SRIBIOS: SRIWIJAYA BIOSCIENTIA

e-ISSN 2722-0680
Vol. 1 No. 2, Desember 2020

THE POTENTIAL OF *Neptunia oleracea* Lour. ON PHYTOREMEDIATION COAL ACID MINE DRAINAGE

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Peer review di bawah tanggung jawab Departemen Biologi Universitas Sriwijaya

Abstract (English):
Environmental problems in coal mining activities include acid mine drainage (AMD). Efforts to overcome the impact of AMD waste can be done by means of phytoremediation. Neptunia oleracea *Lour. is one type of aquatic plant that has the potential to adapt and accumulate heavy metals. So it is necessary to do research with the aim of knowing the potential of N. oleracea in AMD phytoremediation. The phytoremediation potential of* N. oleracea *used a completely randomized design (CRD): without AMD as control (0%), with AMD concentrations of 25%, 50%, 75% and 100%. The results showed that* N. oleracea *has the potential to increase pH by 0.0322/day and reduce Fe content by 0.4760 mg/l/day, Mn 0.5776 mg/l/day, sulfate 0.4809 mg/l/day and reduce TSS by 0.0818 mg/l/day, at 100% AMD concentration. It can be concluded that* N. oleracea *has potential as an AMD phytoremediation agent to be developed in system constructed wetlands (CWs).*

Keywords: Acid Mine Water (AMD), Phytoremediation, Neptunia oleracea *Lour., Potential*

Abstrak (Indonesia)
Permasalahan lingkungan dalam kegiatan penambangan batubara antara lain acid mine drainage (AMD). Upaya penanggulangan dari dampak AMD dapat dilakukan dengan cara fitoremediasi. Neptunia oleracea *Lour. merupakan salah satu jenis tumbuhan air yang berpotensi untuk beradaptasi dan mengakumulasi logam berat. Sehingga perlu dilakukan penelitian dengan tujuan untuk mengetahui potensi* N. oleracea *dalam fitoremediasi AMD. Potensi fitoremediasi* N. oleracea *menggunakan Rancangan Acak Lengkap (RAL): tanpa AMD sebagai kontrol (0%), dengan konsentrasi AMD 25%, 50%, 75% dan 100%. Hasil penelitian menunjukkan bahwa* N. oleracea *berpotensi meningkatkan pH sebesar 0,0322 / hari dan menurunkan kadar Fe sebesar 0,4760 mg / l / hari, Mn 0,5776 mg / l / hari, sulfat 0,4809 mg / l / hari dan menurunkan TSS sebesar 0,0818 mg. / l / hari, pada konsentrasi AMD 100%. Dapat disimpulkan bahwa* N. oleracea *berpotensi sebagai agen fitoremediasi DAL untuk dikembangkan di lahan basah buatan sistem (CWs).*

Kata kunci: Acid Mine Water (AMD), fitoremediasi, Neptunia oleracea *Lour., potensi*

Diterima: November 10, 2020 , Disetujui: December 10, 2020

1. Pendahuluan

Coal mining which is carried out by open pit has an impact on the surrounding environment, which causes a decrease in environmental quality. One of the environmental problems in coal mining activities is related to acid mine drainage (AMD). According to [1], AMD is formed as a result of oxidation of certain sulfide minerals contained in rocks, which react with oxygen in the air in an aqueous environment. Efforts to overcome the problem of the impact of AMD waste can be carried out in various physical, chemical and biological ways. Biologically, it can be done by remediation using water plants.

Phytoremediation is a method of using plants to remove pollutants from contaminated soil or waters [2]. Phytoaccumulator plants such as *Neptunia oleracea* Lour. is a type of aquatic plant from the Leguminaceae family

that has the ability to adapt and accumulate heavy metals. According to [3] *N. oleracea* is able to act as a plant phytoaccumulator against heavy metals. Based on research [4] using *N. oleracea* found that *N. oleracea* can absorb and accumulate metals such as Pb, Cd and Cu to the highest concentration of 10 mg/l. [5] reported that *N. oleracea* was able to adapt to ammonia waste based on the increase in fresh weight and growth rate of ammonia phytoremediation from petrochemical industrial waste.

So it is necessary to do research with the aim of knowing the potential of *N. oleracea* in AMD phytoremediation, to be used as AMD phytoremediation agent in constructed wetlands.

2. RESEARCH METHODS

The research was conducted at the Laboratory of Physiology and Development, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Indralaya. AMD sampling was conducted at the Air Laya Mine, PT. Bukit Asam, Tanjung Enim, South Sumatra. Analysis of heavy metal content, AMD, was carried out at the Laboratory of the Industrial Research and Standardization Center in Palembang, South Sumatra.

