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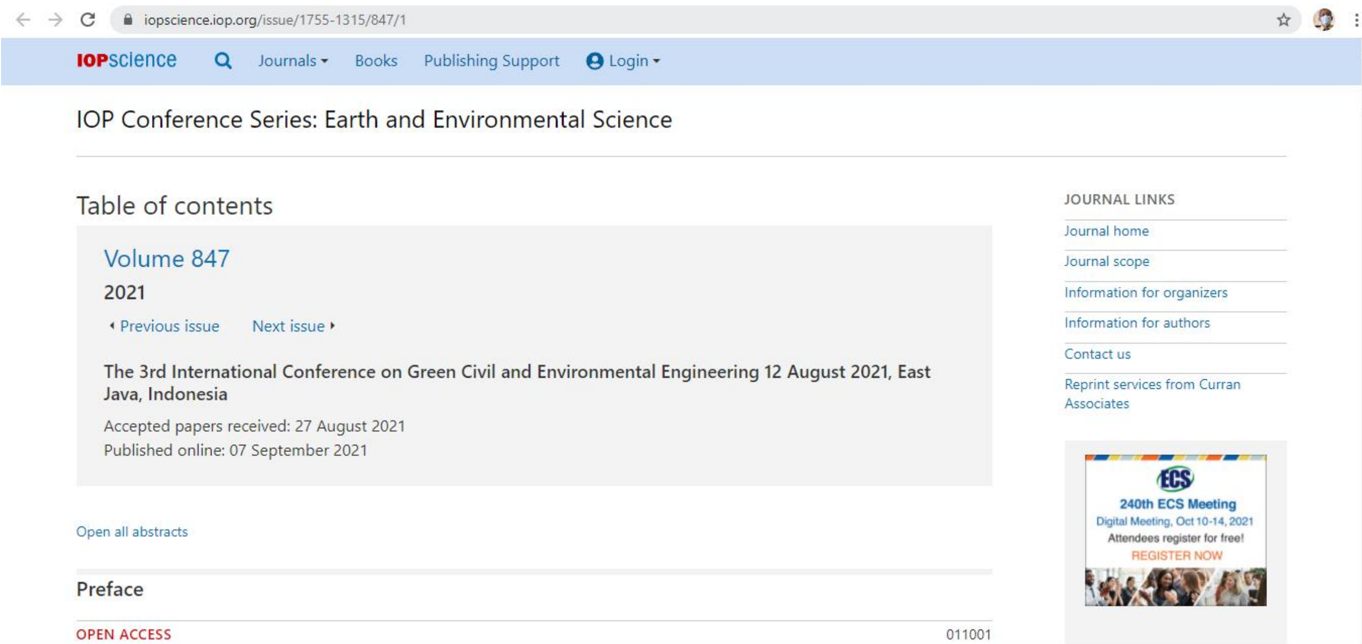

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Effectiveness *Vetiveria zizanoides* plant in ability absorption of heavy metals in coal mining waste

A Andrawina[1], R Ernawati[1], T A Cahyadi[1], W S Bargawa[1], N A Amri[1] and I Ferdian[2]

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Vetiveria zizanoides plants have considerable potential for phytoremediation, because these plants show relatively high ability to accumulate and translocate heavy metals in wetlands and are able to tolerate acidic water pH. The results of the study showed that the *Vetiveria zizanoides* plant has a fairly good survival rate in acid mine water conditions and has a fairly high ability to absorb Fe, Mn and sulfur metals. This is evidenced by the treatment of *Vetiveria zizanoides* plants by planting 20 *Vetiveria zizanoides* stems into acid mine water media without the addition of organic substrates, seen on day 20 after treatment of 20 *Vetiveria zizanoides* stems there was only 1 plant that died, the rest still survive in acidic water conditions. In this treatment, the *Vetiveria zizanoides* plant was able to absorb Fe, Mn and sulfur with an efficiency increase of 93% for Fe metal, 40% for Mn metal and 43% sulfur for 20 days. However, to improve the quality of acid water in this treatment, it was not optimal, so treatment was given with a combination of *Vetiveria zizanoides* and organic substrates. Treatment 3 was the most effective in improving acid mine water quality, because it had an average effectiveness of 58% for increasing the pH of the air and 97% for decreasing the concentration of Fe and Mn metals. With the efficiency of increasing the metal concentration in plants by 16% for Fe metal, 29% for Mn metal and 35% sulfur for 20 days after being given treatment.

