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Evaluating the Effectiveness of Eco Enzyme in Reducing COD, BOD, and TDS of Leachate at Basirih Landfill under Different Contact Time Conditions

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ABSTRACT

Leachate is one of the significant environmental impacts of landfill operations, characterized by high concentrations of both organic and inorganic pollutants. Basirih Landfill, the sole active final disposal site in Banjarmasin City, generates large volumes of leachate that remain inadequately treated according to environmental quality standards. This study aims to evaluate the effectiveness of Eco Enzyme as a natural biological agent in reducing key leachate pollutant parameters—namely Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), and Total Dissolved Solids (TDS)—by considering variations in application method and contact time. A quasi-experimental design was employed, using a *before-after with control* model. Eco Enzyme was applied through surface spraying onto leachate ponds (with contact durations of 3–10 days) and through direct mixing during sampling. Analytical results indicate that Eco Enzyme did not significantly reduce COD within short contact durations, although it demonstrated potential for rapid reaction when applied directly. BOD levels consistently decreased across all sampling points, approaching or meeting national quality standards. Conversely, TDS tended to increase at points with longer contact times, likely due to the accumulation of dissolved compounds from decomposition processes. Therefore, the effectiveness of Eco Enzyme is highly dependent on contact duration and is recommended to be integrated with additional treatment methods such as aeration or filtration to achieve more optimal leachate management.

Keywords: Eco Enzyme, leachate, Basirih Landfill, biological treatment, appropriate technology

INTRODUCTION

Urbanization is one of the most prominent global trends of the 21st century, with more than 55% of the world's population now residing in urban areas—and this figure is projected to rise to 68% by 2050 (United Nations, 2018). Alongside urban growth, the volume of municipal solid waste has also increased significantly, posing serious challenges to environmental management. Inadequate waste management not only leads to soil and water pollution but also exacerbates the impacts of climate change. Organic waste that decomposes anaerobically in landfills produces methane,

a greenhouse gas that is 25 times more potent than carbon dioxide over a 100-year period (IPCC, 2021). Furthermore, leachate generated from waste decomposition contains pollutants that can contaminate both groundwater and surface water bodies.

Solid waste management has become one of the most pressing global environmental issues. According to *What a Waste 2.0* published by the World Bank (Kaza et al., 2018), the global volume of waste is estimated to reach 2.01 billion tons per year and is projected to increase to 3.4 billion tons by 2050 if not addressed through integrated and sustainable management systems. In many developing countries, including Indonesia, the majority of waste is still managed through open or semi-open landfill systems. These practices pose significant environmental and public health risks, one of which is the formation of leachate—a toxic liquid resulting from waste decomposition and rainwater percolation—containing high concentrations of both organic and inorganic pollutants (Kjeldsen et al., 2002; Guerrero et al., 2013). If inadequately treated, leachate may infiltrate into groundwater or flow into surface water bodies, leading to aquatic environmental degradation and serious health risks for surrounding communities.

Moreover, landfills are major sources of greenhouse gas (GHG) emissions, especially methane (CH_4), which is produced during the anaerobic decomposition of organic waste. The Intergovernmental Panel on Climate Change (IPCC) reported that the waste sector contributes approximately 3% of total global GHG emissions, with the highest proportion originating from landfills (IPCC, 2021). Methane has a global warming potential (GWP) 25 times greater than carbon dioxide over a 100-year period, making landfill management a critical sector in climate change mitigation. In response to these challenges, more sustainable, low-emission, and appropriate technology-based waste treatment approaches are urgently needed. One emerging approach is the use of Eco Enzyme—a liquid product of organic waste fermentation that contains active enzymes and beneficial microorganisms. Eco Enzyme shows potential as a biological agent to accelerate the degradation of organic compounds in wastewater, including leachate (Phongthai et al., 2021).