The tools used include the basin bioreactor, Erlenmeyer, cuvette, volumetric flask, filter paper, oven, magnetic stirrer, pH meter, micropipette, atomic absorption spectrophotometer (AAS), and scales. **The materials needed** are distilled water, acetic acid, $BaCl_2$, Buffer A, AMD coal waste water, HNO_3, and *N. oleracea* in the vegetative phase

The design used a completely randomized design (CRD) with *N. oleracea* treatment with different AMD concentrations (0% as a control, 25%, 50%, 75% and 100%)

Acclimatization and treatment *N. oleracea* was acclimatized for 7 days with 95% distilled water and 5% AMD. *N. oleracea* was grown ± 100g in each bioreactor. The treatment was carried out for 15 days.

Measurement of chemical variables from AMD was carried out at the beginning and end of the research. AMD pH measurement is measured every 3 days. Measurement of Fe content was carried out by atomic absorption spectrophotometry (AAS) in accordance with SNI 6989.4: 2009. Measurement of Mn content by atomic absorption spectrophotometry (AAS) is in accordance with SNI 06-6989.5-2004. Measurement of SO_4^{2+} content is carried out in a turbidimetric manner in accordance with SNI 06.6989.20-2004. and TSS was carried out spectrophotometrically according to SNI 06-6989.3-2004.

The phytoremediation ability in the form of pH, TSS, Fe content, Mn content, and sulfate was calculated using the formula [6]:

$$\mu i = \{\ln (Pi / Po)\} / ti$$

Information:
μi : phytoremediation ability *i*
ln : natural log
Pi : observation *i*
Po : initial observations
Ti : time *i*

The data were analyzed of variance using SPSS 16. If there was an effect of the treatment, it was continued with the Duncans Multiple Range Test (DMRT) at the 0.05 sigificant level.

3. RESULTS AND DISCUSSION

The potential of *N. oleracea* in phytoremediation of AMD obtained the following results

Acidity (pH) in Acid Mine Water

Analysis the potential of *N. oleracea* phytoremediation in increasing the AMD pH at different concentrations of AMD is shown in Table 1.

Table 1. Potential *Neptunia oleracea* Lour. in raising the pH in the phytoremediation of acid mine drainage

AMD (%)	pH		Potential
	initial	after	
0	6,15	6,27	0,0013[d]
25	3,22	5,44	-0,0082 [c]
50	2,95	4,13	-0,0265 [b]
75	2,83	3,89	-0,0305[a]
100	2,69	3,79	-0,0322[a]

Note: * Numbers followed by a different letter in each column indicate that Duncan's test is significantly different

In Table 4.1. It was found that *N. oleracea* has the potential to increase AMD pH, presumably because of the nature of *N. oleracea* being able to absorb sulfates. And also *N. oleracea* is a hyper accumulator plant that can absorb and accumulate heavy metals. The potential of *N. oleracea* in increasing pH at AMD concentration of 25% is 0.0082/day. Because at the AMD concentration of 25%, the pH was not too extreme, which resulted in some metals in AMD still in available conditions so that at the AMD concentration of 25% there was a small increase in pH.

In AMD treatment with a concentration of 100% the ability of *N. oleracea* to raise the pH was higher with a potential of 0.0322/ day, it was suspected that *N. oleracea* was in a tense condition. Although *N. oleracea* has the ability to absorb heavy metals, at extreme concentrations *N. oleracea* activity is still able to reduce the pH even though the metal content in the media is quite high. According to [7] stated that plants that have the potential to absorb heavy metals have a tolerance for environments with low pH and stressful environments.

Fe content in Acid Mine Water

Analysis of phytoremediation potential found that *N.oleracea* had a significant effect on reducing Fe content in AMD. The potential of *N. oleracea* phytoremediation in reducing Fe content at different AMD concentrations is presented in Table 2. as follows

Table 2. Potential of Neptunia oleracea Lour. in reducing Fe content in phytoremediation of acid mine drainage

AMD (%)	Fe content (mg/l)		Potential
	initial	Before	
0	0	0	0 [a]
25	1,01	0,15	0,2372 [b]
50	1,50	0,80	0,3437 [c]
75	3,75	2,76	0,4183 [d]
100	6,89	6,05	0,4760 [d]

Note: * Numbers followed by a different letter in each column indicate that Duncan's test is significantly different

Based on Table 2, it was found that there was a decrease in Fe because *N. oleracea* absorbed ion Fe which was used as a micro nutrient for metabolism. The ability of *N. oleracea* to reduce Fe content with a potency of 0.4760 mg/l/day. The high potential of Fe phytoremediation in 100% AMD is suspected that *N. oleracea* can accumulate large amounts of Fe. *N. oleracea* absorbs Fe through its roots in an available form, ion Fe^{2+} in the phytoaccumulation process. According to [8], phytoaccumulation is a mechanism by which plant roots can absorb contaminants along with the absorption of contaminants and water. The contaminant mass is not broken down but is deposited in the shoots and leaves.

