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Effectiveness of Water Bamboo as Phytoremediation Agent BOD and COD Leachate

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Abstract

Leachate is a liquid with an unpleasant odor and dark color that generally contains high organic and anorganic matter. High levels of organic and anorganic matter in leachate will potentially cause environmental pollution if not treated properly. One of the efforts that can be made to overcome these problems is with phytoremediation techniques. This study aims to determine the effectiveness of water bamboo (Equisetum hyemale) as a phytoremediation agent of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) leachate of Jatibarang landfill. This study used experimental research with a one-factorial Complete Randomized Design (RAL) design with three treatments (P0 without water bamboo, P1 750 gr water bamboo, and P2 1000 gr water bamboo). Based on the results of research shows that water bamboo plants can reduce BOD and COD levels. The decrease in leachate BOD levels was caused by the phytoremediation process by water bamboo during the study, where the organic matter content in leachate would be degraded by microorganisms. Meanwhile, COD levels decreased due to the chemical oxidation reaction process and phytoremediation process that runs side by side. The effectiveness of reducing BOD levels most optimally occurred in treatment P2 on day 7 of treatment, which was 28.42%; while the percentage of effectiveness of reducing COD levels most optimally occurred in treatment P2 on day 7 of treatment, which was 39.14%.

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INTRODUCTION

The problem of waste is still the main and crucial thing in life, with the condition of the pile of waste that continues to grow and is quite alarming from year to year. Based on data from the National Waste Management Information System (SIPSN) of the Ministry of Environment and Forestry (KLHK), in 2021 Indonesia produced 29.4 million tons of waste, then the volume of landfills increased by 21.7% in 2022 to 35.83 million tons. Based on the province, the highest volume in 2022 comes from the province of Central Java, which is 5.51 million tons or 15.39% of the total national waste. The large amount of landfill becomes a serious environmental problem if it is not managed properly and simply thrown into the landfill.

Landfill is an area where waste is processed and disposed of after passing through the stages of collection, transfer / transportation, processing, and disposal (Sanusi, 2023). The landfill that is a garbage collection in Semarang City is the Jatibarang Landfill. Jatibarang Landfill has an open system or *open dumping*, which causes water from outside to enter and inundate landfills. So that there is a thick black liquid that smells bad coming out of the garbage pile called leachate (*Leachate*). Leachate or *Leachate* is a liquid with an unpleasant odor and dark color that generally contains high organic and anorganic matter (Muna, 2023; Peng, 2017). High levels of organic and anorganic matter in leachate will potentially cause environmental pollution if not treated properly (Muryani, 2019).

The management of leachate at the landfill has not been managed optimally. This can be seen from the appearance of leachate which is pitch black and smells pungent. This condition is caused by still high levels of BOD and COD contained in leachate. Based on the results of the study Nofiyanto (2019) showed high levels of leachate BOD at the Jatibarang Landfill of 1,395 mg / L, followed by high levels of COD of 2,717 mg / L. Based on this previous research, it can be seen that the levels of BOD and COD leachate of the Jatibarang landfill are still far exceeding the leachate quality standards set by the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 59 of 2016 concerning Leachate Quality Standards for Business and / or Activities of the Final Waste Processing Site for levels the highest BOD is 150 mg / L and COD is 300 mg / L. High levels of BOD and COD that exceed quality standards are one indicator as a potential agent for water pollution.

The appearance of a deep black color and unpleasant odor in leachate is due to the content of BOD and COD in leachate water. *Biological Oxygen Demand* (BOD) is the amount of dissolved oxygen needed by microorganisms (bacteria) to break down organic matter under aerobic conditions. While *Chemical Oxygen Demand* (COD) is the amount of oxygen needed to break down all organic matter in chemical oxidation reactions. The amount of oxygen needed by microorganisms to break down organic matter is directly proportional to the amount of oxygen needed for the oxidation reaction process of decomposing organic matter. The higher the BOD level, the higher the COD level, where the organic matter content in the water is also high.

Phytoremediation is biological processing using plants or microorganisms that are able to remove contaminants from the polluted environment (Yunita, 2023). According to Nofiyanto (2019), states that plant indicators that can be used as phytoremediation agents are able to grow or tolerate high pollutants. Plant has hypertolerant properties because it can tolerate heavy metals with high concentrations in the crown and root tissue, While plants that are able to absorb and accumulate contaminants in waters are called hyperaccumulator plants. This hyperaccumulated plant thus becomes a suitable candidate for an efficient phytoremediation agent (Silviana, 2023). According to Khoirunnisa (2022) said that one of the plants that can be used as a phytoremediation agent comes from the Pteridophyta group because it is able to hyperaccumulate heavy metals. One type of plant that comes from the Pteridophyta group and has the potential as a phytoremediation agent is Water Bamboo (*Hyemale equisetum*).

