

Ammonia and Total Nitrogen Removal Using *Equisetum hymale* Based Phytoremediation in Landfill Leachate

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Abstract: In line with the problems faced by all landfills in Indonesia, the high level of waste entering landfills is not commensurate with the cost and quality of waste management which is still low. The volume of landfill leachate with levels of organic, inorganic and metal content at the Jatibarang landfill has the potential to pollute the Kreo river. The dangerous impact on health and ecosystem continuity if the total ammonia and nitrogen content is too high in Jatibarang landfill leachate, efforts to manage it with a phytoremediation agent are *Equisetum hymale*. This research method is an experiment with a completely randomized design (CRD) designed with the type of *Equisetum hymale* and 3 treatment of *Equisetum hymale* biomass, namely, P0: 0 g, P1: 750 g, and P2: 1000 g of *Equisetum hymale* per 10 liters of leachate, each treatment was repeated 3 times. This phytoremediation is very effective in reducing ammonia levels, the reduction in ammonia levels reached 99.7% and the highest total nitrogen content reached 91.7%. It was concluded that the *Equisetum hymale* was effective in reducing ammonia levels. The effectiveness of reducing ammonia levels and nitrogen levels was most optimal on the third day of P2. The *Equisetum hymale* removed ammonia and total nitrogen up to 70% in variation of contact time.

Keywords: Phytoremediation; Removal; Leachate; Ammonia; Nitrogen.

Introduction

Environmental pollution is the main focus in life, because it can reduce environmental quality (Akhirul et al., 2020). All diverse community activities can produce waste that causes environmental pollution. Waste produced by society can be in the form of solids, liquids or gas. One of the wastes that society produces every day is solid waste such as rubbish, whether organic or inorganic. As the population increases significantly, the amount of waste production can increase, especially household waste (Harjanti & Anggraini, 2020). In several regions in Indonesia, the volume of waste is often overloaded or more than the capacity of the Final Processing Site (Pramesti & Yuningsih, 2023). In line with the problems faced by all landfills in Indonesia, the high level of waste entering landfills is not commensurate with the cost and quality of waste

management which is still low. One of the final processing sites in the city of Semarang is the Jatibarang Landfill with an area of 46,183 ha with a distribution of 27,709.8 ha for disposal land and 18,473.2 ha for leachate pond infrastructure. Currently, Semarang City is implementing a Sanitary Landfill system in its management, but there are obstacles so that this method has not been implemented completely, and is still implementing a controlled landfill system (Susanti et al., 2014). This Controlled Landfill system is a transitional system from the Open dumping system to the Sanitary Landfill system, however, the controlled landfill system at the landfill also has the potential for water from outside to enter the waste and inundate the waste pile, resulting in a thick black liquid coming out of the waste pile which is called leachate. The leachate concentration is quite high because it contains organic, inorganic and heavy metals, requiring treatment before being

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discharged into the environment (Abrauw, 2019). According to (Mastur & Budiyo, 2020), high rainfall seeps into waste piles resulting in large volumes of leachate, potentially polluting the water of the Kreo River which is located near the Jatibarang landfill.

The quality standard limit for waste has been determined by the Semarang City Environmental Service with a maximum of 5 mg/L of ammonia and a maximum of total nitrogen in the waters in group 1, namely 30 mg/L and group 2, namely 60 mg/L. Measurements of ammonia and total nitrogen parameters in 2024 Jatibarang landfill leachate were ammonia levels of 15.71 mg/L and total nitrogen of 61 mg/L, which exceeded the quality standard limits. In 2024, the total ammonia and nitrogen levels of Jatibarang landfill leachate will exceed the established quality standards with leachate ammonia levels of 15.71 mg/L and total nitrogen of 61 mg/L. Characteristics of leachate water: (1) high concentration of leachate water, it dissolves and washes away compound materials in the waste so that the resulting color is dark black, (2) emits an odor, (3) is dangerous in large quantities.

