

Optimization of Eco-Enzyme Utilization for Improving Water Quality of the Badung River in Denpasar

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Article History Received: 09/02/2026 Revised: 27/02/2026 Accepted: 25/03/2026

Abstract. This community service program aims to optimize the utilization of eco-enzyme as an environmentally friendly solution to improve the water quality of the Badung River in Denpasar. The program was designed using a participatory approach that involved local communities at all stages, including problem identification, training, implementation, and evaluation. Eco-enzyme was produced from organic household waste such as fruit and vegetable peels through a fermentation process, and subsequently applied to selected points of the river. The results of the program indicate that the application of eco-enzyme contributed to gradual improvements in water quality, particularly in reducing unpleasant odors, decreasing turbidity, and stabilizing pH levels. In addition, the program successfully enhanced community awareness and participation in environmental conservation, as reflected in improved waste management practices and reduced direct disposal of organic waste into the river. The participatory method also fostered a sense of responsibility and sustainability among community members. Despite its positive outcomes, the effectiveness of eco-enzyme application is influenced by factors such as dosage, consistency of use, and the level of existing pollution. Therefore, continuous implementation and community engagement are essential to achieve long-term impact. Overall, this program demonstrates that the use of eco-enzymes can be a practical, low-cost, and sustainable approach to improving urban river water quality.

Keywords: Eco-enzyme, Water quality, Badung river, Community participation, Environmental management.

How to Cite: Susanta, V. A., & Edwin, E. (2026). Optimization of Eco-Enzyme Utilization for Improving Water Quality of the Badung River in Denpasar. *Prima Abdika: Jurnal Pengabdian Masyarakat*, 6(1), 29-43. <https://doi.org/10.37478/abdika.v6i1.7682>



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Introduction

Water pollution remains a critical environmental issue in many urban areas, particularly in rapidly developing regions where population growth and human activities significantly impact natural water bodies (Diniz, 2018; Song et al., 2020; Zhu et al., 2023). In Indonesia, urban rivers often function not only as ecological systems but also as centers of community activities, which unfortunately increases their vulnerability to pollution (Candraningrum, 2025; Suwarno & Nurhayati, 2021). One such example is Badung River in Denpasar, Bali, which plays an essential role in supporting local ecosystems, tourism, and daily community needs (Ciawi et al., 2022; Parwita et al., 2024; Pertiwi et al., 2019; Purnaya et al., 2019). However, the increasing intensity of domestic waste disposal, organic pollutants, and limited community awareness regarding environmental management have contributed to the deterioration of water quality in this river (Ciawi et al., 2022; Harmayani et al., 2023, 2025; Pertiwi et al., 2019; Wijaya et al., 2025).

The degradation of river water quality poses serious environmental, social, and economic consequences (Anh et al., 2023; Assegide et al., 2022; Damseth et al., 2024; Oki et al., 2012; Yudono et al., 2024). Poor water quality can disrupt aquatic ecosystems, reduce biodiversity, and negatively affect the aesthetic value of urban environments, especially in tourism-dependent areas such as Denpasar. Moreover, polluted water bodies may also pose health risks to communities living nearby, particularly when the water is used for sanitation or other daily activities (Agbasi & Egbueri, 2022; Aralu et al., 2024; Ashong et al., 2025; Genthe et al., 2013; Salam et al., 2024). These challenges highlight the urgent need for sustainable and community-based solutions to improve water quality while simultaneously fostering environmental awareness.

Various approaches have been implemented to address water pollution, ranging from conventional wastewater treatment systems to modern technological interventions (Altowayti et al., 2022; Jha & Siddiqui, 2023; Panigrahi et al., 2025; Rath et al., 2025; Shamim et al., 2026; Tanveer et al., 2023). However, many of these methods require substantial financial investment, technical expertise, and infrastructure, which are often not feasible for community-level implementation (Adom & Simatele, 2024; Barbosa et al., 2016; Eschenbach et al., 2006; Giakoumis & Voulvoulis, 2018; Glinskiene & Daraškevičiute, 2006; Gourbesville & Ma, 2022; Maneewan & Van Roon, 2017). Therefore, there is a growing interest in alternative, low-cost, and environmentally friendly solutions that can be easily adopted by local communities. One promising approach is the utilization of eco-enzyme, a natural liquid produced through the fermentation of organic waste such as fruit and vegetable peels, sugar, and water (Barman et al., 2022; Rathod et al., 2024; Varshini & Gayathri, 2023).

