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ARTICLE

Literature Study on Coal Acid Mine Drainage Management Using Phytoremediation Method

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Abstract: Literature study on the management of Acid Mine Drainage through phytoremediation has become crucial to gain a better understanding of its potential, challenges, and recent developments. The research method employed in this study is Literature Review. Literature Review involves a series of activities related to collecting literature data, reading and note-taking, as well as processing research materials. The findings reveal that using a greater variety of plants provides a more comprehensive overview. The use of diverse plants or more complex phytoremediation systems offers a broader understanding. The evaluation of plant abilities in absorbing iron (Fe) and manganese (Mn) is emphasized. Adding evaluations for other metals or potential pollutants would enhance the research completeness. A decline in plant absorption abilities after ten days is observed, but external factors such as temperature, pH, or environmental conditions affecting this decline are not extensively discussed.

Keywords: Acid Mine Drainage, Phytoremediation, Wetland, Coal, Management.

1. Preliminary

Coal mining is an industrial sector that makes a significant contribution to a country's economy, but along with its development, coal mining also has a negative impact on the environment, especially in the form of Acid Mine Drainage waste. Acid mine drainage is water that has been contaminated by acid compounds and heavy metals due to the interaction of mineral-rich rocks with water and oxygen. The presence of acid mine drainage can threaten water ecosystems, reduce water quality, and have the potential to harm human health and aquatic fauna.

Acid Mine Drainage (AMD) or Corrosive Rock Drainage (ARD) is formed when water and oxygen, as fundamental factors, encounter certain sulfide minerals present in rocks under certain conditions, resulting in an oxidation cycle and flowing water with acidic conditions. In addition to acidic water, the consequences of this synthetic response can arise from the source if high rainfall is sufficient. In general, the water that comes out of this source is called Acid Mine Drainage (AMD) (Aditya Bayu, 2009).

The development of acid mine drainage is usually in conditions where acid mine drainage will form. Identified by atmospheric factors in Indonesia, with high temperatures and rainfall in several areas where mining activities occur, the measures for regulating acid mine drainage have varying characteristics from various countries, because they have unique climatic conditions.

One method that can be used to overcome the problem of acid mine drainage is phytoremediation. Phytoremediation method is a emerging innovations from study about acid water management mine. Phytoremediation is an environmentally friendly technology that uses plants and soil microorganisms to reduce or remove contaminants from water or soil. This method is considered an effective and sustainable solution for managing acid mine drainage, because it is not only capable of cleaning the environment from contaminants, but also has the potential to restore disturbed ecosystem functions.

Basically, phytoremediation involves certain plants that can absorb, accumulate and convert toxic compounds into less dangerous forms. Previous studies have shown that several plant species have good phytoremediation capabilities against acid mine drainage, including the ability to accumulate heavy metals and stabilize water pH.

Several innovations that have emerged from research on phytoremediation in the management of acid mine drainage include the development of plant species that are tolerant of acid mine drainage conditions and are able to absorb heavy metals such as iron, zinc and manganese. This makes it possible to select plants that are most effective in managing acid mine drainage. Innovation is also occurring in the development of monitoring and evaluation techniques to understand the effectiveness of phytoremediation. Monitoring methods include measuring heavy metal concentrations before and after treatment, as well as analyzing plant growth and health during the phytoremediation process. Research continues on more efficient and integrated phytoremediation systems. This includes choosing the right plants, optimal environmental settings, and implementing additional technologies such as efficient irrigation systems. Apart from plants, research is also exploring the role of bacteria and other microorganisms in phytoremediation to change or reduce the toxicity of heavy metals in acid mine drainage. Innovation focuses not only on short-term effectiveness, but also on the long-term effects of using phytoremediation in managing acid mine drainage. This research is important to ensure that this method can provide a sustainable and environmentally friendly solution.

Based on the results of research conducted by Sri Pertiwi Estuningsih (2018), it was found that Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea are aquatic plants that have the potential to be used in AMD phytoremediation, with certain variations in ability depending on the type of plant and the concentration of Acid Mine Drainage (AMD) used. used. Mardalena research (2018), with research results that aquatic plants, such as Water Hyacinth, Floating Fern, and Water Lettuce, can be effective phytoremediation agents in dealing with heavy metal pollution in coal mining wastewater, with varying absorption results depending on the type of metal and type of plant used. Meanwhile, research from Yudha Gusti Wibowo (2022), with the results of artificial Constructed Wetland (CW) research was identified as a low-cost method and can be applied to treat AMD (acid mine drainage). The effectiveness of artificial wetlands as an environmentally friendly, affordable, and practical solution to address AMD, as well as providing comprehensive information on history, impacts, current trends, and potential future applications.

