

Eco enzyme mixture of sludge sediment treatment reduces BOD, COD, TSS, and detergent content in greywater

Efektivitas Campuran Eco Enzyme dan Sedimen Lumpur Pengolahan Limbah terhadap Kandungan BOD, COD, TSS, dan Deterjen pada Greywater

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ABSTRACT

Background: Household activities generate greywater containing pollutants such as BOD, COD, TSS, and detergents, contributing to environmental pollution. Eco enzyme offers a biological alternative to degrade organic waste.

Objective: This study aimed to evaluate the effectiveness of the eco enzyme combined with sludge sediment in reducing greywater pollutants.

Methods: A true experimental study with a pretest–posttest control group design was conducted using four greywater reactors. Eco enzyme doses of 10 ml, 30 ml, and 50 ml per 1000 ml of wastewater were tested, along with a control. The eco enzyme was mixed with 1.5 liters of sludge sediment. The detention time was three days. Sampling was performed once per treatment using purposive sampling. Parameters analyzed included BOD, COD, TSS, and detergents based on SNI standards. Data were analyzed using one-way ANOVA.

Results: The treatment showed no significant effect on BOD reduction ($p=0.48$), but significantly reduced COD ($p=0.01$) and TSS ($p=0.0001$). Detergent reduction was moderate, with the 50 ml dose being the most effective, although not statistically significant ($p=0.07$).

Conclusion: Eco enzyme combined with sludge sediment has potential as a simple biological treatment to reduce COD, TSS, and detergents in greywater. However, additional processes such as aeration are needed to effectively reduce BOD. This research can be the basis for the development of advanced research that can apply eco enzymes to waste, with a longer time and more varied dosage use.

Keywords: BOD, COD, detergents, eco enzyme, mud sediments, TSS

ABSTRAK

Latar Belakang: Aktivitas rumah tangga menghasilkan limbah greywater yang mengandung BOD, COD, TSS, dan deterjen yang berpotensi mencemari lingkungan. Eco enzyme merupakan alternatif biologis untuk menguraikan limbah organik. Penelitian ini bertujuan menganalisis efektivitas eco enzyme yang dikombinasikan dengan sedimen lumpur dalam menurunkan kandungan pencemar greywater.

Metode: Penelitian true experimental dengan desain pretest–posttest control group menggunakan empat reaktor greywater. Variasi dosis eco enzyme yaitu 10 ml, 30 ml, dan 50 ml per 1000 ml limbah, serta satu kontrol. Eco enzyme dicampur dengan 1,5 liter sedimen lumpur. Waktu detensi selama tiga hari. Sampel diambil satu kali tiap perlakuan dengan purposive sampling. Parameter yang diuji meliputi BOD, COD, TSS, dan deterjen sesuai standar SNI. Analisis data menggunakan uji one-way ANOVA.

Hasil: Perlakuan tidak berpengaruh signifikan terhadap penurunan BOD ($p=0,48$), tetapi berpengaruh signifikan terhadap COD ($p=0,01$) dan TSS ($p=0,0001$). Penurunan deterjen tergolong cukup, dengan dosis 50 ml paling efektif meskipun tidak signifikan ($p=0,07$).

Kesimpulan: Eco enzyme yang dikombinasikan dengan sedimen lumpur berpotensi sebagai teknologi biologis sederhana untuk menurunkan COD, TSS, dan deterjen, namun diperlukan proses tambahan seperti aerasi untuk menurunkan BOD. Penelitian ini dapat menjadi dasar pengembangan penelitian lanjutan yang dapat mengaplikasikan eco enzyme pada limbah dengan waktu yang lebih lama dan penggunaan dosis yang lebih bervariasi.

Kata kunci: BOD, COD, deterjen, eco enzyme, sedimen lumpur, TSS

INTRODUCTION

Domestic waste, generated from household activities such as sanitation facilities, as well as commercial and institutional activities, contains high loads of organic and inorganic pollutants. Key pollution parameters from domestic waste include Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nutrients (nitrogen and phosphorus), suspended solids (TSS), and pathogenic microorganisms. When this waste is discharged directly or through inadequate treatment systems into water bodies such as rivers, lakes, or the sea, water quality will decline drastically. Pollution originating from these household activities contributes up to 87% of pollution[1].

