Phytoremediation Of Coal Mining Acid Water
In PT Bukit Asam Tanjung Enim South Sumatera

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Abstract. The using of some water plants to improve the quality of waters which is polluted by acid mine drainage (AMD) containing sulphate(SO₄²⁻) and heavy metal(Fe and Mn) can be used as one of the ways of biological controls which is environmental friendly, accurate, effective and efficient. Research about “The Ability Test Several Types of Water Plants as the Agents Phytoremediation Acid Mine Drainage Coal PT Bukit Asam, TanjungEnim, South Sumatera” aims to know the ability of Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea in phytoremediation acid mine drainage coal at many concentrations. This research use complete randomly plans (CRP), the pattern factorial with two factors, they were water plants (Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea) and concentration of acid mine drainage coal (0%, 25%, 50%, 75% and 100%), every combination was repeated twice. Based on the data from the research, Eichhorniacrassipes, Limnocharisflava, and Neptuniaoleracea are potentially as agent of phytoremediation AMD. The high percentage of decreasing sulphate (SO₄²⁻) at 75% concentration of AMD as media for water plant but the ability of water plant to decreased sulphate is same level. Interaction between kinds of water plants with concentration of AMD effect the percentage of decreasing manganese (Mn), L. flavain 75% concentration of AMD has the percentage of decreasing manganese which is higher than E. crassipes and N. oleracea in different concentration of AMD. By considering its ability of growth in AMD, N. oleracea has a better capability than E. crassipes and L. flav.

Keywords : Phytoremediation, Water Plants, Acid Mine Drainage Coal

1. Introduction
Mining in Indonesia uses an open mining system, due to the release of high coal pyrite (FeS) concentration and the further oxidation of FeS into FeSO₄, these compounds in water decompose produce potential H₂SO₄ in lowering the pH of liquid waste to form acid mine water (AMW). The acidity condition of mine water will dissolve other heavy metals such as Mn, Co, Hg, which are detrimental to the environment. The impact of AMW can be felt directly, if AMW flows into the waters then aquatic life will be poisoned. People in the mining area feel the effects of AMW that pollute the river, they have itchy diseases and river water can not be utilized. If the AMW pollutes the soil, the soil may become acidic and increase the solubility of heavy metals, so the soil becomes an unfavorable medium for plant growth [1].

Acid water resource management activities have been conducted in various ways, both physically and chemically, but they are relatively expensive, inhospitable, ineffective and incomplete. Biological management such as phytoremediation uses a variety of plant species, the implementation is environmentally friendly, thorough, effective, and efficient control of pollutants in the waters [2,3,4].

Research on AMW waste phytoremediation has not been widely discussed. Hyacinth is known as a weed plant, but its ability to live in extreme conditions and multiply rapidly then this plant can be used as a remediator agent. Eichhorniacrassipes has the ability to adapt and be tolerant of acid mine
acid wastes with concentrations of 25%, 50%, 75% and 100%, the root canopy ratio in the treatment shows a proportional comparison respectively [5].

*Limnocharis flava* plant effectively reduces Fe, Mn, BOD, COD, TSS, sulphate, and phosphate levels in Cisande River waters that have contaminated iron (Fe) and manganese (Mn) content higher than the standard applicable water quality. *Limnocharis flava* can absorb Fe as much as 63.99% at Fe 3 ppm concentration and absorb Mn equal to 63.21% at concentration Mn 3 ppm. *Neptunia oleracea* was able to absorb heavy metals Cd, Pb, and Hg in liquor polluted water in Thailand at a concentration of 20% of 89.3% -96.3% within 30 days and also increase the pH [6,7].

The type of plant that suits the waste characteristics as phytoremediation agents is one of the essential elements for successful phytoremediation. The determination of the concentration of the waste also has a role in the success of phytoremediation, since the response of plants to different levels of waste concentration varies, depending on the genetic characteristics and characteristics of the plant [3,8].

This research needs to be done to see the ability of several types of aquatic plants as phytoremediation agents in various concentrations of coal acid mine waste water by measuring the percentage of sulphate and manganese reduction and to see the characteristics of the aquatic plants at the end of the study. It is assumed that in this study *Eichhorniacrassipes, Limnocharisflava* and *Neptuniaoleracea* have different capabilities in the phytoremediation process of acid mine coal water at various concentrations [5,9].

