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Faculty of Mineral Technology
Universitas Pembangunan Nasional "Veteran" Yogyakarta

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# The Effects of Compaction Towards Diversion Channel Base Material

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**Keywords:** compaction, enmbankment, diversion channel, hydrogeology, material properties

ABSTRACT

The sustainability and safety of surface mine operations often depend on various factors, including the hydrology of the area and a suitable plan to address its challenges. Some of the concerns related to hydrological issues include the drainage system and its design preparation. In special cases where river diversion is required, there may be specific issues with the planning and construction process. In such instances, a diversion channel is planned to be built between two closely situated pits. This channel will be constructed upon an embankment consisting of disposal materials. The plan has implications for the spatial positioning and the choice of materials for the channel base. The embankment requires proper treatment and processes during its construction, such as compaction and consolidation. This study addresses the effectiveness of compaction efforts on the material's capacity concerning its physical, mechanical, and hydrogeological properties. The analysis was conducted using correlations between laboratory test results and extracted hydrogeological data using software instrumentation. These correlations specifically examine the changes in compaction values in relation to changes in material properties. The study concludes that compaction efforts have a significant impact on the material's ability to support the diversion channel, making it an effective means of enhancing the material's capabilities

## INTRODUCTION

Hydrology in one of many aspects should be considered and be dealt with in open main operation. The sustainability of mine operation often depends on hydrology engineering to contain and direct surface water from though out the mining area using proper mine drainage systems. One of them is the requirements of a specific channel for diverting body of water to where it is not disrupting the mine operation while it is still safe for the environment.

River diversion has been studied by various researchers and is known in various terms such as watercourse diversion (DNRM, 2015), inter-basin water transfer (Shao & Wang, 2003), river realignment (Erskine, 1992), channelization (Soar & Thorne, 2011), water diversion (Yevjevich, 2001), river deviation

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(McEwan, 1999), and river flow control works (Austlii, 2019), river relocation or river diversion (Flatley, et al., 2018). However, not many have studied the physical, mechanical, and hydrogeological aspects of the channel bed in the form of embankment material itself.

The study area required a diversion channel, which was proposed to be built on an embankment between two closely situated active pits. The embankment itself would consist of an existing consolidated embankment that is older than 5 years, while the channel base would be constructed using new disposal material.

Disposal material is overburden material excavated from the pit to obtain mining objects. The volume of this material tends to expand after being unloaded compared to in situ material because it is loose (Mulyanti et al., 2017). Given that the disposal material is loose, the stockpile material tends to be loose and has high porosity and hydraulic conductivity. Moreover, for the embankment body, which is not compacted and has interconnected cavities, the hydraulic conductivity of the material is higher. When the channel is placed on the embankment material, it allows water to flow, reducing the strength of the material (Supandi et al., 2013, 2018, 2019). The interaction of water with the material has the potential to cause stability disturbances in the disposal heap and affect security in the vicinity of the embankment (Supandi et al., 2016). A higher groundwater level in the material can lead to instability, and vice versa (Riyadi, 2013).

The study aimed to examine how compaction affects the material condition related to the use of embankment material as the base for an open channel. It will investigate the physical, mechanical, and hydrogeological properties of the material due to compaction efforts. Therefore, it seeks to provide information regarding the effectiveness of compaction in enhancing the suitability of embankment material for use as channel bed material. The study will answer whether compaction was effective in maintaining the channel's integrity in the hydrogeological conditions of the embankment material and how this process worked.

## METHODOLOGY

### Compaction and Consolidation

The terms compaction and consolidation are often mistakenly used interchangeably, but there are conceptual differences between the two processes. Compaction is the process of increasing the density of soil or material by compressing its particles and reducing the volume of air without significantly reducing the volume of water within the material. In contrast, consolidation is the reduction of water volume in saturated soil or material, characterized by low conductivity, due to the dissipation of pore water pressure. This process continues until the excess pore water pressure, which increases due to loading-induced stress, is completely dissipated (Craig, 2004).

Compaction is an artificial process that involves using tools and methods to reduce the air in the voids of the soil or material. Consolidation, on the other hand, is a natural process that gradually reduces the water volume in the material as pore water pressure is released over time. Another distinguishing factor between compaction and consolidation is their relationship with time. Compaction is not significantly time-dependent, whereas consolidation is highly time-dependent and the duration plays a crucial role in completing the consolidation process (Bolarinwa et al., 2017).

In civil engineering, the term consolidation is used in the same sense as the physical process of gravitational compaction (Greensmith & Tucker, 1986). Consolidation is defined as the slow outflow of fluid from the pores and the reduction of voids within the material body due to the pressure from overburden (Greensmith & Tucker, 1986). To summarize the key differences between compaction and consolidation, refer to **Table 1** based on the above references.