Based on these problems, a strategy and innovation are needed in reducing BOD and COD levels in leachate. The solution to overcome this is phytoremediation using Water Bamboo plants (*Equisetum hyemale*) to reduce BOD and COD levels of landfill leachate.

METHOD

This research will be carried out in January 2024 at the Jatibarang Landfill in Semarang. The test of BOD and COD levels in leachate water was carried out at the Environmental Laboratory of the Semarang City Environmental Agency.

Figure 1. Jatibarang Landfill Leachate Pond

The materials used include 90 liters of leachate water and 5,250 grams of water bamboo (*Equisetum hyemale*). While the tools used include 9 pieces of plastic gallons measuring 15 liters, 1 bucket of 10 liters, 1 digital thermometer, 1 pH meter, 1 DO meter, 3 dippers, 1 scale, 1 pcs of label paper, 15 pieces of 1 liter jirigen.

This research is an experimental research using *a true experiment* design type *post-test only control group design*. Leachate water sampling was obtained from the leachate storage pond of the Semarang Jatibarang landfill. The research design used was a Complete Randomized Design (RAL) with three levels of treatment and three repeats, so that a total of 9 research units were obtained. The treatment given in this study is as follows:

P0 : 10 liters leachate without bamboo water (control).

P1 : 10 liters leachate + 750 grams bamboo water.

P2 : 10 liters leachate + 1000 grams bamboo water.

Data collection techniques are carried out through experiments and observations. In this study there are two data, namely primary and secondary data obtained from laboratory test results and with the help of tools. Then the results of the data obtained are compared with the leachate quality standards set by the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 59 of 2016 concerning Leachate Quality Standards for Business and / or Activities of Final Waste Processing Sites. The data obtained were then compared with leachate quality standards set by the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. 59 of 2016. Furthermore, the research data was analyzed by homogeneity test before the ANOVA (*Analysis of Variant*) test was carried out.

RESULT AND DISCUSSION

Result and discussion should be presented in the bsed on the research that has been done, results and discussions were obtained about the results of *Biological Oxygen Demand* (BOD) and *Chemical Oxygen Demand* (COD) levels of leachate at the Jatibarang Semarang Landfill which have gone through a phytoremediation process using Water Bamboo plants (*Equisetum hyemale*), as follows:

Water Bamboo Phytoremediation (*Equisetum hyemale*) against Leachate BOD Levels

Biological Oxygen Demand (BOD) is the amount of dissolved oxygen in waters used by microbes to degrade or decompose organic matter in water (Rachman, 2022). High levels of BOD in waters can be an indicator of the amount of pollutant load sourced from dissolved organic substances in these waters. The higher the level of BOD contained in the waters, the worse the quality of these waters or the condition of the waters is polluted. Conversely, the lower the BOD levels in a water, the better the quality of the waters. From the results of measuring leachate BOD levels on the 3rd day and 7th day after treatment are presented in **Table 1** and **Table 2**.

Table 1. BOD Levels Leachate Day 3 Treatment

Treatment	Flattening Power Beginning	Replay Rate (mg/L)			Flattening Power End	Percentage Decline (%)
		1	2	3		
P_0	516	518	518	518	518	-0,38
P_1	516	482	509	474	488,33	5,36
P_2	516	451	485	470	468,66	9,17

Based on these data, it can be seen that water bamboo plants (*Equisetum hyemale*) have effectiveness in reducing BOD levels on the 3rd day after treatment. The percentage of decrease in leachate BOD levels from the highest to the lowest consecutively, namely P_2 by 9.17%; P_1 is 5.36%; and P_0 is -0.38%.

Table 2. BOD Levels Leachate Day 7 Treatment

Treatment	Flattening Power Beginning	Replay Rate (mg/L)			Flattening Power End	Percentage Decline (%)
		1	2	3		
P_0	602	602	602	602	-16,67	602
P_1	401	353	360	371,33	28,03	401
P_2	295	365	448	369,33	28,42	295

Based on these data, it can be seen that water bamboo plants (*Equisetum hyemale*) have effectiveness in reducing BOD levels on the 7th day after treatment. The percentage of decrease in leachate BOD levels from the highest to the lowest consecutively, namely P_2 by 28.42%; P_1 of 28.03; and P_0 of -16.67%. Then a ANOVA test is carried out to determine whether the treatment has a significant effect or not which is presented in **Table 3.** and **Table 4.**

Table 3. ANOVA Test BOD Levels Leachate Day 3 Treatment

Source Diversity	Degree Free	Total Square	Square Center	Fcount	F_{table}	
					5%	1%
Treatment	2	3700,66	1850,33	8,858	5,14	10,92
Error	6	1253,33	208.889			
Total	8	4954				

Based on these data, it can be seen that F_{count} (8.858) > F_{table} (5.14) in treatment, meaning that between treatments show a real difference, and the results of research H_0 rejected and H_1 accepted, so further tests need to be carried out. This shows that the biomass of water bamboo plants (*Equisetum hyemale*) has an effect as a phytoremediation agent on reducing leachate BOD levels.