In South Kalimantan, one of the largest landfill sites is the Basirih Landfill, located in Banjarmasin City. Constructed in 1997 with financial support from the World Bank, the landfill began effective operations in 2000. Covering an area of 39.5 hectares, the facility was originally designed for operation until 2021, but it continues to function as the city's primary final disposal site. With increasing waste generation, the volume of leachate has also grown significantly. Unfortunately, the existing leachate treatment system remains conventional—relying on sedimentation and facultative ponds—which has proven insufficient in reducing pollutant loads to levels that meet environmental quality standards.

According to the Indonesian Ministry of Public Works and Housing Regulation No. 3 of 2013, leachate quality at landfills must comply with the following environmental standards:

- COD (Chemical Oxygen Demand): maximum 300 mg/L
- BOD (Biochemical Oxygen Demand): maximum 150 mg/L
- TDS (Total Dissolved Solids): maximum 2,000 mg/L

These parameters are also used to calculate the Landfill Risk Index, which assesses the potential for environmental contamination from landfill operations, with leachate quality as a primary indicator.

Eco Enzyme has been widely applied at the household level for domestic wastewater treatment, water purification, and as a bio-fertilizer. The liquid is produced through the fermentation of organic kitchen waste—such as fruit peels, brown sugar, and water—over a period of approximately three months. The fermentation process generates active compounds such as protease,

amylase, and lipase enzymes, as well as microorganisms like *Lactobacillus spp.* and *Saccharomyces spp.* (Phongthai et al., 2021). Previous studies have demonstrated that Eco Enzyme can reduce COD and BOD levels in wastewater through its biological and enzymatic activity (Prihantini et al., 2021; Siripong et al., 2020). However, the application of Eco Enzyme for large-scale leachate treatment, particularly in open systems such as treatment ponds at the Basirih Landfill, has received limited scientific attention. The effectiveness of Eco Enzyme is influenced by several technical factors, one of the most critical being contact time—the duration of interaction between Eco Enzyme and leachate. Enzymatic and microbial activity requires sufficient time to perform effectively; therefore, understanding the optimal contact duration is crucial for achieving efficient degradation processes.

Given these conditions, this study aims to evaluate the effectiveness of Eco Enzyme in reducing major leachate pollutant parameters—COD, BOD, and TDS—by considering different application methods and contact durations. The findings are expected to contribute to the scientific development of more affordable and sustainable leachate treatment strategies that can be adopted at both community and local government levels, while supporting compliance with national environmental standards for landfill management.

MATERIALS & METHODS

Study Location

This study was conducted at the Basirih Landfill (TPA Basirih), located in Basirih Subdistrict, West Banjarmasin District, Banjarmasin City. As the only active landfill in the city, TPA Basirih serves as the primary disposal site for municipal solid waste and similar types of waste. The landfill operates under an open dumping system and is equipped with leachate treatment ponds and groundwater monitoring wells. Leachate generation at this site is relatively high and fluctuates, particularly during the rainy season. The current pond-based treatment system has not been able to sufficiently reduce pollutant loads—specifically COD, BOD, and TDS—to meet the environmental quality standards set by the Ministry of Public Works and Housing Regulation No. 3 of 2013. This site was selected due to its relevance as a representative urban landfill facing challenges in sustainable leachate management. The presence of inlet ponds, outlet ponds, and monitoring wells allowed for the field evaluation of the effectiveness of Eco Enzyme in reducing leachate pollutants under real-world conditions.