**Tabel 1.** Key difference between compaction and consolidation

| No | Column Header Goes Here | Column Header Goes Here |
|---|---|---|
| 1 | The load is applied mechanically to compress the material, with the aim of increasing the strength of the material. | Loading occurs continuously with a constant (static) load, causing compression of the saturated material. |
| 2 | Loading in the form of dynamic loads with mechanical methods such as tamping, rolling, and vibration in a relatively short time interval. | Static loading occurs continuously for a long time. |
| 3 | The volume of the material is reduced by removing air from the saturated or dry material. | The volume of the material is reduced due to the exit of pore water from the saturated material. |
| 4 | The load is applied mechanically to compress the material, with the aim of increasing the strength of the material. | Loading occurs continuously with a constant (static) load, causing compression of the saturated material. |
| 5 | Loading in the form of dynamic loads with mechanical methods such as tamping, rolling, and vibration in a relatively short time interval. | Static loading occurs continuously for a long time. |

## Hydraulic Conductivity

The hydraulic conductivity of a material is a main factor in hydrogeology that significantly influences strategic decision-making (Riyadi et al., 2019). Several factors affect the hydraulic conductivity system, including rock mass characteristics such as fracture areas, depth, mineral content within fractures, and lithology (Hsu et al., 2011; Iskandar & Koike, 2011; Cahyadi, 2018). Hydraulic complexity can impact water flow in fractured media, making it more challenging to estimate hydraulic conductivity values (Cahyadi et al., 2017). As depth increases, conductivity values tend to decrease due to the reduction in fracture spacing caused by geostatic stresses (Cahyadi, 2018). Depth also plays a significant role in determining conductivity values (Hsu et al., 2011). In general, materials at shallower depths exhibit higher conductivity values. Gouge content refers to the presence of filling material, typically clay or quartz, within rock fractures. Fractures rich in fillings generally exhibit very low conductivity (Hsu et al., 2011).

## Relationship to Hydraulic Conductivity Value

Material parameters and their correlation with hydraulic conductivity can be determined through a non-linear equation represented by the groundwater characteristic relationship curve. This equation is based on the assumption that the water characteristic curve's shape is influenced by the soil's pore size distribution, as proposed by Fredlund and Xing in 1994.

After a review of various empirical, macroscopic, and statistical models (Leong & Rahardjo, 1997), the model's equation is as follows:

$$K = K_s \cdot \frac{1}{\left(\ln\left(e+\left(\frac{\varphi}{A}\right)^B\right)\right)^C} \quad \text{.............................. (1)}$$

*Ks* represents the saturated hydraulic conductivity, while *K* is the hydraulic conductivity. The parameter 'e' represents the exponential number (approximately 2.7182818), and 'matric suction' characterizes the material. A, B, and C are correction factors that describe the material's characteristics. The coefficients for A, B, and C can be found in **Table 2.**

**Tabel 2.** Coefficient A, B, and C (Leong & Rahardjo, 1997)

| *Material* | A | B | C |
|---|---|---|---|
| *Beit Netofa Clay* | 6746 | 0,55 | 201,1 |
| *Rehovot Sand* | 2,65 | 3,86 | 8,37 |
| *Touchet Silt Loam* | 8,55 | 13,07 | 1,96 |
| *Columbia Sandy Lome* | 6,37 | 12,9 | 2,24 |
| *Supersition Sand* | 3,07 | 6,19 | 3,93 |
| *Yolo Light Clay* | 3,39 | 1,204 | 6,06 |
| *Mine Tailings - Wetting* | 18,28 | 2,51 | 7,49 |
| *Mine Tailings- Drying* | 19,21 | 4,82 | 4,49 |

## Material Strength

The concepts of rock strength refers to the Mohr-Couloumb concepts (RocScience, 2010). Rock strength ($\tau$) is expressed as a parameter consisting of cohesion components ($c$), normal stresses ($\sigma_n$) derived from rock density, pore pressure ($u$), and internal friction angle ($\phi$). Rock strength is expressed in the following equation:

$$\tau = c' + (\sigma_n - u)\, tan \;\; \phi' \text{ ..................... (2)}$$

$$\sigma_n = W.\cos\alpha \text{ ........................................ (3)}$$

The study was conducted using laboratory data for the disposal material used in building an embankment with a diversion channel built on top. The analysis included correlations between laboratory data and values extracted from calculations using RocScience: Slide 6 software, which assesses its hydrogeological capabilities. This analysis aimed to investigate the effect of compaction efforts on hydrogeological properties.

## RESULT

## Laboratory Test Results

Laboratory tests are necessary to obtain the parameters required for conducting slope stability analysis, specifically the physical and mechanical properties of the materials. These laboratory tests aim to acquire physical and geomechanical parameters. In this study, the chosen method for slope stability analysis is the limit equilibrium method, utilizing the Mohr-Coulomb concept of rock strength. In this concept, the cohesion and internal shear angle are the primary factors influencing slope stability analysis. Due to the need for cohesion and the internal friction angle, the scope of the laboratory analysis work includes tri-axial tests. The selection of the tri-axial method yields more optimal results compared to the direct shear test method, as the latter enforces the shearing process in a plane with vertical loading (stress).