2. Materials and Methods

This study used a complete randomized design (RAL) factorial pattern consisting of two factors: water plants (*Eichhorniacrassipes, Neptuniaoleracea* and *Limnocharisflava*) and concentrations of AMW coal (0%, 25%, 50%, 75% and 100%). Each treatment combination was repeated 3 times. This research begins with AMW sampling, then preparation and acclimatization of water plants for 7 days, making bioreactors, measuring the initial content of AMW (sulphate (SO\(_4^{2-}\)) and manganese (Mn), planting water plants into bioreactors in accordance with experimental design, maintenance and observation of water plants for 30 days of treatment. At the end of the treatment, we measured the dry weight of each plant, measurement of final sulphate content (SO\(_4^{2-}\)) and manganese (Mn) and observation of physical characteristics of aquatic plants [10].

3. Results and Discussion

Based on the research that has been done about the ability test of some water plants as phytoremediation agent of acid mine coal water got the following result:

3.1 Percentage of Sulphate Reduction (SO\(_4^{2-}\))

Based on the Variance Analysis test, it is found that the concentration of acid mine water has a significant effect on the percentage of the decrease of sulphate content, while the plant species, the interaction between plant species and the concentration have no significant effect because plants (*Eichhorniacrassipes, Neptunia oleracea* and *Limnocharis flava*) ability that is not different in absorbing and adapting in sulphate stress. Sulphate will be reduced to sulfihidril in order to be utilized by plants to perform its metabolism [7,11].

Further test results of DMRT α 5% AMW concentration on the percentage decrease in sulphate content is presented as follows:

| AMW Conc. (%) | Sulphate (SO\(_4^{2-}\)) | Procent AMW reduction (%) |
|---------------|--------------------------|---------------------------|
|               | Initial (mg/L) | Final (mg/L) |                         |
| **Kₒ (0)**    | 0          | 0           | 0  a                      |
| **K₁ (25)**   | 637,50      | 526         | 17.49  b                   |
| **K₂ (50)**   | 1275        | 762,50      | 40,20  b                   |
| **K₃ (100)**  | 2550        | 1769,83     | 69,41  b                   |
| **K₄ (75)**   | 1912,50     | 1414,66     | 71,76  b                   |

Table 1. Percentage of Sulphate Reduction in Phytoremediation Process at Various AMW Concentrations
Table 2. Percentage of Manganese Decrease after 30 Days of AMW Phytoremediation Process

| Treatment combinations | Mn (mg/L) | Av. Percentage Mn Reductions (%) |
|------------------------|-----------|---------------------------------|
|                        | Initial   | Final                           |
| J1K0                   | 0         | 0                               |
| J2K0                   | 0         | 0                               |
| J3K0                   | 0         | 0                               |
| J3K4                   | 8,20      | 8,18                            |
| J4K4                   | 8,20      | 8,10                            |
| J1K1                   | 2,05      | 2,02                            |
| J1K2                   | 6,15      | 5,40                            |
| J1K3                   | 6,15      | 4,84                            |
| J2K2                   | 4,10      | 3,15                            |
| J2K3                   | 4,10      | 3,15                            |
| J1K4                   | 8,20      | 3,60                            |
| J1K1                   | 2,05      | 0,60                            |
| J1K2                   | 4,10      | 0,35                            |
| J1K3                   | 6,15      | 0,35                            |

Based on Table 1, the high percentage of sulphate reduction in concentrations i.e. 75%, 100% and 50% is significantly different from the percentage of sulphate decrease at 0% and 25% concentrations due to concentrations of 75%, 100% and 50%, respectively, the sulphate content in the media is thought to be utilized by plants for its metabolism such as photosynthesis. The sulphate absorbed by the plant as an important part of ferrodoxin of Fe and S complexes in chloroplasts, is involved in the formation of chlorophyll associated with photosynthesis and some of the carbohydrate, fat and protein formation reactions. Sulphates present in the acid mine water medium at concentrations of 50%, 75% and 100% are thought to be described with the help of microbes present in the rhizosphere so they can be absorbed by plants. Sulphate will be absorbed by plants through roots with the help of sulphate reducing bacteria (SRB) [7].

The low percentage of sulphate reduction at 25% concentration is not significant with 0% concentration, this is because the agent at 25% concentration can adapt to slightly sulphate medium so that its ability is the same on unsullied media. Low sulphate causes the phytoremediation process to be ineffective and efficient. Sulphate deficiency will inhibit protein synthesis and decrease chlorophyll levels.

3.2 Percentage of Manganese Reduction (Mn)

Based on the Variance Analysis test, it is found that the interaction between acid concentration of coal mine water and plants has significant effect on the percentage of manganese degradation as shown in Table 2.

