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Mitigation in erosion control and management of ex-mining water through revegetation and sustainable environmental management technologies

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Mitigation in erosion control and management of ex-mining water through revegetation and sustainable environmental management technologies

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Abstract. In the open-pit mining system that is being carried out by a company in the mining sector with gold and silver commodities, PT Citra Palu Minerals, land clearing can cause soil erosion which can lead to soil sedimentation, increased turbidity of water that will be released into the environment and potential entry soil eroded into the tailings pond at the Dry Tailing Management Facility (DTMF). Therefore, further action is needed to control erosion and sedimentation as well as water management so that the water to be released into the environment is following environmental quality standards that have been set by the government. Before determining and controlling erosion, it is necessary to know the rate of erosion that occurs at the research location, in this study the USLE (Universal Soil Loss Equation) method was used to predict the rate of erosion with the results obtained, namely 17.07 tonnes/ha on the North DTMF slopes and 21.04 tonnes/ha for DTMF South slopes. To reduce the rate of erosion, it is necessary to control erosion by revegetation of the land, create a water drainage system to the sedimentation pond and treat the collected water using biophytoremediation of land with the use of chemicals to accelerate the deposition process, constructed swamp forest to the latest sustainable technology recommended by the Indonesian Academy of Sciences (LIPI).

1. Introduction

Erosion is the occurrence of displacement or transportation of soil or parts of land from one place to another by natural media such as water or wind. Erosion occurs when the soil in one area is eroded and carried away, which is then deposited somewhere. Erosion events generally often occur in wet climates, such as Indonesia which is a tropical region [1].

The process of erosion on slopes such as soil removal, transportation, and sedimentation containing soil grains causes production operations to be disrupted. PT Citra Palu Minerals (CPM) is a gold mining company located in Poboya Village, Palu City, Central Sulawesi Province (Figure 1), where this research was conducted. This area is prone to erosion, especially slope erosion in the Dry Tailing Management Facility (DTMF) area which is precisely located above the pond area dry tailings, where the slope in this area is relatively steep.

