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PHYTOREMEDIATION OF TSS AND TDS FROM LANDFILL LEACHATE BY *Equisetum hyemale*

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ABSTRACT

Leachate contains TSS (Total Suspended Solid) and TDS (Total Dissolved Solid), which causes turbidity and a blackish-brown color in the leachate. One effort that can be made to deal with environmental pollution caused by leachate is phytoremediation. This research aimed to determine the effectiveness of water bamboo (Equisetum hyemale) as a phytoremediation agent for TSS and TDS from Jatibarang landfill leachate. This research was conducted by an experimental study with a completely randomized design (CRD) with three treatment levels and three repetitions. The treatments given in this research were three variations of water bamboo, namely P0: without water bamboo, P1: 750 g water bamboo, and P2: 1.000 g water bamboo. The most optimal percentage reduction in TSS occurred in the P2 on the third day of the study (16.83%). The most optimal percentage reduction in TDS occurred in the P1 on the seventh day of the study (6.56%). While these results are promising, it's important to note that the research has some limitations, such as the short duration of the study and the specific conditions of the Jatibarang landfill. The research results showed that phytoremediation reduces Jatibarang Landfill leachate, especially TSS and TDS levels accumulated by the roots of water bamboo

INTRODUCTION

The sight of piles of rubbish may seem harmless, but the potential threat they pose is urgent. These heaps can later release a black, unpleasant-smelling liquid called leachate. The leachate, a blackish-brown liquid with a distinctive, pungent odor, results from the decomposition of various types of materials mixed in the landfill. This leachate, if not managed effectively, will seep into the soil layers below, causing significant harm

(Rumbruren et al., 2015). The non-optimality of the processing process at the Jatibarang landfill is a pressing issue, evident from the lack of efficiency in handling leachate. This inefficiency is demonstrated in the use of natural soil-based channels and the underperformance of wastewater treatment plant aerators. Untreated leachate can lead to soil and water pollution, particularly in the Kreo River, which is used as an effluent disposal site (Harjanti & Anggraini, 2020).

Physically, the leachate looks cloudy and blackish brown. Cloudy water can indicate the presence of suspended solids in the water. The total suspended solids in wastewater are known as TSS, which are suspended materials (> 1 µm in diameter) retained on millipore filters with a pore diameter of 0.45 µm (Kusniawati et al., 2023). The TSS content consists of mud, fine sand, and microorganisms, which are expressed in weight in units of mg/liter of dry mud in the waste. Meanwhile, according to (Kartikasari et al., 2020), the TDS parameter is caused by ions contained in wastewater. Dissolved solids are in the form of organic and inorganic substances. One of them occurred at the Jatibarang landfill, where it can be seen from the high TDS levels of 6500 mg/L (Widiyanti et al., 2019) and TSS levels of 522 mg/L (Rezagama et al., 2017).

There is a need for appropriate countermeasures to reduce the TSS and TDS levels of Jatibarang landfill leachate so that they comply with the quality standards set out in Minister of Environment and Forestry Regulation No. 59 of 2016 and RI Minister of Health Regulation no. 32 of 2017. According to the regulation, the standard TSS is 100 mg/L. According to the regulation, the standard TDS is 2000 mg/L.

One promising strategy to counter the leachate problem is phytoremediation. As described by (Dewi & Akbari, 2020), phytoremediation is a system where certain plants, in collaboration with microorganisms in the media, can transform contaminants into less or non-dangerous substances, and even into economically viable materials. Water bamboo, an aquatic plant, is a prime candidate for phytoremediation. Its hyperaccumulator properties and high tolerance to pollutants make it an ideal phytoremediation agent. This plant can concentrate heavy metals in its biomass at remarkably high levels. Research by (Widyastuti et al., 2023) has shown that water bamboo, as a hyperaccumulator plant, can reduce the Zn metal content in leachate by an impressive 89.7%.

Meanwhile, water bamboo is also a hyper tolerant plant that can adapt and survive because it has a high tolerance for environmental conditions with high levels of contaminants. According to the measurement results, one of the domestic waste parameters, namely water bamboo plants, efficiently reduces BOD levels on average of 89,99% on tofu industry wastewater. Water bamboo with media (Subsurface Flow Wetlands) can lower the BOD concentration significantly (Nugraha et al., 2015).