The triaxial method accounts for stress conditions that work in both vertical and horizontal directions, representing the resultant of three different stress axes. Disposal material samples were collected from the surface of the embankment slopes, while in-situ material test samples consist of rock core samples obtained through rock core drilling. PT. Indra Karya Persero in Malang, East Java, Indonesia, conducted the laboratory testing and holds competence and certification in this field.

### *Physical Properties*

The testing of material properties for the disposal stockpile was conducted under the assumption that the stockpile materials on-site had been consolidated for over 5 years. Subsequently, the consolidated embankment material would be dismantled to create a channel. In specific areas, voids were identified, necessitating the use of material from the demolished embankment to fill them. Compaction tests were performed to determine the material's density under optimum conditions, which involved assessing the embankment material's density and water content. The combination of solids and water content at a certain point would reach the peak compaction level. If any of these values are exceeded after reaching the peak condition, compaction will decrease.

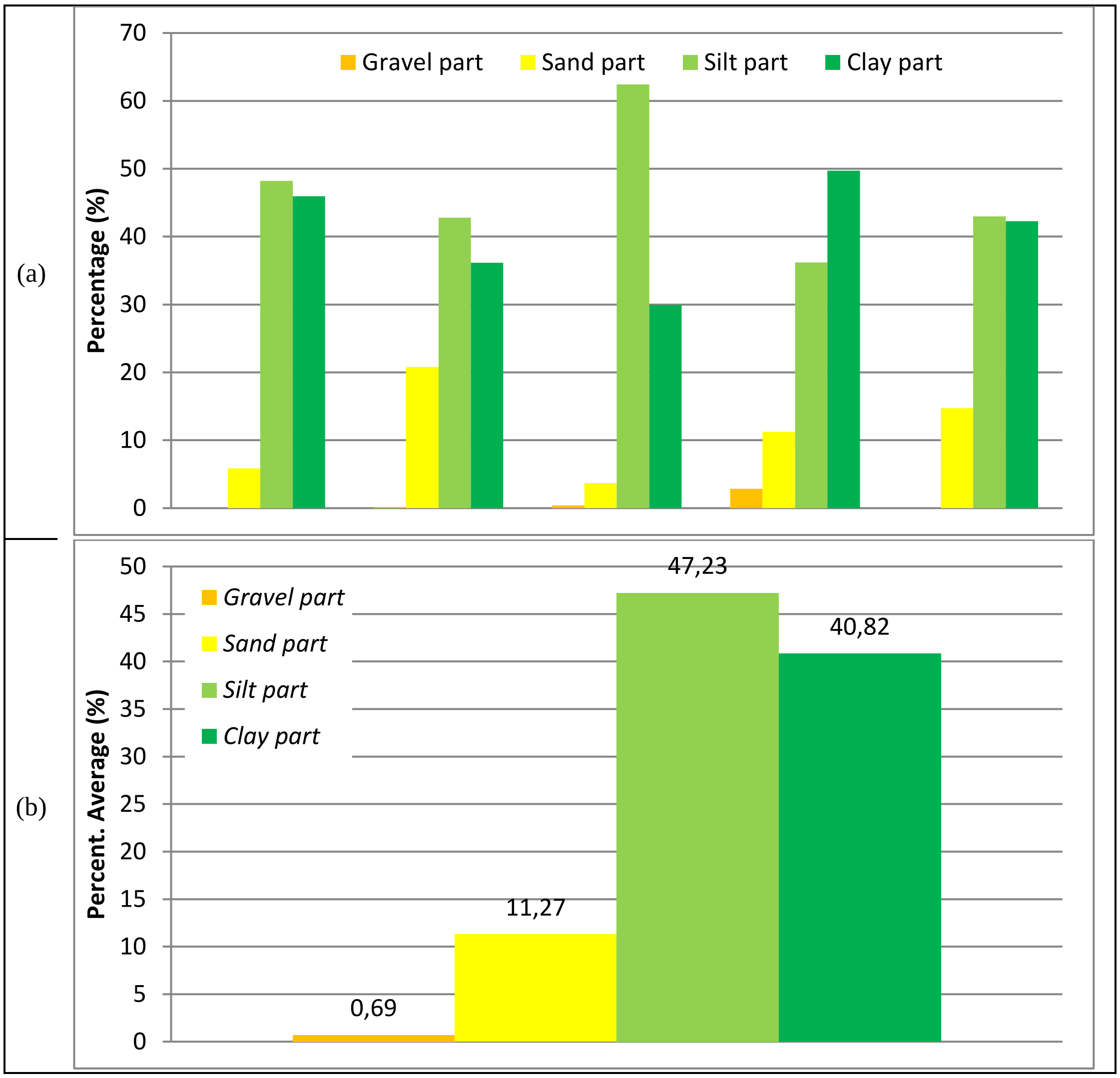


**Figure 1.** (a) Percentage of grain size of the embankment material sample. (b) Percentage of the average grain size of the same embankment material

The grain size test measurements show that the weathered and consolidated disposal heap material at the study site has an average grain size dominated by 47.23% silt, 40.82% clay, and 11.27% sand, with a minor component of 0.69% gravel. Based on the results of the grain size test, the data follows a normal distribution, with all data falling within one standard deviation from the average value ($\mu \pm \sigma$).