The danger to the health and continuity of the ecosystem if the total ammonia and nitrogen content is too high is eutrophication, where excess nitrogen content in the water causes rapid growth of aquatic plants, thereby blocking light from entering the water and affecting the photosynthesis process, which results in low levels of dissolved oxygen in the water and ammonia. which is poisonous in excessive amounts and slows aquatic growth, causing death. Excessive ammonia and total nitrogen content in water until the water is consumed will result in damage or inflammation. In general, excess substances if they enter the body will be toxic and cause serious disorders in certain body organs.

Efforts to manage leachate waste content in landfills require management in the form of phytoremediation (Sitia & Jusward, 2022). According to (Zhang et al., 2010), phytoremediation takes the form of an artificial wetland system (Constructed Wetlands) for managing waste using physical, chemical and biological processes. Biological process using plants as phytoremediation. Plants will collaborate with microorganisms in the media so that they can change, stabilize or destroy contaminants to become reduced or not dangerous at all, with economic value (Artiyani, 2011). One of the plants used as a phytoremediation agent is *Equisetum hymale*.

The *Equisetum hymale*, a type of marginal aquatic plant which has advantages in care, easy growth and resistance to external influences. Based on previous research results, it shows that this *Equisetum hymale* provides optimal phytoremediation at fairly high liquid waste concentrations, apart from that there is chemical migration and the optimal detention time is 14 days

(Sitia & Jusward, 2022). Based on the background written, this research uses *Equisetum hymale* as a phytoremediation agent for the value of ammonia levels and the value of.

Method

The research observed was the *Equisetum hymale* as a phytoremediation agent in reducing the total ammonia and nitrogen levels of Leachate. This research was carried out at the Jatibarang Landfill Semarang, Central Java, Indonesia. Laboratory tests were carried out at the Semarang City Government Environmental Service Semarang. The standard plant size to remediate 1 liter of sample fluid requires 5 grams of plant wet weight. This research method is an experiment with a completely randomized design (CRD) designed with the type of *Equisetum hymale* and 3 variations of *Equisetum hymale* biomass (P0: 0 g, P1: 750 g, and P2: 1000 g *Equisetum hymale*). Research samples were taken using purposive sampling, namely in stage 1 aeration ponds. The experimental units were as follows: P0: 0 g of *Equisetum hymale* /10 liters of leachate waste, P1: 750 g of *Equisetum hymale* /10 liters of waste leachate, P2: 1000 g *Equisetum hymale* /10 liters of waste leachate. Each treatment was repeated 3 times.

Result and Discussion

Characteristics of Jatibarang Landfill Leachate

The characteristics of Jatibarang landfill leachate waste are that it is dark black, cloudy and has a distinctive, strong organic aroma. Physically, the Jatibarang landfill leachate used during the research appeared to dissolve into one with no sediment, no residue and no visible lumps on the surface of the leachate before it was treated. Previous tests were carried out on leachate samples with the aim of determining total ammonia and nitrogen levels. Initial total ammonia and nitrogen levels of Jatibarang landfill leachate, in Table 1

Table 1. Initial characteristics of Jatibarang Landfill leachate

Parameter	Unit	Test Results	Regulation
Amonia	mg/L	15,71	10
Nitrogen	mg/L	61	60

Ammonia Levels

Equisetum hymale, can reduce leachate ammonia levels. Based on research data, this management provides significant value in reducing ammonia levels in leachate waste. On the third day of treatment, that the percentage decrease in leachate ammonia levels

experienced a large increase in P2, while on the seventh day of treatment, the largest percentage decrease in ammonia levels occurred in P2 which can be seen in Figure 1.