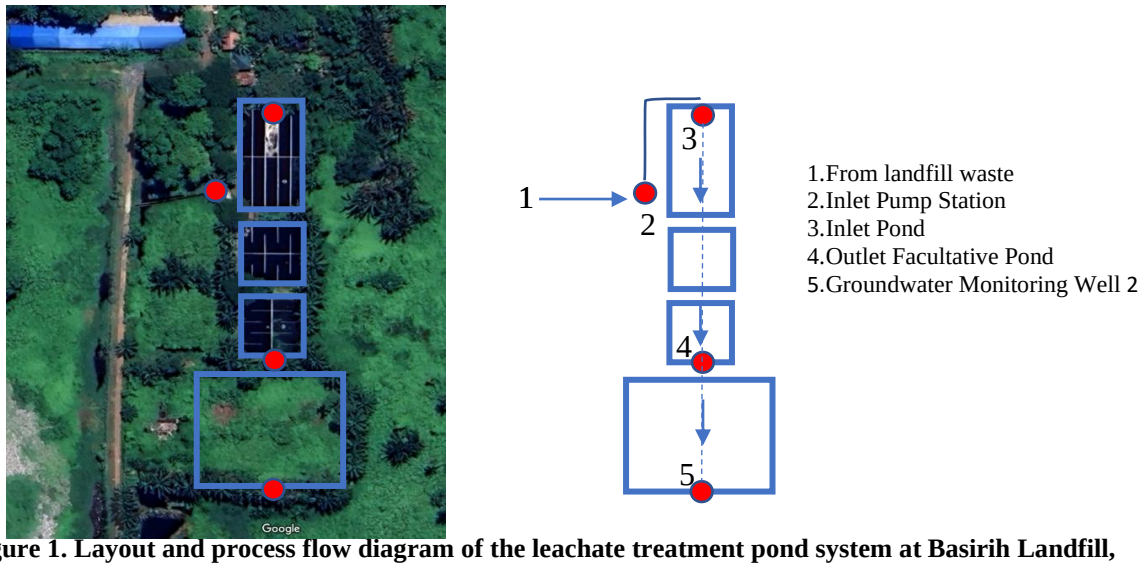

Figure 1. Layout and process flow diagram of the leachate treatment pond system at Basirih Landfill, consisting of anaerobic, facultative, maturation ponds, and final discharge area.

Experimental Design and Treatment

This study employed a quasi-experimental design using a *before-after with control* model to evaluate the influence of Eco Enzyme application on leachate pollutant concentrations. This model enabled comparisons between treated and control samples collected from the same location and time, allowing any observed changes to be attributed to the presence of Eco Enzyme and its contact time. The study focused on two key variables that influence the effectiveness of Eco Enzyme: Application method (direct application to ponds vs. direct addition to sample bottles) and contact duration (3–10 days vs. less than 1 hour)

The treatment of Eco Enzyme was implemented through two methods:

a. Application of Eco Enzyme Prior to Sampling

In this method, Eco Enzyme was directly applied to the leachate ponds at a dilution ratio of 1:500.000. The application was carried out on April 19, 2025, to allow reaction time between the active compounds in the Eco Enzyme and the leachate prior to sampling and laboratory analysis.

The two pond locations for this treatment were:

- Leachate Inlet (Initial Pond) — receiving untreated leachate.
- Leachate Outlet (Facultative Pond) — final treatment pond before discharge or infiltration.

Sampling was conducted between April 22 and 29, 2025, resulting in estimated contact durations of 3 to 10 days, depending on the sampling location. This approach aimed to assess the effectiveness of Eco Enzyme in situ, with sufficient time for enzymatic and microbial activity to take place.

b. Addition of Eco Enzyme at Time of Sampling

In the second method, Eco Enzyme was added directly to leachate samples collected from the field. This approach was designed to simulate laboratory conditions and evaluate the immediate effects of Eco Enzyme with very short contact times (less than 1 hour). The addition was performed during sampling on April 22, 23, and 27, 2025, at two locations:

Leachate Inlet (Pump Station) — where leachate enters the treatment system.

Outlet Well 2 — a groundwater monitoring well around the landfill site.

For each treatment sample with Eco Enzyme, a corresponding control sample without Eco Enzyme was collected simultaneously and analyzed using the same methods and instruments. This ensured that any observed changes in COD, BOD, and TDS values could be confidently attributed to the influence of Eco Enzyme rather than other external factors. This dual-method approach provided comparative insights into the effectiveness of Eco Enzyme under both natural (extended contact) and immediate (short contact) conditions. Thus, the study not only evaluated the impact of Eco Enzyme presence but also examined the importance of reaction time as a critical factor in successful biological leachate treatment.