Based on this description, it is important to conduct research to determine the effectiveness of water bamboo as a phytoremediation agent for TSS and TDS leachate. From the results of this research, the ability of water bamboo to reduce TSS and TDS levels in leachate will likely be known.

MATERIALS AND METHODS

Wastewater samples were collected from the central wastewater treatment unit in Jatibarang Landfill. This research, which is of significant importance to the field of wastewater treatment, used experimental research with three treatments and three repetitions. The treatments given in this research were three variations of water bamboo biomass (0 g, 750 g, and 1.000 g). The leachate required for one treatment was 10 liters. Water bamboo undergoes acclimatization for one week so they can adapt to the new environment. Then, the plants were contacted with leachate water for seven days, starting from when the water bamboo was put into the research treatment bucket. Total dissolved solids (TDS), pH, Dissolved oxygen (DO), total suspended solids (TSS), and temperature were tested. The effectiveness of reducing TSS and TDS values was calculated from the percentage difference between initial and final levels after treatment. Levene tests were carried out to assess data normality and homogeneity, respectively. The analyzed parameters were processed using the variance method (ANOVA) followed by Tukey's test.

RESULTS AND DISCUSSION

Characteristics of Jatibarang Landfill Leachate

Before treatment, a preliminary test was carried out on the leachate sample to determine the initial TSS and TDS levels. The TSS and TDS levels of the Jatibarang landfill leachate in Semarang can be seen in Table 1.

Table 1. Characteristics of Jatibarang Landfill Leachate

Parameter	Unit	Test Results
TSS	mg/L	105
TDS	mg/L	1026

Based on this data, it can be seen that the initial TSS levels still exceed the quality standards, while the initial TDS levels of the Jatibarang Landfill leachate are below the quality standards set by the Republic of Indonesia Minister of Environment and Forestry Regulation Number 59 of 2016 and Minister of Environment Regulation Number 5 of 2014.

TSS Levels

Data on the progress of the TSS levels during the research can be seen in Figure 1.

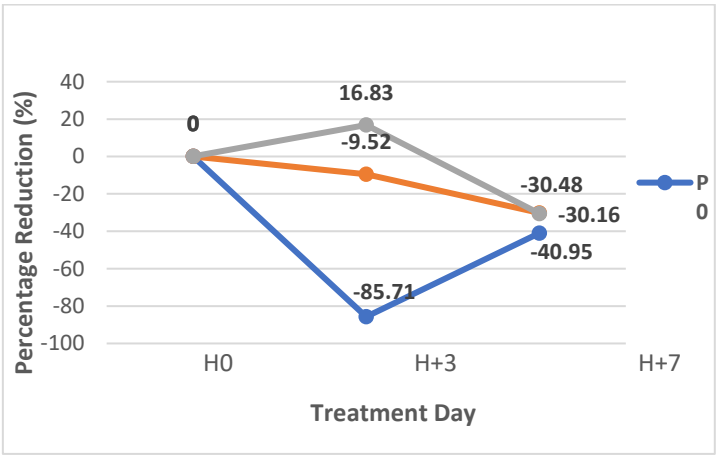

Figure 1. Graph of TSS levels in phytoremediation processing using *Equisetum hyemale*

Based on these data, the percentage decrease in TSS levels on the third day from highest to lowest, respectively, namely P2 (16.83%), P1 (-9.52%), and P0 (-85.71%). Meanwhile, the percentage increase in TSS levels on the seventh day from the highest to the lowest, respectively, namely P1 (-30.16%), P2 (-30.48%), and P0 (-40.95%). On the third day of treatment, the highest percentage reduction in TSS occurred in P2.

Meanwhile, on the seventh day of treatment, the highest percentage reduction in TSS occurred in P1.

The research data was then conducted with a homogeneity test to determine whether the sample data group came from a population with the same (homogeneous) or different (heterogeneous) variance. The effectiveness of the research methods is evident, as the results were carried out by various tests to determine whether the treatment had a significant effect. If the results of the variety test show that the treatment has a significant impact, then further tests will be carried out.