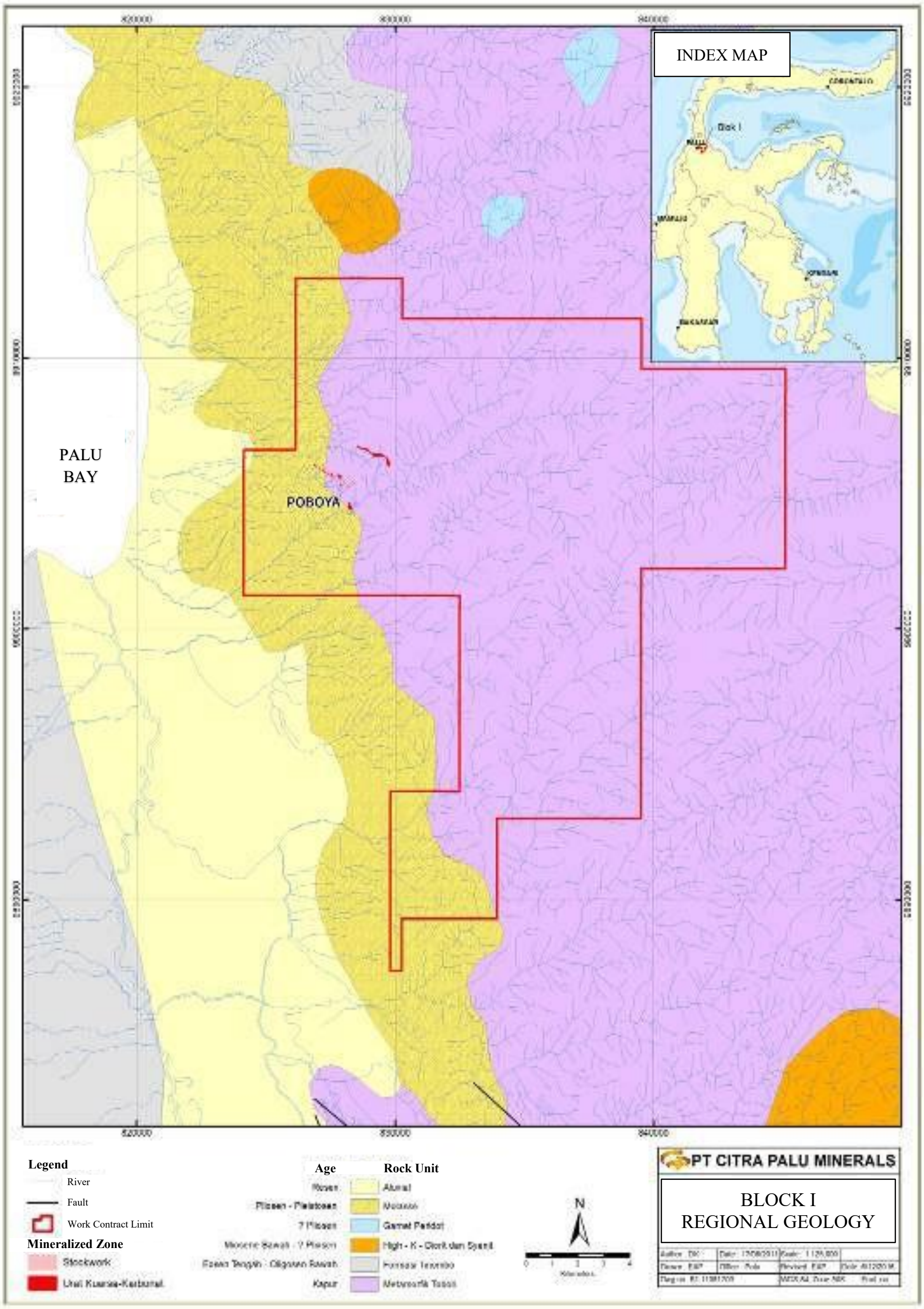

Figure 1. Regional geology of the research site.

If erosion on the slopes of the DTMF area (Figure 2) is allowed to slowly erode the soil layer on the slope which will reduce the strength of the soil in holding water and also the loss of valuable nutrients in the soil so that later it will be difficult for plants to grow. If the fertility of the soil and the holding capacity of the soil is decreasing and the soil is not strong enough to withstand erosion, there will be a potential for landslides to occur. The occurrence of erosion on this slope can also disturb the tailings pond below it, if the eroded soil enters the tailings pond, the planned dam capacity can change and is likely to exceed capacity or overflow.

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In addition, Figure 3 shows the long-section and cross-section at the location where this research was carried out. It can be seen in Figure 4 that the contour from east to west of the DTMF area decreases, while the south to north contour forms a basin where the middle or the lowest part is the tailings stockpile area (Figures 5 and Figure 6). From the long-section and cross-section images, it shows the vulnerability of the slopes of the study site to erosion and even landslides if left open without preventive measures. Erosion carried by runoff can cause sedimentation which will affect the quality of water that will be discharged into rivers or the environment. If the quality of water released into the environment does not meet the water quality standards set and is then used by the community, it will harm the community, such as the emergence of diseases caused by unclean water, and does not rule out the possibility of causing death. This water-borne sediment can also cause other negative impacts, namely, if the sediment is carried downstream of rivers and/or beaches, it can cause silting which can lead to flooding and/or overflowing of water to the land [2]. Therefore, the company has a social and environmental responsibility to realize the principles of good and correct mining management (Good Mining Practice), by Omnibus Law on Job Creation, Law Number 11 of 2020 concerning environmental protection and management to maintain the quality of water released from mine location according to the predetermined quality standards.

