Journal of Sustainable Development Science
Vol. 6, No. 1, June 2024, pp. 1-7
e-ISSN: 2715-9140 | p-ISSN: 2722-919X

Simple Prototype Design of Phytoremediation Installation in Small Pilot Scale of Acid Mine Drainage Passive Treatment

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ABSTRACT

Phytoremediation is usually applied to passively treat Acid Mine Drainage (AMD) by constructing a wetland. To increase the success of the AMD treatment method, laboratory trials were carried out on a pilot scale, and the experimental results were applied on an actual scale. Therefore, a simple design will be prepared for this research that replicates the wetland work system. This research aimed to produce a prototype that could be used for initial testing of phytoremediation on a smaller scale before being applied to field conditions. The installation design was created using Adobe Illustrator software. The trial lasted two months, using modified acid water and flowing it periodically as controlled droplets via an infusion tap into the media that used *Typha* sp and *Pistia stratiotes* L as phytoremediator agents. This equipment was tested with three acidity levels, 4, 5, and 6, repeated twice for two months. Results showed that the prototype was built using three buckets arranged in layers, each with its function. The phytoremediation process had successfully occurred in this study, and installation was suitable to support the process. There was a change in AMD acidity around the plants for five weeks and an increase in acidity the fourth week after treatment at the outlet. It could be seen that AMD with lower acidity levels resulted in greater plant damage in the sixth week, but *Typha* sp still showed resistance to an acidic environment.

Keywords: *Prototype design, phytoremediation, Acid Mine Drainage, Pilot scale, passive treatment*

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1. INTRODUCTION

Acid Mine Drainage (AMD) is wastewater formed through chemical reactions and biological activities (Armaiki *et al.,* 2019). Rocks containing sulfides in the presence of oxygen and water undergo oxidation to form sulfuric acid, so they have a pH <4 (Wahyudin *et al.,* 2018). Low pH causes an increase in the solubility of heavy metals in water (Rahmat and Nopi, 2018).

AMD with low acidity levels and high levels of the heavy metals Fe and Mn could disturb aquatic ecosystems, inhibit plant growth, and poison living creatures. This impact's emergence requires AMD processing before releasing it into the environment (Rahmalia *et al*., 2020).

One of the remediation techniques for AMD-polluted environments is phytoremediation (Emil and Rizki, 2024). Phytoremediation uses plants to remove pollutants from contaminated soil or water (Rondonuwu, 2014). This technique is an innovative, economical, and relatively safe environmental technology (Sidauruk and Patricius, 2015). The process occurs in the leaves, stems, roots, or outside around the roots with the help of enzymes released by plants (Bonauli *et al.,* 2014). The types of plants used as phytoremediation are water hyacinth, *E. dulcis*, *Typha sp* and *Pistia stratiotes* L, that have effectiveness and resistance when reducing metal content in acid mine drainage (Asri *et al*., 2022).

Phytoremediation research could generally be carried out directly in the field, but initial information is often needed on how the phytoremediation system would work. Information regarding suitable plant types, input current from voids, the type of metal to be adsorbed, and the method. Phytoremediation is usually applied to passively treat AMD by constructing a wetland. The advantage of this method is that it does not require high investment costs. Constructed wetland is a method of treating AMD that uses plants to increase pH or absorb metals (Liu *et al.,* 2022). To increase the success of the AMD treatment method, laboratory trials were carried out on a pilot scale, and the experimental results were applied on an actual scale.

Research on pilot-scale AMD treatment has been reported by Chostak *et al.* (2023). A pilot device was developed containing sorbent material slices for use under an upward continuous flow in a treatment system. The research was a pilot scale for active acid mine drainage treatment. Research on active acid mine drainage treatment was also carried out by Nasir *et al*. (2016); the study stated that a small-scale plant consisting of the sand filter, ultrafiltration, and reverse osmosis for the treatment of AMD was designed and tested using a synthetic solution of AMD. Meanwhile, a pilot-scale design for the passive treatment of AMD using phytoremediation methods has not been found yet. Therefore, a simple design will be prepared for this research that replicates the wetland work system. fication). The constructed wetlands (CW) system is quite effective for controlling AMD where biological processes occur in the interactions between the plants that make up the CW vegetation (Henny *et al*., 2010). The principle of a constructed wetland is utilizes symbiosis between aquatic plants and rhizosphere that microorganisms in a medium around the plant root system to help increase the pH and reduce the concentration of dissolved Fe and Mn metals as well as total suspended solid) in acid mine water (Maulida dan Ipung, 2023). This research aimed to produce a prototype that could be used for initial testing of

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phytoremediation on a smaller scale before being applied to field conditions.