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Effectiveness *Vetiveria zizanoides* plant in ability absorption of heavy metals in coal mining waste

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Abstract. *Vetiveria zizanoides* plants have considerable potential for phytoremediation, because these plants show relatively high ability to accumulate and translocate heavy metals in wetlands and are able to tolerate acidic water pH. The results of the study showed that the *Vetiveria zizanoides* plant has a fairly good survival rate in acid mine water conditions and has a fairly high ability to absorb Fe, Mn and sulfur metals. This is evidenced by the treatment of *Vetiveria zizanoides* plants by planting 20 *Vetiveria zizanoides* stems into acid mine water media without the addition of organic substrates, seen on day 20 after treatment of 20 *Vetiveria zizanoides* stems there was only 1 plant that died, the rest still survive in acidic water conditions. In this treatment, the *Vetiveria zizanoides* plant was able to absorb Fe, Mn and sulfur with an efficiency increase of 93% for Fe metal, 40% for Mn metal and 43% sulfur for 20 days. However, to improve the quality of acid water in this treatment, it was not optimal, so treatment was given with a combination of *Vetiveria zizanoides* and organic substrates. Treatment 3 was the most effective in improving acid mine water quality, because it had an average effectiveness of 58% for increasing the pH of the air and 97% for decreasing the concentration of Fe and Mn metals. With the efficiency of increasing the metal concentration in plants by 16% for Fe metal, 29% for Mn metal and 35% sulfur for 20 days after being given treatment.

1. Introduction

Aquatic plants have an important role in geochemical processes in artificial wetlands based on the active and passive transport of their elements [1]. The process of absorption of heavy metals from soil and sediment through plant roots is known as phytoremediation. Phytoremediation techniques can be a good choice in wastewater management systems because they are relatively inexpensive and friendly as a suitable treatment option for developing countries [2].

Plants have a very important role in removing pollutants. The absorption of heavy metals by plants in the wetland system is leaves and roots. Submerged rooted plants have the potential to extract metals from sediment and water, whereas rootless plants can only extract metals from water [3]. The rate of metal removal by plants varies widely, depending on the rate of plant growth and the concentration of heavy metals in plant system. Metal uptake rates per unit area of wetland are often much higher for herbaceous plants. In the case of uptake heavy metals in leaves, it is passive movement in the water phase through cracks in the cuticle or through the stomata to the cell wall and then the plasmalemma [3].

Sediment pH, the context of organic matter and plant genotype, can have a marked effect on metal uptake. Metal bioaccumulation is based on root uptake but also plants can accumulate relative amounts of metals by uptake of leaves from atmospheric deposits in plant leaves [3].

Phytoremediation has a role in a constructed wetland system by using water plants to accumulate metals in water and soil. The use of plants that are able to associate with bacteria or mycorrhizae will greatly assist in the process of managing acid mine drainage. With the right design, a passive treatment system can have a lifespan of more than 20 years which is useful for reducing the acid mine drainage is also very important to support rehabilitation and reclamation activities of ex-mining areas [4].

Phytoremediation is an alternative in conventional wastewater treatment in developing countries, as suggested by previous researchers (Ghosh and Singh, 2005). Successful application of the technique depends on identifying plant species with the appropriate set of characteristics [5]. In assessing the phytoremediation potential of a species, researchers often emphasize the very high biomass production, bioaccumulation, and tolerance to heavy metals by plants [6]. Hyperaccumulator plants with the capacity to hold very high amounts of heavy metals (usually 0.1% to 3% of dry weight) are even more desirable. In this regard, the *Vetiveria zizanoides* plant shows considerable potential as a candidate for phytoremediation, as it exhibits relatively high accumulation and translocation capabilities of heavy metals in artificial wetlands. In addition, this plant is also able to tolerate low water pH as well as the influence of dissolved metal concentrations such as iron, manganese, and sulfur. This can be seen from during the 20 days of the research process, there were still some plants that had no signs of wilting.