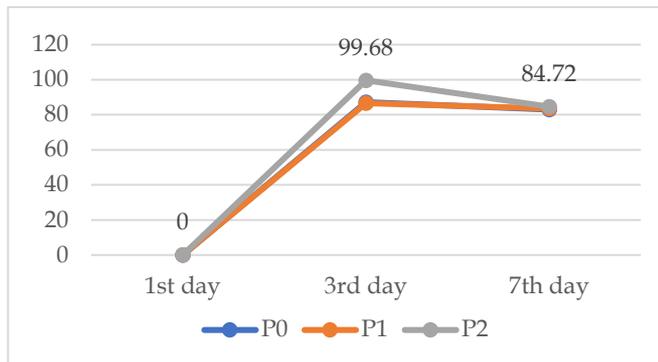


Figure 1. Percentage Decrease Ammonia Levels

Ammonia quality standards are set in Government Regulation no. 82 of 2001 with a maximum ammonia level of 5 mg/L. In the research, it was found that the ammonia levels contained in the leachate after phytoremediation decreased sharply. This phytoremediation is very effective in reducing ammonia levels in leachate, the reduction in ammonia levels reached 99.68%.

The decrease in ammonia levels by *Equisetum hymale* can be seen on the third day of P2, with initial ammonia levels of 15.71 mg/L which exceeds the quality standard and decreased on the third day with levels of 0.05 mg /L. *Equisetum hymale* with hyperaccumulator properties have the ability to concentrate pollutants in very large biomass. *Equisetum hymale* with dense, long, fibrous roots that spread in all directions with high absorption capacity are able to reduce ammonia levels. Not all plants can have hyperaccumulator properties, only certain plants have a strong and long fibrous root system, because the process occurs in the roots, for example in water hyacinth plants, vetiver and many more (Widyasari, 2021). Meanwhile, hypertolerant plants that are able to adapt and survive the stress of high levels of pollutants, *Equisetum hymale* do not directly absorb pollutants but adapt first to the environment to create conditions that support the decomposition process of pollutants and provide opportunities for microorganisms found in the rhizosphere. to grow and adapt to the acclimatization stage.

The success of phytoremediation can be seen from the plants absorption capacity for pollutants and the plants residence time requirements in phytoremediation (Sitia & Jusward, 2022). Plant as a phytoremediator agent utilizes inorganic nutrients through its root (Enduta et al., 2011). The roots of *Equisetum hymale* also have great potential, the more root tissue, the wider the rhizosphere

zone, the morphology of *Equisetum hymale* with dense, dense and long fibrous roots. The roots will produce excretory fluid, namely exudate fluid, this is important because this fluid is used to attract microorganisms to stick to the roots so that microorganism activity occurs. The young root is the main site of nutrient absorption because the lignification process has not occurred yet. The nutrient absorption process by the old roots is slower due to the thick epidermis and hypodermis tissues caused by the lignification process (Jampeetong et al., 2012).

In the research carried out, there was a decrease in ammonia at P0, as a result of P0 not being covered so it evaporated due to the high environmental temperature, and the boiling point of ammonia was at 330 C. This not only happened at P0 but also at P1 and P2 in very small amounts. In P1 and P2 most of the decline was caused by phytoremediation of *Equisetum hymale*. Mechanisms in ammonia phytoremediation include phytouptake, phytostimulation, rhizodegradation, phytostabilization, phytotransformation, phytodegradation and phytovolatilization.

At the phytouptake stage, the adsorption process absorbs ammonia content by the roots of *Equisetum hymale* by converting ammonia (NH_3) into ammonium (NH_4^+) due to the reaction of ammonia (NH_3) with water (H_2O) (Herlambang and Marsidi, 2003). Active transport in plant roots also occurs, which absorbs ammonium (NH_4^+) from leachate which requires ATP to move ions against the concentration gradient through the cell membrane. There is transformation and assimilation of ammonium with the enzymes glutamine and glutamate synthase, ammonium (NH_4^+), glutamate is absorbed by the roots of the water bamboo plant with the help of ATP to be integrated into organic compounds through reactions catalyzed by the results of glutamine. This glutamine will be reacted with α -ketoglutarate to form 2 glutamate molecules which can be used in nitrogen assimilation. This phytostimulation stage produces exudate fluid released through the rhizosphere zone to attract microorganisms to grow in this zone, as well as exudate fluid as a source of carbon and nutrients that will support the activity of microorganisms in the nitrification stage. Adaptation and growth of microorganisms begins at the acclimatization stage before the research begins. Entering the rhizodegradation stage, the decomposition process occurs and collaboration occurs between microorganisms and *Equisetum hymale*. There is a nitrification process where microorganisms use the ammonia content in leachate as nutrients. Nitrification by microorganisms around the roots, by oxidizing ammonia (NH_3) with the help of oxygen (O_2) to become nitrite (NO_2^-) and nitrite (NO_2^-) with the help of oxygen (O_2) will be oxidized to become nitrate (NO_3^-) which

occurs in the rhizosphere zone, which produces energy and is used by microorganisms for growth and metabolic processes.