2. METHODS

The installation design was created using Adobe Illustrator software. Installation testing was in the Greenhouse of the Faculty of Agriculture, UPN Veteran Yogyakarta. The trial lasted two months, using modified acid water and flowing it periodically as controlled droplets via an infusion tap into the media. The test plants used were *Typha* sp (cat tail) and *Pistia stratiotes* L. This equipment was tested with three acidity levels, 4, 5, and 6, repeated twice. The study was performed for two months.

The installation design is shown in Figure 1 A. The materials used are H_3PO_4, pH meter, EC meter, and TDS meter. Seedlings of each species were transferred to buckets. The observations were measurements of the pH around the plant (second bucket) and the pH around the outlet (third bucket), the average percentage of damage.

3. RESULT AND DISCUSSION

Installation Design

The results of the installation design obtained a simple design using buckets arranged in tiers (Figure 1). It was built using three buckets arranged in layers, each with its own function. The first bucket had a diameter of 35 cm and a height of 42 cm and functioned as a container for the source of acid water. The first bucket had a 3/16 inch hose on the bottom side to drain the acid water to the next bucket. An infusion tap was added to the end of the hose to regulate the flow of the acid water that will flow. The second bucket, with a diameter of 30 cm and a height of 26 cm, functioned as a place for the phytoremediation process by using soil as planting media and *Typha sp* and *P. stratiotes* L as phytoremediation agents. The bucket was filled with ⅔ of the soil. *Typha sp* was planted filled with water up to ± 5 cm above the soil's surface, and the *P. stratiotes* L were spread on the surface. The second bucket had a 3/16-inch hose to maintain the water level and channel the acid water collected from the second to the third bucket. The third bucket had a diameter of 50 cm and a height of 22 cm. It collected the output of water, which had undergone a phytoremediation process by *Typha* sp and *P. stratiotes* L.

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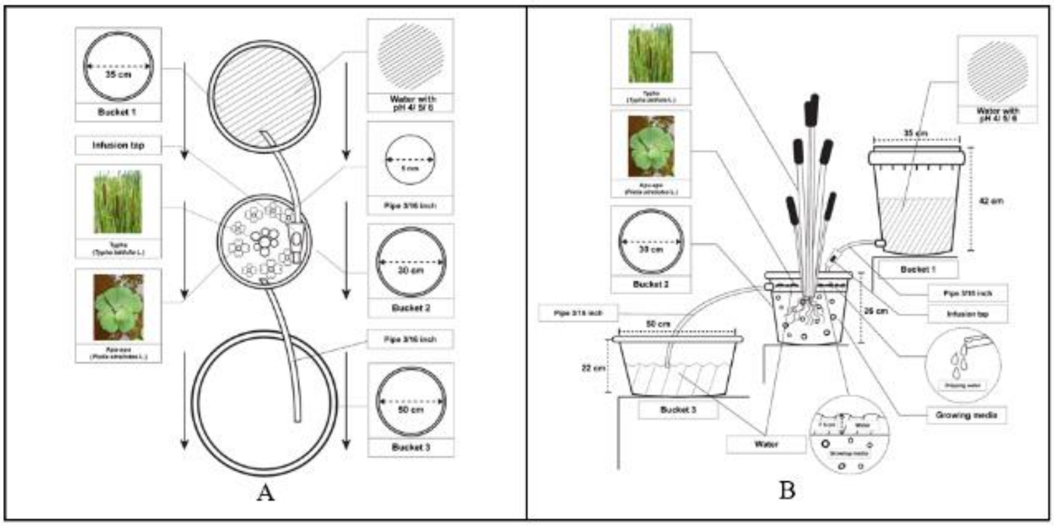
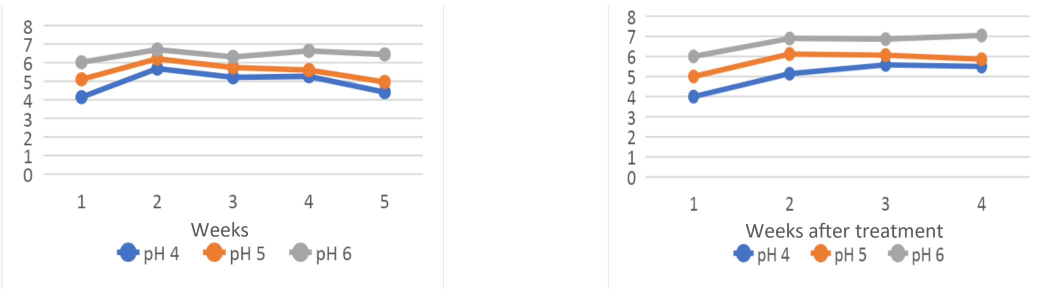