2. Materials and methods

This study used an experimental method by conducting an experiment planting *Vetiveria zizanoides* in an experimental reactor. The materials used in this research are:

a) Plastic tub used as experimental adhesive;
b) Acid mine drainage;
c) Soil as a media planting;
d) The organic material used is bokashi fertilizer;
e) Aerators are used to provide treatment so that the water experiences movement (only used in ponds with treatment 4).

The experimental reactor has dimensions of 60 cm x 47 cm x 40 cm with the experimental design used consisting of 1 control pond and 3 ponds with different treatments which can be seen in (Figure 1). The treatment arrangement in this experiment was a combination of organic substrates and *Vetiveria zizanoides* consisting of:

a) Without treatment (control), the amount of soil is 10 kg and the volume of Acid Mine Drainage (AMD) is 28 liters.
b) Treatment 1 (AMD + soil + 20 stems of *Vetiveria zizanoides*), with 10 kg of soil and 28 liters of AMD volume.
c) Treatment 2 (AMD + soil + organic substrate + 20 stems of *Vetiveria zizanoides*), with 10 kg of soil, 10 kg of organic substrate and 28 liters of AMD volume.
d) Treatment 3 (AMD + soil + organic substrate + 20 stems of *Vetiveria zizanoides*), with 10 kg of soil, 10 kg of organic substrate and 28 liters of AMD volume. In treatment 4, the experimental pond was given an aerator which functions to provide treatment of water movement in the pond.

Observations were made on the development of *Vetiveria zizanoides* plants for 20 days after being given the treatment. Then an analysis of the effect of *Vetiveria zizanoides* on the improvement of the quality of acidic water in the experimental reactor was also carried out for 20 days. Then on the 20th day after giving the treatment, samples of *Vetiveria zizanoides* were taken for laboratory analysis. With the parameters tested include the metal content of iron, manganese and sulfur.