Sampling and Testing Schedule

- Sample Collection:
  - April 22, 2025: Leachate Inlet & Outlet Ponds
  - April 23, 2025: Outlet Well 2
  - April 27, 2025: Leachate Inlet (Pump Station)
- Laboratory Testing:
  - COD and TDS: April 29, 2025
  - BOD: May 8, 2025 (using 5-day incubation/BOD_5 method)

Laboratory Analysis Methods

All laboratory analyses were performed at the Environmental Engineering Laboratory, Faculty of Engineering, Lambung Mangkurat University, using the following standard procedures:

a. COD (Chemical Oxygen Demand) Analysis

COD was determined using the permanganate oxidation method (acidic oxidation), which involves oxidizing organic substances with potassium permanganate ($KMnO_4$) in the presence of

sulfuric acid (H_2SO_4). The COD value was calculated based on the volume of oxidizing agent consumed. This method followed SNI 6989.73:2009, and results were expressed in mg/L O_2.

b. BOD (Biochemical Oxygen Demand) Analysis

BOD analysis followed the Modified Winkler Method, which measures the difference in dissolved oxygen (DO) concentrations between day 0 and day 5 of incubation (BOD_5). The procedure complied with SNI 6989.72:2009. DO was determined by titration using sodium thiosulfate ($Na_2S_2O_3$) with starch as an indicator. Samples were incubated for five days at 20 ±1°C in the dark.

c. TDS (Total Dissolved Solids) Analysis

TDS was analyzed using the electrometric method with a digital TDS meter, where electrical conductivity served as an indicator of the dissolved solids concentration. This procedure followed SNI 06-6989.27-2005 and was conducted in a temperature-controlled laboratory environment.

Table 1. COD, BOD, and TDS Levels in Leachate Samples Treated

Sample Description	Date	COD (mg/L)	TDS (mg/L)	BOD (mg/L)
Leachate Inlet (Pond)	22 April 2025	3431.62	1994	175.00
Leachate Inlet (Pond) + Eco Enzyme	22 April 2025	3431.62	1970	150.00
Leachate Outlet (Facultative Pond)	22 April 2025	3860.57	797	166.67
Leachate Outlet (Facultative Pond) + Eco Enzyme	22 April 2025	3860.57	1550	137.50
Groundwater Monitoring Well 2	23 April 2025	3002.67	845	141.67
Groundwater Monitoring Well 2 + Eco Enzyme	23 April 2025	2573.71	828	133.33
Leachate Inlet (Pump Station)	27 April 2025	4289.52	2660	120.83
Leachate Inlet (Pump Station) + Eco Enzyme	27 April 2025	4289.52	2660	108.33
Leachate Outlet (Facultative Pond)	27 April 2025	3002.67	1530	108.33

Eco Enzyme Used

The Eco Enzyme used in this study was produced through the fermentation of organic kitchen waste (fruit peels), brown sugar, and water at a ratio of 1:3:10. The mixture was fermented for three months in a sealed container. Prior to application, the Eco Enzyme was filtered to remove solid residues to avoid interference during laboratory analysis.

Data Analysis

The data were analyzed using a descriptive quantitative approach by comparing the COD, BOD, and TDS values between:

- Samples with and without Eco Enzyme treatment
- Locations treated with early application (contact time ≥ 10 days) and those treated during sampling
- Measured concentrations and the environmental quality standards as defined in the Ministry of Public Works Regulation No. 3/2013, namely:
  - COD ≤ 300 mg/L
  - BOD ≤ 150 mg/L
  - TDS ≤ 2,000 mg/L

Percentage reduction was also calculated to determine the relative effectiveness of Eco Enzyme at each observation point.