Household activities that use detergent extensively in the washing process can cause water pollution if used in excessive concentrations. Surfactants in detergents, in certain amounts, can create foam that is unsightly and covers the surface of water. This can impact the diffusion of oxygen from the air, slowing the process of oxygen diffusion from the air, thus reducing dissolved oxygen levels in the water and disrupting the life of aquatic organisms. Phosphate and surfactant content can also cause eutrophication in water bodies[2].

Greywater, which is household waste originating from leftover washing water that is generally not treated prior, becomes a pollutant burden for rivers receiving household waste. Numerous methods have been used to treat greywater waste to reduce environmental pollution, including the use of bioball biofilters, phytoremediation, and eco-enzymes. Treatment using the bioball biofilter and phytoremediation methods can reduce the fat and detergent content of greywater by up to 48.5%[3]. Meanwhile, the use of eco-enzymes can reduce the nitrogen and phosphate content in laundry waste by up to 25%[4].

Eco-enzyme liquid products are derived from the fermentation process of organic waste with the addition of sugar or molasses as a substrate in water. The compounds produced in the fermentation of sugar and organic waste have antibacterial health benefits. Several studies have shown that eco-enzymes can inhibit the growth of *Aeromonas hydrophila*, *Enterococcus faecalis*, *Escherichia coli*, and *Staphylococcus aureus* bacteria. Other research indicates that eco-enzyme-based health products are used as disinfectants, hand sanitizers, antiseptic soaps, and cosmetic ingredients[5]. Organic waste, the raw material for making eco-enzymes, contains carbon, hydrogen, and oxygen, which are easily broken down or degraded by microorganisms. This organic waste is generally kitchen scraps, such as leftover fresh fruit and vegetables. Eco-enzymes are a complex solution for reducing environmental pollution from organic waste[6]. Some organic waste that has been studied as an eco-enzyme ingredient and has antibacterial properties is papaya peel, pineapple peel, orange peel, and eucalyptus leaf waste[7],[8],[9],[10],[11].

Eco-enzymes, besides their health benefits, can also be an alternative for processing domestic and industrial waste. In restaurant wastewater treatment, oil and fat levels can be reduced by 98% with the addition of 5% eco-enzyme for 48 hours. COD levels can be reduced by up to 75% with the addition of 1% eco-enzyme[12]. The addition of eco-enzyme to the processing of tofu industrial waste can reduce COD content by 98.95%,

BOD by 51.11% and TSS by 73.7%[13]. The addition of eco-enzymes to several waste characteristics, according to previously described research, explains that the pollutant content of waste can be reduced, making it more environmentally friendly and minimizing pollution.

Sedimentation sludge from wastewater treatment serves as a growth medium or medium for microorganisms to degrade organic matter in wastewater. Generally, this sedimentation sludge is simply reused in wastewater treatment or compacted and used as backfill. Sludge is rich in organic matter, which serves as a source of carbon and energy for microbes[14]. Sludge sediment can be used as a wastewater treatment material to improve the quality of wastewater from the tofu industry[13]. The use of eco-enzyme from leftover kale and orange peel can be used as a mixed ingredient in laundry waste processing, which can reduce BOD, COD, and phosphate content[15]. The results of this study can be used to treat liquid waste, particularly greywater, to ensure its quality meets environmental standards when discharged into the environment. The purpose of this study was to analyze the effectiveness of adding eco-enzymes mixed with treated sludge sediment in reducing greywater pollutant content.

METHODS

Study Design

This study employed a true experimental design using a pre-test and post-test with a control group approach. The research was conducted from May to July 2025 at the Department of Environmental Health, Poltekkes Kemenkes Surabaya. The study aimed to evaluate the effectiveness of eco enzyme treatment on greywater quality under controlled laboratory conditions.

Data Source and Sampling Procedure

The sample consisted of greywater collected from household wastewater outlets flowing into drainage channels. Sampling was conducted using purposive sampling, with samples taken once for each treatment dose and detention time. The greywater was distributed into four reactors, including one control reactor without treatment.

