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Review On The Effect Of Vegetation On Waste Treatment In Mining Wetlands

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ABSTRACT

This study discusses the influence of vegetation growth on waste treatment in mining wetlands. Mining wetlands are wastewater treatment systems that use plants as treatment agents. The aim of this research is to provide information on the impact of vegetation growth in mining wetlands on the effectiveness of waste treatment. The method used is a literature review by searching for articles and scientific journals related to the influence of vegetation growth in mining wetlands. The research results indicate that vegetation growth in mining wetlands has a positive effect on the effectiveness of waste treatment. The more plant species that grow, the better the waste treatment. The pH and TSS levels of the water in the wetlands also increase with the presence of vegetation. Moreover, the levels of Fe, Mn, Pb, and decreased with the presence of vegetation. Additionally, the vegetation with the best productivity while maintaining its condition is Typha sp. This plant can also survive in wetland areas with high water levels. In conclusion, the presence of vegetation has a positive impact on waste treatment in mining wetlands and can be an effective solution to address water pollution in mining areas.

INTRODUCTION

Open mining activities will have an impact on subsequent environmental degradation processes. Open mining areas have the potential to expose pyrite minerals to the surface. This can trigger the oxidation of pyrite minerals and the formation of SO42-. The oxidation reaction is biologically mediated by *Thiobacillus thiooxidans* bacteria, which produce soil acidity by generating sulfuric acid (Munawar, 2011; as cited in Sandrawati et al., 2019).

The impact of acid mine drainage is not limited to the mining site itself; what is of greater concern is the contamination of water sources outside the mining area, which poses a significant danger to the environment, especially for living organisms. The management of acid mine drainage should be carried out by every mining company in accordance with the obligations stipulated in Ministerial Regulation No.

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7 of 2014 concerning the Implementation of Reclamation and Post-Mining Activities in Mineral and Coal Mining Businesses (Hengen, 2014; as cited in Andrawina et al., 2020).

Passive methods have also become a preferred choice and are frequently employed in acid mine drainage treatment. Constructed wetlands, including their low cost and simple mechanisms, are one of the methods used. Constructed wetlands for treating acid mine drainage resulting from coal mining waste can apply various types of active or passive treatments using wetland plant species that function in reducing heavy metal content in mining wastewater (Shoeran, 2005; as cited in Andrawina et al., 2020).

Wetlands are also implemented in arid regions for clean water supply (Dzikus, 2008; as cited in Sucahyo et al., 2018). Furthermore, their further development is used for natural ecosystem processes in water quality neutralization, such as pH adjustment and the reduction of dissolved metal content in water (Coulton, 2003; as cited in Sucahyo et al., 2018). The acidity level of acid mine drainage ranges from 2 to 4 (Garcia, 2001; as cited in Sucahyo et al., 2018).

This study aims to analyze the influence of vegetation on waste treatment in wetlands in mining areas. The analyzed vegetation's influence includes its effects on pH levels, TSS values, and the levels of Fe, Mn, Pb, and As.

METHODOLOGY

The research method employed in this study is a literature review, which aims to analyze relevant literature including articles and scientific journals regarding the influence of vegetation growth on waste treatment in mining wetlands. In the field of research, particularly in the creation of scientific works, literature review is commonly known as a literature survey. Therefore, it can be said that literature review is an analytical activity that involves critiquing existing research on a specific topic within a particular field of knowledge. The process begins by collecting data from various articles and scientific journals that discuss vegetation in mining wetlands. Searches are conducted using academic search engines such as Google Scholar, ScienceDirect, and Scopus. The keywords used in the search include "mining wetland," "vegetation," "waste treatment," and "influence." Article selection is carried out by considering relevance to the topic, research quality, and publication year. The collected data consists of secondary data regarding the discussion on the influence of vegetation growth on mining wetlands as well as the discussion on the influence of vegetation on mining waste management.

RESULT

The Influence of Aquatic Plants on Ph Value

Based on Aryanto's study (2015), it is explained that by implementing the aerobic wetland method in the treatment of acidic mine water, the pH of the AMD can increase. The passive AMD treatment method used in this research employs the SAPS (Successive Alkalinity Producing Systems) and AW (Aerobic Wetland) methods.