Based on the results of the homogeneity test, the TSS on the third day of treatment can be seen that the homogeneity significance value is 0.057 > 0.05 with *a Levene Statistic* of 4.816, indicating that the sample data group comes from a population that has the same variance (homogeneous). Meanwhile, the results of the homogeneity test for TSS on the seventh day of treatment showed that the homogeneity significance value was 0.065 > 0.05, with *a Levene Statistic* of 4.478, indicating that the sample data group comes from a population with the same variance (homogeneous).

The results of the TSS test for various levels of leachate on the third and seventh days of treatment have significant implications. The Fcount (9,49) > Ftable (5,14) on treatment on the third day means H0 is rejected and H1 is accepted, indicating the need for further tests. Meanwhile, the Fcount (4,83) < Ftable (5,14) on treatment on the seventh day means H0 is accepted and H1 is rejected, also indicating the need for further tests. These results show that the water bamboo biomass did not significantly affect reducing TSS levels.

The coefficient of diversity value of leachate TSS levels on the third day of the study was 5.88%. The coefficient of diversity value obtained is less than 10%, so the follow-up test uses Tukey's. Based on Tukey's test results, it can be seen that phytoremediation of TSS levels on the third day of the study, P0 was significantly different from P1 and P2, P1 was substantially different from P0 but not significantly different from P2, while P2 significantly different from the P0, but not substantially different from the P1.

Based on the results of research that has been carried out, water bamboo can reduce TSS levels to below-quality standards. The research results are effective if the percentage reduction in TSS levels is 80 – 90%. In this study, the most optimal reduction in TSS

levels occurred in the P2 on the third day of the study, it was 16.83% with an average TSS level of 87.33 mg/L. Meanwhile, the increase in TSS levels occurred in the P0 on the third day of the study, it was -85.71% with an average TSS level of 195 mg/L. However, the increase was in the treatment with water bamboo, namely in P2 on the seventh day of the study it was -30.48%. Based on the BNT test results, it can be seen that phytoremediation of TSS levels on the third day of the survey, P0, was significantly different from P1 and P2, and P1 was substantially different from P0 but not significantly different from P2. In contrast, the P2 is significantly different from the P0 but not substantially different from the P1.

This study's decrease in TSS levels was due to the phytoremediation process carried out by water bamboo through *phytoextraction*, *rhizofiltration*, and *biodegradation*. In *phytoextraction*, water bamboo attracts pollutants from leachate water, so suspended particles with a light mass will accumulate around plant roots. Meanwhile, suspended particles with a heavy mass will settle in the research treatment bucket. During the process *of rhizofiltration,* Pollutants are absorbed by plant roots and stick to the roots, forming a thin layer on the surface. TSS particles act as adsorbents captured in the root pores in this process. Bacteria that live in symbiosis in plant roots break down pollutants around the roots during *biodegradation*. The organic material in TSS will be broken down by rhizosphere bacteria, which coexist symbiotically with the roots. Plants usually release compounds, such as sugar, alcohol or acids containing organic carbon, which function as an energy source for bacteria to reproduce because this symbiosis is mutualistic. TSS particles are converted into harmless compounds so that they are beneficial for the development of water bamboo.

The environmental conditions in temperature, pH and dissolved oxygen were measured at the research location at 11 pm. High ecological temperatures will increase the photosynthesis process of plants. As environmental temperatures rise, the absorption capacity of plants will also increase. The temperature of the leachate greatly influences the solubility of oxygen, where the higher the temperature, the oxygen solubility will decrease and vice versa. This happens because increasing temperature causes gas and water molecules to gain energy. As a result, the weak molecular interaction between water and oxygen gas is more easily broken down so that oxygen can escape. The temperature of the leachate also affects the concentration of the ions in it, which then affects the water

pH. This causes the higher the water temperature, the higher the water pH. The increase in pH in the phytoremediation treatment is due to the organic acid mineralization process in the waste.

In this study, a decrease in TSS levels by quality standards only occurred in the P2 one-third of the study. The quality standards stipulated in the Republic of Indonesia Minister of Environment and Forestry Regulation No. 59 of 2016 are 100 mg/L. Meanwhile, other treatments still exceed these quality standards. The most optimal reduction in TSS levels uses 1000 grams of water bamboo because of the plant's ability to absorb solid particles in leachate water through the plant roots. Water bamboo can also increase the oxygen content in water through photosynthesis. Higher oxygen content can increase soil microbial activity, which can help reduce TSS levels. The cloudy condition of the leachate makes it difficult for sunlight to reach the bottom of the water, thereby inhibiting the photosynthesis process and reducing the oxygen content in the water. Pollutants contained in leachate in the form of high solids can affect the aquatic environment such as TSS. TSS levels in waters can be influenced by several factors, such as particle deposition, temperature, salinity, brightness, pH, and DO.