Variables of the Study

The independent variable in this study was the dosage of eco enzyme applied to greywater (10 ml, 30 ml, and 50 ml per 1000 ml of wastewater). The dependent variables were greywater quality parameters, including Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and detergent levels.

Data Collection

Greywater samples were placed into batch reactors prior to treatment. Three reactors were equipped with continuous aeration, while one reactor served as a control without treatment. Eco enzyme was added to the treatment reactors at different doses (10 ml, 30 ml, and 50 ml per 1000 ml of greywater). The determination of dosage and detention time was based on preliminary trials and references from previous studies. The treatment process was conducted with a detention time of 3 days.

Measurement and Instruments

Water quality parameters were measured before and after treatment using standardized methods: BOD (SNI 6989.72-2009), COD (SNI 6989.2-2009), TSS (SNI 06-6989.3-2004), and detergent levels (SNI 06-6989 (1).30-2005). Measurements were conducted to assess the effectiveness of the eco enzyme treatment in improving greywater quality.

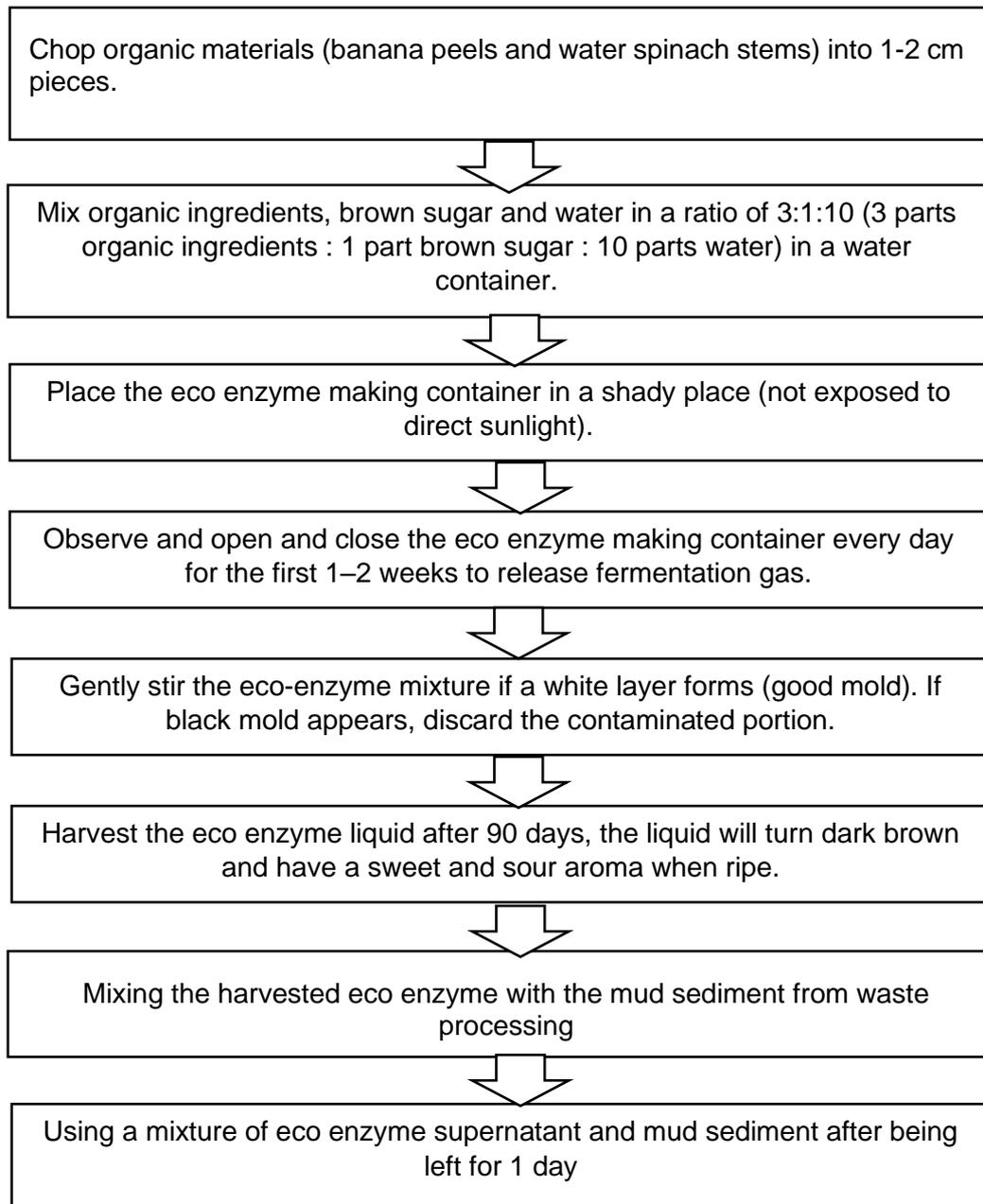


Figure 1. Procedure for making an eco enzyme

The reactor, which is used in greywater processing with a batch system, is shown in figure 2:



Figure 2. Greywater Wastewater Treatment Reactor before Applying the Eco Enzyme

Ethical Considerations

This study did not involve human or animal subjects; therefore, ethical approval was not required.

Data Analysis

The collected data were processed through data cleaning, coding, and tabulation. Statistical analysis was performed using one-way ANOVA to compare differences in greywater quality parameters before and after treatment across different eco enzyme doses. A significance level of $p < 0.05$ was applied.

RESULTS