The plant is able to perform rhizofiltration and rhizodegradation in the absorption of heavy metal manganese [1,4]. DMRT test results α 5% interaction between species of aquatic plants and acid concentration of mine water to the percentage of manganese decrease is presented Table 2. E. crassipes and N. oleracea at 100% concentration, low percentage of Mn decrease is due to the concentration of 100% manganese is too high and the plant can not tolerate it anymore, so the ability of plants to absorb manganese and other nutrients decreases. Nutrient uptake by roots is selective, but some nutrient ions uptake can be competitively inhibited by other ions with different valencies such as K⁺ ions whose uptake can be inhibited by Ca²⁺, Mg²⁺, SO₄²⁻, Ca⁺⁺ ions or Mn⁺⁺. At too high a concentration, essential elements can cause poisoning and inhibition of the absorption of other nutrients will increase [12].

The percentage of manganese E. crassipes decrease at 50% and 75% concentrations was not significant with percentage of manganese decrease by N. oleracea at concentrations of 50% and 75%. At this concentration plants can still utilize the manganese contained in the growing medium for
metabolic processes, especially in the light phase of photosynthesis. Manganese serves as activators of various enzymes, breaking H₂O molecules (water photolysis) in the light phase of photosynthesis and is a structural component of the chloroplast membrane system used for chlorophyll synthesis [13].

Based on Table 2, it is expected that *Limnocharis flava* has better ability to decrease manganese than *E. crassipes* and *N. oleracea* because *L. flava* has long and thick fibrous roots which helps the process of absorption of pollutant through roots. *L. flava* can decrease manganese in B3 contaminated waste, the highest accumulation of manganese is found in root organ, because the root is directly related to contaminated manganese planting media. Manganese that have been absorbed, will be distributed to the leaves [14,15].

*L. flava* is also thought to work with microorganism for manganese degradation process in its root zone. The plant will form chelate (phytochelatin) if it is in heavy metal stress, the formation of this chelate is the response of plants to be able to adapt in a poisonous environment. Manganese absorbed in the form of valence two (Mn²⁺) will chelate with organic compounds produced by microbes in the area around the roots. Substances that chelated manganese is the type fitosiderofor, then manganese will be brought to the root cell through active transport [15,16].

3.3 Measurement of Dry Weight

Variant Analysis Test (ANAVA) got result that interaction between acid concentration of acid water and type of aquatic plants significantly affect dry weight *E. crassipes*, *N. oleracea* and *L. flava*. The nutrient content contained in the acid mine water medium is an additional nutrient for the plant. The plant can utilize well the nutrients in the form of sulphate (SO₄²⁻) contained in acid mine water media to form proteins as the constituent parts of the body cell [17].

Further test results of DMRT at 5% interaction between species of aquatic plants and acid concentration of mine water to average dry weight of aquatic plants are presented in Table 3.

**Table 3. Average Dry Weight of Water Plant after 30 Days of Phytoremediation Process**

| Treatment combinations | Av. dry weight (gram) |
|------------------------|-----------------------|
| J₃K₄                   | 8.04 a                |
| J₃K₀                   | 8.70 a                |
| J₃K₃                   | 8.46 a                |
| J₃K₀                   | 13.29 ab              |
| J₃K₁                   | 16.75 bc              |
| J₃K₁                   | 16.84 bc              |
| J₃K₃                   | 17.88 bc              |
| J₃K₂                   | 18.04 bc              |
| J₃K₄                   | 21.13 bc              |
| J₃K₄                   | 22.97 c               |
| J₃K₇                   | 32.20 d               |
| J₃K₁                   | 36.06 d               |
| J₃K₂                   | 37.11 d               |
| J₃K₀                   | 38.43 d               |

Description: The numbers followed by the same letters show no significant difference in the DMRT test.

The average dry weight of low consecutive on treatment of *L. flava* concentration of 50%, 100%, 0% and 75% acidic water was not significant with *E. crassipes* concentration 0%, respectively. The low average dry weight of *L. flava* due to *L. flava* is not resistant to acid acid water stress so many organs are dead. *L. flava* is a type of herbaceous plant in which the organ is relatively susceptible to pollutant stress and can not be used as a phytoremediation agent for long periods (30 days). *L. lava* usage is used as phytoremediation agent of river water contaminated by hazardous materials in the form of Fe and Mn content only within 6 days. The average dry weight of low consecutive on treatment of *L. flava* concentration of 50%, 100%, 0% and 75% acidic water was not significant with *E. crassipes* concentration 0%, respectively. The low average dry weight of *L. flava* due to *L. flava* is not resistant to acid acid water stress so many organs are dead. *L. flava* is a type of herbaceous plant in which the
organ is relatively susceptible to pollutant stress and can not be used as a phytoremediation agent for long periods (30 days). *L. lava* usage was used as phytoremediation agent of river water contaminated by hazardous materials in the form of Fe and Mn content only within 6 days.