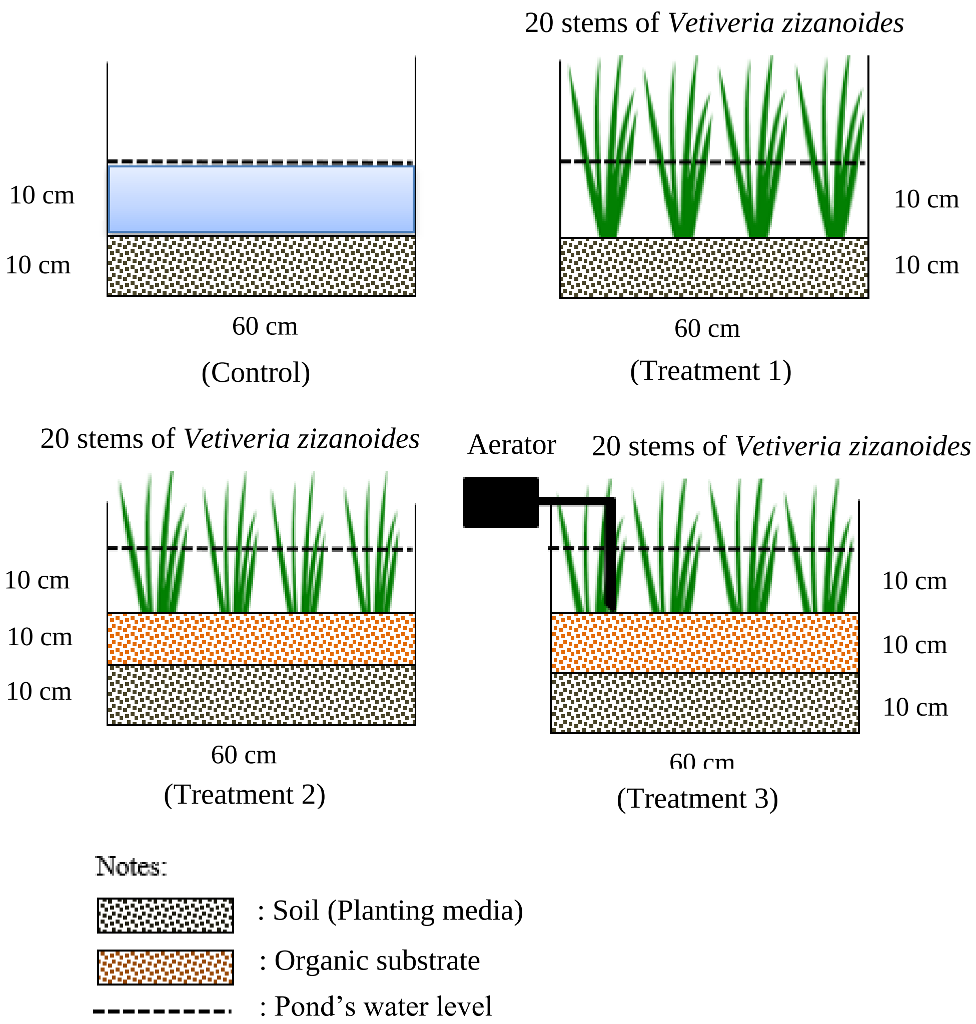


Figure 1. Experimental reactor design

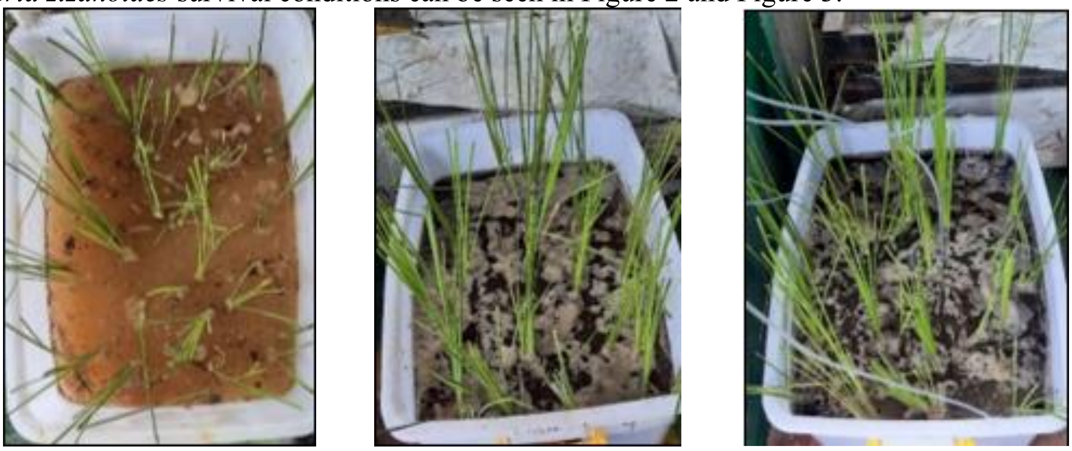
3. Results and discussion

3.1. Vetiveria zizanoides plant survival

At the time of the study, it was seen that in treatment 1 starting on the 12th day after the plants were put in water there were 14 *Vetiveria zizanoides* stems experiencing signs of wilting and 1 stem experiencing death, while on the 20th day there were 17 stems experiencing signs of wilting and 1 stem experienced death. So, from a total of 20 *Vetiveria zizanoides* stems given in the first treatment, only 2 stems survived without any signs of wilting. The death of *Vetiveria zizanoides* plants in treatment 1 was due to the tolerance limits of plants to heavy metals such as iron and manganese which were absorbed by *Vetiveria zizanoides* so that they affected the condition of plants.

