# PERFORMANCE OF BIOFILTER AND WATER HYACINTH PHYTOREMEDIATION FOR LEACHATE TREATMENT

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**Abstract**

Leachate is a significant pollutant source with the potential to cause environmental damage, particularly through soil infiltration that degrades groundwater quality. This study evaluates a treatment method combining aerobic biofilters and phytoremediation to reduce pollutant levels in leachate from the Ngipik Landfill, Gresik Regency. The treatment utilized biofilters with varying media—bioballs, plastic straws, and oyster shells—integrated with phytoremediation using water hyacinth (Eichhornia crassipes) in a continuous downflow system with a 24-hour retention time. Sampling was conducted from day 0 to day 3. Analysis followed standard procedures: SNI 6989.72:2009 for BOD, SM APHA 24th Ed. 2540 D (2023) for TSS, and SM APHA 24th Ed. 3112 B (2023) for Hg. The results indicate that this combined method effectively reduces pollutants, achieving maximum reduction efficiencies of 83% for BOD (bioball media), 94% for TSS (plastic straw media), and 93% for Hg across all media types.

**Keywords:** Leachate, Biofilter, Phytoremediation, Water Hyacinth.

## 1. INTRODUCTION

The main issue in waste management occurs at Final Disposal Sites (FDS) that still use open dumping systems. This method allows waste to be piled up and left exposed without further treatment, leading to the formation of leachate. As the volume of waste piles increases, the amount of leachate produced also grows. Leachate is formed from the decomposition of organic matter that mixes with rainwater and seeps through the waste layers, carrying various dissolved and suspended pollutants. The presence of leachate is a concern because it has the potential to degrade the quality of the surrounding water environment near the FDS ( Ling et al., 2017).

Leachate treatment generally still relies on conventional methods, such as coagulation–flocculation and chemical oxidation. Although these methods are quite effective, they have limitations in terms of high operating costs and energy consumption (Pereira et al., 2016).

Alternative technologies based on biological processes, such as biofilters and phytoremediation, are beginning to be developed as methods for treating leachate. Phytoremediation is an environmentally friendly and cost-effective method because it harnesses the natural ability of plants and microorganisms to absorb and reduce pollutant concentrations in water, with relatively low costs and maintenance requirements compared to physical and chemical methods.

Several aquatic plants are known to have potential for phytoremediation, one of which is Eichhornia crassipes (water hyacinth), which can absorb heavy metals, excess nutrients, and other pollutants. This plant is tolerant of contaminated environments, has a rapid growth rate, and produces high biomass that can be reused after the phytoremediation process.

In addition to water hyacinth, water bamboo also has potential for heavy metal removal. The combined application of biofilter and phytoremediation technologies using aquatic plants can improve leachate treatment performance, with biofilters breaking down pollutants through microbial activity, while the plants absorb heavy metals through their root systems (Panneerselvam & Priya, 2021).

Although biofilters and phytoremediation have each been shown to reduce heavy metal concentrations, their effectiveness remains limited. The integration of these two methods is expected to improve treatment efficiency, particularly in reducing BOD, TSS, and mercury concentrations in leachate.

## 2. MATERIALS AND METHODS

### Sampling

The leachate used was sourced from the Ngipik Landfill in Gresik Regency, with a raw water requirement of 12 liters per day obtained from leachate collected at that site. Characteristic testing was conducted at the Environmental Engineering Laboratory, measuring parameters such as BOD, TSS, and the heavy metal mercury (Hg). The analysis results were then compared against quality standards based on Ministry of Environment and Forestry Regulation No. 59 of 2016 regarding Landfill Leachate Water Quality Standards.

### Reactor Design

### Biofilter Reactor

The biofilter reactor measures 20 cm in length, 20 cm in width, and 30 cm in depth. The flow rate entering a single reactor is 12 liters divided by a retention time of 24 hours, resulting in 0.5 L/h. Since three biofilter reactors are used, the total flow rate is 0.5 × 3 = 1.5 L/h.

### Phytoremediation Reactor

The phytoremediation reactor measures 36 cm in length, 30 cm in width, and 8 cm in depth. The reactor has a volume of 8,640 $cm^3$ or 8.6 liters. The flow rate entering the reactor is 8.6 liters divided by 24 hours, resulting in 0.35 L/h.

### Number of Plants

The diameter of the plant net pot is 5 cm, with a spacing of 8 cm between plants (left and right), resulting in a total space requirement of 13 cm per plant. Three plants can be placed along the length of the reactor (36 cm), and three plants can also be placed along the width of the reactor (30 cm). Therefore, the number of water hyacinth plants required in each reactor is 6.