Table 4. ANOVA Test BOD Levels Leachate Day 7 Treatment

Source Diversity	Degree Free	Total Square	Square Center	Fcount	F_{table}	
					5%	1%
Treatment	2	107344,88	53672,44	24,625	5,14	10,92
Error	6	13077,33	2179,55			
Total	8	120422,22				

Based on these data, it can be seen that F_{count} (24.625) > F_{table} (5.14) in treatment, meaning that between treatments show a very real difference, and the results of research H_0 rejected and H_1 accepted, so further tests need to be carried out. This shows that the biomass of water bamboo plants (*Equisetum hyemale*) has an effect as a phytoremediation agent on reducing leachate BOD levels. Based on the data from the study, there was a difference in the decrease in the level of BOD Leachate on the 3rd and 7th days. On the 3rd day after treatment, the highest percentage of decrease in leachate BOD levels occurred in P2 at 9.2%. The same thing happened on the 7th day after the treatment, where P2 had the highest percentage of reduction in BOD levels, which was 28.5%. The results of the study showed that there was a level of effectiveness in reducing the level of BOD leachate during the study. This is due to the decomposition process of organic matter by aerobic bacteria in leachate liquid waste and there is also a phytoremediation process carried out by water bamboo plants (*Equisetum hyemale*). In the mechanism of the phytoremediation process by the aquatic bamboo plant, most of the decrease in pollutants occurs in the root part of the plant. This is because plant roots have direct contact with the source of contaminants in leachate. Aquatic bamboo plants (*Equisetum hyemale*) has fibrous and long roots, so the contact surface area between the roots and leachate will be larger.

The presence of rhizosphere microbes in the roots that can decompose contaminants by absorbing them from the water (Margowati & Abdullah, 2017). The decomposition results will later accumulate in plant stems to leaves, and then evaporate into the atmosphere in the form of less harmful pollutants (Febriningrum & Nur, 2021). Data on the development of the percentage reduction in leachate BOD levels at the Jatibarang Semarang landfill during the study can be seen in **Figure 2.**

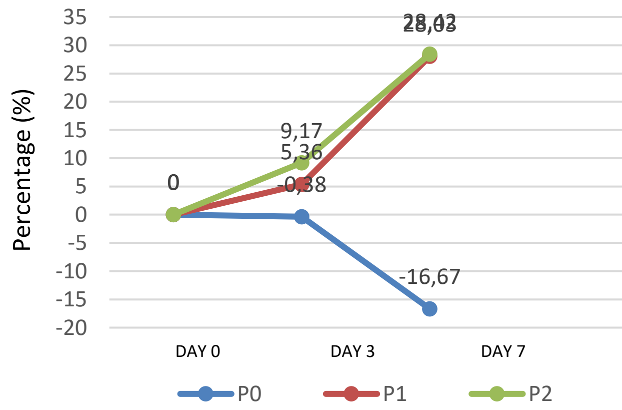

Figure 2. Effectiveness of Leachate BOD Reduction

According to Mubarak et al., (2020); Riyanto, (2023) Declares that the water bamboo plant (*Equisetum hyemale*) has a high silicate content, functioning as a binder for pollutant particles. The decrease in BOD levels in phytoremediation techniques is also influenced by the ability of plants to absorb and accumulate pollutants. These hyperaccumulated plants have the capacity to absorb contaminants into plant tissues and convert them into less harmful forms (Silviana & Rachmadiarti, 2023). Bamboo plants (*Equisetum hyemale*) also has hypertolerance to metal elements, because it can tolerate heavy metals with high concentrations in the crown and root tissue (Candra et al., 2019).

Based on the results of the study, there was a decrease in BOD levels influenced by the phytoremediation mechanism. The pollutants in leachate will be accumulated by plant roots through the Rhizofiltration process (*Rhizofiltration*). Then there is a biological reaction where the rhizosphere microbes around the roots will convert the organic matter in the leachate pollutant into other simple compounds such as water and carbon dioxide, this process is called Rhizodegradation (*Rhyzodegradetion*).

Pollutants that are no longer harmful are then released through the process of plant transpiration in the form of CO_2 and H2O in the process of phytobolatylation (*Phytovolatization*). Carbon dioxide (CO_2) the results of the degradation of organic matter will then be used by plants as a starting material for the photosynthesis process, CO_2 will be processed during photosynthesis and produce oxygen, this oxygen is used and utilized by aerobic bacteria in liquid waste to degrade the organic matter contained in it. So that in the phytoremediation cycle of BOD by water bamboo plants, the oxygen from plant photosynthesis will be distributed throughout the plant, including to the roots. With the principle of diffusion, oxygen will flow to the leaves towards the stem of the plant and will go to the root system of the plant. Oxygen from photosynthesis will enter the water through plant roots and then be used by microorganisms to degrade organic matter into other simple compounds (Hafidzah et al., 2024; Marlany et al., 2023; Riyanto, 2023). This is supported by Yolanda & Heriyanti, (2024) that the supply of oxygen to decomposing microorganisms can help reduce the levels of organic substances contained in the waste.