Eco-enzyme has gained increasing attention in recent years due to its multifunctional properties and potential environmental benefits. Previous studies have shown that eco-enzyme contains beneficial microorganisms and enzymes that can help decompose organic pollutants, reduce odors, and improve water quality (Agustin & Widyaningrum, 2026; Hastuti et al., 2025; Permatananda & Pandit, 2023; Salvi et al., 2024; Sisri & Surtikanti, 2022; Soleha et al., 2025; Tuhumury et al., 2024; Wikaningrum & Anggraina, 2022). Additionally, the production of eco-enzyme supports waste reduction by utilizing household organic waste that would otherwise contribute to environmental pollution. This aligns with the principles of circular economy and sustainable waste management, making eco-enzyme not only a solution for water treatment but also a strategy for reducing solid waste at the source.

Despite its potential, the application of eco-enzyme in river water treatment, particularly in the context of community service programs, remains relatively underexplored. Most existing studies focus on laboratory-scale experiments or limited field applications, with insufficient emphasis on community involvement and practical implementation. In the case of Badung River, efforts to improve water quality have been carried out through government programs and environmental campaigns. However, these initiatives often face challenges related to community participation, sustainability, and long-term impact. Therefore, integrating eco-enzyme utilization into community-based environmental programs presents an innovative approach that combines scientific knowledge with active public engagement.

Community participation plays a crucial role in the success of environmental management initiatives (Ananga et al., 2020; Anas et al., 2023; Khurun'in et al., 2024). Empowering local communities to actively contribute to river conservation efforts can enhance the effectiveness and sustainability of such programs. Through education, training, and direct involvement in eco-enzyme production and application, communities can develop a sense of ownership and responsibility toward their environment (Angriani et al., 2019; Kusin et al., 2019; Lamprom et al., 2025). This participatory approach not only improves environmental outcomes but also strengthens social cohesion and environmental awareness among community members.

In addition, the use of eco-enzyme as a water treatment alternative is highly relevant in the context of sustainable development goals (SDGs), particularly those related to clean water and sanitation, sustainable cities and

communities, and responsible consumption and production (Al-Astani Tengku Din et al., 2025; Mandal et al., 2025). By promoting the use of eco-enzyme, this initiative supports environmentally friendly practices that are accessible, affordable, and adaptable to local conditions. Furthermore, it encourages behavioral change at the household level, which is essential for achieving long-term environmental sustainability.

Considering the environmental challenges faced by Badung River and the potential benefits of eco-enzyme, it is necessary to explore and optimize its application as a community-based solution for improving water quality. This study aims to address the gap between theoretical knowledge and practical implementation by involving local communities in the production and utilization of eco-enzyme. The optimization process includes identifying appropriate methods of application, determining effective dosages, and evaluating the impact on water quality parameters.

Therefore, the purpose of this community service activity is to optimize the utilization of eco-enzyme to improve the water quality of Badung River in Denpasar. Specifically, this study seeks to (1) increase community awareness and participation in environmental conservation, (2) provide practical training on eco-enzyme production and application, and (3) evaluate the effectiveness of eco-enzyme in enhancing water quality. Through this integrated approach, it is expected that the program will not only contribute to environmental improvement but also promote sustainable practices within the community.

In conclusion, addressing water pollution in urban rivers requires innovative, inclusive, and sustainable solutions. Eco-enzyme offers a promising alternative that combines environmental benefits with community empowerment. By optimizing its utilization in Badung River, this study contributes to the development of practical and scalable approaches for improving water quality while fostering a culture of environmental responsibility among local communities.

Implementation Method

This community service activity was designed as a participatory, solution-oriented program to improve the water quality of the Badung River in Denpasar by optimizing eco-enzyme utilization. The program's implementation consisted of several systematic stages: preliminary assessment, preparation, implementation, monitoring, and evaluation. Each stage was carried out collaboratively between the service team and the local community, the main partners, to ensure the program's sustainability and effectiveness.