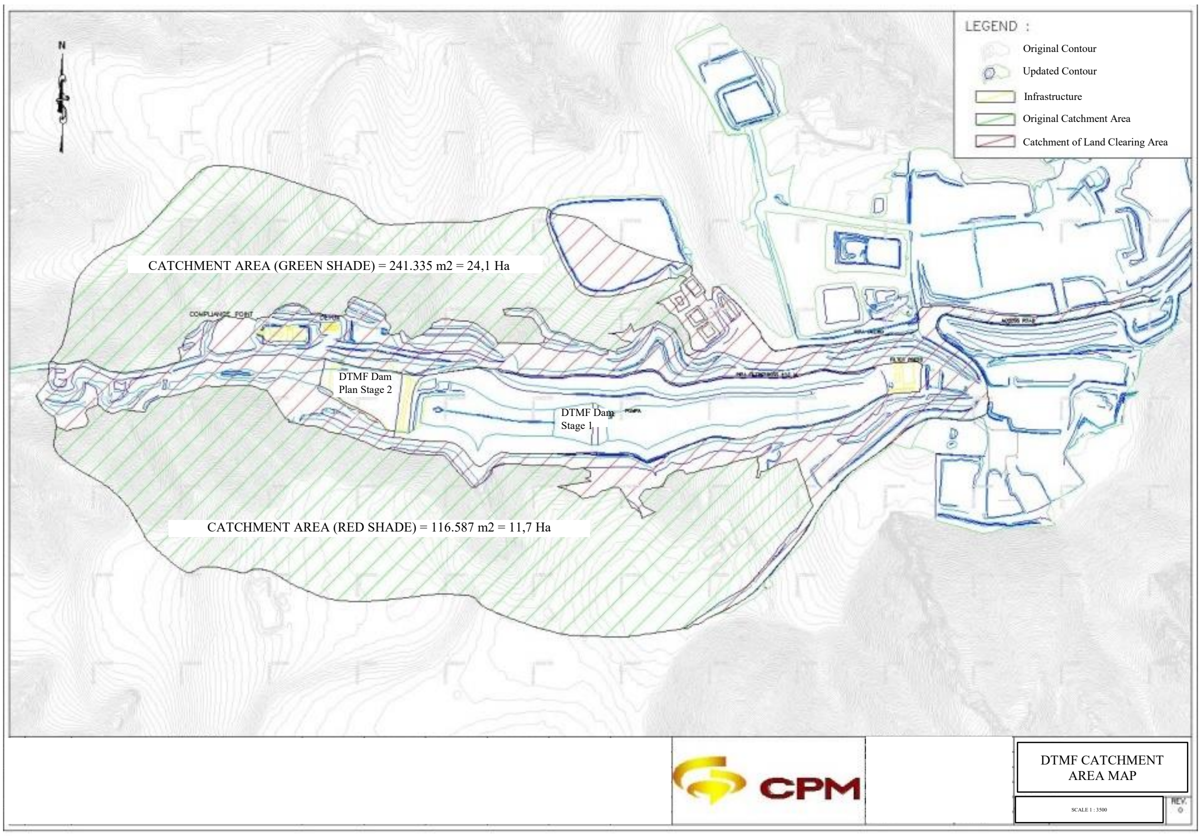
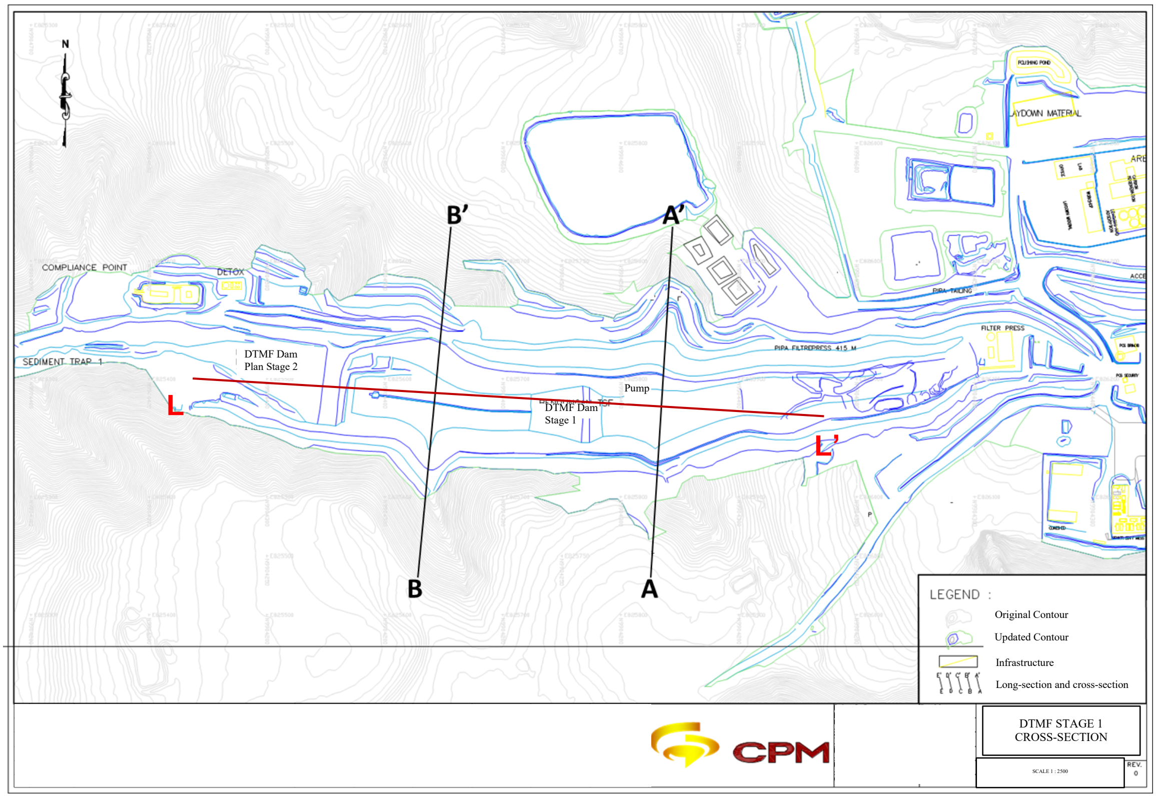