(a)

(b)

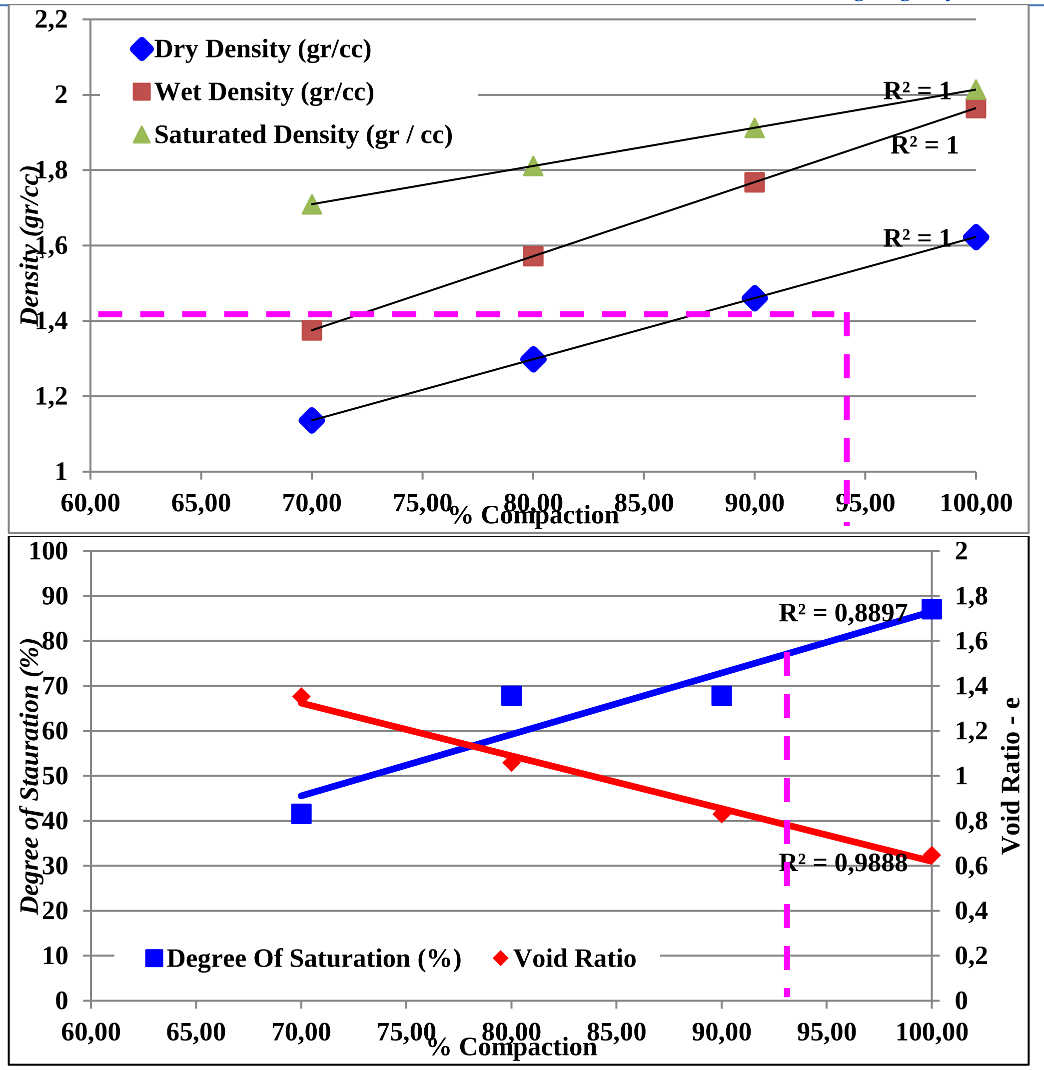


**Figure 2.** (a) Correlations of percent compaction to material densities. (b) Correlation of degree of saturation and void ratio to percent compaction

The compaction parameter is specified in terms of percent compaction. Percent compaction refers to the dry density of the material expressed as a percentage of its maximum possible density, achieved at a specific moisture content. The material is considered to be at maximum compaction when it reaches 100% compaction. This ideal condition can be attained under controlled laboratory conditions, where both moisture content and density can be precisely regulated. In real-world field conditions, achieving 100% maximum compaction requires the careful management of compaction efforts and consolidation time, which can be challenging to control. The compaction value was determined by simulating various compaction conditions, including 70%, 80%, 90%, and 100%. The consolidated embankment material found in existing embankments in the field exhibited a compaction value of 93%. This determination was based on a comparison of density values, degree of saturation, void ratio, and water content. The suitability of this value also validates the correlation curves established between percent compaction and material properties.

Plotting was conducted using the values of properties and the percentage of compaction to illustrate the relationship between the properties of the embankment material at various compaction states. The plotted values represent the average results from each of the 5 samples for each laboratory test. The laboratory test results for the embankment material follow a normal distribution, with the requirement that all data falls within the range of 2 times the standard deviation ($\mu \pm 2\sigma$) for each point when testing physical and mechanical properties.