TDS Levels

Data on the progress of the TDS levels during the research can be seen in Figure 2.

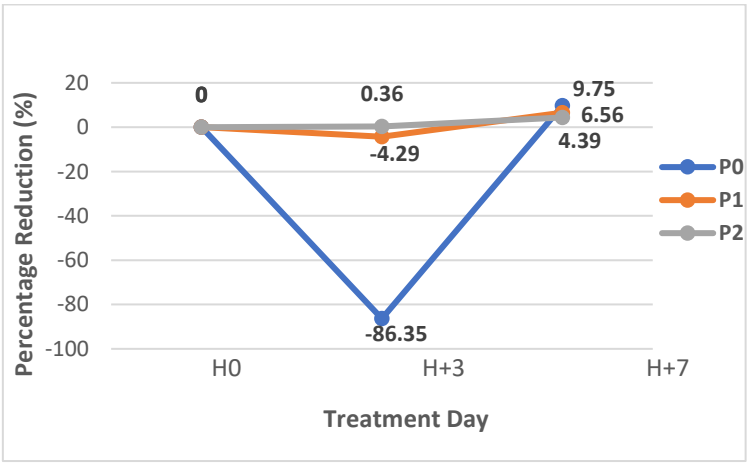

Figure 2. Graph of TDS levels in phytoremediation processing using *Equisetum hyemale*

Based on these data, the percentage decrease in TDS levels on the third day from highest to lowest, respectively, namely P2 (0.36%), P1 (-4.29%), and P0 (-86.35%). Meanwhile, the percentage decrease in TDS levels on the seventh day from the highest to the lowest, respectively, namely P0 (9.75%), P1 (6.56%), and P2 (4.39%). The

treatment did not have a significant effect in reducing TDS levels. On the third day of treatment, the highest percentage reduction in TDS levels occurred in P2. Meanwhile, on the seventh day of treatment, the highest percentage reduction in TSS levels occurred in P0.

The results of the homogeneity test for TSS levels on the third day of treatment showed that the homogeneity significance value was 0.056 > 0.05 with *a Levene Statistic* of 4.820, indicating that the sample data group comes from a population with the same variance (homogeneous). Meanwhile, based on the results of the homogeneity test for TSS levels on the seventh day, it can be seen that the homogeneity significance value is 0.063 > 0.05, with *Levene Statistic* of 4.551 indicating that the sample data group comes from a population that has the same variance (homogeneous).

The results of the various TSS test results on the third day of treatment showed that Fcount (2,44) < Ftable (5,14) on treatment, meaning H0 accepted and H1 rejected so there is no need for further testing. This shows that the water bamboo biomass did not affect reducing TSS levels. Meanwhile, based on the results test on the variety of TDS levels on the seventh day of treatment, it can be seen that Fcount (1,28) < Ftable (5,14) on treatment, meaning H0 accepted and H1 rejected, so there is no need for further testing. This shows that the water bamboo biomass did not affect reducing TSS levels.

Based on the results of research that has been carried out, it can be seen that water bamboo plants can reduce TDS levels to below-quality standards. In this study, the treatment with the most optimal reduction in TDS levels occurred in the P0 on the seventh day; it was 9.75% with an average TDS level of 926 mg/L. Meanwhile, the treatment that had increased TDS levels occurred in the P0 on the third day of the study; it was -86.35% with a TDS level of 1912 mg/L. For treatments using water bamboo, the most optimal reduction occurred in P1 on the seventh day of the study, which was 6.56%, while the increase happened in P1 on the third day of the study, which was -4.29%.

This study's decrease in TDS levels was due to the phytoremediation process carried out by water bamboo through *phytoextraction rhizofiltration*. In *phytoextraction*, the root pores of water bamboo capture fine particles and trap them on the root surface. Process *rhizofiltration*: Plant roots carry out the process of adsorption or absorption of contaminants by the roots so that they stick to the plant roots, forming a thin layer on the surface. In the reactor tank, slow flow occurs so the root pores can filter and absorb the

solution contained in TDS. Plant roots play a role in filtering particles, which then separates water from fine particles in TDS. Next, in *phytovolatilization*, polluted substances absorbed by plants are broken down and produce other harmless substances. The results of this breakdown will go through a transpiration process and then evaporate into the atmosphere.