Eco-enzyme is a fermented product made from a mixture of organic waste (fruit/vegetable peels), sugar (molasses/brown sugar), and water in a ratio of 3:1:10. The 90-day fermentation process produces a multifunctional liquid containing organic acids, enzymes, and beneficial microorganisms. Eco-enzyme has been tested as an alternative material in liquid waste treatment due to its ability to break down pollutants, neutralize odors, and reduce pathogenic bacteria.

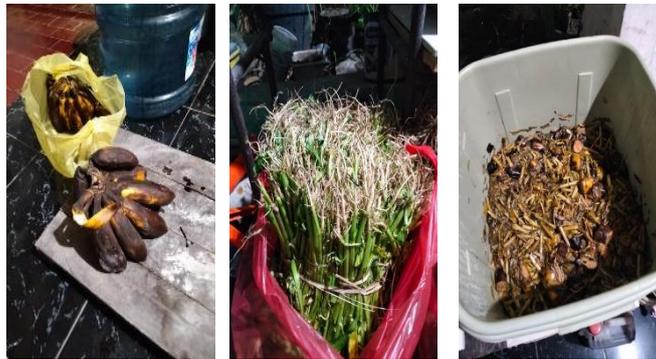


Figure 3. Eco enzyme from Banana Peel and Kale

Figure 3 shows the production of eco-enzyme from organic materials, following the eco-enzyme manufacturing procedure. The organic materials used are a mixture of banana peels and kale stems, which are added to a brown sugar starter culture. After 90 days of fermentation, the eco-enzyme is harvested and mixed with the sludge sediment from wastewater treatment. After mixing the eco-enzyme with the sediment for one day, the supernatant is applied to greywater wastewater.

After adding the eco enzyme to the waste, the following results were obtained in Table 1:

Table 1. BOD, COD, TSS and Detergent content in eco-enzyme treatment

Parameter	Control		Addition of an eco-enzyme			Quality standards (mg/L)	Sig.
	H-0	H-3	10 ml (mg/L)	30 ml (mg/L)	50 ml (mg/L)		
Treatment time	H-0	H-3	H-3	H-3	H-3		
BOD	40,5496	486,6334	527,062	486,5538	466,419	30	0.48
COD	44,9174	659.58	626,524	538,933	490,401	50	0.01
TSS	48	1205	288	253.33	270	50	0.0001
Detergent	0.9458	0.741	0.79188	0.7511	0.506	10	0.07

Table 1 shows that by adding an eco-enzyme to greywater waste and leaving it for 3 days, the BOD, COD, and TSS content increased. This is due to the presence of mixed

mud sediment, and there is increased microorganism activity, so that oxygen requirements increase, which can increase BOD and COD levels after the eco-enzyme and sludge sediment are mixed with waste. From several doses of eco-enzyme applied to waste, results showed that a dose of 50 ml of eco-enzyme per 1000 ml of waste was able to reduce BOD, COD, TSS, and detergent content. According to statistical test results, COD and TSS parameters showed significant differences between treatment groups ($p < 0.05$). A dose of 50 ml eco-enzyme per 1000 ml of wastewater reduced COD and TSS the most compared to other eco-enzyme doses.