Leachate contains organic matter in the form of hydrocarbon compounds. The hydrocarbon compounds contained in leachate include fats ($C_3H_5(RCOO)_3$), protein ($RCHNH_2COOH$), and carbohydrates ($C_6H_{12}O_6$) (Said & Hartaja, 2018). Fats, proteins, carbohydrates in hydrocarbon compounds found in leachate organic matter come from the decomposition process or pose for the decay of organic waste such as food scraps, fruit and vegetable scraps, leaves, animal manure, etc. These complex hydrocarbon compounds, namely fats, proteins, and carbohydrates, will be degraded by enzymes such as lipolimicity, protease, and cellulase produced by rhizosphere bacteria (Riyanto, 2023).

For organic matter containing hydrocarbon compounds in the form of fats ($C_3H_5(RCOO)_3$), will be broken down by lyophilic bacteria i.e. *Staphyllococcus aureus* and *Pseudomonas sp.* by producing lipase enzymes so that it can degrade fat into simpler substrates. This substrate will be hydrolyzed into pyruvic acid. This pyruvic acid will enter the bacterial krebs cycle which will eventually produce a product in the form of carbon dioxide (CO_2) and water (H_2O) (Fidiastuti & Suarsini, 2017). As for the degdradation of protein hydrocarbon compounds ($RCHNH_2COOH$) broken down by proteolytic bacteria i.e. bacteria *Bacillus* by producing protease enzymes to degrade protein compounds into anorganic materials in the form of fatty acids and ammonia (NH_3), fatty acids are one of the sources of energy in the respiration process with products in the form of carbon dioxide (CO_2) and water (H_2O). While ammonia (NH_3) which is an anorganic material will later go through an oxidation process to produce compounds in the form of nitrites with the help of bacteria *Nitrosomonas*, then the nitrite will be converted back by bacteria *Nitrobacter* into nitrate, this nitrate is what functions for the growth and development of plants (Fitriana & Asri, 2021). On the degradation of carbohydrate hydrocarbon compounds ($C_6H_{12}O_6$) The rhizosphere microbes that play a role are bacteria *Cellulomonas sp.* which is a group of cellulolytic bacteria that produce cellulase enzymes to break down glucose into methane, water, and carbon dioxide (Khastini et al., 2022).

The phytoremediation cycle of BOD water bamboo plants is presented in **Figure 3**

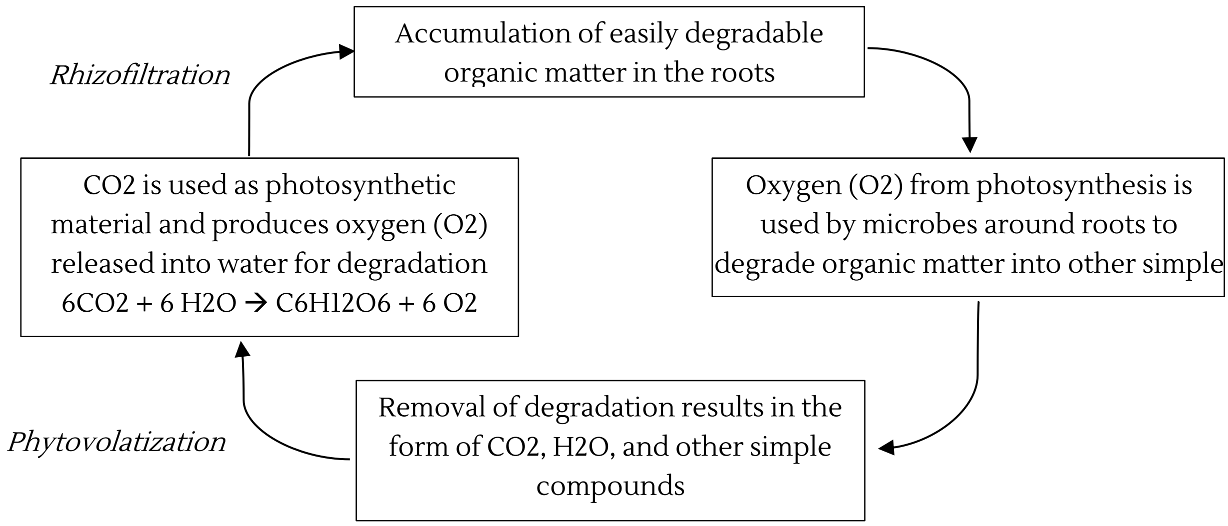

Figure 3. Water Bamboo Plant BOD Phytoremediation Cycle

The organic matter in the waste has been degraded or decomposed, so microorganisms no longer need oxygen to decompose or decompose dissolved and suspended organic matter in the liquid waste. So that the amount of oxygen needed by microorganisms to decompose organic matter or BOD levels can be reduced. The least BOD content in the waters, the number of organisms in the waters is getting smaller (Hafidhin et al., 2023). This is in line with the statement Riyanto, (2023) that the number and activity of microorganisms have a significant influence on the value of BOD.