In treatment 2, it began to appear on the 12th day after the plants were put in water, there were 14 stems experiencing signs of wilting, then on the 20th day there were 19 stems withering. So that out of a total of 20 plants given in this second treatment, only 1 stem still survives without any signs of wilting. Whereas in treatment 3, it was seen that on the 12th day after the plants were put in water, there were 16 stems that had wilted, then on the 20th day there were 17 stems that had wilted. So that from a total of 20 plants given in this 3rd treatment, only 3 stems still survive without any signs of wilting.

In treatment 2 and 3, *Vetiveria zizanoides* were able to survive because of the availability of nutrients derived from organic matter. Another thing can also be caused by the stimulation of the growth of sulfate-reducing bacteria from organic substrates which helps in accelerating the deposition of heavy metals so that the heavy metal concentrations in the 3rd and 4th treatments are not too high. *Vetiveria zizanoides* survival conditions can be seen in Figure 2 and Figure 3.



(a) Treatment 1 (b) Treatment 2 (c) Treatment 3

Figure 2. The condition of *Vetiveria zizanoides* on the 0th day after treatment

(a) Treatment 1 (b) Treatment 2 (c) Treatment 3

Figure 3. The condition of *Vetiveria zizanoides* on the 20th day after treatment

3.2. Effectiveness of *Vetiveria zizanoides* in heavy metal absorption

Plants are an important component in the remediation process in wetland environments. The role of plants is to provide sites for microbial attachment, remove oxygen from their roots and provide a source of organic material for heterotrophic microbes. So that the reduction and oxidation processes of sulfate, iron and manganese will be more prevalent in the root area because of the high abundance of microorganisms, including reducing bacteria [7].

In this study, laboratory testing was carried out on *Vetiveria zizanoides* plants to determine the effectiveness of the ability of *Vetiveria zizanoides* in absorption of heavy metals (iron, manganese and sulfur) in the management of acid mine drainage. The results of laboratory analysis of plants before and after treatment can be seen in Table 1.

Table 1. Concentrations of sulfur, iron, and manganese in *Vetiveria zizanoides*.

Type of Testing	Test Result			
	Before Treatment	Treatment 1	Treatment 2	Treatment 3
Iron (ppm)	552.10	8,230.51	710.51	657.35
Manganese (ppm)	139.00	232.85	168.43	195.65
Sulfur (%)	0.33	0.58	0.50	0.51

From Table 1 above, it can be calculated the effectiveness of increasing the concentration of iron, manganese and sulfur metals. A measure that states how far the target (quantity, quality and time) has been achieved is called effectiveness [8]. The greater the percentage of targets achieved, the higher the effectiveness. Therefore, in analyzing the effectiveness of increasing the concentration of iron, manganese and sulfur metals. can use the following equation [9].

$$\% \text{ Effectiveness Increase} = 1 - \frac{Ca}{Ct} \text{ x } 100 \% \quad (1)$$

$$\% \text{ Decreasing effectiveness} = 1 - \frac{Ct}{Ca} \text{ x } 100 \% \quad (2)$$

Description:
Ca = initial concentration
Ct = final concentration

Table 2. Average effectiveness of increasing iron, manganese and sulfur concentration in *Vetiveria zizanoides*.

Type of Testing	Test Result		
	Treatment 1	Treatment 2	Treatment 3
Iron (%)	93%	22%	16%
Manganese (%)	40%	17%	29%
Sulfur (%)	43%	34%	35%

The results showed that the concentration of iron, manganese and sulfur was higher in *Vetiveria zizanoides* plants found in treatment 1. That is, with an increase in efficiency of 93% for ferrous metals, 40% for manganese and sulfur metals by 43% for 20 days after being given. treatment. This is because in treatment 1 there is no addition of an organic substrate so that the active role in the absorption of iron, manganese and sulfur metals is only in *Vetiveria zizanoides* plants. The high concentration of metals contained in these plants causes the plants to wither and experience death.