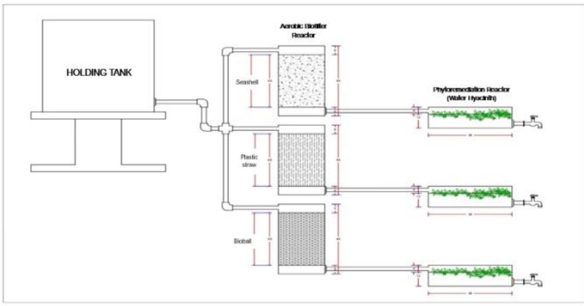


**Figure 1.** Reactor Design

This leachate treatment utilizes a combination of biofilter and phytoremediation methods. The research setup consists of one collection tank connected to three reactors containing different types of biofilter media. Reactor A uses oyster shell media, Reactor B uses plastic straw media, while Reactor C uses bioball media. Each reactor consists of two compartments: a biofilter tank and a phytoremediation tank, both operated continuously. During the phytoremediation stage, all three reactors use water hyacinth (Eichhornia crassipes) as the phytoremediation medium. The reactor design model used in this study is shown in Figure 1.

### Conduct of Research

Research preparations were carried out by introducing leachate samples into a collection tank and directing the flow into the biofilter reactor, then adjusting the flow rate according to the plan. Next, seeding was performed using EM4 and molasses for 16 days until a biofilm formed, accompanied by a permanganate test to monitor microbial growth.

The acclimatization process in the biofilter reactor lasted 4 days with wastewater concentrations of 25%, 50%, 75%, and 100%, and the water hyacinth plants were acclimatized for 5 days. A Range Finding Test (RFT) was then conducted on the plants using the same concentration variations.

The experiment continued with the operation of the reactor according to the planned flow rate. Treated water samples were collected every 24 hours for 3 days after passing through the phytoremediation tank, then analyzed in the laboratory to determine water quality parameters.

## 3. RESULT AND DISCUSSION

### Initial Condition of Waste

The leachate used in this study was sourced from the Ngipik Landfill in Gresik Regency, with a total raw water requirement of 36 liters used for two treatment processes each day. Prior to treatment, the leachate was first analyzed at the East Java DLH Environmental Laboratory to determine the levels of BOD, TSS, and Hg. Physically, the leachate was initially dark black, turbid, and malodorous. The initial concentration results of the leachate before treatment are presented in Table 1.

**Table 1.** Initial Characteristics of Wastewater

| No. | Parameter | Unit | Quality Standard | Result |
|---|---|---|---|---|
| 1 | BOD | mg/liter | 150 | 503 |
| 2 | TSS | mg/liter | 100 | 116 |
| 3 | Hg | mg/liter | 0.005 | 0.003 |

*) Regulation of the Minister of Environment and Forestry No. 59 of 2016 concerning Landfill Leachate Quality Standards.

Table 1 shows that the BOD, TSS, and Hg levels in the leachate still do not meet the quality standards established in Ministry of Environment and Forestry Regulation No. 59 of 2016 on Quality Standards for Landfill Leachate. Therefore, pretreatment is required using a combination of aerobic biofilter and phytoremediation technology with water hyacinth, as well as variations in biofilter media such as oyster shells, plastic straws, and bio balls.

### The Effect of Biofilter Media Variations on the Reduction of BOD Concentration

Leachate treatment was carried out by combining biofilter and phytoremediation methods to reduce BOD levels using three different types of biofilter media. Therefore, the treatment process was conducted in three separate reactors to compare the effectiveness of each biofilter medium. The first reactor used oyster shell media, the second reactor used plastic straw media, and the third reactor used bio ball media. The results of the analysis were then used to calculate the percentage reduction in BOD levels. The effect of variations in biofilter media on the reduction of BOD levels is presented in the graph in Figure 2.

