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LABORATORY SIMULATION FOR REDUCING WATER TURBIDITY BY WATER HYACINTH TO MEET COAL WASTEWATER DISCHARGE IN PARINGIN PIT LAKE

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Abstract. Coal mining with an open-pit mining method can created the formation of pit lake filled with high turbidity water which has the potential to pollute and cannot be utilized if not managed properly. Treatment to reduce water turbidity to meet quality standards with chemicals is a common, but during post mining period, it is necessary to reduce the processing, which is expensive and uncertain, turning into a natural process and lower cost. The aim of this study is to analysis on the role of water hyacinth as macrophytes in reducing water turbidity on three different water sources for treatment. Water hyacinth is an aquatic plant that can be used to reduce water pollution such as high levels of turbidity in water quality. The experimental results showed that not significant on TSS < 200 mgL^{-1} but significantly different results, on TSS values between 200 – 400 mgL^{-1} and TSS > 400 mgL^{-1} and to be the basic reference data of the number of plants used in experiment to enlarge it on a field scale.

Keyword: *pit lake, run off, turbidity, wastewater compliance parameter, water hyacinth*

Introduction

The water hyacinth (*Eichhornia crassipes*) is one of the most invasive aquatic plant species in the world (Chandra & Gerhardt, 2008; Tobias et al., 2019). Invasive species are plant or animal species that have succeeded to reach a new habitat with or without human assistance and are able to adapt to the new conditions and spread quickly within the new area (Simberloff, 2010). The water hyacinth is a monocotyledon belonging to the family of Pontederiaceae. It is a perennial floating macrophyte with thick rounded green leaves, lavender blue flowers with a central yellow dot organized in spike inflorescence and dark purple to black roots with rhizomes and stolon's (VonBank et al., 2018).

Water hyacinth is an aquatic plant that can be used to reduce water pollution such as high levels of turbidity in water quality (Tedford et al., 2019). As generally runoff water in mining, which in some conditions does not meet the quality standards to be released into public bodies, the condition of wastewater that will enter the Paringin pit lake has quality with a high level of turbidity plus the use of an active coal stockpile where the runoff water also flows to Paringin pit lake (Triwibowo et al., 2021)

Coal mining with an open-pit mining method can created the formation of pit lake filled with contaminated water which has the potential to pollute the surrounding area and cannot be utilized if not managed properly (Tuheteru et al., 2021; Low et al., 2016). The ex-mining site over time is gradually filled with water resulting in the formation of pit lake. The pit lake is a description of the mining location using the open-pit mining method which is then filled with runoff and ground water (Bargawa et al., 2019)

In an effort to utilize wastewater from pit lakes, efforts to manage the water quality are a must as an obligation. The water quality of pit lake is categorize as good if the water can be used according to its utilization and comply. The water conditions are maintained in accordance with quality standards so that they are not contaminated by materials or particles or other substances so that runoff water from the pit lake can ultimately be used, especially to support the aquatic life of biota (Bargawa et al., 2019). Utilization of compliance water from the pit lake during the mine closure period will provide further benefits after the mining activities ceased to support industrial interests or surrounding community needs (McCullough et al., 2020).

Methodology

Research Location

The research area was in the mining area of PT Adaro Indonesia in the administrative Tanjung District, South Kalimantan Province, Indonesia where the location as mentioned in Figure 1 (left). PT Adaro Indonesia (hereinafter referred to as “Adaro Indonesia”) commenced mining activities started in Paringin Pit as one of the main pits at her mining concession area (right). Figure 2 shows the position where the Paring Pit Lake which accommodates runoff water from the catchment is approximately 150 ha area and includes runoff water from the stockpile (right) which is still operating. Paringin is already prepared to enter mine closure (Triwibowo et al., 2021).

Figure 1. Research area location (left) and Paringin pit lake location (right)

Experiment Design

It was prepared 20 experimental boxes (length 80 x wide 40 x height 40 cm each box) to study the role of water hyacinth to reduce the level of water turbidity as a simulation water flow of catchment area to Paringin pit lake. The experimental box was placed in two level grade position where 10 boxes in a higher position were put water hyacinth in five boxes then compared to five boxes without plants. The other 10 boxes lower grade position were without treatment but were places for the water to flow before it flowed out of the experimental box as Figure 2 (right).

Source water with three different conditions on Total Suspended Solid (TSS) qualities, namely treatment of water sources of TSS < 200 mgL^{-1}, TSS 200 – 400 mgL^{-1}, and TSS > 400 mgL^{-1} was flowed from a reservoir equipped with a stirrer so that the turbidity level was evenly distributed. Water flows through pipes connected to each experimental box to ensure all boxes receive water flow with the same water flow as in Figure 2 (left).