The main physical property of a material is its density, which consists of values representing dry, wet, and saturated conditions, respectively. A more compact material should have a higher density. The correlation between density values and percent compaction is shown in **Figure 2a.** Density values increase with the increase in percent compaction..

Compaction of embankment material serves to compress the material. Materials with a higher percent compaction will have a smaller void ratio as the pores in the material become smaller due to compression, making the material denser. As the voids decrease, the density of the material increases. Denser materials have fewer voids or pores in the mass, and the water content is also reduced. Meanwhile, saturation increases due to the decreasing void ratio as it approaches the solid state. The correlation between void ratio values and degree of saturation values with percent compaction is shown in **Figure 2b**. Additionally, the correlation between water content and percent compaction is shown in **Figure 3**.

Based on the physical property tests, it can be concluded that as the material's percent compaction increases, its density also increases (**Figure 2a**). This is supported by the decrease in void ratio as percent compaction increases (**Figure 2b**). The increase in density is a result of the reduction in voids within the material, leading to an increase in mass per unit volume. As percent compaction increases, the water content decreases, but the degree of saturation increases. This indicates that the storage capacity of denser materials decreases (saturation occurs more rapidly) in line with the increase in percent compaction..

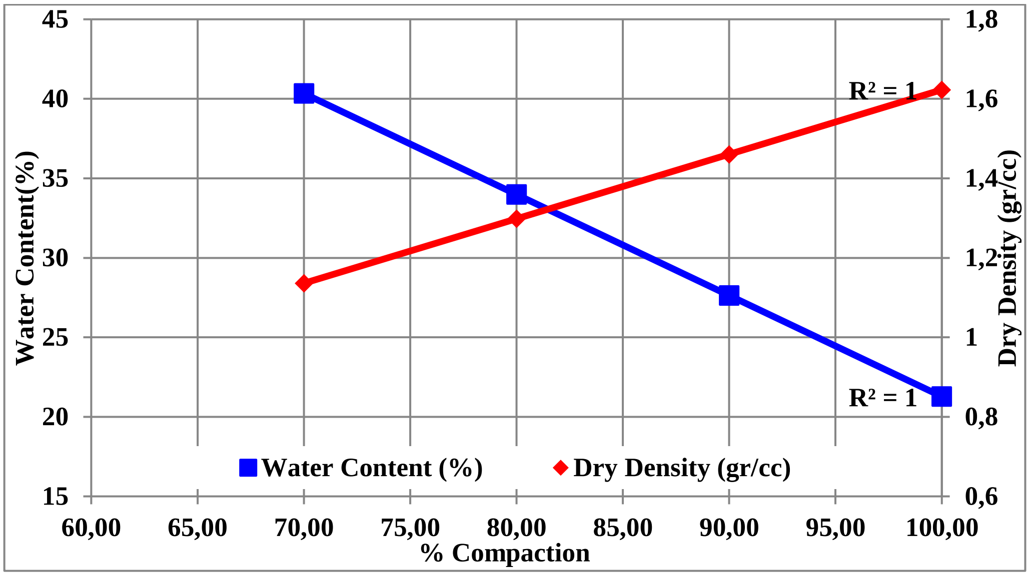


**Figure 3**. Correlations of water content and dry density to percent compaction

## *Mechanical Properties*

Laboratory tests were conducted to evaluate the mechanical properties of the material, employing tri-axial tests to determine both cohesion and internal friction angles at compaction levels of 80%, 90%, and 100%. The average values of these properties were then graphed against the degree of compaction to understand the relationship between compaction and material properties, as depicted in Figure 4. Materials subjected to higher compaction ratios exhibited greater cohesion and internal friction angles, highlighting that compaction not only optimizes physical properties but also enhances mechanical properties.