Figure 1. Design of Phytoremediation Installation in Small Pilot-Scale of Acid Mine Drainage Passive Treatment A) Top view, B) Side view

Installation's Test



A B

Figure 2. (A) pH around the plant (second bucket) and (B) outlet pH (third bucket)

Installation trials were carried out on *Typha sp* and Pistia stratiotes in an acidic environment to determine whether changes in pH occurred during the remediation process. The results showed that there was a change in the pH of the water around the plants for five weeks (Figure 1A), while at the outlet after the acidic water passed through the plants, there was an increase in pH in the fourth week after treatment (Figure 1B). This showed that a phytoremediation process had successfully occurred, and installation was suitable to support the process. *Typa sp* is a plant that could be a phytoremediator agent. *Typha sp* is a grass, rhizomatous plant with long, green, slender stems (Maharani *et al*., 2023). *Typha latifolia* effectively remediated cadmium in acid mine drainage by raising the pH to around 7 and removing 95-96% of Cd, showing potential as a heavy metal hyperaccumulator (Maharani dan Setyo, 2021). This plant could absorb more heavy metals, Cr, Hg, and Pb, than water hyacinth and *P. stratiotes* L (Irhamni *et al*., 2018). *Typha angustifolia* also has many root hairs, so the root surface area will be larger, and the root range will be wider (Akhmad *et al*., 2021).

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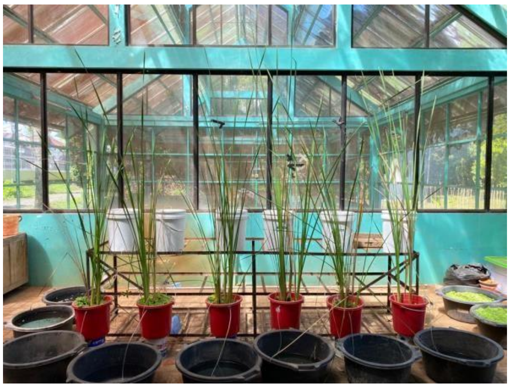
P. stratiotes L. is a phytoremediator plant that can process waste in heavy metals or organic or inorganic substances *Pistia stratiotes* L. has great potential to absorb heavy metals such as Fe, Zn, Cu, Cr, and Cd without causing other toxicity (Izzah *et al*., 2017). It also has a fast growth rate, is easy to find and has high adaptability to climate (Novi *et al*., 2019).

Table 1. Percentage of clumps' browning (%) during AMD treatment for the last three weeks

Weeks	Percentage of clumps' browning (%)		
	pH 4	pH 5	pH 6
4th	20,81	20,00	20,46
5th	28.94	24,29	22,90
6th	32,17	25,90	20,97



A

B

Figure 3. A) Phytoremediation Installation in Small Pilot-Scale of Acid Mine Drainage Passive Treatment B). Damage caused by AMD in Typha sp and *P stratiotes* L

The acidity level is one of the factors that can influence water biochemistry; where at a pH value of less than 4, some aquatic plants will die because they cannot tolerate low pH (Cahyanto *et al*., 2018). The acidic environment influenced the plant damage level, characterized by the clumps' browning. The browning data is shown in Table 1. Damage was calculated by comparing the browning of *Typha sp* clumps with healthy clumps. It could be seen that AMD with lower acidity levels resulted in greater plant damage in the sixth week. Even though they experienced greater damage, Interestingly, *Typha sp* still showed resistance to an acidic environment without any media engineering, such as zeolite or lime. These results also align with research conducted by Sulthoni *et al*. (2014), which states that *Typha sp* could survive in a water pH of 2.89-2.96 and a soil pH of 3.5-4.05. However, after 30 days, observations showed a decrease in plant biomass of 50.2% and the number of cattail plant clumps by 81.7%.

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P. stratiotes L. showed positive results with several plants remaining alive as indicated by the plants still being green. These results are in line with Yanti *et al*., (2021), most *P. stratiotes* L. are not able to survive in acidic environmental conditions, but some plants are still able to survive, due to being able to adapt to polluted environmental conditions.

4. CONCLUSION

A prototype design was successfully built and tested in a small-scale pilot that used a passive treatment method. The design was suitable for running the phytoremediation process using Typha sp and *P stratiotes* L. Even though there was a decrease in acidity at the outlet, the results of these studies did not reflect the actual conditions due to using the artificial AMD, and it would be different in the field.

ACKNOWLEDGMENT

We would like to express our sincere thanks for the opportunity to contribute to this journal. This research is the result of a collective effort involving many parties, and we are grateful for their support and guidance. Thank you to the editors for their hard work in compiling this journal and providing valuable input that has improved the quality of our writing. Also, we would like to express our deep appreciation to the reviewers for their valuable time in providing suggestions and constructive criticism.

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