Justification of Method Selection

The selection of research methods in this study was based on practical, technical, and scientific considerations, tailored to the site characteristics and research objectives. The main reasons for adopting a quasi-experimental approach and standardized laboratory analyses are as follows:

1. **Relevance to Actual Leachate Management Conditions in the Field**
   The *before-after with control* quasi-experimental model was chosen because it reflects the reality of leachate treatment systems at the Basirih

Landfill, where full control over environmental variables is not feasible. In landfill wastewater management, variables such as flow volume, waste composition, and weather conditions cannot be strictly controlled. Hence, this model was considered more realistic and applicable for assessing the impact of Eco Enzyme intervention on leachate quality parameters.

2. **Simplicity and Cost-Effectiveness**
   This method employs a simple, low-cost treatment technology using locally available materials—Eco Enzyme—which aligns with appropriate technology and environmentally friendly principles. The fermentation process can be carried out by local communities or educational institutions with minimal cost. Consequently, the experimental design, which does not require specialized reactors or industrial-scale treatment systems, provides an effective solution for addressing the limited leachate treatment facilities at the Basirih Landfill.
3. **Compliance with National Standards and Laboratory Practice**
   All analytical methods used in this study—permanganate oxidation for COD, the modified Winkler method for BOD, and the electrometric method for TDS—were conducted in accordance with Indonesian National Standards (SNI) and the *Standard Methods for the Examination* of *Water and Wastewater* (APHA, 2017). These methods are widely adopted in environmental engineering laboratories across Indonesia, including the Environmental Engineering Laboratory, Faculty of Engineering, Lambung Mangkurat University, where all water quality analyses in this study were performed. Such standardization ensures that the results are reproducible, nationally comparable, and scientifically valid for practical reference.

RESULT

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a key parameter for evaluating wastewater quality, including landfill leachate. COD measures the total amount of oxygen required to oxidize organic compounds—both biodegradable and non-biodegradable—into simpler molecules. High COD levels indicate a significant organic pollution load, which may severely impact aquatic ecosystems. This study aims to assess the effectiveness of Eco Enzyme in reducing complex organic compounds in the leachate at Basirih landfill. As described in the methodology section, two treatment schemes were applied: Direct application of Eco Enzyme into the leachate pond, allowing for natural contact over 3–10 days. And, direct addition of Eco Enzyme to the sample bottle at a 1:500,000 ratio during sampling (short-contact scenario). Laboratory tests using the permanganometric method yielded the following results:

a. No COD Reduction at Sampling Points Treated with Eco Enzyme for 3 Days

Two sampling locations that received direct Eco Enzyme application for three consecutive days showed no changes in COD concentration. This suggests that a 3-day contact duration was insufficient to significantly reduce the dissolved organic pollutant load. Detailed results are as follows:

- Leachate Inlet (Pond): COD remained unchanged at 3431.62 mg/L, the same as before Eco Enzyme treatment.
- Facultative Leachate Outlet: COD remained at 3860.57 mg/L after three days of treatment, with no reduction observed.

These findings indicate that a 3-day Eco Enzyme treatment was ineffective in lowering COD levels at heavily polluted sites, possibly due to:

- Insufficient contact time for bioconversion of complex organic compounds,

- Unfavorable environmental conditions for microbial activity within the Eco Enzyme,
- Or inadequate Eco Enzyme concentration for the level of contamination.

b. COD Reduction Observed at Sampling Point Treated with Eco Enzyme During Sampling

In contrast, the Outlet of Well 2, which did not undergo prior Eco Enzyme treatment but was directly dosed with Eco Enzyme during sampling, showed a notable COD reduction:

- Initial COD: 3002.67 mg/L
- COD after Eco Enzyme application: 2573.71 mg/L
- COD reduction: 428.96 mg/L, equivalent to approximately 14.3%

This result suggests that direct application of Eco Enzyme during sampling may have triggered a rapid chemical or biological reaction in the short term, or that the interaction between Eco Enzyme and compounds in the sample was more effective under controlled conditions, despite the absence of extended contact time.

Further investigation is required to clarify:

- Whether the effect is temporary or sustained,
- Whether the reduction was due to enzymatic action, oxidative processes, or mere dilution,
- How parameters such as concentration, pH, temperature, and contact time influence the efficacy of Eco Enzyme in COD reduction.