This nitrification process converts ammonia thereby reducing the concentration or levels of ammonia in the leachate. *Equisetum hymale* then absorb what is produced and assimilate it back into ammonia in plant cells which is then used in *Equisetum hymale* metabolism to form organic nitrogen such as amino acids and proteins. In this phytostabilization stage, at this stage several enzymes and mechanisms will play a role in stabilizing the compound so that it does not spread widely to other parts. The next stage is phytotransformation, degradation by plants with pollutant compounds are broken down into simpler and less toxic compounds, while enzyme degradation from the *Equisetum hymale* itself breaks down complex organic compounds into simple compounds. In the phytodegradation stage, in the *Equisetum hymale* body, nitrate (NO_3^-) will be reduced back to ammonia (NH_3) through the enzymes nitrate reductase and nitrite reductase and then integrated into organic compounds. Synthesis of amino acids and proteins occurs using glutamate, glutamine, ammonia (NH_3) in the formation process which supports plant growth and development. Apart from that, nitrate is absorbed and transported to other parts.

Plant tissue transport (xylem) absorbs pollutants from the roots to the upper parts of the plant (stems and leaves), the main part of which is carried out by transpiration flow. Meanwhile, plant tissue, namely phloem, modified compounds or metabolic products can be transported through the phloem to other parts of the plant. In the phytovolatilization stage, the stem of the *Equisetum hymale* acts as a substitute for leaves for photosynthesis, the transpiration process occurs, namely evaporation of ammonia which is absorbed and released through the stem by epidermal cells in the form of gas and released into the air into the atmosphere. The photosynthesis process that occurs in *Equisetum hymale* allows the release of oxygen in the stems instead of leaves and the release of oxygen through a diffusion process to the roots through the aerenchyma tissue. Oxygen that reaches the roots can be released into the rhizosphere zone through exudate fluid so that the roots are rich in oxygen and bacterial growth occurs.

Roots are able to absorb more pollutants than stems and leaves because they have a wider surface area so that in the phytoremediation process of *Equisetum hymale*, most of the reduction in pollutants occurs in the plant roots, this is because the plant roots are in direct contact with the source of the pollutants produced. *Equisetum hymale* are also supported by polluting enzymes such as nitroreductase, lactase, dehalogenase, peroxidase and nitrilase which are found in the roots, stems and leaves.

Plants take up mainly three forms of nitrogen (nitrate ions, urea, and ammonium ions). Once ammonia is present in the plant cell, it is incorporated into proteins and other organic combinations through a biochemical reaction. However, only the ammonium ion is assimilated into the organic molecules in the plant tissues by means of enzymatic process (Masclaux-Daubresse et al., 2010).

This rhizosphere zone is important in phytoremediation, it can break down pollutants with the help of enzymes and transport pollutants in the growing environment to the root cells and there is a symbiosis of microorganisms, namely bacteria with *Equisetum hymale* in breaking down complex organic materials. into simple molecules or ions which will be absorbed by plant roots, as well as an absorption process (Ramadhani et al., 2019). Ammonium and nitrate ions are the principal sources of nitrogen for plant growth and are necessary in larger amount than the other mineral nutrients. In comparison to nitrate, ammonium is absorbed by the *Equisetum hymale* more quickly. It should be noted that the ammonium ions can be directly absorbed by the roots of the plants or as a result of nitrate ion reduction, it is further assimilated into the amide amino group of glutamine by the glutamine synthetase and subsequently, into glutamic acid by the glutamate synthase. These two enzymes resulted in the assimilation of most of the ammonium ions (Masclaux-Daubresse et al., 2010).