Water Bamboo Phytoremediation (*Equisetum hyemale*) against Leachate COD Levels

Chemical Oxygen Demand (COD) is the amount of oxygen needed to oxidize by chemical reactions in organic materials, COD is measured based on the results of the amount of oxygen consumption during a chemical reaction (Pramesti &; Yuniningsih, 2023). According to Ristiyanto (2020) COD can be used as an indicator in identifying pollution that occurs in waters by chemical compounds in the form of industrial pollutants, toxic chemicals, and organic matter that is difficult to decompose biologically, the higher the COD contained in water means the worse the quality of the waters. From the results of measuring leachate BOD levels on the 3rd day and 7th day after treatment are presented in **Table 5** and **Table 6**

Table 5. COD Levels Leachate Day 3 Treatment

Treatment	Flattening Power Beginning	Replay Rate (mg/L)			Flattening Power End	Percentage Decline (%)
		1	2	3		
P_0	1280	1125	1125	1125	1125	12,1
P_1	1280	1044	1064	1016	1074,66	18,64
P_2	1280	990	1084	1032	1035,33	19,11

Based on these data, it can be seen that water bamboo plants (Equisetum hyemale) have effectiveness in reducing COD levels on the 3rd day after treatment. The percentage of reduction in leachate COD levels from the highest to the lowest consecutively, namely P2 of 19.11%; P1 is 18.64%; and P0 is 12.1%.

Table 6. COD Levels Leachate Day 7 Treatment

Treatment	Flattening Power Beginning	Replay Rate (mg/L)			Flattening Power End	Percentage Decline (%)
		1	2	3		
P_0	1280	1326	1326	1326	1326	-3,59
P_1	1280	851	760	762	791	38,2
P_2	1280	634	780	923	779	39,14

Based on these data, it can be seen that water bamboo plants (*Equisetum hyemale*) have effectiveness in reducing COD levels on the 7th day after treatment. The percentage of reduction in leachate COD levels from the highest to the lowest consecutively, namely P_2 by 39.14%; P_1 at 38.2%; and P_0 at -3.59%. Then a ANOVA test is carried out to determine whether the treatment has a significant effect or not which is presented in **Table 7.** and **Table 8.**

Table 7. ANOVA Test COD Levels Leachate Day 3 Treatment

Source Diversity	Degree Free	Total Square	Square Center	Fcount	F_{table}	
					5%	1%
Treatment	2	15076,22	7538,11	8,08	5,14	10,92
Error	6	5597,33	932,88			
Total	8	20673,55				

Based on these data, it can be seen that F_{count} (8.08) > F_{table} (5.14) in treatment, meaning that between treatments show a real difference, and in research results H_0 is rejected and H_1 is accepted, so further tests need to be carried out. This shows that the biomass of water bamboo plants (*Equisetum hyemale*) has an effect as a phytoremediation agent on reducing leachate COD levels on the 3rd day of treatment.

Table 8. ANOVA Test BOD Levels Leachate Day 7 Treatment

Source Diversity	Degree Free	Total Square	Square Center	Fcount	F_{table}	
					5%	1%
Treatment	2	585578	292789	37,247	5,14	10,92
Error	6	47164	7860,66			
Total	8	632742				

Based on these data, it can be seen that F_{count} (37.247) > F_{table} (5.14) in treatment, meaning that between treatments show a real difference, and the results of research H_0 rejected and H_1 accepted, so further tests need to be carried out. This shows that the biomass of water bamboo plants (*Equisetum hyemale*) has an effect as a phytoremediation agent on reducing leachate COD levels on the 7th day of treatment. Data on the development of the percentage reduction in leachate BOD levels at the Jatibarang Semarang landfill during the study can be seen in **Figure 4**.

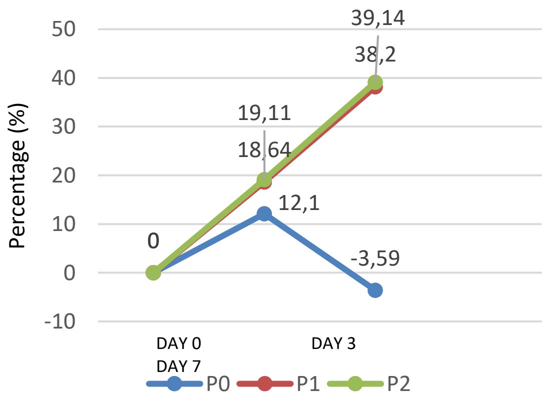

Figure 4. Effectiveness of Reducing Leachate COD Levels

The results of the study obtained P1 and P2 treatment showed a decrease in COD levels which was influenced by the mechanism of phytoremediation and decomposition of organic matter by microorganisms and the decomposition of anorganic materials through chemical oxidation process. According to Sasmitamihardja & Siregar, (1996) states that one of the products produced by plants in the photosynthesis process is oxygen (O_2). The oxygen produced during photosynthesis will be used for materials in aerobically oxidizing chemical reactions to oxidize anorganic compounds. The process of oxidation chemical reaction to degrade organic matter is as follows:

Anorganic Substances + → Other Simple Compound Oxidizers

Source: (Novela & Gods, 2019)

The decrease in COD levels in the study is also due to the process of chemical oxidation and phytoremediation, where pollutants or organic matter and anorganic substances in leachate will be accumulated by plant roots through the Rhizofiltration process. Then there is a biological reaction where the rhizosphere microbes around the roots will convert the organic matter in the leachate pollutant into other simple compounds such as water and carbon dioxide. As for anorganic materials, they will go through a chemical oxidation reaction with the help of oxygen from photosynthesis into simple compounds that are less harmful and are used by plants for growth and development, the process is called *Rhyzodegradetion*. The next process is *Phytostabilization*, where the less harmful pollutant compounds are transformed into plant tissues, both stems and leaves. Pollutants that are no longer harmful are then released through the process of plant transpiration in the form of CO_2 and H_2O in the process of *phytovolatization*.

Carbon dioxide (CO_2) resulting from the degradation of organic matter and anorganic matter will then be used by plants as a starting material for the photosynthesis process, carbon dioxide (CO_2) will be processed during photosynthesis and produce oxygen, this oxygen is used and utilized for microorganisms in biological processes and also used as an oxidizer in the chemical oxidation process to degrade anorganic materials.

In leachate there are anorganic materials, where these anorganic materials are difficult to degrade by biological reactions, so oxidants in the form of oxygen and other compounds are needed to degrade the anorganic materials in the chemical oxidation process. The anorganic materials contained in leachate include ammonia, potassium, phosphate, calcium, magnesium, and other heavy metal compounds such as iron (Fe), lead (Pb), zinc (Zn), copper (Cu), and cadmium (Cd).

The anorganic materials contained in leachate in the form of ammonia compounds come from the process of decomposition, weathering, and decomposition of plants and the rest of dead organisms in the garbage (Pay et al., 2021; Ramadhan & Yusanti, 2020). According to Satria et al., (2019) states that ammonia is a form of nitrogen in waste, in aerobic conditions ammonia will be converted into nitrate through several processes, then the nitrate will be used by plants. In the process of decomposition, ammonia (NH_3) will react with water to ammonium (NH_4), this ammonium will later be oxidized into nitrite form (NO_2) and nitrate (NO_3). The oxidation reaction chemically decomposes ammonia in leachate liquid waste according to (Ivontianti et al., 2022) as follows:

1. Ammonia to ammonium
   $NH_3 + H_2O \rightarrow NH_4 + OH$
2. Ammonium to nitrite
   $NH_4 + O_2 \rightarrow NO_2 + 2H + 2H_2O$
3. Nitrile to nitrate
   $NO_2 + O_2 \rightarrow 2NO_3$

Nitrate (NO_3) will be translocated to plants for the growth and development process. According to (Wibowo et al., 2020) Nitrates are needed by plants to repair damaged body tissues, the formation of chlorophyll, protoplasm, proteins, and nucleic acids.

Potassium is one of the anorganic materials in liquid waste, the high potassium in waste is caused by the formation of acids during decomposition (Akbari et al., 2022). The process of decomposition of potassium in the chemical oxidation process is as follows:

$$4K + O_2 \rightarrow 2K_2O$$

Source: Tri Andini & Dewati, (2020)

The result of the chemical oxidation process of potassium with the help of oxygen produces potassium oxide. According to (Oktrisna et al., 2017) potassium oxide (K_2O) It has an important role such as a transport medium (translocation) and activator of enzymes during metabolism because it contains K ions.

According to Apriyani, (2017) high levels of phosphate in waters cause high levels of nutrients so that eutrophication occurs. According to (Hidayat et al., 2018) phosphate oxidation reaction process (PO_4^{3-}) into the primary orthophosphate ion ($H_2PO_4^-$) or secondary orthophosphate $(HPO)_4^{2-}$), as follows:

1. Phosphate to primary orthophosphate
   $PO4^{3-} + H_2O \rightarrow H_2PO4^- + OH^-$
2. Primary orthophosphate becomes secondary orthophosphate
   $H_2PO4^- + H_2O \rightarrow HPO4^{2-} + H_3O^+$

Phosphate content in plants in the form of primary orthophosphate ions ($H_2PO_4^-$) or secondary orthophosphate $(HPO)_4^{2-}$) is energy transfer and and stimulates plant root growth (Lesmana et al., 2023).