Table 2. Summary Table of COD Test Results

Sampling Point	Eco Enzyme Treatment Method	Contact Time	Initial COD (mg/L)	Final COD (mg/L)	COD Reduction (mg/L)	% Reduction
Leachate Inlet (Pond)	Poured Eco Enzyme	3 days	3431.62	3431.62	0.00	0.0%
Facultative Leachate Outlet	Poured Eco Enzyme	3 days	3860.57	3860.57	0.00	0.0%
Outlet Well 2	Eco Enzyme added directly during sampling	No contact time	3002.67	2573.71	428.96	14.3%

These findings demonstrate that Eco Enzyme application via pond irrigation with a 3-day contact period is not yet effective in significantly lowering COD levels. This is consistent with the nature of organic compounds in leachate, which often include complex and recalcitrant substances (such as humic and fulvic acids) that require prolonged decomposition times and specific conditions—such as agitation, aeration, or optimal temperature—for effective breakdown by microorganisms or active enzymes in the Eco Enzyme. In contrast, COD reduction was observed in a sample treated directly with Eco Enzyme in a more homogeneous and controlled environment (inside a sample bottle). This suggests that, under limited-volume and enclosed conditions, enzymatic activity in Eco Enzyme may react more rapidly—although the reduction still did not meet the required standard (≤ 300 mg/L, based on Ministry of Public Works Regulation No. 3 of 2013).

The persistently high COD values at the pond sites further suggest that the degradation process of organic compounds via Eco Enzyme is slow and may require contact durations longer than 3 days, or even additional treatment steps such as aeration, sedimentation, or coagulation, to break down complex organic chains into simpler forms. These results are consistent with the findings of Phongthai et al. (2021), who reported that a minimum of 7–14 days of contact is required for Eco Enzyme to produce a significant reduction in COD in domestic wastewater. Siripong et al. (2020) also emphasized the importance of aeration and mixing to enhance the enzymatic and

microbial performance during organic decomposition.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is a key indicator used to measure the amount of oxygen required by aerobic microorganisms to decompose organic matter present in water. BOD reflects the level of biodegradable organic pollution and serves as one of the main parameters in determining pollutant loads in wastewater, including landfill leachate. BOD testing in this study was conducted using the Winkler method with a five-day incubation period (BOD_5).

The results indicate that all sampling points exhibited a reduction in BOD values following Eco Enzyme treatment—either through prior pond irrigation or direct addition during sample collection. The detailed results are presented Table 3:

Table 3. Summary of BOD Reduction After Eco Enzyme Treatment

Location	Before Eco Enzyme (mg/L)	After Eco Enzyme (mg/L)	Reduction (mg/L)
Leachate Inlet (Pond)	175.00	150.00	25.00
Facultative Outlet	166.67	137.50	29.17
Leachate Inlet (Pump)	120.83	108.33	12.50
Outlet Well 2	141.67	133.33	8.34

All initial BOD values exceeded the regulatory threshold (≤ 150 mg/L, as stipulated in the Indonesian Ministry of Public Works Regulation No. 3/2013). However, after treatment, two locations—Leachate Inlet (Pond) and Facultative Outlet—achieved values that approached or even met the environmental quality standards. In contrast to COD, the BOD parameter consistently decreased following Eco Enzyme application, including at sampling points that only received direct dosing during sample collection. This indicates that Eco Enzyme is more effective at targeting simpler and more readily biodegradable organic compounds—such as sugars, short-chain proteins, and simple carbon-based substances—that typically dominate the BOD load in leachate.