The initial stage involved a preliminary assessment to identify the main problems related to water pollution in the Badung River. This stage was conducted through direct observation, informal interviews with local residents, and documentation of environmental conditions. The assessment focused on identifying sources of pollution, community behavior regarding waste disposal, and the level of public awareness toward environmental conservation. The results of this stage served as the basis for designing appropriate intervention strategies tailored to the community's needs and conditions.

The preparation stage included developing educational materials, procuring tools and materials, and coordinating with community representatives. The tools used in this activity included plastic fermentation containers, measuring cups, stirring tools, and water-quality testing kits. The main materials used for eco-enzyme production consisted of organic waste such as fruit and vegetable peels, brown sugar or molasses, and clean water.

In addition, simple water quality indicators, such as pH, turbidity, and odor, were used to assess the treatment's effectiveness. All materials and tools were selected based on their availability, affordability, and ease of use to ensure that the community could independently replicate the process.

The implementation stage involved a series of training and hands-on activities conducted directly with community members. The training was delivered using simple and communicative language to ensure that all participants could easily understand the concepts and procedures. The activity began with an educational session on environmental issues, the importance of river conservation, and the benefits of eco-enzyme. This was followed by a practical demonstration of eco-enzyme production, including the proper ratio of ingredients, fermentation process, and storage techniques. Participants were then guided to produce eco-enzyme independently under the supervision of the service team.

After the fermentation period, the application stage was carried out by introducing eco-enzyme into selected points along the Badung River. The dosage and method of application were adjusted based on preliminary observations and existing references to ensure optimal results. The application process was conducted collaboratively with community members to encourage active participation and a sense of ownership. In addition to direct application to the river, participants were also encouraged to use eco-enzyme in their households as a sustainable environmental practice.

Monitoring and evaluation were conducted to assess the effectiveness of the program and the impact of eco-enzyme utilization on water quality. Monitoring activities included periodic observations and measurements of water quality parameters such as pH level, turbidity, and odor before and after the application of eco-enzyme. Data were collected and documented systematically to track changes over time. In addition, qualitative data were obtained through participant feedback, interviews, and observations of changes in community behavior and awareness.

The data obtained from both quantitative and qualitative approaches were analyzed using descriptive statistical methods. Quantitative data, such as water quality measurements, were analyzed by comparing the average values before and after treatment to identify trends and improvements. Meanwhile, qualitative data were analyzed through data reduction, categorization, and interpretation to understand the social impact of the program. The results of the analysis were then used to evaluate the effectiveness of the intervention and to formulate recommendations for future improvements.

Overall, this method emphasizes a participatory approach that integrates scientific knowledge with community engagement. By involving the community in every stage of the program, from planning to evaluation, this activity aims not only to improve water quality but also to foster long-term environmental awareness and sustainable practices among local residents.

Result and Discussion

The implementation of the community service program on the optimization of eco-enzyme utilization for improving the water quality of the Badung River in Denpasar yielded both quantitative and qualitative outcomes. These results reflect not only the environmental impact of eco-enzyme application but also the social transformation within the participating community. The discussion presented in this section integrates findings from

field observations, water quality measurements, and community engagement activities.

Environmental Condition and Initial Findings

The preliminary findings of this study indicate that the Badung River is experiencing moderate to high levels of pollution, as evidenced by increased turbidity, unpleasant odor, and fluctuating pH levels ranging from slightly acidic to neutral. From an academic perspective, these conditions can be interpreted as a direct consequence of anthropogenic pressures, particularly domestic activities from densely populated settlements along the riverbanks. Household waste, including organic matter, greywater discharge, and inadequate waste management practices, constitutes a primary source of contamination that significantly contributes to the degradation of water quality.

Theoretically, these findings are consistent with the framework proposed which emphasizes that rivers in highly populated regions are particularly vulnerable to water quality degradation due to the accumulation of untreated domestic waste and insufficient sanitation infrastructure. Such pressures not only affect physical parameters, such as turbidity, but also alter chemical and biological characteristics, including pH instability and increased microbial activity (Adetunji et al., 2023; Aqel et al., 2024; Cong et al., 2025; Shukla et al., 2024; Zhang et al., 2024).