In leachate, there is a content of calcium anorganic substances in the form of calcium carbonate ($CaCO_3$) which comes from fish bone waste, shells, and egg shells (Handayani & Syahputra, 2017; Prakoso & Udjiana, 2023). The oxidation reaction of calcium carbonate ($CaCO_3$) as follows:

$$CaCO_3 + 2H + \rightarrow Ca^{2+} + CO_2 + H_2O$$

Source: Hariyanto et al., (2020)

Oxidation results of calcium carbonate ($CaCO_3$) in the form of Ca ions 2+ will be used by plants to stimulate root growth(Hasmeda et al., 2021).

Magnesium in leachate comes from fruit peels, soybean shells, leaves, coffee grounds, and paper or cardboard (Bachtiar et al., 2018; R. A. Putra et al., 2021; Putri et al., 2022). According to Neneng & Saraswati, (2019) states that magnesium can be absorbed by plants in the form of Mg^{2+}. The oxidation reaction of magnesium is as follows:

$$Mg + 1/2\ O2 + H_2O \rightarrow Mg^{2+} + 2OH^-$$

Source: (Amrulloh et al., 2016)

According to Neneng & Saraswati, (2019) states that magnesium in the form of Mg^{2+} It is part of plant chlorophyll that cannot be replaced by other elements. Magnesium plays a role in the activation of enzymes involved during the process of respiration (Rasyidah & Manalu, 2022).

According to Karamina et al., (2021; Nofiyanto et al., (2019) Leachate contains heavy metal anorganic materials such as iron (Fe), lead (Pb), zinc (Zn), copper (Cu) and cadmium (Cd). The heavy metal content in leachate comes from various types of waste such as waste from electronic devices, batteries, paints, cans, pipes, electrical tools, fertilizer use, industrial emissions, and buildings (Febrianto & Buchari, 2024; Puspitarini et al., 2023; Sari & Afdal, 2017). The equation of chemical oxidation reactions from heavy metals in waste is as follows:

1. Iron (Fe^{2+}) to Ferihydroxide ($Fe(OH)_3$)
   $4Fe^{2+} + 3O2 + 6H_20 \rightarrow 4Fe(OH)_3$
   Source: Situmorang, (2016)
2. Lead (Pb2+) to Lead dioxide (PbO_2)
   $Pb^{2+} + H_2O_2 \rightarrow PbO_2 + 2H^+$
   Source: Patmawati et al., (2023)
3. Zinc (Zn) to Zinc oxide (ZnO)
   $2Zn + O_2 \rightarrow 2ZnO$
   Source: Larasati et al., (2017)
4. Copper (Cu) to Cupri oxide (CuO)
   $2Cu + O_2 \rightarrow 2CuO$
   Source: Anami et al., (2020)
5. Cadmium (Cd) to Cadmium oxide (CdO)
   $Cd+ + 1/2\ O^2 + H_2O \rightarrow CdO + 2H^+$
   Source: Ulfa, (2018)

In heavy metals that have undergone a chemical oxidation reaction with the help of oxygen released by plants at the phytoremediation mechanism, the toxicity content of heavy metals in leachate can be reduced (Aryanti, 2020).

According to Haviz et al., (2021); Neneng & Saraswati, (2019) stated that changes in the chemical structure of heavy metals can reduce the ability of heavy metals to immobilize. Copper plays an important role in the formation of lignin, plays a role in the stability of the cell membrane, iron is involved in the transport of electrons during photosynthesis, and other stable forms of heavy metals can interact with rhizosphere microbes to increase microbial activity roots (Khasanah et al., 2021). The COD phytoremediation cycle of aquatic bamboo plants is presented in **Figure 5**