The working mechanism of Eco Enzyme relies on fermentative microbial activity and enzymes such as protease, amylase, and lipase, which naturally facilitate the decomposition of organic matter. The observed reduction in BOD also suggests that Eco Enzyme has the potential to enhance biological activity in leachate treatment systems, especially when sufficient contact time and aerobic conditions are provided. These findings are consistent with those of Prihantini et al. (2021), who reported that Eco Enzyme significantly reduced BOD in domestic wastewater within less than 7 days. This study further supports the idea that Eco Enzyme can be applied within existing pond-based treatment systems without the need for major infrastructure modifications, provided that the treatment is carried out continuously.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) measures the total concentration of dissolved substances in water, including inorganic ions (such as sodium, calcium, and chloride) and soluble organic compounds. This parameter is essential for assessing the salinity level of leachate and its potential impact on groundwater quality. TDS was measured using an electrometric method with a digital TDS meter.

The results showed a significant increase in TDS at one sampling point, while other points remained relatively stable:

Table 4. Changes in TDS Before and After Eco Enzyme Treatment

Location	*Before Eco Enzyme (mg/L)*	*After Eco Enzyme (mg/L)*	*Change*
Leachate Inlet (Pond)	1994	1970	↓ 24
Facultative Outlet	797	1550	↑ 753
Leachate Inlet (Pump)	2660	2660	– (no change)
Outlet Well 2	845	828	↓ 17

The notable increase in TDS at the Facultative Outlet after approximately 10 days of Eco Enzyme contact suggests the accumulation of dissolved substances in the leachate. This is most likely due to the decomposition of organic matter by enzymes in the Eco Enzyme, which produces new soluble compounds such as amino acids, low molecular weight organic substances, and inorganic ions previously bound in complex forms.

This indicates that while biodegradation is occurring, the by-products of organic decomposition have not yet precipitated or been separated from the liquid phase, resulting in higher TDS levels. However, this does not necessarily imply that Eco Enzyme worsens leachate conditions. Rather, it underscores the need for additional post-treatment processes—such as sedimentation or filtration—to effectively reduce TDS concentrations.

Although TDS levels remain within the permissible limit (≤ 2000 mg/L, based on Indonesian Ministry of Public Works Regulation No. 3/2013), the spike at the final pond is noteworthy as it indicates an increase in dissolved substances generated by biological degradation. This emphasizes that while Eco Enzyme facilitates organic matter breakdown, its application should ideally be integrated with further treatment stages to ensure comprehensive water quality improvement.

DISCUSSION

The findings of this study indicate that the effectiveness of Eco Enzyme in reducing leachate quality parameters—namely COD, BOD, and TDS—varies depending on the application method and environmental conditions. Chemical Oxygen Demand (COD) measures the total concentration of oxidizable organic compounds, including complex and recalcitrant substances. The application of Eco Enzyme with a short contact time (< 3 days) under open pond conditions proved ineffective in lowering COD levels. This suggests that the biodegradation of complex organics, such as humic and fulvic acids commonly found in landfill leachate, requires longer contact duration and more supportive treatment environments. Interestingly, the addition of Eco Enzyme directly into the sample during collection appeared to trigger a rapid reaction, although the resulting COD reduction was still insufficient to meet environmental standards. This effect is likely due to initial enzymatic or oxidative activity, which could be enhanced through subsequent treatment processes. Therefore, a combined approach involving Eco Enzyme and supplementary oxidation techniques such as aeration is recommended to optimize the degradation of complex organic matter (Muliarta et al., 2023).

In contrast, Biochemical Oxygen Demand (BOD) responded more positively to Eco Enzyme treatment. BOD levels consistently decreased at all sampling points, regardless of whether the treatment involved prior application or immediate dosing during sampling. The fact that BOD values approached or even met environmental quality standards indicates that Eco Enzyme is effective in accelerating the breakdown of readily biodegradable compounds, such as simple sugars and short-chain proteins. Dinesh and Dinesh (2023) similarly found that Eco Enzyme could significantly reduce BOD in domestic wastewater within less than seven days, due to the fermentative microbial activity and presence of active enzymes such as protease, amylase, and lipase. These findings strengthen the potential of Eco Enzyme as a biological agent in existing leachate treatment systems,

particularly in stabilization ponds. Moreover, BOD appears to be more sensitive than COD as an early indicator of biological treatment performance using Eco Enzyme.