Furthermore, the elevated turbidity observed in this study can be explained through the water quality assessment perspective, where suspended particles and dissolved organic matter serve as key indicators of aquatic pollution. Organic materials entering the river undergo microbial decomposition, leading to increased biological activity and oxygen demand, which in turn disrupts the ecological balance of the aquatic system (Gómez et al., 2023; Passerini et al., 2016; Perwira et al., 2020; Ylla et al., 2012). This process also contributes to the emergence of unpleasant odors, as identified in the field observations of this research.

In the Indonesian context, these results align with some findings that pH, turbidity, and organic content are critical indicators in assessing water pollution levels. Water bodies contaminated by domestic waste typically exhibit unstable pH values and elevated turbidity due to increased suspended materials and biological processes (Faisal et al., 2015; Lestari et al., 2021; Musa et al., 2021; Subehi et al., 2016; Yani et al., 2019). This correspondence reinforces the interpretation that the condition of the Badung River reflects the general characteristics of urban river pollution.

Conceptually, these results indicate a strong interrelationship between community behavior, environmental management systems, and aquatic ecosystem quality. Rivers function not only as natural hydrological systems but also as socio-environmental spaces that are heavily influenced by human activities. Consequently, the degradation of water quality observed in this study underscores the necessity of implementing interventions that are not solely technical but also social and educational in nature. Participatory and sustainable approaches are essential to promote behavioral change, enhance environmental awareness, and ultimately restore the ecological function of the river.

Implementation of Eco-Enzyme and Community Participation

The introduction of eco-enzyme as an alternative solution was met with a positive response from the community. During the training sessions,

participants demonstrated a high level of enthusiasm and engagement, particularly during the hands-on activities of eco-enzyme production. The use of simple language and practical demonstrations proved effective in facilitating knowledge transfer, allowing participants to understand the concept and benefits of eco-enzyme easily.

The production of eco-enzyme using locally available organic waste not only provided a solution for liquid waste treatment but also addressed the issue of solid waste management at the household level. Participants were able to utilize fruit and vegetable waste that would otherwise be discarded, thereby reducing the volume of organic waste in the environment as seen on Figure 1. This dual benefit highlights the potential of eco-enzyme as an integrated approach to environmental management.



Figure 1. Socialization about eco-enzyme

Furthermore, the participatory approach adopted in this program played a crucial role in enhancing community ownership and responsibility. Community members were actively involved in every stage of the process, from production to application, which contributed to the sustainability of the initiative. The collaborative application of eco-enzyme in selected areas of the river also fostered a sense of collective action toward environmental conservation.



Figure 2. Community involvement

Changes in Water Quality Parameters

Following the application of eco-enzyme, observable changes in water quality were recorded over the monitoring period. One of the most noticeable

improvements was the reduction of unpleasant odors in the treated areas. This change can be attributed to the enzymatic activity of eco-enzyme, which facilitates the decomposition of organic pollutants responsible for odor production. This finding is supported by the study conducted by Galintin et al. (2021), which demonstrated that eco-enzyme derived from organic waste is effective in breaking down biodegradable compounds and reducing odor-causing substances in wastewater systems.

In terms of turbidity, there was a gradual decrease in the level of suspended particles in the water. Although the improvement was not drastic within a short period, consistent application of eco-enzyme showed a positive trend toward clearer water conditions. This result is in line with the findings of Yong et al. (2022), who reported that eco-enzyme contributes to the reduction of suspended solids and enhances water clarity through the degradation of organic matter and the promotion of natural sedimentation processes.



Figure 3. *Badung river condition*

The pH level of the water also showed a tendency to stabilize after the application of eco-enzyme. While initial measurements indicated fluctuations in pH, post-treatment observations revealed a more balanced condition approaching neutral levels. This stabilization is crucial for sustaining aquatic organisms and maintaining ecological equilibrium. Previous research by Yustiani et al. (2023) further supports this finding, indicating that eco-enzyme can help regulate pH levels by promoting biochemical processes that buffer extreme acidity or alkalinity in polluted water.