In this context, a literature study regarding the management of acid mine drainage using phytoremediation is very important to gain a better understanding of the potential, obstacles and current developments in the implementation of this technology. By understanding the conceptual framework and results of previous research, we can design effective and sustainable acid mine drainage management strategies. Therefore, this literature research aims to present a comprehensive review of the application of phytoremediation in the management of acid mine drainage and identify the potential of plants and microorganisms that are most effective in overcoming this problem.

2. Research Methods

The research method used is Literature Study. Literature study involves a series of activities that include methods for collecting library data, reading and taking notes, and processing research materials. In this research, several research collections were carried out in the form of theses and journals as review material. Some previous research used is:

Name, Year	Title	Research methods	Research result
Sri Pertiwi Estuningsih et al (2018)	*Phytoremediation Of Coal Mining Acid Water In*PT Bukit Asam Tanjung Enim South Sumatra	completely randomized research design (completely randomly planned/CRP) with a factorial pattern of two factors, namely the type of aquatic plants (Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea) and the concentration of	This research shows that Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea have potential as AMD phytoremediation agents, with each plant having certain advantages, especially in reducing sulfate and manganese

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Name, Year	Title	Research methods	Research result
		coal mine wastewater (0%, 25%, 50%, 75%, and 100%).	levels at different AMD concentrations. N. oleracea showed better growth ability in AMD environment
Mardalena (2018)	*The Absorption of Iron (Fe) and Manganese (Mn) from Coal Mining Wastewater with Phytoremediation Technique Using Floatingern (Salvinia natans), Water Lettuce (Pistia stratiotes) and Water Hyacinth (Eichornia crassipes)*	This research uses an experimental method by observing the effect of phytoremediation using certain aquatic plants on the concentration of iron and manganese in coal mine liquid waste over a predetermined time period.	This research shows that phytoremediation using certain aquatic plants can be an effective solution in reducing iron and manganese content in coal mine liquid waste, which can contribute to water quality restoration efforts before being discharged into public waters.
Aurora M. Pat-Espadas, (2018)	*Review of Constructed Wetlands for Acid Mine Drainage Treatment*	Conduct a literature review to collect the latest information regarding the use of Constructed Wetlands (CW) in Acid Mine Drainage (AMD) processing. Investigate methods that have been proposed or tested in the literature to address specific factors that influence the efficiency of CW in treating AMD, such as high acidity levels	Research result: Identifies SS-CW as an efficient choice in AMD processing. Explain the synergistic interactions between CW components that determine the removal of heavy metals. Highlights the crucial role of plant-microorganism interactions in symbiotic mechanisms for heavy metal removal and tolerance.
		and toxic metal concentrations	Recommend strategies such as addition of organic amendments and inoculation of AMD bacterial consortia to improve heavy metal removal efficiency. Suggests careful design of experiments from laboratory scale to full scale to optimize the balance between CW component selection, construction costs, and operational costs. Addresses the main limitations of CW in treating AMD, especially the effects of heavy metal toxicity, by selecting CW components that match the characteristics of AMD.
Fitri Arum Sekarjannah (2023)	*Phytoremediation of Acid Minerainage with Melaleuca cajuputi, Nauclea orientalisand Vetiveria zizanioides in Floating Treatment Wetland*	Research Design (Research Design): Using a Completely Randomized Design (CRD) research design with 3 treatments and control/no plants. Each treatment had 3 replications, so	FTW, either with or without plants, is able to increase pH and reduce the concentration of dissolved Mn by 75.31-90.74%. Hyperaccumulator plants such as Melaleuca cajuputi, Nauclea orientalis, and Vetiveria

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Name, Year	Title	Research methods	Research result
		there were a total of 12 experimental units. Hyperaccumulator Plants: Select several hyperaccumulator plants, such as Melaleuca cajuputi, Nauclea orientalis, and Vetiveria zizanioides, to be tested in the Floating Treatment Wetland (FTW) system.	zizanioides play a role in binding heavy metals through the process of chelation by organic materials, absorption by plants, and deposition in the form of metal sulfides. The organic-based FTW system also showed an increase in biological oxygen demand (BOD) load of 61.08-79.71%, indicating a positive impact on microbial life in the system.