The SAPS method is a passive AMD treatment method using organic matter and limestone in a vertical arrangement. The SAPS pond consists of water (0.3 – 1.8 m), organic matter (0.15 – 0.60 m), and limestone layer (0.60 – 1.5 m). In this pond system, organic matter will deplete oxygen and convert $Fe3+$ to $Fe2+$. This condition leads to the breakdown of limestone to produce bicarbonate, thereby increasing the solubility of limestone. The increase in solubility is due to the rise in $CO2$ pressure, resulting in the decomposition of the organic layer, which subsequently neutralizes the acidity in the AMD.

On the other hand, the AW method is a passive AMD treatment method using aquatic plant vegetation and organic matter planting media with a specific area. This method employs the Typha angustifolia water plant on organic matter (compost, sawdust, dry grass, or animal waste) and water at a height of around 0.1 – 0.5 m. Organic matter will consume oxygen and create an oxygen-free environment known as anoxic conditions. Typically, before entering the AW pond, the AMD will pass through a settling pond with a depth of 1.5 – 2.5 m to reduce $Fe(OH)3$ content. In the settling pond, the AMD will stay for 8 – 24 hours. The AW pond system operates by treating water that is net alkaline (water that is basic and has a high iron concentration) through oxidation reactions, causing metals to precipitate. The AW Pond functions efficiently when the pH is > 5.5.

In Aryanto's study (2015), five ponds were used, employing both methods. The ponds were arranged alternately: SAPS 1 – AW 1 – SAPS 2 – AW 2 - Outlet. The limestone used in SAPS 1 and SAPS 2 ponds amounted to 128.075 for each pond with an 80% concentration. Furthermore, the number of Typha Angustifolia plants in AW 1 and AW 2 ponds was 702 plants for each pond. The pond system is depicted in Figure 1, and the pond function specifications are provided in **Table 1**.

Keterangan :
1 : SAPS 1 Pond
2 : AW 1 Pond
3 : SAPS 2 Pond
4 : AW 2 Pond
5 : Outlet Pond

Figure 1. Ilustration on pond system

Table 1. Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

Pond	Media	Function
SAPS	Limestone and organic matter	1. Increasing alkalinity through the release of bicarbonate ions from limestone. 2. Increasing alkalinity and precipitating metals.
AW	Organic matter and Typha Angustifolia water plant	1. Increasing alkalinity and precipitating metals. 2. Absorbing Fe and Mn metals.

Sampling in this research was conducted monthly over a period of 4 months, and pH data collection was performed using a spectrometer. Throughout the course of the testing, the pH of each pond was obtained as follows: The AMD at the inlet of SAPS 1 pond had a pH range of 3.02 – 3.32. The AMD at the inlet of AW 1 pond had a pH range of 3.06 – 3.35. The AMD at the inlet of SAPS 2 pond had a pH range of 3.13 – 3.36. The AMD at the inlet of AW 2 pond had a pH range of 6.57 – 6.9. The AMD at the outlet pond had a pH range of 6.59 – 6.73. The pH parameter before and after AMD treatment using the SAPS and AW methods is shown in **Table 2.**

Table 2. Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

Parameters	Before	After	Kepmen LH Number 113 of 2013 Criteria
pH	3,13	6,63	6 - 9

The Influence of Aquatic Plants and Water Flow Rate on Total Suspended Solid Levels and pH Value

Total Suspended Solids (TSS) are particles that are insoluble in water and have smaller size and weight compared to sediment. The decrease in TSS levels in the pond is related to the presence of plant roots. The positive charge of the plant root hairs can attract colloidal particles with opposite charges, such as suspended solids. This can cause these particles to adhere to the plant roots and be absorbed and assimilated by plants and microorganisms over time. Therefore, if the plants have long roots, the TSS levels will decrease.

Based on the research conducted by Prabowo et al. (2019), constructed wetlands can reduce the concentration of TSS in AMD. This study was carried out in the wetland area of PT. Bukit Asam, South Sumatra, with sampling conducted once per week for a duration of 3 weeks at both the inlet and outlet points. The results of TSS sampling are presented in **Table 3**.