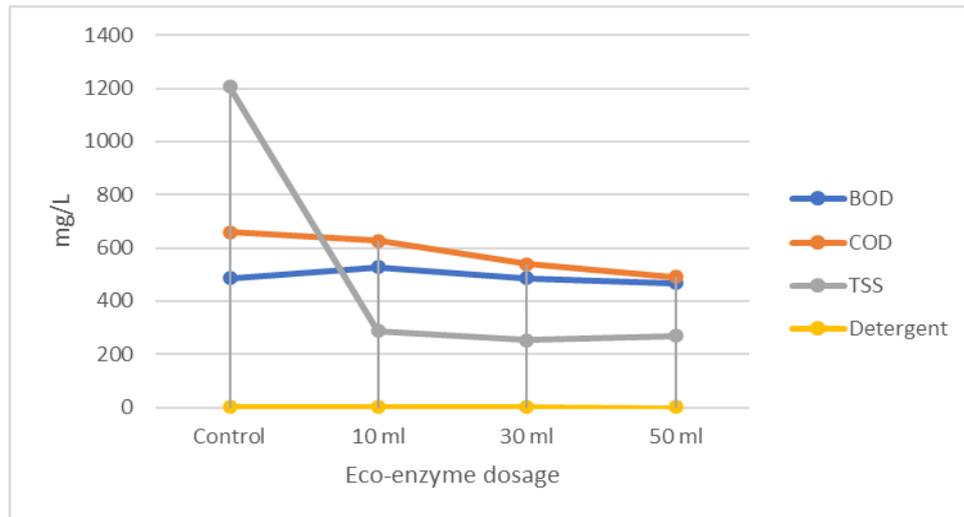


Figure 4. BOD, COD, TSS, and Detergent content in greywater treatment with eco enzyme doses of 10, 30, 50 ml per 1000 ml on the 3rd day ($x =$ dose of eco enzyme addition; $y =$ BOD, COD, TSS, Detergent content)

Figure 4 shows a decrease in BOD, COD, TSS, and detergent parameters after the addition of eco-enzyme at all three doses. The addition of eco-enzyme at a dose of 50 eco-enzymes per 1000 ml of wastewater significantly reduced BOD, COD, TSS, and detergent levels compared to the other doses.

DISCUSSION

According to Regulation of the Minister of Environment and Forestry (Permen LHK) Number P.68/Menlhk-Setjen/2016 concerning domestic waste quality standards, domestic waste originates from households, offices, apartments, markets, public facilities, and other commercial activities. Domestic waste generally contains various pollutant parameters that can negatively impact the environment and public health if not managed properly.

Component chemicals in wastewater originate from organic matter such as food waste, feces, urine, and other easily decomposed biological materials. Wastewater parameters that indicate this content are BOD and COD. Nutrients (nitrogen and phosphorus) in domestic wastewater originate from detergents, food waste, and human waste. Suspended Solids (TSS) in wastewater originate from solid particles such as sand, soil, and organic matter that can settle in water bodies.

Eco-enzyme can reduce COD, BOD, TDS, and MPN in domestic waste after 5 days of treatment[16]. The decrease in ammonia concentration increased with increasing concentration of the eco-enzyme given to water samples, with a linearity of 97.3%[17]. Eco enzyme can also reduce the detergent content in liquid waste[18]. Eco-enzymes are a sustainable and cost-effective solution for wastewater treatment, particularly for domestic and agricultural wastewater. Although they have not fully replaced

conventional treatment technologies, eco-enzymes can serve as an effective complement to biological treatment processes.