Figure 2. Catchment area in DTMF map.



Note: Section L for long section; sections A and B for cross sections

Figure 3. Long-section and cross section at the PT Citra Palu Minerals dry tailing management facility research location.

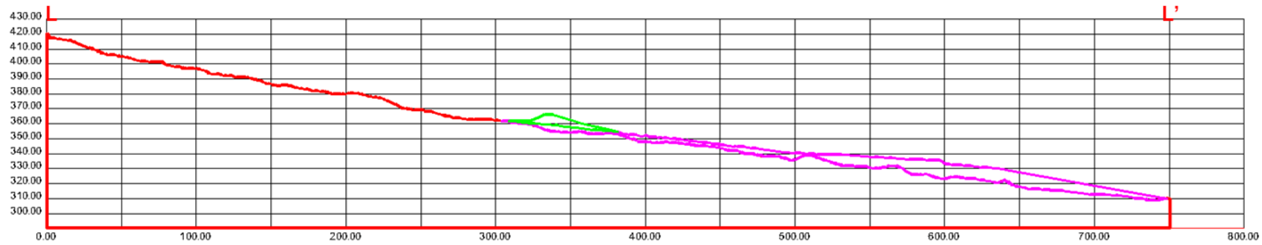


Figure 4. Long-section and cross section at the PT Citra Palu Minerals dry tailing management facility research location.

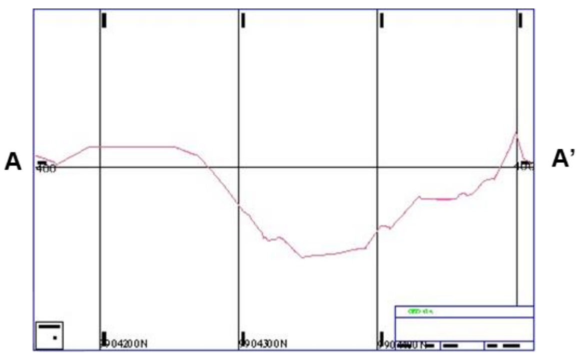


Figure 5. Cross-section A.

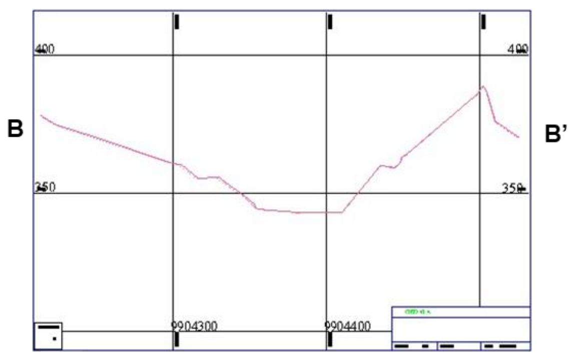


Figure 6. Cross-section B.

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2. Research Methodology

Before determining what steps or solutions to control erosion and sedimentation must be done, first know the amount of erosion and sedimentation rates that occur at the research location. After knowing the amount and classified the erosion using Erosion Hazard Classification by the Ministry of Forestry 2009 [3], subsequently, it can be determined what solution should be done. Due to the limited time and equipment available, the data obtained were processed using the Universal Soil Loss Equation (USLE) method to obtain the predicted erosion rate. The data is in Table 1 below:

Table 1. Data used in the study.