Table 3. Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

Comparison	Research Output		
	Week 1	Week 2	Week 3
TSS in the inlet (mg/l)	405	443	621
TSS in the outlet (mg/l)	6	3	2
Flow rate (m^3/s)	0,21	0,14	0,08

The concentration of TSS in AMD decreases upon entering the wetland and exiting to the outlet pond. From the first week to the third week, all TSS concentrations decrease, reaching levels of 2-6 mg/l. According to Arroyo et al. (2010); cited in Prabowo et al. (2019), the reduction in TSS concentration is due to plants being able to attract oppositely charged colloidal particles from the positively charged root hairs, such as suspended solids. Consequently, these particles adhere to the roots, are absorbed, and assimilated by the plants and microorganisms.

In addition to the influence of plants, water flow also affects the rate of TSS reduction. From Table 3, it can be observed that slower water flow leads to a greater decrease in TSS concentration. This phenomenon occurs because slower water flow provides more time for plants to perform the particle absorption process. As a result, the quantity of absorbed particles increases, leading to a more substantial reduction in TSS concentration.

The Effect of Aquatic Plants on Fe Level

The iron (Fe) content plays a role in plant photosynthesis, chlorophyll formation, and respiration. However, if the Fe level accumulates excessively, it can cause deficiencies in other nutrients such as Mn, P, K, Ca, and Mg. Based on the research conducted by Yunus et al. (2018), it is stated that plants play a crucial role in the remediation processes in wetland environments. The functions of plants in wetlands include oxygen release from their roots, providing attachment sites for microbes, and supplying a source of organic material for heterotrophic microorganisms. Reduction and oxidation processes primarily occur around the root zones due to the abundant presence of reducing microorganisms in this region of the plants. The results of the Fe concentration measurements accumulated in the Water Hyacinth and Nutgrass plants were converted into Bioconcentration Factors (BCFs). The measured results of the accumulated Fe concentration in Water Hyacinth and Nutgrass plants are presented in **Table 4**.

Table 4. Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

Parameters	Days					
	0	5	10	15	20	25
Temperature (0C)	37,2	37,3	37,5	37,3	37,1	37,7
Water pH in the outlet	3,20	3,97	4,64	4,70	4,96	5,31
Fe conc. Fe in water hyacinth	1.946,79	10.263,00	5.468,77	39.329,83	7.734,46	5.986,11
Fe conc. Fe in cattail plant	3.709,87	23.371,00	20.071,08	18.858,59	9.229,45	19.935,26

The data in the table above is then converted into Biokinetic Concentration Factor (BCF) values. BCF is a parameter used to determine the potential of plants as accumulators of Fe in plant dry weight conditions. BCF can be calculated using the following formula :

$$BCF = \frac{Metal\ concentration\ in\ plants}{The\ concentration\ of\ metals\ in\ acid\ mine\ water}$$

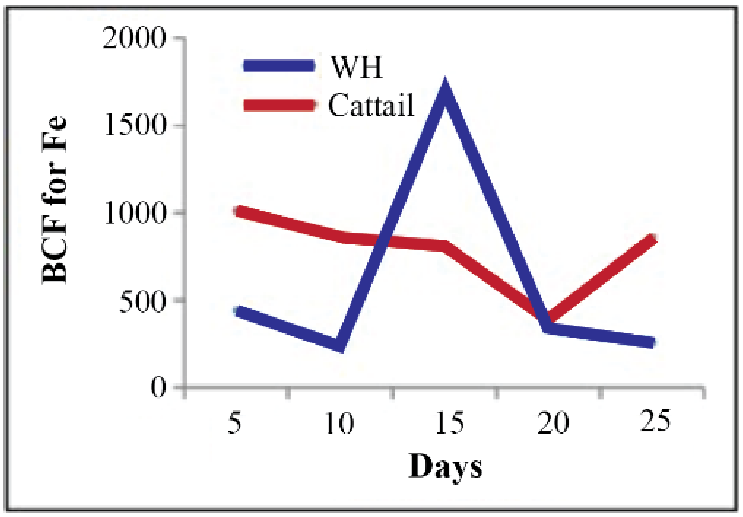

Figure 2. BCF for Fe in hyacinth and cattail plants (Yunus et al., 2018).