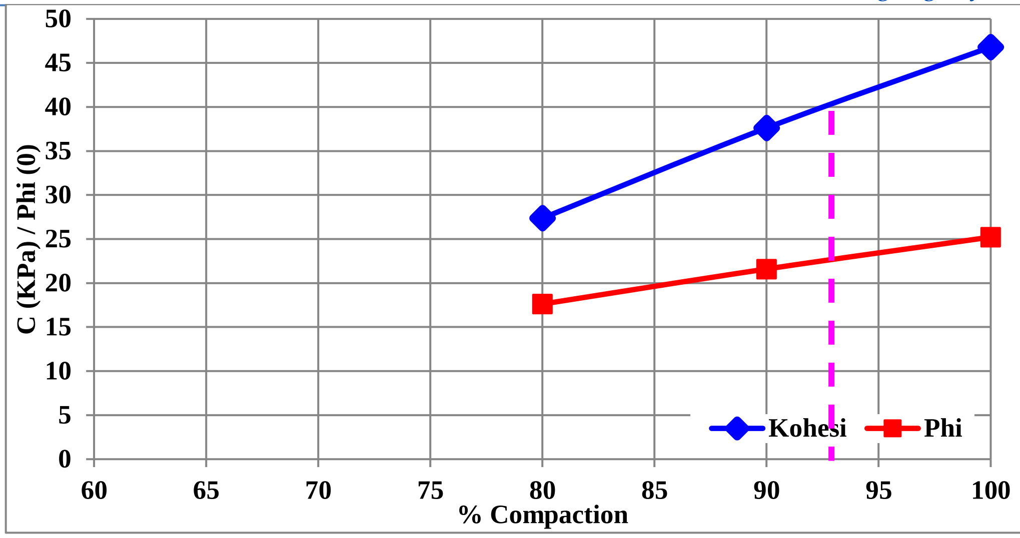


**Figure 4**. Correlation of cohesion value and internal friction angle ($\phi$) to the value of percent compaction

## Effect of Compaction toward Hydraulic Properties

### *Change in Matric Suction*

To understand the changes in hydraulic properties due to compaction, an analysis was performed on groundwater parameters using RocScience: Slide 6 software instrumentation. Different values of water content were considered based on the hydraulic parameter model by Fredlund and Xing (1994) and Leong and Rahardjo (1997) for material criteria in mine tailings, specifically the wetting condition. The matric suction value was extracted and correlated with its respective water content variable. The correlation of matric suction to water content is illustrated in **Figure 5a**. The analysis reveals that matric suction tends to decrease as the water content of the material increases. Furthermore, the relationship between water content at each percent compaction and matric suction is depicted in **Figure 5a**. The value of matric suction can be correlated with the degree of percent compaction, as shown in **Figure 5b**. This figure demonstrates how the moisture content and matric suction of the embankment material change with varying percent compaction. It becomes apparent that increasing compaction results in reduced water content due to decreasing porosity.

### *Compaction Relationship with Hydraulic Conductivity*

The calculation of hydraulic conductivity values was performed under various compaction conditions (ranging from 70% to 100%) to determine the ratio of conductivity in the presence of compaction. These calculations were based on Equation (1). The coefficient values A, B, and C, specific to the embankment material in this study, were selected for "Mine Tailings - Wetting," as listed in **Table 2**. These criteria were determined for materials in their initial dry state undergoing a wetting process. The values of water content and matric suction at a specific compaction level can be obtained from **Figure 5b**.

**Figure 6** illustrates the relationship between hydraulic conductivity values, calculated based on percent compaction, and moisture content. As the water content in the material decreases, the matric suction increases. This increase in matric suction, induced by reduced water content, leads to a decrease in the hydraulic conductivity of the material. Consequently, as the percent compaction increases, the hydraulic conductivity value decreases. This, in turn, regulates the amount of water flowing through the material. Thus, it is evident that compaction efforts can mitigate the impact of water flow within the channel, influencing the hydrogeological conditions of the embankment material.