The nutrient content in waste is also used by bacteria to grow until it reaches an optimal point (exponential phase), which is where continuous decomposition occurs by bacteria so that in conditions there is a significant decrease in ammonia levels. The decrease reached 90%, while the following day until seventh day the ammonia level rose to 8% from the ammonia level on third day, it is estimated that the bacteria had entered the death phase.

Plant biomass in research also influences the decomposition process of pollutants, the more plant biomass, the more roots there will be and the decomposition will accelerate (Nashrullah, 2017). Water bamboo ability to release certain chemical compounds can break down organic material trapped in the root zone. Absorption by root cells then dissolves into the xylem and vertical transport occurs from the roots to the stem to the leaves. Carried to all parts of the body by plant tissue, namely phloem (Baroroh et al., 2018).

In P0, hypoxic conditions occur due to reduced dissolved oxygen in the landfill leachate so that many bacteria die and are unable to reproduce because they are saturated with nutrients and enter the death phase. The ammonium ions are toxic and not permitted to be stored in plants. Hence, the ammonium ions are either oxidized nitrate ions, assimilated to produce amino

acids, or converted to amides (Mitra, 2015). An increase of ammonium uptake in plants and storage may result in cell damage and further leads to cell death (Mattson N. & Leatherwood R., 2017). In P1 and P2, they reached the tolerance threshold for contaminant concentrations or experienced poisoning, causing wilting and death and rotting of many *Equisetum hymale* organs.

Total Nitrogen (TN) Levels

In this research, *Equisetum hymale* can reduce the total nitrogen of leachate. Based on research data, this management provides significant value in reducing total nitrogen levels in leachate waste. On the third day of treatment, you can see in the graph that the percentage decrease in total nitrogen content of leachate experienced a large increase in P2, while on the seventh day of treatment, the largest percentage decrease in total nitrogen occurred in P2 (see Figure 2).

In this research, we found a decrease in total nitrogen levels in Jatibarang landfill leachate due to a phytoremediation using water bamboo as the phytoremediation. The highest reduction in total nitrogen levels reached 91.74% in P2. In the research, there was a fluctuating process in the total nitrogen content of each replication in each test.

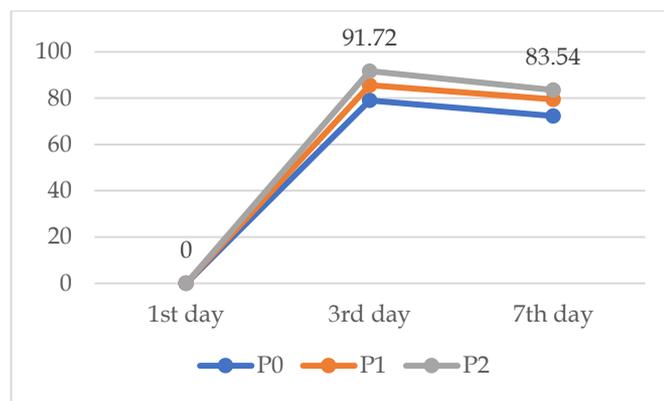


Figure 2. Percentage Decrease Total Nitrogen (TN) Levels

Total Nitrogen (TN) is the total level of nitrogen which forms the compounds Nitrate (NO_3^-), Nitrite (NO_2^-), Ammonia (NH_3) and ammonium ion (NH_4^+) as well as organic molecules contained in nitrogen. Total nitrogen levels are almost always found in waste water which is directly disposed of in the water, resulting in high productivity of eutrophication. Total nitrogen measurement parameters are often carried out in waters, the same is the case in this study as a test for determining total nitrogen levels in leachate waste. Total Nitrogen quality standards are stipulated in the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 with a maximum total nitrogen content value for group (1) 30 mg/L and group (2) 60

mg/L in waste (Regulation of the Minister of Environment and Forestry, 2016).