Although this study primarily focused on simple water quality indicators, the observed improvements are consistent with prior research highlighting the effectiveness of eco-enzyme in reducing organic pollutants and improving environmental conditions. Nevertheless, the degree of improvement is influenced by several factors, including the concentration of eco-enzyme applied, the frequency of application, and the initial pollution load of the river. These variables should be carefully considered in future implementations to optimize the effectiveness of eco-enzyme as a sustainable environmental intervention.

Social Impact and Behavioral Changes

In addition to environmental improvements, this program also generated significant social impacts within the community. One of the key outcomes was the increase in environmental awareness among participants. Through educational sessions and direct involvement in eco-enzyme production,

community members gained a better understanding of the relationship between human activities and environmental degradation.



Figure 4. *The process of pouring eco-enzyme solution*

This increased awareness was reflected in changes in community behavior, particularly in waste management practices. Several participants reported a reduction in the habit of disposing of organic waste directly into the river, opting instead to process it into eco-enzyme. This behavioral shift is a critical step toward long-term environmental sustainability, as it addresses the root cause of pollution rather than merely treating its effects.

Moreover, the program strengthened social cohesion by encouraging collaboration and collective action. Community members worked together in producing and applying eco-enzyme, which fostered a sense of unity and shared responsibility. This aspect is particularly important in community-based environmental programs, where the success of the initiative largely depends on active participation and cooperation.

Challenges and Limitations

Despite the positive outcomes, several challenges were encountered during the implementation of the program. One of the main challenges was the time required for the fermentation process of eco-enzyme, which typically takes several weeks to months. This delay limited the immediate availability of eco-enzyme for large-scale application, requiring careful planning and continuous production by the community.

Another challenge was the variability in the quality of eco-enzyme produced by participants. Differences in the composition of raw materials, fermentation conditions, and adherence to procedures resulted in variations in the effectiveness of the final product. This highlights the need for continuous guidance and standardization in the production process to ensure consistent results.

In terms of water quality improvement, the impact of eco-enzyme was gradual and localized. Given the scale of the river and the continuous input of pollutants, the application of eco-enzyme alone may not be sufficient to achieve significant improvements without complementary measures. Therefore, eco-enzyme should be considered as part of an integrated approach to river management that includes waste reduction, policy support, and infrastructure development.

Conclusion and Suggestion

The implementation of eco-enzyme utilization as a community-based approach to improving the water quality of the Badung River in Denpasar demonstrates that environmentally friendly and low-cost solutions can

effectively address urban water pollution when combined with active community participation. This program successfully achieved its primary objectives, namely increasing community awareness of environmental issues, equipping participants with practical skills in producing and applying eco-enzyme, and contributing to the gradual improvement of water quality indicators such as odor reduction, turbidity, and pH stabilization.

Rather than merely providing a technical solution, this initiative highlights the importance of behavioral change and community empowerment as key factors in sustainable environmental management. The involvement of local residents in all stages of the program fostered a sense of ownership and responsibility, which is essential for ensuring the continuity of environmental conservation efforts. The findings suggest that eco-enzyme utilization is not only effective as a complementary method for water treatment but also serves as an educational tool to promote sustainable waste management practices at the household level.

However, the impact of eco-enzyme application on river water quality is gradual and requires consistent and long-term implementation to achieve more significant results. Therefore, the sustainability of this initiative depends on the commitment of the community as well as support from relevant stakeholders. The integration of eco-enzyme utilization into broader environmental programs and policies is necessary to maximize its effectiveness and scalability.

For future follow-up, it is recommended that continuous training and mentoring be provided to the community to ensure the consistency and quality of eco-enzyme production. Standardization of production procedures and application methods is also needed to optimize the effectiveness of the solution. In addition, further studies should incorporate more comprehensive water quality parameters, such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), and microbial analysis, to obtain a more accurate evaluation of environmental impact.

Moreover, collaboration with local government, environmental agencies, and academic institutions should be strengthened to support the expansion and sustainability of the program. The development of community-based environmental groups or eco-enzyme centers could serve as a platform for continuous education, production, and distribution of eco-enzyme. Finally, integrating this initiative with public awareness campaigns and waste management programs will enhance its long-term impact and contribute to the creation of a cleaner and more sustainable river environment in Denpasar.

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