No.	Data	Type of Data	Data Collection Methods	Used in formulas
1	Slope	Primer	Direct observation using Total Station	Length and Slope Factors
2	Slope length	Primer	Direct observation using Total Station	Length and Slope Factors
3	Cover Ground Conditions	Primer	Direct observation	Ground cover factor
4	The direction of water flow	Primer	Topographic maps	Catchment area
5	Soil Characteristics	Primer	Laboratory test	Erodibility factor
6	Actual erosion rate measurement	Primer	Peg method	Actual erosion rate
7	Research location coordinate data	Primer	Total Station	C and P Factors
8	Rainfall data	Secondary	BMKG and corporate environment department data	Erosivity factor
9	Topographic & As built Data	Secondary	Corporate data	Data processing software Surpac
10	Map of research locations	Secondary	Corporate data	Direction of water flow
11	Soil density	Secondary	Laboratory test	Sedimentation rate
12	Mud density	Secondary	Laboratory test	Sedimentation rate
13	The density of solid particles	Secondary	Laboratory test	Sedimentation rate
14	Soil structure	Secondary	Corporate data	Erodibility factor

The rate of erosion calculation formula using USLE method is :

$$A = R \times K \times L \times S \times C \times P \tag{1}$$

Where:
A = the rate of erosion (tons/ha/year)
R = rainwater erosivity factor [4]

$$R = 2{,}21 \times \text{average monthly precipitation}^{1{,}36} \tag{2}$$

K = Soil erodibility factor [5]

$$= [1{,}292\ \{2{,}1\ (\text{Grain size}^{1{,}14}\ (10^4)(12 - \%\ \text{organic material}) + 3{,}25\ (\text{soil structure code} - 2) + 2{,}5\ (\text{soil sectional permeability class} - 3)\}]/100 \tag{3}$$

LS = Length and slope factors

$$= (\text{slope length}^{0{,}5}) \times \{0{,}01386 + 0{,}00967\ \text{slope} + 0{,}001386\ (\text{slope}^2)\} \tag{4}$$

C = Land cover vegetation factor (Guide of Mine Water Management in Umaga, 2013)
P = Conservation action factor (Conservation of Soil and Water Resources in Suripin, 2004)

Where the data used to calculate the rate of erosion on the north and south DTMF slopes are as follows:

Table 2. Data to calculate the rate of erosion.

Data	Area	
	DTMF U	**DTMF S**
R	0.56	0.56
K	0.5	0.5
LS	67.87	83.63
C	0.9	0.9
P	1	1

3. Result and Discussion

Table 2 showed that for the erodibility factor (K) from the results of laboratory tests of soil samples at the research site, if the existing soil type is known, it is easier to determine the parameters of the soil such as soil organic matter, texture, structure, and soil permeability [5]. The percentage of dust is 14.98%, sand is 70.77%, and clay is 14.27% which is included in the sandy loam category (according to the texture triangle, USDA). The rate of erosion that occurred at the research location was included in the category of serious erosion hazard levels according to the Erosion Hazard Classification, Ministry of Forestry 2009, shown in Table 3. Erosion Hazard Classification describes the level of threat of damage caused by erosion on land. The level of erosion hazard is determined by rain erosivity, soil erodibility, length and slope, ground cover vegetation, and land use or land cultivation [6].

Table 3. Erosion hazard classification.

Class of erosion danger level	Soil loss (ton/ha/year)	Remark
I	<15	Very light
II	16-60	Light
Class of erosion danger level	**Soil loss (ton/ha/year)**	**Remark**
III	60-180	Moderate
IV	180-480	Heavy
V	>480	Very heavy

where the data on the rate of erosion in the month of research are listed in Table 3 below:

Table 4. Erosion rate in the research in September - October 2020

Location	Erosion Rate (ton / ha)	Erosion Hazard Class
North DTMF	17.07	Heavy
South DTMF	21.04	Heavy

