is aeration, which introduces oxygen into water bodies to enhance natural pollutant breakdown processes, reduce harmful microorganisms, and support aquatic life [31]. Various aeration methods, including mechanical, hydraulic cascade, and diffused air, have been proven to effectively decrease pollution levels and improve water quality [32].

The Lambiki River holds great significance for the residents of Brgy. Sta. Teresa 2nd as it provides convenient connectivity to the town proper. Despite its important role, the river has been negatively impacted by significant pollution and degradation resulting in negative effects on water quality, native ecosystems, and the communities reliant on it. While serving as an important channel for transportation and fishing, pollution from various sources has compromised its integrity, giving rise to ecological and health-related concerns. There is an essential need for the restoration of the Lambiki River to safeguard its sustained functionality and ecological well-being.

Fig 1 Lambiki River

This study assessed the water quality (DO, BOD, COD) of the Lambiki River within the defined study area of Brgy. Sta. Teresa 2nd during the 2024 dry season, utilizing DAO 2021-19 [33] standards as a benchmark. The efficacy of a prototype aeration system was evaluated under controlled conditions, acknowledging potential factors such as resident activities and seasonal variations. A comprehensive sustainable river management plan was developed, emphasizing non-structural rehabilitation strategies and community engagement to ensure long-term water quality improvement. The scope of this study was geographically limited to the specified area and did not extend to other rivers or locations.

II. METHODOLOGY

This research is focused on the restoration of the polluted Lambiki River in Brgy. Sta. Teresa 2nd, Lubao, Pampanga. It aims to improve river water quality through a two-phase rehabilitation program that comprises both structural and non-structural components. These include activities such as water quality testing, focus group discussions, and the implementation of a prototype aeration system.

A. Research Design

The study employs a Mixed Method approach, which integrates quantitative data assessment with qualitative analysis. This approach is appropriate for comprehensive research requiring both statistical analysis and in-depth comprehension. Quantitative data aids in identifying patterns, while qualitative data offers detailed insights, thus enhancing the credibility and robustness of the research outcomes.

B. Research Locale

The research is conducted in Brgy. Sta. Teresa 2nd, Lubao, Pampanga, with a specific focus on the Lambiki River, which plays an important role in the local ecosystem and community despite being heavily polluted.

Fig 2 Brgy. Sta. Teresa 2nd, Lubao, Pampanga

C. Research Instrument

An open-ended questionnaire is utilized as the research instrument to identify potential causes of river water quality degradation and potential improvement programs. This questionnaire is designed to ensure accuracy, consistency, and minimum respondent bias. It is validated by a psychometrician to maintain objectivity and minimize technical errors, thereby enabling respondents to freely express their knowledge, feelings, and understanding, contributing valuable qualitative data.

D. Data Gathering

For data gathering, water samples are collected from three points along the Lambiki River following the Standard Operating Procedure (SOP) of the EChem Environmental Testing Laboratory. Specific volumes are collected for different parameters at each point to assess the current state of the river and inform the aeration tank dimensions and potential facility locations.

These are the point locations in Lambiki River:

- Point 1: The Lambiki River before entering the Sta. Teresa 2nd
- Point 2: The Lambiki where it entered the Brgy. Sta. Teresa 2nd
- Point 3: The Lambiki River after passing in the Brgy. Sta. Teresa 2nd

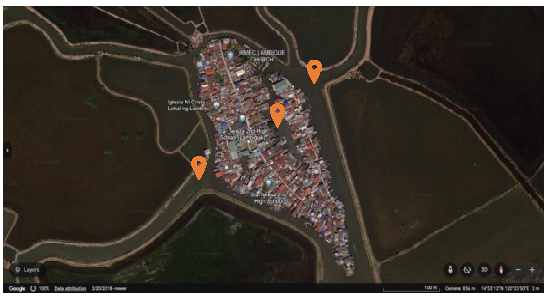

Fig 3 Point Location in Lambiki River

Additionally, focus group discussions with officials from the Municipal Environment and Natural Resources Office (MENRO) and the barangay captain help identify potential causes of water quality degradation.