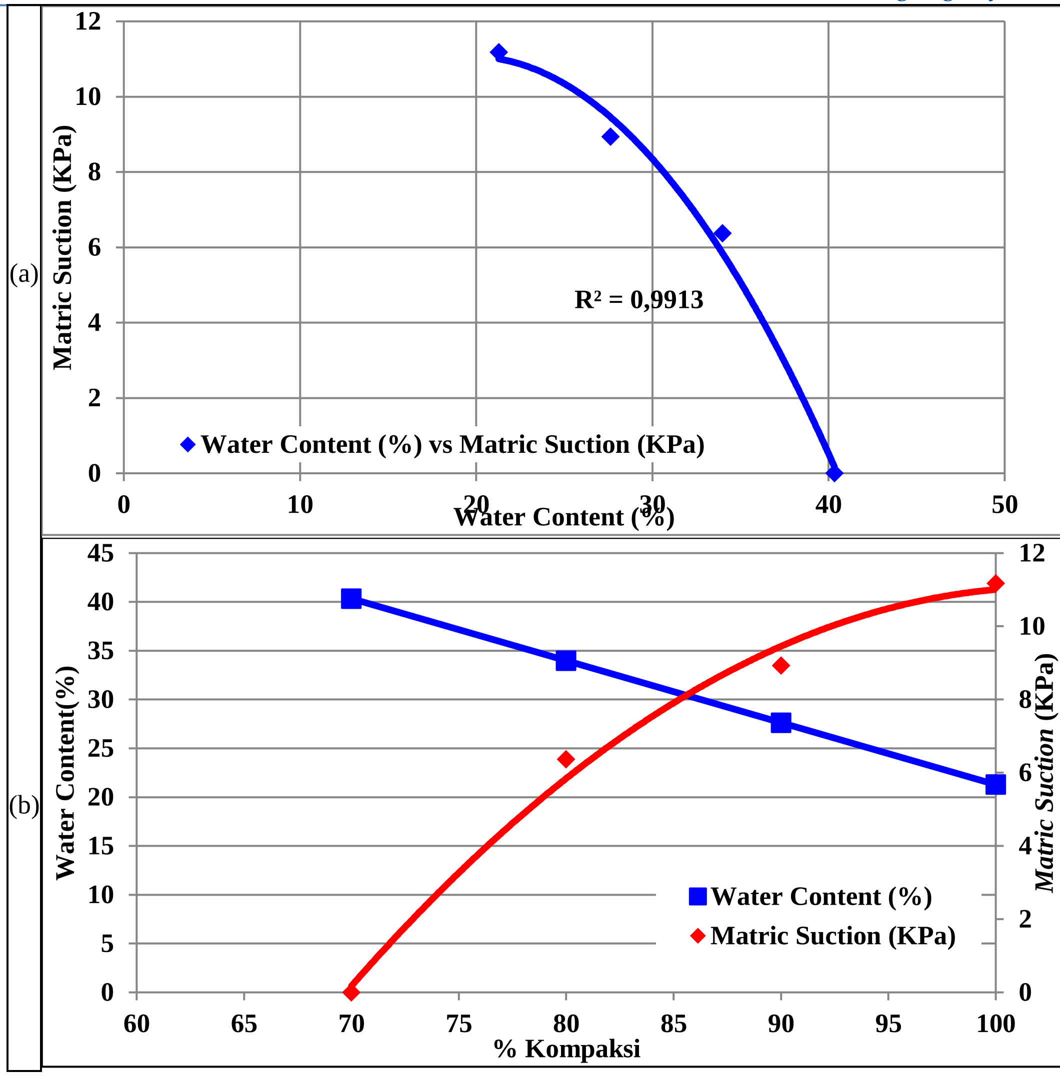


**Figure 5.** (a) Correlation of matric suction to water content. (b) Moisture content and matrix suction in each percent compaction.

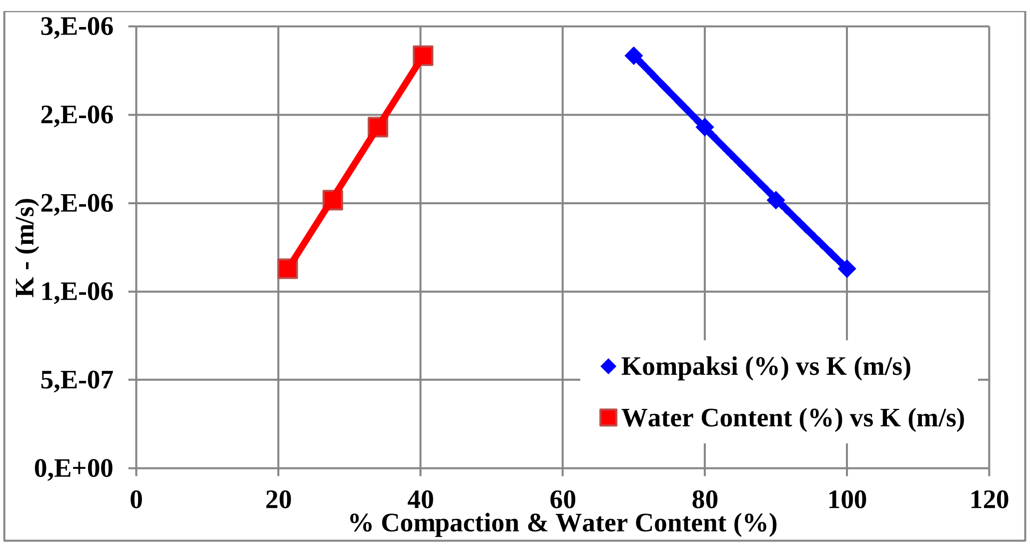


**Figure 6**. Correlation of hydraulic conductivity values to percent compaction and water content

## CONCLUSION

Based on the results of the analysis of the laboratory test results of the embankment material, if compaction efforts were made, there will be changes in the characteristics of the material as follows:

a. Density will increase linearly with the increase in percent compaction. This is due to a reduction in voids within the material. The decrease in void ratio with increasing percent compaction causes the mass-to-volume ratio to increase.
b. The greater the percentage of compaction, the lower the water content becomes as the degree of saturation increases. This indicates that the storage capacity of the more compacted material has decreased, causing it to become saturated more quickly.
c. The hydraulic conductivity of the material decreases as saturation increases, due to a smaller void ratio and a denser material.

The higher the percent compaction, the lower the hydraulic conductivity value. A smaller hydraulic conductivity value will inhibit infiltration and water flow in the embankment material. Therefore, it was evident that compaction effort is effective for mitigating the impact of flow in the channel on the hydrogeological conditions of the embankment material.

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# Phytoremediation Agent of Mercury Waste on Indonesian Small-Scale Gold Mine Using Hyacinth

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environmental, hyacinth, small-scale gold mine, wastewater

ABSTRACT

Amalgamation is the common method to process and purified gold in a tube in small-scale mine worldwide, especially in Indonesia. The method uses mercury (Hg) to bind gold metals, which pollutes the environment. Therefore, this reviewed paper aims (i) to assess the environmental impact of small-scale gold mine in Indonesia and (ii) to evaluate the used hyacinth to ameliorate the deterioration on surface water quality. Hyacinths potentially reduce Hg levels in gold mining wastewater. Hyacinths are proved to absorb heavy metal in mercurial wastewater of gold mining. The addition of 500 gr/L hyacinth to mercurial wastewater would decrease 79.7% of Hg concentration. The more hyacinths, the more Hg levels will be absorbed.