3. Results and Discussion

Sri Pertiwi Estuningsih Research (2018), Phytoremediation of Coal Mining Acid Water in PT Bukit Asam Tanjung Enim South Sumatra. This study focused on the reduction of sulfate (SO42-) and manganese (Mn) contents, as well as the dry weight and physical characteristics of aquatic plants under various acid concentrations. Research shows that the concentration of Acid Mine Drainage significantly influences the percentage reduction in sulfate content. The study suggested that there were no significant differences in the ability of E. crassipes, N. oleracea, and L. flava to absorb and adapt to sulfate stress. The presence of Sulfate Reducing Bacteria (SRB) in the rhizosphere is described as a key factor in facilitating sulfate uptake by plants. Concentrations of 75%, 100%, and 50% showed significant differences in sulfate reduction compared to concentrations of 0% and 25%. The ability of plants to use sulfate for metabolism is emphasized, and the help of microbes in the rhizosphere is highlighted for sulfate uptake.

Fitri Arum Sekarjannah (2023), this research discusses several key aspects related to processing acid mine drainage (AMD) using Floating Treatment Wetlands (FTW). The following are the main findings: pH, ORP, and Enumeration of Sulfate-Reducing Bacteria: The presence of plants in FTW did not have a significant effect on changes in AMD pH compared to controls. Aquatic plants such as Eichhornia crassipes, Pistia stratiotes, and Salvinia molesta do not significantly affect pH changes. Application of organic materials plays an important role in increasing pH by creating reducing conditions. A reduction in oxidation-reduction potential (ORP) to -270 mV was observed, creating anaerobic conditions suitable for Sulfate Reducing Bacteria (SRB). SRB uses sulfate, sulfite, or thiosulfate ions as electron acceptors in metabolic processes. Dissolved Fe increased in all treatments over the 12-week observation period, which was caused by the marsh plants changing oxidation-reduction conditions. Mn solubility is reduced, with different plants showing different degrees of reduction. Possible mechanisms for the decrease in metal concentrations involve sulfide formation, uptake of metals by plant tissues, uptake of metals by organic matter, and biosorption of metals by microorganisms in marsh environments. The concentration of Total Suspended Solids (TSS) is reduced through the sedimentation process and microorganism/plant activity. Plant root length influences TSS reduction, with longer roots producing lower TSS values. Biological Oxygen Demand (BOD) initially increases due to the addition of organic material, but gradually decreases as the source of organic material decreases. Plants and organic matter increase the absorption of heavy metals. Cation exchange capacity (CEC) influences the ability of organic materials to absorb or exchange metal cations. Rhizofiltration by plant roots, especially vetiver, eucalyptus, and lonkida, shows potential in removing Fe and Mn from AMD. Heavy metals are absorbed by plants and chelated by organic matter, then deposited as metal sulfides in sediments.

Mardalena (2018), This research discusses the ability of aquatic plants such as Salvinia natans (Floating Caladium), Pistia stratiotes (Water Cress), and Eichornia crassipes (Water Hyacinth) in absorbing iron (Fe) and manganese (Mn) from coal mining wastewater, that Floating Fern has the highest ability to absorb iron (Fe), namely 47.17 mg/kg and an increase percentage of 228.309%. Meanwhile, for manganese (Mn) absorption, Water Hyacinth showed the highest percentage increase, namely 1227.619%. Decreased Levels of Iron (Fe) and Manganese (Mn) in Coal Mining Wastewater after the Phytoremediation Phase: that the uptake of iron (Fe) and manganese (Mn) by all plants

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continued to increase during the 30-day treatment period. The highest iron absorption was found in the Water Hyacinth plant (Eichornia crassipes) at 73.077%, while Water Hyacinth also absorbed manganese (Mn) well at 69.487%. Absorption Growth Trend every Ten Days: It can be seen that the absorption capacity of all plants tends to decrease after ten days, influenced by factors such as temperature, pH, solar radiation, and water salinity.