Physical Characteristics of Water Plants Changes in root color at AMW concentrations (0%, 25%, 50%, 75% and 100%) in Root’s *E. crassipes* as in Figure 1

![Figure 1. Root’s *E. crassipes*](image)

Before treatment

![0% 25% 50% 75% 100%](image)

After treatment

The higher the acid water concentration, the root color on *E. crassipes* and *N. oleracea* are fade, hair loss of roots also increases whereas for *L. flava* at 100% concentration blackened this is because the agent die and cause root rot as shown in Fig. 1, 2, and 3. High concentration sulphate and heavy metals contained in the media allegedly affect the physical condition of the roots causing the falling of new roots or root hair because the roots are the organs that directly intersect with the media. Root is the organ that will experience the first damage due to the roots that intersect directly with contaminated planting media [18].

Acid water contains micro nutrients used by plants for the metabolism of one of the micro nutrients ie copper (Cu). The presence of Cu in the media affects the growth and root characteristics. *E. crassipes* that are in heavy Cu metal stress will give a fading color response with increasing acid concentration of acidic water. Heavy metal stress causes intracellular and extracellular damage due to the presence of Cu triggering the seizure of other binding protein minerals so that the absorption of other elements decreases. Excess Cu also inhibits the level of permeability plasmalema and resulted in the destruction of the cell wall of the roots. Damage to the root cell wall can cause a fall of new roots and root hairs. The more heavy metal absorbed, the color of the roots will fade [1, 4].
3.4. Leaf color changes at AMW concentration (0%, 25%, 50%, 75%, and 100%) in leaf’s E. crassipes

Figure 4. Leaf’s E. crassipes

Figure 4 shown that the morphology of E. crassipes leaves at 0% concentration (control) and 100% of severe necrosis and chlorosis, whereas at concentrations of 25% to 75% of leaf states is better this shows that E. crassipes is less able to adapt, can not grow well on non-pollutant media (0%) and with pollutants at high concentrations (100%) [19].

Leaf color of N. oleracea before treatment at each concentration is almost the same that is dark green. Leaf color changes in N. oleracea is indicated by the occurrence of chlorosis until the leaf falled. At 0% concentration, the leaves of N. oleracea still look healthy while at concentrations of 25% to 100% of N. oleracea leaves have chlorosis and leaf loss as shown in Figure 5 [4].

Figure 6. Leaf’s L. flava

In L. flava chlorosis occurs in the leaves. The chlorosis in L. flava begins with a green leaf color that changes into a reddish and then turns yellow and eventually dies. The increasing concentration causes growth to be further hampered as shown in Figure 6. According to Salisbury & Rossa (1995) chlorosis that begins with a leaf turns red is a symptom of phosphorus deficiency. Acid water is suspected to contain no phosphorus. E. crassipes, N. oleracea and L. flava at a concentration of 100% damage and leaf fall in a high degree, suspected leaf tissue and chlorosis due to the high accumulation of heavy metals [20].
4. Conclusions
Based on research that has been done about the ability test of several types of aquatic plants as phyto remediation agent of acid mine coal water of PT. Bukit Asam, TanjungEnim, South Sumatera can be summarized as follows:

- *Eichhornia crassipes*, *Neptunia oleracea* and *Limnocharis flava* have potential as phyto remediation agents of acid mine coal water.
- High percentage of sulphate reduction (SO4) is concentration of 75% acidity of mine water as a medium for growing aquatic plants whereas for the species of water plants (*Eichhornia crassipes*, *Neptunia oleracea* and *Limnocharis flava*) have the same ability to lower sulphate.
- *Limnocharis flava* at a concentration of 75% mine acid water is more likely to decrease manganese (Mn) in phyto remediation of acid mine coal water compared to *Eichhornia crassipes* and *Neptunia oleracea* in various concentrations of acidic acid water.
- *Neptunia oleracea* at various concentrations has a high dry weight value than *Eichhornia crassipes* and *Limnocharis flava* which show that *Neptunia oleracea* is able to grow well in acid mine water media than *Eichhornia crassipes* and *Limnocharis flava*.

Prospective
Based on the results of research that has been obtained that can be done to study the environmental aspects of AMW phyto remediation activities on the microcosm scale and can then be applied to the AMW processing in the coal mining industry.

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