E. Data Analysis

Descriptive analysis is used to summarize and describe the laboratory test results, while transcripts from focus group discussions are analysed using Coding analysis and Interpretative Phenomenological Analysis (IPA) to acquire individual experiences in-depth and categorize them into themes or categories.

F. Rehabilitation Program

Structural Prototype Set-Up

A prototype aeration system was constructed to address water quality indicators such as dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). The prototype utilized a glass rectangular tank measuring 24 inches in length, 12 inches in width, and 12 inches in height (609.6mm x 304.8mm x 304.8mm).

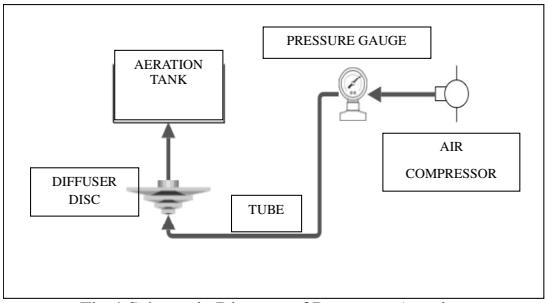

Fig 4 Schematic Diagram of Prototype Aeration

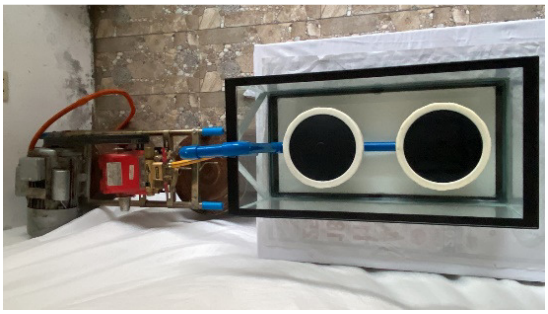

Fig 5 Top View of The Actual Prototype Aeration Set-Up

Fig 6 Front View of the Actual Prototype Aeration Set-Up

Non - Structural Design

This research introduces an alternative approach to river management, emphasizing a non-structural method. It outlines the process of developing a model for aeration and conducting Focus Group Discussions (FGD) to identify factors contributing to the degradation of river water quality. The sustainable river management strategy is important for ensuring the essential success of the restoration project, with particular emphasis placed on community involvement in Brgy. Sta. Teresa 2nd.

Effective communication of the river management plan to all community members is essential in garnering their participation and cooperation. The plan will be elaborated in a visual representation outlining the stages of the structural design program, encompassing vision development, issue identification, goal setting, scheduling, oversight, implementation, and program maintenance. This visual aid, presented in Figure 7, serves as a guide for the structural restoration endeavour. The development of this visual aid was influenced by the works of Philips and Bennett [34].

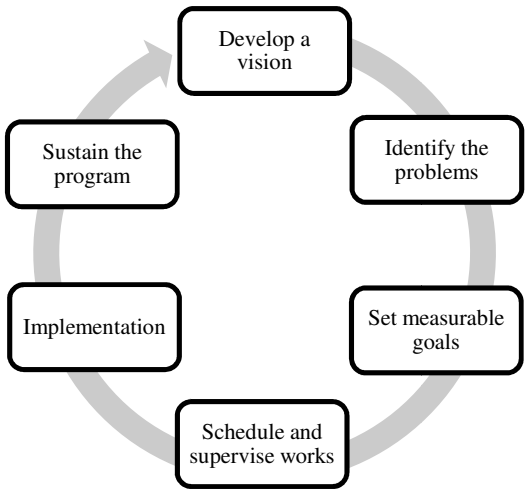

Fig 7 Sustainable River Management Plan Flow-chart

III. RESULTS AND DISCUSSION

A. Classification of Lambiki River as per DAO 2021-19

TABLE I
WATER BODY CLASSIFICATION AND USAGE OF FRESHWATER (DAO 2021-19)