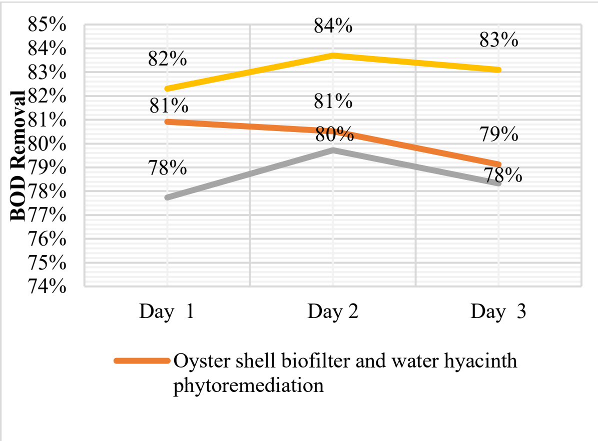


**Figure 2.** Decrease in BOD Levels

The graph in Figure 2 shows the percentage reduction in BOD over three days of observation using three combinations of biofilter media and phytoremediation with water hyacinth. The combination of bioball media and water hyacinth phytoremediation showed the highest BOD reduction efficiency compared to the other two combinations, namely 82% on the first day, increasing to 84% on the second day, and decreasing slightly to 83% on the third day. Meanwhile, the combination of oyster shell biofilter and water hyacinth phytoremediation showed a relatively stable trend, with a BOD reduction percentage of 81% on the first and second days, then decreasing to 79% on the third day. The combination of plastic straw biofilter and water hyacinth phytoremediation, however, showed an increase in BOD reduction from 78% on the first day to 80% on the second day, before dropping back to 78% on the third day.

Overall, the bioball and water hyacinth combination was the most effective method for reducing BOD levels during the observation period, both in terms of stability and the highest reduction percentage achieved. The decrease in BOD levels observed in each reactor indicates that all reactors are functioning properly in reducing daily BOD levels. The daily decrease in BOD between input and output values is due to the performance of the biofilter reactor, which utilizes microbial activity to break down organic compounds in the wastewater. This biodegradation process reduces the oxygen demand required for the breakdown of organic compounds, resulting in a decrease in BOD concentration in the wastewater (Apelabi *et al*., 2021).

According to (Zahra, S. A., Sri Sumiyati, 2023), the reduction in BOD levels in wastewater is attributed to the presence of organic compounds that serve as a nutrient source for microorganisms within the biofilter system. These microorganisms utilize the organic compounds in their metabolic processes, thereby breaking down pollutants into simpler and relatively harmless compounds. Additionally, the phytoremediation process through rhizodegradation also plays a significant role in reducing BOD levels. Rhizodegradation is the process of organic compound breakdown by microorganisms living in symbiosis in the plant root zone (rhizosphere). This process can occur in various plant parts, such as leaves, stems, and roots, as well as around the root zone with the aid of enzymes produced by the plant. Some plant species are even capable of releasing specific enzymatic compounds that can accelerate the degradation of organic pollutants (Yunita & Asmoro, 2023).

**The Effect of Biofilter Media Variations on the Reduction of TSS Concentration**

Treatment of leachate for Total Suspended Solids (TSS) was conducted by combining biofilter and phytoremediation methods using three different types of biofilter media. Therefore, the treatment process was carried out in three separate reactors to compare the effectiveness of each media. The first reactor used oyster shell media, the second reactor used plastic straw media, and the third reactor used bioball media. The results of the analysis were then used to calculate the percentage reduction in TSS levels. The effect of variations in biofilter media on the reduction of TSS levels is presented in the graph in Figure 3.

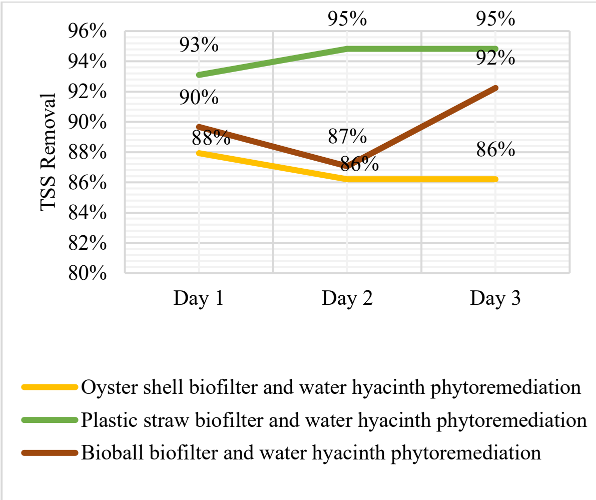


**Figure 3.** Decrease in TSS Levels

Figure 3 shows the percentage reduction TSS based on three combinations of biofilter media and water hyacinth phytoremediation over three days of observation. The combination of a plastic straw biofilter and water hyacinth phytoremediation showed the highest and most consistent TSS reduction efficiency, namely 93% on the first day, increasing to 95% on the second day, and remaining stable at 95% on the third day. The combination of bioball biofilters and water hyacinth phytoremediation showed fluctuations in efficiency, with a 90% TSS reduction on the first day, decreasing to 87% on the second day, and then increasing again to 92% on the third day. Meanwhile, the combination of oyster shell biofilter and water hyacinth phytoremediation tended to experience a gradual decrease in efficiency, from 88% on the first day to 86% on the second day and remained at 86% on the third day. Based on these results, it can be concluded that the plastic straw biofilter medium is the most effective medium for consistently reducing TSS levels, while the bioball medium shows good potential but with lower stability, and the oyster shell medium provides the lowest efficiency among the three tested media.