The pH concentration in the leachate influences the TDS concentration. The acidity level in pH can cause increased solubility of organic and inorganic substances so that the TDS concentration becomes high. High TDS levels indicate that the leachate at the Jatibarang landfill is polluted by dissolved solids originating from landfills mixed with rainwater. These solid particles influence the color of the leachate to become blackish-brown and smelly. This shows large amounts of organic material pollution in the leachate at the Jatibarang landfill. The oxidation process in surface water is accelerated by high concentrations of organic matter, which impacts the dissolved oxygen content in the water (Paramita, Wardhani, and Pharmawati 2017).

TDS levels will increase or decrease in response to organic and inorganic substances not completely decomposed by bacteria in the roots. Decomposing large organic materials into smaller ones can cause the TDS value to fluctuate; the TDS value begins to fall due to bacteria using organic material as an energy source. The decrease in pH during the phytoremediation process affects the total organic substances, where the lower the pH value, the higher the organic substances in the waste will be, which affects the TDS value (Novita et al., 2020). Apart from that, photosynthesis carried out by plants can also supply oxygen, which will be used to decompose organic matter and solid particles found in leachate water. If there is sufficient oxygen, the microorganisms symbiotic in plant roots can break down more organic contaminants.

The treatment of P1 and P2 experienced a decrease in TDS levels on the seventh day, even though they had not yet reached optimal levels. Decreased TDS levels in P1 and P2 are caused by the ability of the roots of water bamboo to absorb pollutants, both those found in water bodies and sediments. Water bamboo's ability to absorb organic materials in leachate is also caused by the presence of rhizosphere microbes, a type of symbiotic relationship between bacteria and fungi that can decompose and utilize organic and inorganic substances found in water as a food source (Khaer & Nursyafitri, 2019).

Water bamboo has dense, fibrous-type roots that spread in various directions, so it has a high absorption capacity for pollutants. This plant has a rhizosphere, which carries pollutants in the planting medium to the root cells, which will then be degraded by enzymes in the roots. The ability of water bamboo to absorb organic material in leachate is also caused by rhizosphere microbes in the roots. Rhizosphere microbes are a symbiosis of bacteria and fungi that break down organic and inorganic substances found in water. In absorbing colloidal particles floating in water bodies, the roots of water bamboo will function as a filter. Plant roots absorb pollutants in the solution during the process of absorbing pollution by plants. Plant roots will absorb dissolved substances along with water. In the translocation process, after pollutants penetrate the endodermis layer of plant roots, they are passed to the top via transport tissue (xylem and phloem) to other parts of the plant.

The ability of water bamboo and rhizosphere microbes in the roots is supported by the root's significant absorption and accumulation capacity for contaminants, causing leachate turbidity levels to decrease. Organic and inorganic materials in leachate can be reduced by rhizospheric microbes found in the roots of water bamboo. In plant roots, pollutants will be absorbed from water and sediments, and the dissolved materials will accumulate in other parts of the plant. Water bamboo roots will filter for absorbing colloidal particles floating in water bodies. Pollutants will be accumulated into dissolved materials in various parts of the accumulator plant so that the TDS levels in the leachate are reduced. The process of degradation of organic material by water bamboo roots, changes in the temperature of the reactor environment, and biological processes by the activity of microorganisms caused TDS levels to fluctuate during the research so that the measurement results sometimes experienced increases or decreases.

CONCLUSION

Based on the research results, it can be concluded as follows: The most optimal percentage reduction in TSS occurred in the P2 on the third day of the study (16.83%). The most optimal percentage reduction in TDS occurred in the P1 on the seventh day of the study (6.56%). The research results show that phytoremediation can reduce Jatibarang Landfill leachate, especially TSS and TDS levels accumulated by the roots of water

bamboo. Phytoremediation by the water bamboo treatment method was proven to reduce pollutants and enhance the water quality. Importantly, this method is safe to be implemented as it is environmentally friendly, providing reassurance for its potential use in waste management.

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