Classification	Intended Beneficial Use
Class AA	Public Water Supply Class I is Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require only approved disinfection to meet the latest PNSDW
Class A	Public Water Supply Class II - Intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration, and disinfection) to meet the latest PNSDW
Class B	Recreational Water Class I - Intended for primary contact recreation (bathing, swimming, etc.)
Class C	Fishery Water for the propagation and growth of fish and other aquatic resources Recreational Water Class II For boating, fishing, or similar activities For agriculture, irrigation, and livestock watering
Class D	Navigable waters

TABLE II
WATER QUALITY GUIDELINES FOR PRIMARY PARAMETERS (DAO 2021-19)

Parameter	Unit	Water Body Classification			
		A	B	C	D
BOD	mg/L	3	5	7	15
Dissolved Oxygen (minimum)	mg/L	5	5	5	2
COD	mg/L	-	-	-	-

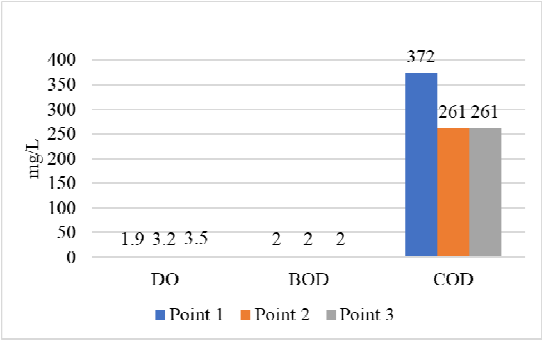

Fig 8 Lambiki River Water Laboratory Test Result of No Aeration

According to the guidelines established in the DENR Administrative Order (DAO) 2021-19, the Lambiki River has undergone categorization based on its intended purpose, being specifically designated as fishery water. However, analysis of water samples from the Lambiki River, as depicted in Figure 8, revealed discrepancies in key parameters such as DO, BOD, and COD, failing to align with the specifications outlined for classification C (fishery water) in DAO 2021-19 (see Table II). The levels of DO were determined to be below the prescribed minimum standard for classification C, signifying the incapacity of the Lambiki River to sustain aquatic life. Inadequate DO levels may result in the inability of fish and other aquatic organisms to survive [35]. To enhance the Lambiki River to classification C under DAO 2021-19, a prototype aeration system was introduced to improve these parameters.

B. Lambiki River Water Quality Laboratory Test Result

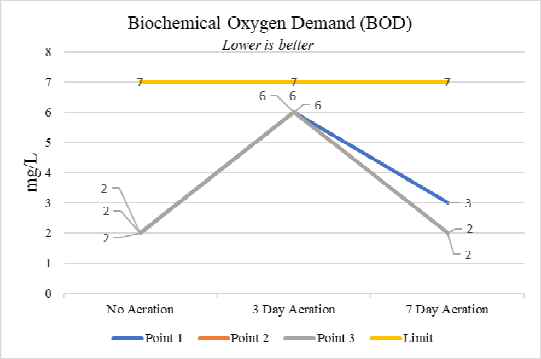

Fig 9 Biochemical Oxygen Demand (BOD) in mg/L

The five-day BOD test of the Lambiki River water before aeration showed low organic pollution levels, adhering to DAO 2021-19 guidelines (Figure 9). After three days of aeration, BOD levels increased slightly but remained within acceptable limits. This initial rise, attributed to increased microbial activity and organic matter breakdown, aligns with findings by Yunita et al. [36]. Despite this temporary increase, BOD levels ultimately decreased over the seven-day aeration period, indicating effective organic matter reduction.

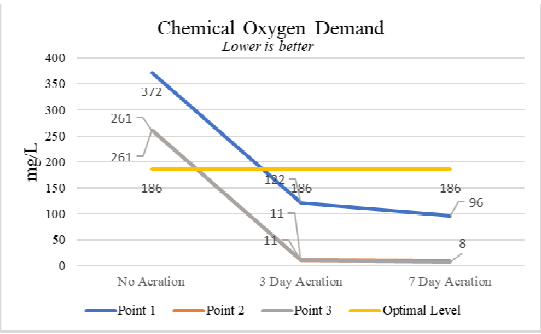

Fig 10 Chemical Oxygen Demand (COD) in mg/L

The COD test of the Lambiki River water revealed a decrease in COD levels after both three and seven days of aeration (Figure 10). This suggests that the aeration process effectively improves water quality by reducing organic matter pollution, aligning with research findings by Li and Liu [37].