With respect to Total Dissolved Solids (TDS), this study found that Eco Enzyme was not effective in reducing TDS levels. In some cases—particularly where contact time was longer—TDS levels even increased. This increase may be attributed to the accumulation of soluble degradation products such as amino acids and low molecular weight organic compounds, as well as the release of previously bound inorganic ions during organic matter breakdown. Although TDS values remained within regulatory limits, the observed increase indicates that Eco Enzyme tends to promote solubilization rather than removal of pollutants. As such, its application should be paired with physical separation processes such as sedimentation or filtration to prevent a rise in dissolved pollutant loads. This observation aligns with the findings of Muliarta et al. (2023), who reported elevated TDS levels following Eco Enzyme spraying on landfill leachate in Suwung due to incomplete separation of the resulting soluble compounds.

Overall, the study emphasizes that Eco Enzyme shows the highest potential for BOD reduction, has moderate or delayed effects on COD, and requires complementary treatment steps to address TDS. Therefore, Eco Enzyme-based leachate treatment should be designed as part of an integrated, multi-stage system that combines biological, physical, and chemical technologies tailored to each specific pollution parameter.

CONCLUSION

Based on the findings of this study regarding the effect of Eco Enzyme on leachate quality parameters at the Basirih Landfill in Banjarmasin City, the following conclusions can be drawn:

1. Eco Enzyme showed limited effectiveness in reducing COD levels in landfill leachate. Application of Eco Enzyme to leachate ponds for 3–10 days did not result in a significant decrease in COD concentrations. Reduction was only observed at the sampling point where Eco Enzyme was directly added during sample collection, but even then, the COD level remained above the regulatory threshold (< 300 mg/L). This suggests that the complex organic compounds present in leachate require further treatment, such as aeration or filtration, for optimal degradation.
2. Eco Enzyme consistently reduced BOD levels, both at locations treated through prior application and at those where Eco Enzyme was added during sampling. BOD reduction occurred at all sampling points, with values approaching or meeting the environmental quality standard (≤ 150 mg/L). This indicates that Eco Enzyme is effective in accelerating the decomposition of biodegradable organic compounds, and it can be considered a reliable biological agent for leachate treatment.
3. TDS increased at the location with a longer Eco Enzyme contact time, particularly at the facultative pond. This was likely due to the accumulation of degradation by-products such as low molecular weight organics and soluble ions, which increased the total dissolved content in the water. Although TDS levels remained within the permissible limit (≤ 2000 mg/L), the increase indicates that Eco Enzyme application should be followed by physical separation processes (e.g., sedimentation or filtration) to prevent the buildup of dissolved pollutants.
4. The effectiveness of Eco Enzyme is highly dependent on contact time and application method. A minimum contact period of 7–10 days is recommended for optimal results, particularly for BOD reduction. For parameters such as COD and TDS, the use of complementary treatment technologies is strongly advised.

Table 5. Summary of Eco Enzyme Effectiveness by Parameter

Parameter	Effectiveness	Notes
COD	Low	Requires >10 days contact and additional treatment
BOD	High	Consistent reduction at all sampling points
TDS	Ineffective / Increased	Needs to be combined with filtration or sedimentation

Recommendations

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

1. Eco Enzyme can be applied as a biological agent for BOD reduction in existing pond systems at the Basirih landfill, with routine application schedules and passive mixing systems to enhance biological reactions.
2. For COD reduction, Eco Enzyme should be combined with aeration, coagulation, or sedimentation systems to accelerate the oxidation of complex and recalcitrant organic compounds.
3. Regular monitoring of TDS is essential, especially in the final ponds, to prevent the accumulation of degradation by-products that could compromise leachate quality.
4. Further research is needed to explore variations in dosage, application frequency, and fermentation duration of Eco Enzyme in order to determine the most effective formulation at landfill scale.
5. The use of Eco Enzyme can be incorporated as part of a community-based and green technology approach to leachate management, aligning with sustainable practices and local community empowerment.

Declaration by Authors

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