Sediment sludge from water treatment is generally not reused and simply becomes landfill, even though sediment is produced daily in wastewater treatment. Sludge sediment can be used as a wastewater treatment material to improve the quality of tofu industry wastewater. Sludge is characterized by being rich in organic matter, which serves as a source of carbon and energy for microbes. Sedimentation sludge from wastewater treatment serves as a growth medium or medium for microorganisms to degrade organic matter in wastewater[19]. However, mud sediment can be used as an eco-enzyme mixture as an alternative waste processing method that can reduce the COD content of tofu waste by up to 98.95% and, BOD by up to 51.11%, and TSS by up to 73.7%[13]. Microorganisms grown in waste processing can potentially reduce the surfactant content in domestic waste[19].

Based on the laboratory test data provided, the BOD, COD, TSS, and Detergent parameters were compared with the quality standards of Governor Regulation (Pergub) No. 72 of 2013 concerning wastewater quality standards referred to by the parameter inspection laboratory. Both BOD, COD, and TSS still exceeded the quality standards. The detergent content had met the quality standards and experienced a significant decrease[20].

BOD and COD levels remain high (BOD > 30 mg/L and COD > 50 mg/L), indicating increased microbial activity, leading to increased oxygen demand. This is due to a rapid surge in oxygen consumption, which is used by microorganisms to degrade organic matter in the waste. Because the waste does not receive additional oxygen from aeration, BOD and COD values remain high, indicating a significant difference between the available oxygen and the oxygen required by microorganisms. Biofilter treatment can be added to reduce BOD and COD levels in domestic waste[21].

The TSS content increases due to the addition of sludge sediment from wastewater treatment, which is added for further processing, such as aeration, adding air to the wastewater treatment. With the addition of sludge sediment and eco-enzymes, the TSS content in the wastewater decreases significantly. The addition of activated sludge treatment, in this case, sediment, can reduce the TSS content. The effect of the amount of activated sludge added to the wastewater causes a significant decrease in the TSS value. The higher the amount of activated sludge added, the more significant the decrease in the TSS concentration value. This is related to the activity of microorganisms in the activated sludge, which aids the decomposition process, so that suspended solids easily settle and can reduce the existing TSS value[22]. Aerobic processing also has an impact on reducing the TSS content in waste[23]. Meanwhile, the addition of eco-enzymes to waste can reduce TSS content by up to 88% due to the presence of protease, amylase, and lipase enzymes, as well as biocatalytic properties that can support the activity of microorganisms in degrading organic substances[1],[24].

The detergent content after treatment with the addition of the eco-enzyme to the sediment mixture has met the quality standards and experienced a significant decrease on the 3rd day. The decrease in the level of surfactant parameters as one of the compounds in the detergent is directly proportional to the amount of enzymes contained in the eco-enzyme, which acts as a catalyst to accelerate the decomposition of organic materials in domestic wastewater[3].

The advantage of this research is that it combines alternative waste treatment methods, namely by reusing the sediment from waste processing and adding organic materials in the form of environmentally friendly eco-enzymes. The limitation of this research is that the time used in applying eco-enzymes to the waste is only 3 days, so

the data obtained is still limited. The implications of using eco-enzymes in waste treatment are very capable of being applied by the general public, where the use of eco-enzymes is environmentally friendly and can reduce the amount of organic waste produced. The addition of sediment from waste processing and eco-enzymes to greywater can reduce the pollutant load in the water body receiving the waste, so that heavier pollution can be minimized due to household activities.

CONCLUSION

All treatments with the addition of eco-enzyme at doses of 10 ml, 30 ml, and 50 ml did not show a significant effect on reducing BOD values compared to the control. However, significant differences were found between treatments in COD and TSS parameters, indicating that the eco-enzyme is potentially effective in reducing the levels of certain pollutants. For detergent parameters, there were no significant differences, although the treatment with a dose of 50 ml showed detergent values that tended to be lower than the others. Overall, the use of eco-enzyme shows potential in reducing pollutant content in greywater.

Communities can utilize organic kitchen waste to produce eco-enzymes, which can then be used in household wastewater treatment to reduce pollutant levels. The results of this study can serve as a basis for further research with longer contact times and a wider range of dosages to optimize the effectiveness of eco-enzymes in household wastewater treatment.

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