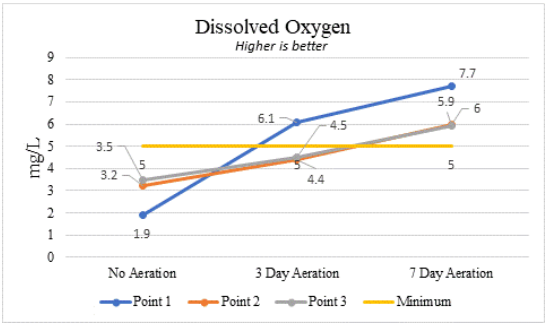

Fig 11Dissolved Oxygen (DO) in mg/L

The prototype aeration system significantly improved DO levels in the Lambiki River (Figure 11). Initial DO levels were below the DAO 2021-19 minimum for classification C. After three days of aeration, DO levels increased, particularly at point 1, indicating enhanced support for aquatic life. By the seventh day, all three points surpassed the minimum DO level, demonstrating the effectiveness of aeration in improving water quality.

C. Discussion of Themes and Sub-themes of Interview

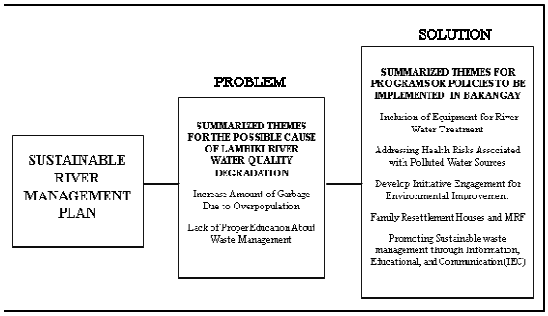

Figure 12Framework of Summarized Themes

The degradation of Lambiki River's water quality is attributed to overpopulation, increased waste generation from industrial and household sources, and unsustainable community practices such as untreated sewage and agricultural runoff. These factors overwhelm the river's natural purification processes, posing significant health risks to the surrounding ecosystem and human population.

Lack of awareness and education on environmental conservation and proper waste management further worsens the problem. Residents often contribute to pollution through improper waste disposal, highlighting the need for targeted educational initiatives.

A proposed comprehensive rehabilitation program includes structural interventions like aeration to enhance oxygen levels and support aquatic life, and non-structural strategies addressing health risks from polluted water. Community engagement is emphasized, involving residents in planning, implementation, and monitoring to foster ownership and responsibility. This approach has proven successful in similar projects like the Pasig and Marikina River rehabilitations.

An Information, Education, and Communication (IEC) program focused on solid waste management is essential to promote informed, environmentally responsible behaviours. By raising awareness of the consequences of improper waste disposal, the IEC program aims to ensure the long-term sustainability of rehabilitation efforts.

D. Sustainable River Management Plan

Chapter 1: Introduction

The Lambiki River, crucial for biodiversity, livelihoods, and water security, faces pollution and erosion challenges. To restore ecological health and water quality, a comprehensive plan aims to improve water quality and ecosystem health, reduce pollution and habitat damage, engage the community in river conservation, implement structural and non-structural methods, and ensure stakeholder cooperation and sustained funding. Key issues include pollution and waste management challenges, policy and resource deficiencies, and the need for community awareness and participation.

Chapter 2: Barangay Profile

Sta. Teresa 2nd, located in Lubao, Pampanga, faces significant environmental risks due to low elevation and overpopulation.

Chapter 3: Legal/Institutional Framework

Sta. Teresa 2nd adheres to Municipal Ordinance No. 2 of 2001 for solid waste management. The barangay lacks adequate permitting processes and compliance frameworks but is working to enhance stakeholder participation through various environmental activities.