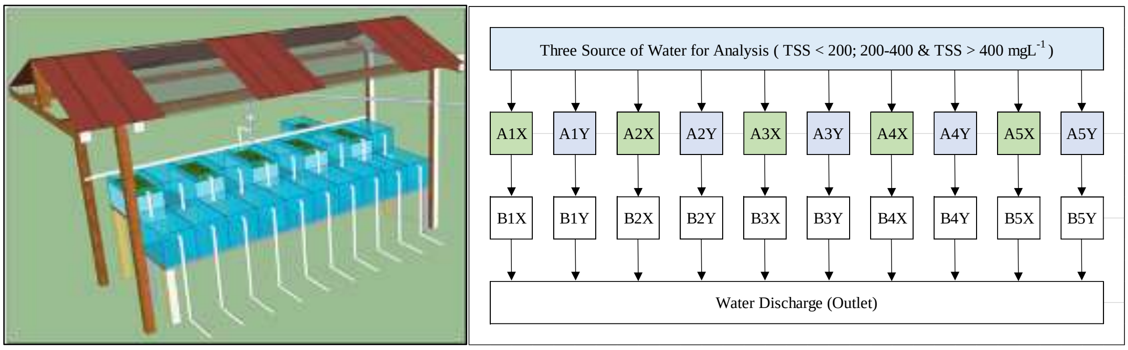

Figure 2. Laboratory simulation design for water hyacinth treatment

Water Sampling and Analysis

The study is a two factor (box with and without water hyacinth) experiment with five replicants. Twenty experimental artificial tanks consisting of plastic boxes with dimension of 80 x 40 x 40 m were used for this study. The boxes were placed side by side where five boxes with and five boxes without water hyacinth placed higher than other ten boxes without water hyacinth. The water flow each of the 10 boxes above it to the 10 boxes below it.

Water sampling started since day 1st to day 14th then to analysis references with the parameter of mining coal operation wastewater of South Kalimantan Governor Regulation number 036, year of 2008 namely pH 6-9; TSS < 200 mgL^{-1}; Fe < 7.0 mgL^{-1}; Mn < 4.0 mg L^{-1}; and Cd < 0.05 mg L^{-1} and to see the result of the treatment with and without water hyacinth, the comparation on data of day 14th.

Result and Discussion

Effect of Water Hyacinth Treatment on pH and TSS changes

Water hyacinth treatments on three treatment water sources with different TSS conditions showed changes in pH from the day 1st of observation to day 14th. Observation of pH at TSS < 200 mgL^{-1} showed an increase in pH on day 14th compared to day 1st as reference with the linear equation $Y = 0.024 X + 7.4445$ ($R^2 = 0.5996$). For the treatment at TSS 200 – 400 mg L^{-1}, it showed a decrease in pH with the linear curve equation $Y = - 0.0058 X + 7.731$ ($R^2 = 0.00161$) as well as the treatment at condition TSS > 400 mgL^{-1} showed as references with linear equation $Y = - 0.0196 X + 7.7168$ ($R^2 = 0.1269$).

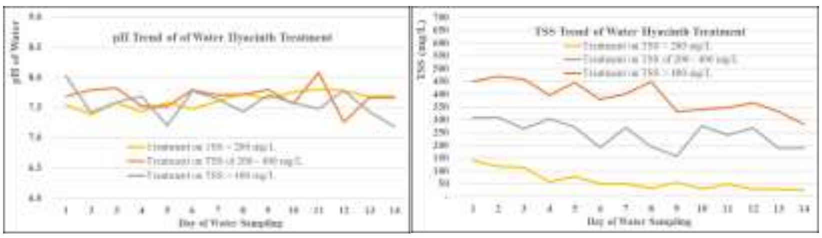

Figure 3. Trend of pH and TSS on treatment of water hyacinth on day 1st to 14th.

The results of the static analysis of the t-test showed that the pH of water hyacinth treatment compared without treatment on the 14th day at TSS <200 mgL^{-1} showed a significant difference with P = 0.020. The treatment at TSS 200 – 400 mgL^{-1} showed a significant difference with P = 0.004 and TSS > 400 mgL^{-1} also showed a significant difference with P = 0.004. Considering meeting the regulation, all pH is complied with standard of pH 6 – 9.

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Water hyacinth treatment showed a change in TSS from day 1st of observation to 14th. Observations on the three treatment sources showed a decrease if the observations on the 14th were compared to the 1st. The decrease in the value of TSS under TSS < 200 mgL^{-1} with a linear equation is Y= - 7.8287 X + 120.14 (R^2 = 0.7622), treatment under TSS condition 200 - 400 mg L^{-1} with a linear equation is Y= - 7.4987 X + 301.73 (R^2 = 0.3776) and treatment at TSS condition > 400 mgL^{-1} as illustrated in the linear equation Y = - 2.11 X + 480.29 (R^2 = 0.7457).