From the BCF graph for the Fe content, it can be concluded that water hyacinth plants will experience growth inhibition when the water pH is < 4. Water hyacinth exhibits optimal growth at pH levels of 5.5-7. Based on this, water hyacinth will exhibit higher absorption at higher pH conditions and over a longer period of time. On the other hand, reed canary grass can grow well at pH < 4. Although reed canary grass shows better growth compared to water hyacinth, the BCF values for reed canary grass tend to be lower than water hyacinth at pH levels of 5.5-7. Another factor is that at pH < 4, the availability of soluble cations for approaching plant tissue is greatly limited. As pH increases, the binding of metals to plant tissues also increases. At low pH, metal cations are hindered by the repulsive forces from H+ ions on adsorbent sites. Based on Yunus et al. (2018), a study on different metals found that the accumulation of Zn, Pb, As, Fe, and Cd by water hyacinth and reed canary grass increases as pH increases.

The Effect of Aquatic Plants on Mn Concentration

Manganese (Mn) is a trace element required by plants for chlorophyll synthesis, acting as a coenzyme, serving as an activator for certain respiration enzymes, participating in nitrogen metabolism, and photosynthesis reactions. The distribution and composition of Mn metal in the pond indicates that the Mn metal content is relatively consistent across the surface, middle, and bottom of the pond. Mn metal is not easily precipitated.

The research was conducted on Water Hyacinth and Nutgrass for a duration of 25 days in a 60 m² Constructed Wetland (CW) divided into 2 points. The first point was planted with Water Hyacinth, while the other side was planted with Nutgrass. Data was collected consistently every 5 days, with water samples collected from both the inlet and outlet points, each comprising 100 mL and repeated 3 times. Samples from both plants were also collected at 2 points, near the inlet and near the outlet. Each sampling session commenced with pH and water temperature measurements. Based on Yunus et al. (2018), the results of the accumulated Mn concentration measurements in Water Hyacinth and Nutgrass plants can be observed in **Table 5**. Meanwhile, data in the table **Table 5** was then converted into Bioconcentration Factor (BCF) values as shown in the **Figure 3**.

Table 5. Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

Parameters	Days					
	0	5	10	15	20	25
Temperature (0C)	37,2	37,3	37,5	37,3	37,1	37,7
Water pH in the outlet	3,20	3,97	4,64	4,70	4,96	5,31
Fe conc. Fe in water hyacinth	4,03	10,28	7,95	23,89	26,93	28,56
Fe conc. Fe in cattail plant	5,88	27,43	7,93	3,18	36,86	29,06

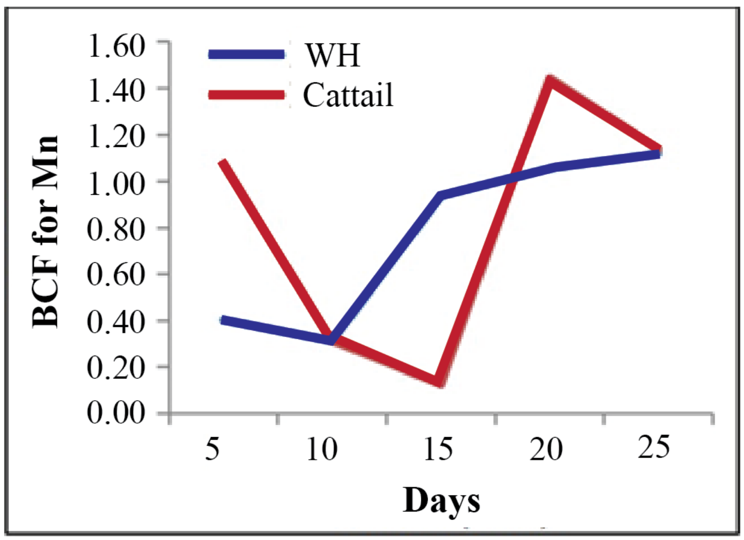

Figure 3. BCF for Mn in hyacinth and cattail plants (Yunus et al., 2018)

From the FBK graph for Mn content, it can be concluded that the growth of water hyacinth is inhibited when the water pH is < 4, while it experiences good growth between pH 5.5-7. Water hyacinth shows higher Mn absorption at higher pH conditions and longer duration, as observed from the increasing trend of Mn FBK from day 10 to day 25. On the other hand, water fern shows excellent growth at pH < 4. Although the growth of water fern is better than that of water hyacinth, the Mn FBK values for water fern tend to be lower from day 10 to day 15 and experience a significant increase on day 20.