Chapter 4: Plan Strategy

The vision is to restore the Lambiki River to a clean and thriving ecosystem that supports biodiversity, livelihoods, and residents' well-being. Targets include improving water quality for aquatic life and recreation, reducing pollution through waste management and community involvement, strengthening ecological resilience and habitat continuity, and promoting sustainable behaviours and environmental stewardship. Strategies to achieve these targets include installing an aeration system, establishing a Materials Recovery Facility (MRF), organizing community clean-up drives and waste management initiatives, conducting Information, Education, and Communication (IEC) campaigns, and incentivizing sustainable practices.

Chapter 5: Aeration System

The aeration system will involve site evaluation and design, equipment selection, installation and testing, monitoring and maintenance, stakeholder engagement, energy efficiency, public education, integration with other water management strategies, contingency planning, and research to improve the technology.

Chapter 6: Social and Environmental Aspects

The rehabilitation program aims to improve livelihoods through fisheries, aquaculture, and eco-tourism, leading to better public health and community empowerment. It prioritizes environmental justice and equity by ensuring fair resource access, inclusive decision-making, and targeted interventions for vulnerable populations. The program also emphasizes cultural preservation by incorporating indigenous knowledge, protecting heritage sites, and raising awareness of the river's cultural significance.

Chapter 7: Cost Estimates/Financial Aspects

Funding for the Lambiki River rehabilitation program will be sought from government grants and subsidies, international aid and donor funding, corporate sponsorship and philanthropy, public-private partnerships, and community contributions and volunteerism. Budget planning will prioritize activities for impact and cost efficiency, implement

a phased rollout with specific timelines, include contingencies for unforeseen expenses, and ensure regular monitoring and evaluation of expenditures.

Chapter 8: Implementation Plan

The implementation plan consists of three phases: Phase 1 involves stakeholder mapping, consultation workshops, and developing a project plan with communication channels. Phase 2 focuses on on-site assessments, procuring materials, engaging contractors for aeration system installation, and implementing habitat restoration activities. Phase 3 centres on community engagement through clean-up drives, educational workshops, the development of materials, and utilizing diverse communication channels for awareness campaigns.

Chapter 9: Monitoring and Evaluation

Monitoring and evaluation of the project will include regular water quality testing, biological assessments of aquatic biodiversity, community surveys for feedback, and annual reviews to assess progress and adapt strategies.

Chapter 10: Risk Management

Risk management involves identifying potential risks and developing mitigation strategies, including diversifying funding sources and building partnerships to ensure the project's resilience and success.

Chapter 11: Communication and Outreach

The program will engage the public through various communication channels and develop educational materials for schools and community centres to raise awareness about river conservation and sustainable waste management.

Chapter 12: Policy and Advocacy

The plan advocates for stricter waste management regulations through engagement with local policymakers and collaboration with environmental advocacy groups.

IV. CONCLUSIONS

This study successfully achieved its primary goal of developing a comprehensive, two-phased rehabilitation program for the Lambiki River. Initial water quality assessments revealed the river's failure to meet the minimum standards for fishery classification, primarily due to low dissolved oxygen levels and high biochemical and chemical oxygen demands. However, the implementation of a prototype aeration system over seven days led to significant improvements in water quality, successfully meeting the required standards for aquatic life.

Furthermore, community interviews identified overpopulation, unsustainable community practices, and inadequate waste management as the main contributors to the river's degradation, highlighting the need for a multifaceted approach to rehabilitation. The resultant sustainable river management plan, informed by these insights, emphasizes non-structural interventions such as community education, waste management initiatives, and policy advocacy alongside technical solutions like aeration.

The findings of this study emphasize the critical role of community participation, environmental awareness, and innovative solutions in addressing water pollution challenges. This research not only provides a practical blueprint for restoring the Lambiki River but also serves as a valuable model for other local governments grappling with similar environmental issues. By combining scientific analysis with community engagement, this study demonstrates a holistic approach to river rehabilitation that can be replicated and adapted to diverse contexts, ultimately contributing to healthier ecosystems, improved public health, and sustainable resource management.

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