The results of the static analysis of the different t test showed that the TSS of water hyacinth treatment compared without treatment on the day 14th at TSS < 200 mgL^{-1} showed no significant difference (P = 0.232) but all TSS values in this treatment met the quality standards, both national and international regulations. regional. The treatment at TSS 200 – 400 mg L^{-1} showed a significant difference with P = 0.013 and TSS > 400 mg L^{-1} also showed a significant difference with P = < 0.001. Water hyacinth treatment can improve the TSS value, change from not compliance to be comply with regulation applicable on treatment of TSS 200 – 400 mg L^{-1}.

Content of Fe, Mn, and Cd Water Result

Water hyacinth treatments in three treatment water sources with different TSS conditions showed changes in Fe, Mn, and Cd observation on day 1st to 14th. Observation of Fe at TSS < 200 mgL^{-1} showed a decrease in Fe on day 14th compared to 1st with a linear equation Y= - 0.0202 X + 0.2612 (R^2 = 0.3503). For the treatment on TSS 200 – 400 mg L^{-1} showed a decrease in Fe with linear curve equation Y= -0.0087 X + 0.3496 (R^2 = 0.17712) as well as treatment at TSS condition > 400 mg L^{-1} showed a decrease as illustrated in the linear equation Y = - 0.0211 X + 0.6563 (R^2 = 0.31).

Observation of Mn on TSS < 200 mg L^{-1} showed a decrease on day 14th compared to 1st with the linear equation Y= -0.0007 X + 0.014 (R^2 = 0.3728). For the treatment at TSS 200 – 400 mg L^{-1} showed an increase in Mn with a linear curve equation Y = 0.00005 X + 0.0143 (R^2 = 0.0028). Treatment at TSS condition > 400 mg L^{-1} showed a decrease as illustrated in the linear equation Y = -0.0012 X + 0.0279 (R^2 = 0.2642).

Observation of Cd on TSS < 200 mg L^{-1} showed a decrease on day 14th compared to 1st with the linear equation Y = -0.30007 X + 0.014 (R^2 = 0.3728). For the treatment on TSS 200 – 400 mg L^{-1}, it showed a decrease in Cd with a linear curve equation Y = -0.0002 X + 0.0037 (R^2 = 0.3090). Treatment on TSS > 400 mg L^{-1} showed a decrease as illustrated in the linear equation Y = -0.0007 X + 0.0022 (R^2 = 0.1356).

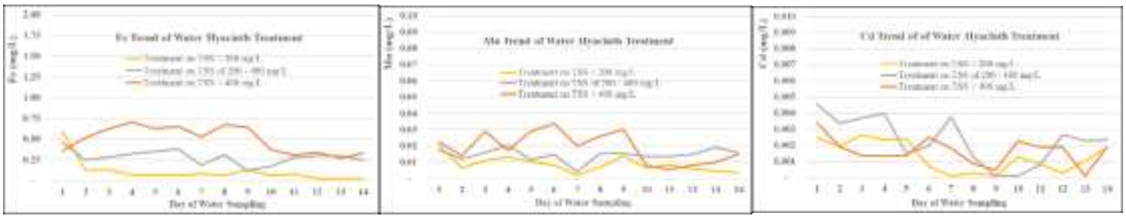

Figure 4. Trend of Fe, Mn, dan Cd on treatment of water hyacinth on day 1st to 14th.

The results of the static t-test analysis showed that Fe, Mn and Cd in the water hyacinth treatment compared without treatment on the day 14th of Fe were not significantly different on TSS < 200 mg L^{-1} (P = 0.912), TSS 200 - 400 mg L^{-1} (P = 0.681) and TSS > 400 mgL^{-1} (P = 0.883) showed no significant difference, similarly for Mn was not significantly different either on TSS < 200 mgL^{-1} (P = 0.885), TSS 200 - 400 mg L^{-1} (P = 0.895); TSS > 400 mgL^{-1} (P = 0.805) and the results of Cd on TSS < 200 mgL^{-1} (P= 0.907), TSS 200 - 400 mgL^{-1} (P = 0.685), and TSS > 400 mgL^{-1} (0.997) but All observations have met the quality standard values in accordance with applicable regulations.