Sri Pertiwi Estuningsih Research (2018), This research may have shortcomings because it only considers three types of plants (E. crassipes, N. oleracea, and L. flava). Using a wider variety of plants can provide a more comprehensive picture. This study focused on sulfate and manganese content, but did not consider other parameters that may be relevant in the context of phytoremediation, such as heavy metals or other chemical parameters.

Fitri Arum Sekarjannah Research (2023), This research involves many variables, such as pH, ORP, TSS, BOD, and others. This complexity can make it difficult to isolate the individual effects of these factors. This research focuses more on certain plants in the FTW. Plant variations or more complex phytoremediation systems can provide broader understanding.

Mardalena Research (2018), This research only considers three types of aquatic plants. A more varied selection of plants can provide more general and relevant results. This research only evaluates the ability of plants to absorb iron (Fe) and manganese (Mn). Additional evaluation of other metals or other potential contaminants will increase the completeness of the study. The study noted a decrease in plant absorption capacity after ten days, but did not discuss in detail external factors such as temperature, pH, or environmental conditions that might influence this decrease.

The first suggestion is to develop a more detailed conceptual framework for this literature study. In this case, it involves key elements related to phytoremediation in the management of coal mine acid water. The second suggestion is to include literature on different phytoremediation methods that have been applied in coal mine acid water management. For example, studies of effective plants, absorption mechanisms, and the role of microorganisms in phytoremediation. Involves evaluating the success of a case study of phytoremediation in the management of coal mine acid water. Analysis of effectiveness, challenges, and lessons learned from practical applications in the field can provide valuable insights. The next suggestion is to consider literature that discusses the impact of phytoremediation on environmental and social aspects. This may include ecological impact analysis, role in water resource conservation, and local community response and participation. Includes literature on the latest technology and innovations in phytoremediation of coal mine acid water. This may include the latest research, new methods, or technologies that can improve the efficiency of the phytoremediation process. Another suggestion is to include literature studies that discuss sustainability aspects in phytoremediation of coal mine acid water. Evaluation of economic, social and ecological aspects in the long term can provide a holistic view of the sustainability of this method.

4. Conclusion

The conclusions and suggestions in this journal are as follows:

Conclusion

1) Phytoremediation of acid mine drainage (AMD) is a promising method for reducing contaminants such as sulfate, manganese, iron and other heavy metals using aquatic plants.
2) Research shows that various types of aquatic plants such as Eichhornia crassipes, Pistia stratiotes, and Salvinia molesta have the potential to reduce concentrations of contaminants such as sulfate, manganese, iron, and other heavy metals.
3) The use of Floating Treatment Wetlands (FTW) and the addition of organic materials can increase the effectiveness of phytoremediation by creating conditions that support the growth of sulfate reducing bacteria (SRB) and increasing the pH and appropriate reduction conditions.
4) Although the research provides valuable insights, there are still some shortcomings such as the lack of variety of plants evaluated, focus on certain parameters without considering other relevant parameters, and limitations in considering external environmental factors that may influence phytoremediation outcomes

Suggestion

a. Development of a More Detailed Conceptual Framework: Future research could begin by developing a more detailed conceptual framework to guide AMD phytoremediation research. This may include identifying key elements relevant to phytoremediation in the context of AMD

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management, such as the types of plants used, environmental factors and parameters to be evaluated.

b. Plant Variation and More Complex Phytoremediation Systems: Future research could expand the variety of plants evaluated and use more complex phytoremediation systems. Integrating more plant species and different phytoremediation system structures could provide a broader understanding of the potential and limitations of the method.

c. More Holistic Research: In addition to considering the technical aspects of phytoremediation, research also needs to take into account the environmental and social impacts of using this method. Evaluation of ecological impacts, contributions to water resource conservation, and local community responses and participation can provide a more holistic understanding of the effectiveness and sustainability of AMD phytoremediation.

d. Technology Innovation and Development: Including literature on the latest technologies and innovations in AMD phytoremediation can pave the way for new discoveries that can improve process efficiency. This may include research into new methods, newer technologies, or more innovative approaches to the use of plants and microorganisms.

e. Research Related to Sustainability: Future research can expand the analysis of the sustainability of AMD phytoremediation by considering long-term economic, social and ecological aspects. Cost-benefit evaluations, contribution to local community empowerment, and long-term effects on ecosystems need to be considered to gain a more comprehensive understanding of the sustainability of this method.

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