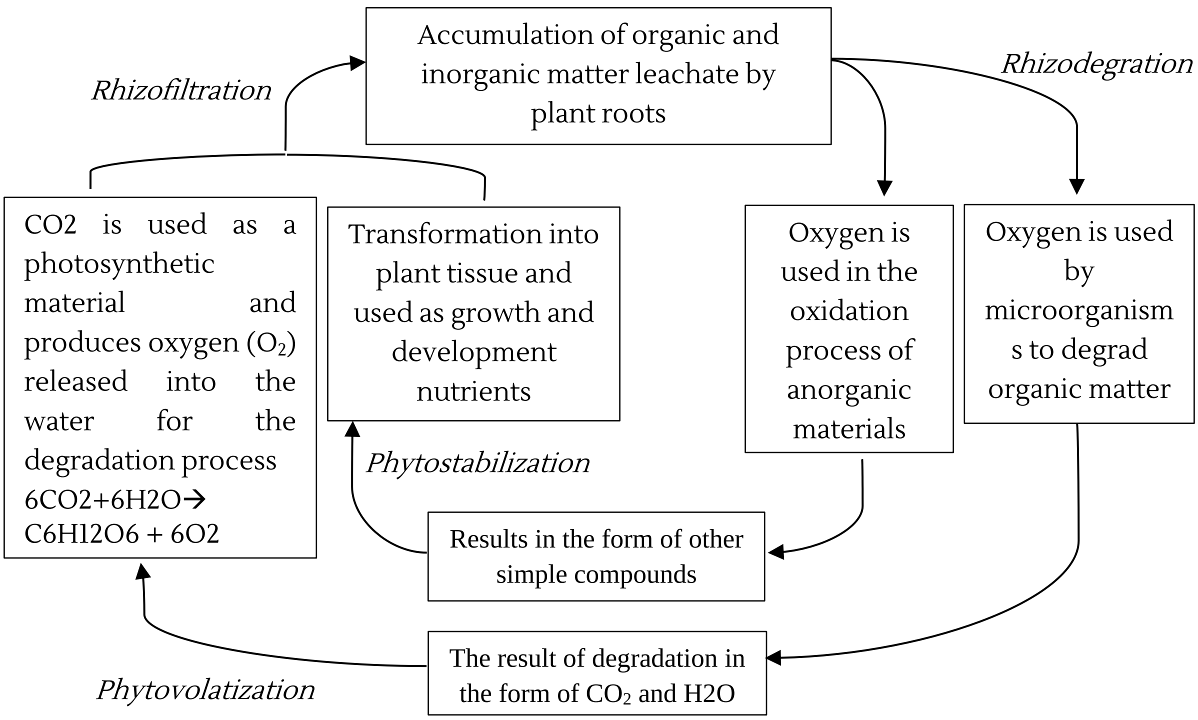

Figure 5. Water Bamboo Plant COD Phytoremeditiation Cycle

The decrease in COD levels in phytoremediation techniques is also influenced by the ability of plants to absorb and accumulate pollutants. Water bamboo plants (*Equisetum hyemale*) are hypertolerant and hyperaccumulator. These hyperaccumulated plants have the capacity to absorb contaminants, in hyperaccumulation pollutants will be absorbed by plant roots and concentrated in plant tissues or decomposed into harmless forms (Silviana &; Rachmadiarti, 2023). Bamboo plants (*Equisetum hyemale*) also has hypertolerance properties to metal elements, because it can tolerate heavy metals with high concentrations in the crown and root tissue (Candra et al., 2019)

The decrease in *Chemical Oxygen Demand* (COD) levels in P_1 and P2 treatment is due to pollutants in leachate that have been degraded by water bamboo plants during the phytoremediation process. When the organic matter in the waste has been degraded or decomposed, there is no longer an oxidation chemical reaction that requires oxygen to decompose or decompose the dissolved and suspended organic matter in the liquid waste. So that the amount of oxygen needed to decompose organic matter in the process of chemical oxidation or COD levels can be reduced.

At the end of the research period the condition of water bamboo plants (*Equisetum hyemale*) dry, wilted, and yellow. This is because water bamboo plants have reached their threshold or saturation point in tolerating the absorption of pollutant levels in leachate so that many plants experience death (Roni, 2020).

In the research that has been done, there was the largest decrease in leachate BOD levels from the initial average of 516 mg / L to 369.33 mg / L. The same thing also happened to COD levels, there was a decrease from the initial average levels of 1280 mg / L to 779 mg / L. and/or Final Waste Processing Site Activities for the highest levels of BOD 150 mg/L and COD of 300 mg/L.

In the research conducted, the percentage of effectiveness of reducing BOD levels by 28.42% and COD by 39.14%. In previous research, namely in research Al Kholif (2020) stated that water bamboo is able to set aside BOD levels of 95.43% and COD levels of 89.67% in domestic waste. This is supported by research Margowati &; Abdullah, (2017) which states that water bamboo is able to reduce COD levels in household waste to reach 76.35% and BOD levels by 86.19%. Then research Kholisah et al., (2022) which states that the efficiency of removing BOD levels in tofu liquid waste occurs on days 10 to day 15 of 79.10%. This difference is due to the characteristics of the waste used, where leachate waste has stronger and more dangerous properties than domestic waste and tofu liquid waste. Leachate water waste is very dangerous because the concentration of organic matter content is very high formed due to the decomposition process of waste by microorganisms so that it releases a black and concentrated liquid.

CONCLUSION

Based on the results of the research that has been done, it can be concluded as follows:

1. Water bamboo plants (*Equisetum hyemale*) are effective in reducing the levels of *Biological Oxygen Demand* (BOD) leachate. The effectiveness of reducing BOD levels most optimally occurred in treatment P_2 on the 7th day of the study, which was 28.42%; while the effectiveness of reducing BOD levels was lowest in P_0 treatment on day 7 of the study, which was -16.67%.
2. Water bamboo plants (*Equisetum hyemale*) are effective in reducing the levels of *Chemical Oxygen Demand*

(COD) leachate. The effectiveness of reducing COD levels most optimally occurred in treatment P_2 on day 7 of the study, which was 39.14%; while the effectiveness of reducing COD levels was lowest in treatment P_0 on day 7 of the study, which was -3.59%.

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