Table 1. Result of t-test and compliance status of water hyacinth treatment

Parameter	Water for Treatment	Water Hyacinth Treatment	Without Water Hyacinth	Different	%	t-test	Regulation Compliance Status	
							National	Regional
pH	TSS < 200	7.69	7.83	(0.15)	(1.85)	Significant (P=0.020)	Comply	Comply
	TSS 200 - 400	7.67	7.82	(0.15)	(1.89)	Signficant (P=0.004)	Comply	Comply
	TSS > 400	7.19	7.31	(0.12)	(1.70)	Signficant (P=0.004)	Comply	Comply
TSS	TSS < 200	26	29	(3.16)	(10.90)	Not signficant (P=0.232)	Comply	Comply
	TSS 200 - 400	190	241	(51.23)	(21.22)	Significant (P=0.013)	Comply	Not Comply
	TSS > 400	283	417	(133.16)	(31.96)	Significant (P<0.001)	Not Comply	Not Comply
Fe	TSS < 200	0.0247	0.0241	0.0006	2.53	Not Signficant (P=0.912)	Comply	Comply
	TSS 200 - 400	0.2490	0.2413	0.0077	3.19	Not Signficant (P=0.681)	Comply	Comply
	TSS > 400	0.3323	0.3243	0.0080	2.46	Not Signficant (P=0.883)	Comply	Comply
Mn	TSS < 200	0.0035	0.0037	(0.0002)	(4.84)	Not Signficant (P=0.885)	Comply	Comply
	TSS 200 - 400	0.0161	0.0157	0.0003	2.19	Not Signficant (P=0.895)	Comply	Comply
	TSS > 400	0.0150	0.0143	0.0007	4.95	Not Signficant (P=0.805)	Comply	Comply
Cd	TSS < 200	0.0019	0.0019	(0.0001)	(4.64)	Not Signficant (P=0.907)	Comply	Comply
	TSS 200 - 400	0.0023	0.0021	0.0003	13.03	No Significant (P=0.685)	Comply	Comply
	TSS > 400	0.0021	0.0022	(0.0000)	(1.90)	Not Signficant (P=0.997)	Comply	Comply

Water Hyacinth role reducing Total Suspended Solid (TSS)

Suspended solids are solids that cause turbidity in water that is not dissolved and cannot settle directly and consists of particles that are smaller in size and weight than sediments. Turbidity of surface water from scattered clay particles can hinder the development of aquatic ecosystems (Sukmono, 2018). Turbidity is an important characteristic of aquatic ecosystems. It controls the penetration of sunlight into the water column, thereby affecting the absorption of solar energy and the distribution of heat generated, the level of biological activity and the aesthetic appearance of the water body due to many factors affecting it in various timescales (Izuangbe et al., 2015; Leeuwen et al., 2015).

A possible mechanism to reduce turbidity from surface runoff from stockpiles is through the application of chemicals so that wastewater with very high TSS conditions can be reduced but continuous chemical application cannot be carried out because entering post-mining surface runoff must reduce the cleaning chemicals carried out and enhance natural processes. This reduced purification can provide biogenic carbon dioxide (CO_2) (Poon, Cossey, Balaberda, & Ulrich, 2021). Turbid water can become clear because the organic materials in the liquid waste can be reduced by rhizosphere microbes found in water hyacinth roots. The trick is to absorb organic matter from waters and sediments, then accumulate this dissolved material into its body structure (Lawrence et al., 2015). Sulfate-reducing bacteria can increase pH also or restore neutral pH by reducing sulfate to sulfide (H_2S) and releasing hydroxyl ions (OH^-) (Abdullah & Nafie, 2017). The water pollutant will be absorbed by plant roots after being degraded by microorganisms into simpler compounds so that the nutrient content in wastewater is consumed by microorganisms (Tanjung et al., 2019) the the percentage rate of

TSS decrease in treatment without water hyacinth (control) is due to the precipitation gravity alone (Göransson et al., 2013).
Program monitoring also enables stakeholders to evaluate the chemical evolution of lakes over time, to initiate corrective actions to avoid poor water quality (if necessary) The monitoring program also facilitates improved pit lake prediction by identifying additional processes that need to be included in the conceptual model and guiding the calibration of model parameters (Gammons et al., 2009). By building up dense mats with up to two million plants per hectare, the water hyacinth alters water quality by reducing light penetration and dissolved oxygen due to the constant rotting of the mat base (Villamagna & Murphy, 2010). Its evapotranspiration rate can exceed ten times the water evaporation rate of open water bodies making it particularly dangerous for shallow lakes (Cong Manh et al., 2019).
These changes are altering aquatic ecosystem abiotic factors and negatively affect the aquatic fauna and flora communities. The low light penetration under water hyacinth mats decreases phytoplankton abundance which in turn leads to a reaction chain affecting aquatic invertebrate, fish and bird communities (Villamagna & Murphy, 2010). Prediction of the hydrology and water quality of lakes is critical to developing appropriate and cost-effective treatment measures (Castendyk et al., 2015; Ulrich et al., 2012).

Conclusion
Based on the results of observations and discussions in this study, it can be concluded that the treatment of coal wastewater with water hiyacinth on day 14 is significantly effective in reducing TSS.
Modeling is an indispensable tool for assessing the range of potential water quality parameters. The basic principles and conceptual challenges of design and process that should be considered in modeling pit lake water quality and improving the accuracy of those predictions, and for ranking the chemical sensitivity of pit lake water to environmental processes to determine which are the most significant.

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