It is necessary to control to reduce the rate of erosion and sedimentation as well as to treat polluted water such as in this study is the total suspended soil before it is released into the environment. Study recommendations for erosion rate control using civil and vegetative engineering methods are carried out by making rip-rap channels due to the erosion of existing channels at the research site, namely by using large rocks on the channel walls to reduce the velocity of water flow so that the channels are not easily eroded, and facilitate runoff water carrying layers. the soil drains into a settling pond. Erosion prevention is closely related to draining because erosion occurs when surface water flows from high places to low places where cracks appear on bare land. As a result, the flowing water will continue to grow. Erosion occurs when the soil is not protected by both plants and other retaining materials such as crushed stone, concrete and others [7]. Then the next civil engineering method is to make a settling pond for treatment of the water which is located after the sediment trap which also serves as a monitoring pond so that it the quality standards where for water treatment it is recommended to use a polyacrylamide flocculant $(C_3H_5NO)n$ to speed up the deposition process by inducing flocculation by neutralizing the surface charge of particles or by forming bridges between individual particles. The functional groups should ideally be positively charged to allow for interactions with the negatively charged microalgal cells which then the particles will fuse to bind to each other thereby increasing the particle weight which accelerates the deposition process [8]. For the vegetative method, namely slope revegetation using vetiver plants as a fast-growing plant and soil conditioner (phytoremediation). Vetiver plants have many advantages, they are resistant to any soil conditions, have deep fiber roots, and are not eaten by livestock because the research location contains a lot of cows and goats.

If the recommended control is carried out, it can reduce the erosion hazard level that was previously classified as heavy to the moderate category by changing the C factor (soil cover vegetation) and the P factor (special soil conservation measures), as shown in Table 4:

Table 5. Erosion rate before and after erosion control plan

Location	**Erosion Rate (ton / ha)**	
	Before	**After**
North DTMF	17.07	10.93
South DTMF	21.04	13.47

4. Conclusion and Recommendations

Based on the results of the study it can be concluded that erosion can disrupt operational activities in mining activities and also the sustainability of the ecosystem around the mine. There are 2 principles of environmental science that can be considered in the future direction of conservation, namely the principle of interaction and sustainability [9]. Therefore, before aggravating conditions at the mine site by continuous erosion and sedimentation that occurs due to runoff water that erodes the soil layer, it is necessary to control and treat water. Before determining erosion control, it is necessary to know the rate of erosion that occurs at the site. After calculating the research location, it was found that the predicted erosion rate in the study month was 17.70 tonnes/ha for North DTMF and 21.04 tonnes/ha for South DTMF. Erosion control can be carried out by civil engineering methods (rip-rap channels and settling ponds) and vegetative (revegetation using vetiver plants). Which is where if the slope revegetation plan is carried out it will reduce the rate of erosion to 10.93 tonnes/ha for North DMTF and 13.47 tonnes/ha for South DTMF. In addition, erosion control can be carried out by implementing artificial swamp forests as a follow-up or alternative to treat ex-mining water sustainably by using Eucalyptus and Longkida planting which is useful for absorbing and accumulating Fe, Mn, Cu, Zn and Pb [10]. The next technology that can be used is water treatment using Plasma Nanobubble technology from LIPI research to add dissolved oxygen in water so that it can activate decomposing microorganisms that live in used water. mining and sediment [11].

The aforementioned erosion control can be modified by implementing currently developed technologies. Numerous technologies such as distillation, treatment with chemical disinfectants, sand filtration, reverse osmosis, and membrane filtration have been used in the past to purify water. One of the water treatment research that has been carried out during 2015 - 2019 by the Indonesian Institute of Sciences

(LIPI) can be used as an alternative to treating contaminated ex-mining water using Nanobubble Plasma technology which functions to water purification in water that has a high total suspended solids [12]. Moreover, among the technologies already mentioned above, reducing water discharge is derived from environmental law that have led industries to use advanced wastewater treatment such as membrane filtration [13]. Membrane filtration is a relatively new method but not a new invention, the varying nature and complexity of wastewater makes room for more improvements, having some advantages such as scalability, low power consumption, free from chemicals, and low operational temperature [14]. A membrane can be described as a thin layer of material that is capable of separating materials as a function of their physical and chemical properties when a driving force is applied across the membranes [15]. The membrane filtration system can be further improved by incorporating nanofibrous media. Nanofibers possess high porosities and well-connected pore structures, good permeability, therefore, they are ideal candidates for water purification [16]. Furthermore, treatment of ex-mining water can also be carried out by artificial swamp forests as an alternative that requires minimal and low-cost management. Previously, PT Citra Palu Minerals, using the services of a third party, PT Antares, performed maintenance on ex-mine water using polyacrylamide flocculants to speed up the deposition process. The application of artificial swamp forest as a technology for passively handling ex-mining water can be done by remote sensing for land change monitoring using aerial photographs via drones and Geographic Information Systems (GIS) for swamp forest planning.

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