The biofilter media serves to slow down the flow of wastewater, thereby enabling optimal interaction between the wastewater and the microorganisms living within the biofilm. This process begins with a filtration mechanism that traps and binds suspended solids, effectively reducing the TSS levels in the wastewater (Agustina *et al.*, 2022). In addition, the decomposition process carried out by microorganisms plays a key role in reducing TSS levels. The biofilter layer also serves as a medium for filtering solid particles while gradually breaking down organic matter, thereby improving the efficiency of wastewater treatment. (Saputra *et al*., 2020). The phytoremediation process also contributes to the reduction of TSS through sedimentation and filtration mechanisms in the plant root zone. Plant roots act as natural filters capable of trapping solid particles in leachate, thereby significantly reducing TSS concentrations (Pramesti, T. A., & Mirwan, 2023).

**The Effect of Biofilter Media Variations on the Reduction of Mercury Concentrations**

The treatment of leachate for the heavy metal parameter mercury (Hg) was carried out by combining biofilter and phytoremediation methods using three different types of biofilter media. Therefore, the treatment process was conducted in three separate reactors to compare the effectiveness of each biofilter medium. The first reactor used oyster shell media, the second reactor used plastic straw media, and the third reactor used bioball media. The results of the analysis were then used to calculate the percentage reduction in Hg concentration. The effect of variations in biofilter media on the reduction of Hg concentration is presented in the graph in Figure 4.

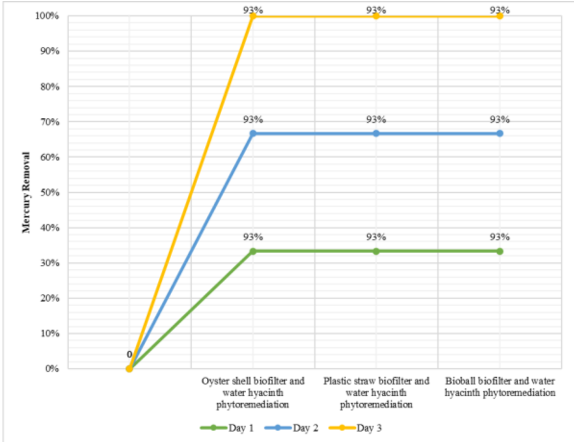

**Figure 4.** Reduction in Mercury Levels

Figure 4 shows a graph of the percentage reduction in mercury (Hg) levels over three days of observation using three combinations of biofilter media and phytoremediation with water hyacinth. The results show that all combinations of biofilters and phytoremediation performed relatively similarly, consistently reducing Hg levels by 93% from the first day through the third day. This indicates that the combination of biofilter and phytoremediation methods is effective in reducing Hg levels in leachate.

The effectiveness of this reduction in mercury levels is supported by the ability of water hyacinth (Eichhornia crassipes) to absorb and accumulate heavy metals. According (Sayow *et al*., 2024), Water hyacinth is an aquatic plant with high potential for absorbing heavy metals because it can survive in polluted water, has a rapid growth rate, and is capable of accumulating heavy metals in a relatively short period of time. The absorption of heavy metals by water hyacinth occurs through a phytoremediation mechanism, in which heavy metals in the water are absorbed by the root system and subsequently distributed throughout the plant gradually (S. Rahayu, 2022). These phytoremediation mechanisms involve several key processes, namely Phyto stabilization, which absorbs and retains heavy metals within plant tissues; phytodegradation, which is the breakdown of pollutants through enzymatic activity produced by plants; and phytovolatilization, which is the conversion of pollutants into gaseous forms that are then released into the atmosphere through plant organs, such as leaves (Nurhidayanti *et al.*, 2021).

## 4. CONCLUSION

The combination of biofilter and phytoremediation methods using water hyacinth has proven effective in reducing BOD, TSS, and Hg levels in leachate. The reduction percentages for the oyster shell biofilter reached 80% for BOD, 87% for TSS, and 93% for Hg; for the plastic straw biofilter, they reached 79% for BOD, 94% for TSS, and 93% for Hg; and for the bio ball biofilter, they reached 83% for BOD, 90% for TSS, and 93% for Hg. Among these three media, the bio ball biofilter demonstrated the highest overall efficiency, followed by oyster shells and plastic straws, as it provides optimal conditions for biological processes and metal absorption, making it the best alternative for environmentally friendly and sustainable leachate treatment.

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