Due to the absorption of *Equisetum hymale* and the nitrification process. There was a decrease in total nitrogen at P0 due to P0 not being covered so that the nitrate (NO_3^-) in the process of nitrogen returning to the atmosphere changed nitrate into nitrogen gas so that there was a decrease even in small amounts. only occurs at P0 but also P1 and P2. In P1 and P2, most of the decrease was caused by phytoremediation of *Equisetum hymale*, namely assimilation by the process of forming amino acids from inorganic nitrogen. Ammonium is not a toxic compound. In an adequately oxidated environment, ammonia will be transformed into an intermediate nitrite. Nitrite is a relatively unstable compound because, on sufficient oxygen, it will easily be oxidated by nitrobacter to nitrate. The nitrite changes in the environment were still in control because of the adequate level of oxygen (Nuwansi et al., 2019).

Mechanisms in phytoremediation include phytostimulation, rhizofitration, rhizodegradation, phytodegradation and phytovolatilization. In the fixation process, the nitrogenase enzyme plays a role in converting nitrogen compounds in gas form (N_2) into nitrogen compounds which are absorbed by plants or reprocessed in the nitrogen cycle. The nitrogen in this gas (N_2) will be converted by plants into NH_3 . In the phytostimulation stage, this plant produces exudate which is released through the rhizosphere zone, thereby attracting microorganisms that grow in that zone, and the nitrification stage produces exudate as a source of carbon and nutrients to support the activity of microorganisms. Adaptation and growth of microorganisms begins with an adaptation phase before research begins. After entering the decomposition stage in the roots, the decomposition process occurs and cooperation between microorganisms and *Equisetum hymale* occurs.

At the rhizofitration stage, the adsorption process converts ammonia (NH_3) into ammonium (NH_4^+) through the reaction of ammonia (NH_3) and water (H_2O), and the ammonia content is absorbed from the *Equisetum hymale* roots (Herlambang & Marsidi, 2003). *Equisetum hymale* roots also have active transport to absorb ammonium (NH_4^+) from exudates, which requires ATP to move ions across cell membranes against a concentration gradient. Entering the rhizodegradation stage, conversion and assimilation of ammonium occurs using glutamine and the enzyme glutamate synthase. Ammonium (NH_4^+) and glutamate are absorbed into the water bamboo roots using ATP and incorporated into organic compounds through reactions catalyzed by the glutamine reaction. This glutamine reacts with alpha-ketoglutarate to form two

glutamate molecules that can be used for nitrogen assimilation.

There is a nitrification process by microorganisms around the *Equisetum hymale* roots that oxidize ammonia (NH_3) to nitrite (NO_2^-) with the help of oxygen (O_2), and nitrite (NO_2^-) to nitrate (NO_3^-) with the help of oxygen (O_2) by means of oxidation. Rhizodegradation stage, in the rhizosphere zone, energy is produced and used for microbial growth and metabolic processes. Next is the phytodegradation stage, the *Equisetum hymale* is then soaked in water and absorbs the resulting substances, which are then assimilated by microorganisms to convert ammonium ions (NH_4^+) into a form of organic nitrogen which is used for the synthesis of amino acids, proteins and other organic molecules. Ammonia is used in plant metabolism to form organic nitrogen, such as amino acids and proteins. At this plant stabilization stage, there are several enzymes and mechanisms whose job is to stabilize the compound so that it does not diffuse widely to other parts. Decomposition by plants at this stage, pollutants are broken down into simpler and less toxic compounds, while enzymatic degradation from the plants themselves break down complex organic compounds into simpler compounds. During the decomposition stage, nitric acid water (NO_3^-) is reduced to nitrogen gases (N_2) through a series of enzymatic reactions carried out by denitrifying bacteria. 1) Reduction of nitrate to nitrite, 2) Reduction of nitrite to nitric oxide, 3) Reduction of nitric oxide to nitrous oxide, 4) Reduction of nitrous oxide to nitrogen gas. The final result of denitrification is nitrogen gas (N_2) which will be released into the atmosphere.