The efficiency of increasing metal concentration in treatment 2 was 22% for iron, 17% for manganese and sulfur by 34% for 20 days after treatment. And in treatment 3 has an increase efficiency of 16% for iron, 29% for manganese and sulfur by 35% for 20 days after being given treatment. The concentrations of iron, manganese and sulfur metals contained in the *Vetiveria zizanoides* plant in treatment 2 and treatment 3 were not too high due to the influence of the organic substrate so that they can stimulate sulfate-reducing bacteria which will react with dissolved metal ions. The high concentration of iron and manganese in plant tissue is influenced by the high concentration of these elements in the organic substrate. The existence of composting with the addition of alkaline materials can be an alternative in reducing the concentration of iron and manganese [10].

3.3. Effectiveness of increasing water pH and decreasing heavy metals

The effectiveness of increasing pH and decreasing heavy metals was influenced by the treatment using *Vetiveria zizanoides* and organic substrates. Based on the results of the calculation of the effectiveness of each treatment, the average effectiveness can be seen in Table 3.

From Table 3, it can be seen that in treatment 1 by planting *Vetiveria zizanoides* in the experimental reactor without a combination of organic substrates has not been able to improve the quality of acid mine drainage. The table shows that the effectiveness of increasing the pH of water in treatment 1 is only 17%, meaning that the increase in water pH is very small and the resulting pH still does not meet the quality standards of coal mining waste. Likewise, for the effectiveness of decreasing the manganese concentration, in treatment 1 there was an increase in the manganese concentration by

49% from the initial concentration. This is thought to be due to conditions of low water pH, because manganese deposition depends on pH and Fe^{2+} concentration, where manganese will form a stable precipitate at high pH and very low Fe2+ concentration. This phenomenon can also be caused by AMD at low pH resulting in an increase in metal desorption and mineral solubility which results in an increase in the concentration of toxic heavy metals [11]. And in treatment 1 this does not use a combination of organic substrates so that the only active role in decreasing the manganese concentration is absorption by the plants themselves.

Table 3. Average effectiveness of each treatment.

Parameter	Treatment			
	Before Treatment	Treatment 1	Treatment 2	Treatment 3
pH	2%	17%	58%	58%
Iron	9%	73%	94%	97%
Manganese	9%	-49%	76%	97%

Treatment 3 = Highest effectiveness

For the results, the average effectiveness in treatment 2 and treatment 3 was not too different, but there was a significant difference in the increase in the concentration of manganese. The increase in manganese metal concentration was seen more quickly in treatment 3. This is because in this treatment the aeration process was experienced in the experimental reactor. So that it causes the supply of oxygen to the roots of the plant to take place properly. With a good oxygen supply, the development of microorganisms in this system will be better so that the decrease in manganese concentration can be seen more quickly.

In bacterial metabolism on organic substrates, microbial-driven reduction of sulfates and iron is a naturally occurring process in wetland sediments that facilitates the removal of metals from acid mine drainage through an increase in pH, which in turn results in the deposition of metals as either hydroxides or sulfides [12].

4. Conclusion

a.) In the study, it was shown that *Vetiveria zizanoides* plants can thrive in acidic water pH conditions. *Vetiveria zizanoides* is able to survive in the experimental reactor with treatment conditions 1, 2 and 3. In treatment 1, it can be seen that of the 20 *Vetiveria zizanoides* stems only 1 plant has died, meaning that the plant is still able to survive in acidic water conditions even without the influence of the substrate. organic. This proves that *Vetiveria zizanoides* is very tolerant of acid mine drainage.

b.) Treatment 2 and treatment 3 are treatments that have a high effectiveness value in managing the quality of acid coal mine water. The high concentration of sulfur, iron and manganese metals in *Vetiveria zizanoides* is influenced by the high concentration of these elements in the organic substrate. This can be seen in treatment 1, the concentration of Fe and Mn metals in *Vetiveria zizanoides* is very high compared to plants found in treatment 2 and treatment 3, because there is no addition of organic substrates in treatment 1. So that the ability of plants to absorb heavy metals is proportional to the amount of material. organics added to the growing medium.

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