Content of Mn in Acid Mine Water

Phytoremediation using *N. oleracea* has the potential to reduce Mn content at different AMD concentrations, as presented in Table 3.

Table 3. Potential of *Neptunia oleracea* Lour. in reducing Mn content in the phytoremediation of acid mine drainage

AMD (%)	Mn content (mg/L)		Potential
	initial	after	
0	0	0	0[a]
25	2,89	0,59	0,3519 [b]
50	4,68	3,20	0,5381 [c]
75	6,34	5,47	0,5737 [c]
100	7,31	5,79	0,5776 [c]

Note: * Numbers followed by a different letter in each column indicate that Duncan's test is significantly different

Table 3 shows that *N. oleracea* is able to reduce Mn content in AMD. *N. oleracea* has hyper accumulator properties of heavy metals so it is suspected that *N. oleracea* is other than utilize Mn as a micro nutrient for metabolism and enzyme activator, also accumulated in the roots or shoots of plants. The potential of *N. oleracea* in reducing Mn content at 100% AMD concentration is 0.5776 mg/l/day. At concentration 100% AMD treatment, the initial concentration of Mn was high so that the roots of *N. oleracea* formed a chelator to absorb Mn. The formation of chelate compounds is the response of plants to adapt to a toxic environment, so that metals in the substrate can be accumulated in plants.

Content of Sulfate in Acid Mine Water

Phytoremediation using *N. oleracea* has the potential to reduce sulfate content at different AMD concentrations, as presented in Table 4.

Table 4. Potential of *Neptunia oleracea* Lour. in reducing sulfate content in the phytoremediation of acid mine drainage

AMD (%)	Sulfate content (mg/L)		Potential
	intial	After	
0	0	0	0 [a]
25	945,8	615,75	0,4392 [b]
50	1141,1	718,08	0,4500 [c]
75	1525,9	724,96	0,4505 [c]
100	1898,9	1144,73	0,4809 [d]

Note: * Numbers followed by a different letter in each column indicate that Duncan's test is significantly different

Table 4 shows that *N. oleracea* was able to reduce sulfate levels at each concentration of AMD treatment. It is suspected that *N. oleracea* is hyper-tolerant of high sulfate concentrations, by absorbing sulfate as a nutrient for growth and metabolism. Another reason is because *N. oleracea* belongs to the Luguminoceae family which fixates in large quantities.

According to [9], sulfur is used by plants as a constituentphytoremediation with constructed wetlands for AMD.
of certain vitamins, coenzyme A, and glutathione, can
fix nitrogen and as part of the nitrogenase enzyme.

The amount of TSS (Total Suspended Solid) in Acid Mine Water

N. oleracea in AMD phytoremediation has a significant effect on reducing TSS. The potential of *N. oleracea* phytoremediation in reducing TSS at different AMD concentrations can be seen as in Table 5.

Table 5. Potential of *Neptunia oleracea* Lour. in lowering the TSS value in the phytoremediation of acid mine drainage

AMD (%)	TSS		Potential
	intial	After	
0	0	0	0 [a]
25	4	1	0,0091[a]
50	9	4	0 0,0359 [b]
75	16	9	0 0,0595 [c]
100	48	13	0,0818 [d]

Note: * Numbers followed by a different letter in each column indicate that Duncan's test is significantly different

Table 5. shows that *N. oleracea* can reduce TSS at each AMD concentration, this is because *N. oleracea* is able to absorb and accumulate metals as nutrients. *N. oleracea* can also take advantage of the decomposition of organic matter as nutrients, causing good growth at 100% AMD concentration. The ability of *N. oleracea* to reduce TSS values was higher at 100% AMD concentrations with a potency of 0.0818 mg / L / day. This is because *N. oleracea* has long roots and has a large number of plants in the bioreactor. [10] explained that the many plant roots and length and the more the number of plants, the greater the decrease in TSS in the waters.

5. CONCLUSION

Based on the results of research on the potential of *N. oleracea* in the phytoremediation of AMD, the following conclusions are obtained:

Neptunia oleracea has the potential to increase AMD pH, reduce Fe, Mn, sulfate and TSS to 100% AMD concentrations with respective potencies of 0.0322/day, 0.4760 mg/l/day, 0.5776 mg /l/day, 0.4809 mg/l/day and 0.818 mg/l/day. So that *N. oleracea* has the potential to be developed as vegetation in

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