Plant Productivity In Wetland

The research conducted by Munawar (2007) is a study of passive treatment, where the main principle is to allow chemical and biological reactions to occur naturally. This involved using 15 types of aquatic plants selected for their health, divided into two groups. One group of plants, each consisting of one sapling, was planted in 10 kg of muddy medium in a plastic bucket and continuously flooded with AMD to a depth of 2-4 cm. Meanwhile, the other group was planted in the same muddy medium and flooded with rainwater to the same height.

The study was divided into several experimental groups : (1) Isolation, identification, and propagation of sulfate-reducing bacteria (SRB), (2) Anaerobic incubation of organic substrate with AMD (pH 3.80 and EC 1090 uS/cm), (3) Selection of acid-tolerant aquatic plant species, and (4) Construction of a small-scale wetland. The research was conducted over a span of two years, starting in June 2004.

According to Munawar (2007), aquatic plants in wetlands have several important benefits, which are as follows:

a. For substrate consolidation, where plant roots hold the substrate together and increase water residence time in the wetland.
b. Stimulating microbial processes, where plants provide surfaces for microbial attachment, release oxygen, and provide a source of organic matter for heterotrophic microbes.
c. Providing habitat for wildlife, where plants can supply food and offer protection for aquatic animals.
d. In terms of aesthetic function, wetlands with abundant aquatic plants are much more visually pleasing compared to wetlands without vegetation.

According to Sandrawati et al. (2018), the research estimated plant productivity based on biomass weight and yield. Biomass weight (fresh) was calculated based on the harvested results in the form of tiles, which were then converted to hectares. The measurement results of plant productivity are shown in the table below.

Table 6. Plant Productivity (Sandrawati et al., 2018)

Vegetation	Amount	Biomass Weight (kg)	Productivity (ton/ha)
Typha sp	6	3,84	17,11
Cyperus sp	2	0,58	16,67
Eichornia Crassipes	7	3,14	31,38

From the data in the table above, it can be observed that the plant *Eichhornia crassipes* has the highest productivity, which is 31.38 tons/ha. However, the size of this plant decreases over time. This is suspected to be due to the lack of nutrients in *Eichhornia crassipes*, considering that in the last pond, the solubility of nutrients, especially Fe, Mn, and SO4, is very low. This is because *Eichhornia crassipes* plants cannot withstand prolonged exposure to acid mine water, which can lead to nutrient toxicity. It can be concluded that *the Eichhornia crassipes* is not recommended to be grown in constructed wetlands for acid mine water.

The biomass produced by *Typha sp*. is smaller than that of *Eichhornia crassipes*, but it exhibits better growth conditions. *Cyperus sp*. can generate biomass in a similar amount to Typha sp. When using both plants, attention should be given to the growth conditions, as *Cyperus sp.* is more tolerant to severe moisture conditions. Therefore, to achieve high biomass and good plant quality, Typha sp. is preferred as the plant in constructed wetlands compared to *Cyperus sp.* and *Eichhornia crassipes*.

CONCLUSION

The utilizations of vegetation in wetlands can increase the pH from its initial value of 3.13 to 6.63. It can reduce the TSS (Total Suspended Solids) levels. Additionally, the TSS levels are also influenced by the flow velocity or water discharge. The faster the water flows, the decrease in TSS content caused by vegetation in the wetland would be lower. It also can reduce the Fe (Iron) levels. The concentration of Fe in water hyacinth plants increased up to a maximum concentration of 39,329. The concentration of Fe in sedge plants increased up to a maximum concentration of 23,371. The Mn (Manganese) levels can also be reduced, the concentration of Mn in water hyacinth and sedge plants reached the highest concentration at 28.56 and 36.86, respectively. Different plant species will result in greater biomass. Higher biomass will improve the quality and condition of the plants.

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