Ammonia (NH_3) by the enzymes nitrate reductase and nitrite reductase in the *Equisetum hymale* body and incorporated into organic compounds. The synthesis of amino acids and proteins takes place using glutamate, glutamine, and ammonia (NH_3) in a formative process that supports *Equisetum hymale* growth and development. In addition, nitrates are absorbed and transported to other parts. Transport of plant tissue, or xylem, absorbs pollutants from the roots to the upper parts of the plant (stems and leaves) largely due to transpiration. On the other hand, through phloem, modified compounds or metabolites are transported to other plant parts through the phloem. During the phytovolatilization stage of the plant, *Equisetum hymale* stems act as substitute leaves for photosynthesis. The transpiration process occurs, which is released into the atmosphere. The photosynthesis process that occurs in *Equisetum hymale* releases oxygen in the stems, not in the leaves, thereby releasing oxygen to the roots through a diffusion process through the aerenchyma tissue. Oxygen that reaches the roots is released through exudates into the rhizosphere area, so that the roots are enriched with oxygen and cause the growth of bacteria.

In the phytoremediation, activity between *Equisetum hymale* and microorganisms occurs in roots which have a large surface area so they are able to absorb more and greater pollutants than the surface of stems and leaves (Nashrullah, 2017). *Equisetum hymale* are also supported by polluting enzymes such as nitroreductase, lactase, dehalogenase, peroxidase and nitrilase which are found in the roots, stems and leaves. *Equisetum hymale* roots have a rhizosphere whose function is to transport pollutants from the landfill leachate media into the root cells which are then broken down by enzymes and bacteria in the *Equisetum hymale* roots, namely the symbiosis of bacteria with the *Equisetum hymale* in decomposing organic material. Complex pollutants become simple molecules and simple ions which are absorbed by plant roots and in the absorption process (Ramadani et al., 2021).

The photosynthesis process in *Equisetum hymale* allows the release of oxygen in the roots so that the roots are rich in oxygen and bacterial growth occurs. Apart from that, the total nitrogen content as a nutrient or food is used in bacterial growth to the optimal point where bacterial decomposition occurs continuously, decreasing the total nitrogen level by 85%, on the following day until the seventh day the total nitrogen level increases to 7% of the total nitrogen content on third day, the bacteria are estimated to die. Bacteria that experience the death phase result in less than optimal performance of the roots. Apart from that, the dissolution of dead bacterial bodies causes the roots to rise so that the *Equisetum hymale* roots become saturated. Treatments P1 and P2 reached the tolerance threshold for contaminant concentrations or experienced poisoning, causing wilting to death and decay of many *Equisetum hymale* organs.

In P0, hypoxic conditions occur due to reduced dissolved oxygen in the leachate so that many bacteria die and are unable to reproduce because they are saturated with nutrients and enter the death phase. In P1 and P2, they reached the tolerance threshold for contaminant concentrations or experienced poisoning, causing death and decay of many *Equisetum hymale* organs.

Conclusion

Based on the results of research, it is concluded as follows *Equisetum hymale* are effective in reducing ammonia levels. The most optimal effectiveness of reducing ammonia levels in the P2 on third day of the research (99.7%). Meanwhile, the lowest effectiveness of ammonia occurred in the P0 treatment on the seventh day of the study (83.1%). *Equisetum hymale* are effective in reducing total nitrogen (TN) levels. The most optimal effectiveness of reducing total nitrogen levels occurred

in P2 on third day of the study (91.7%). Meanwhile, the lowest effectiveness of ammonia occurred in the P0 treatment on seventh day of the study (72.4%). *Equisetum hyemale* has been proven to be used as a phytoremediation agent that is quite effective in removed ammonia and total nitrogen level, up to 70% in variation of contact time.

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Author Contributions

Conceptualization, M. U., L. P. F., S., A. T. W.; methodology, M U.; validation, M. U., S.; formal analysis, L. P. F., A. T. W.; investigation, L. P. F.; resources, L. P. F.; data curation, M. U.; writing—original draft preparation, M. U., L. P. F.; writing—review and editing: M. U.; visualization: S., A. T. W.; All authors have read and agreed to the published version of the manuscript

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Conflicts of Interest

The authors declare no conflict of interest.

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