## INTRODUCTION

Indonesia's geological map shows that the distribution of potential gold reserves in Indonesia is evenly distributed throughout all provinces, making Indonesia in the seventh position of the world's largest gold producer [1]. Indonesia has 2,600 tons of gold reserves or 5% of the world's total gold reserves of 50,300 tons of gold with national gold production in 2021 of 90,000,000 kg [2]. This record is up compared to the previous 86,000,000 kg for 2020. This production is the amount of figures from contract of work companies (KK) and Mining Business Permits (IUP) recorded in the mineral and coal mining sub-sector. The small-scale gold mining sector contributes 17-20% of world gold production [1].

Gold is one of the precious metals most widely used by humans as jewelry, foreign exchange reserves, and can also be used for investment. As the age of gold grows, the need for gold will increase, gold that has a high economic value will encourage humans to develop methods for extracting gold. Gold mining activities can indeed increase people's income, however, gold mining can also be detrimental if in its implementation without being followed by the process of processing waste products correct processing of gold [3]

Small-scale gold mining is a gold mining activity carried out by individual miners and small

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businesses with limited capital investment and production [3]. Small-scale gold mining activities generally operate illegally and exploit marginal gold reserves located in remote areas with hard-to-reach access such as in protected forests and even in conservation areas [3]. Gold ore processing carried out by small-scale gold mining generally uses mercury to separate the gold content from other minerals. A study conducted by UNEP in 2013 showed that mercury released from small-scale gold mining activities reached 727 tons or about 37% of global emissions [4].

According to the Decree of the Minister of Environment No. 202 of 2004 concerning wastewater quality standards for businesses and or activities of mining gold and ore and or copper explained that the maximum Hg content environmental quality standard is 0.005 ppm [5]. Mercury that is wasted into the environment will undergo bioaccumulation and biomagnification in the food chain, generally forming methyl mercury which is very dangerous for living things besides that environmental recovery caused by mercury is economically very expensive.

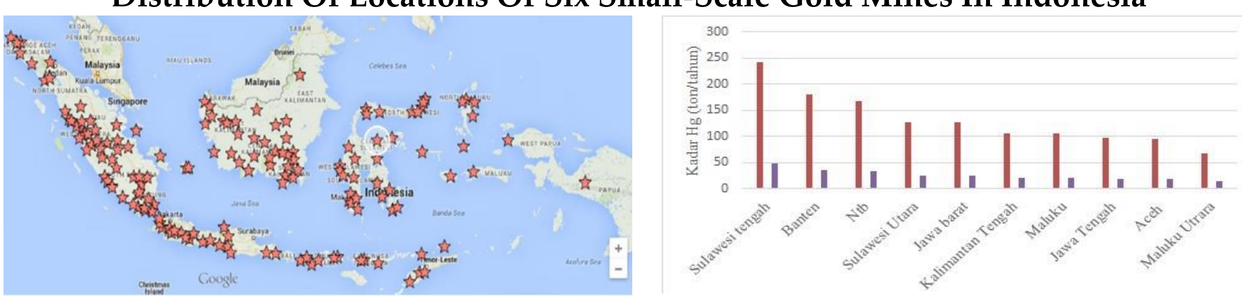
## METHODOLOGY

### Compaction and Consolidation

To examine the mercury content, as conducted by shelga, et al. is by making control variables and free of them. The control variables used are wastewater containing mercury that is not added with hyacinths, for the variable of free wastewater that hyacinths are added weighing 300 gr / L, 400 gr / L, and 500 gr / L, respectively, wastewater that is not added with hyacinths is marked with a sample K. For addition with hyacinths 300 gr / L is marked with sample X1, the addition of hyacinths of 400 gr/L is marked with sample X2, and the addition of hyacinths of 500 gr/L is marked with sample X3. The number of samples taken was 24 samples. The step of this experiment is quite easy, namely after preparing the sample, then it is enough to just let it sit for 9 days, after that just check the Hg level using spectrophotometry on each sample. In the experiments that have been carried out, that the results of each sample treatment X1, X2, and X3 have different results of decreases In the difference in mercury (Hg) reduction that occurs between groups indicates that there is an influence or relationship between the weight of hyacinths or without the addition of hyacinths.

## RESULT

### Distribution Of Locations Of Six Small-Scale Gold Mines In Indonesia




(a) (b)

**Figure 1.** (a) (a) Locations of small-scale gold mining activities in Indonesia (Source: Ministry of energy and mineral resources, 2016). (b) Data showing mercury usages (red) and emissions (purple) in 10 most affected provinces by the use of mercury in small-scale gold mining

Small-scale gold mining activities are found in almost all provinces in Indonesia. The activities are spread across 197 regencies or cities throughout the country. Most of the gold processing process being conducted in the industry is amalgamation using mercury. The distribution of small-scale gold mining sites could be observed in Figure 1 (a), which took place in major cities and regions. Based on the 2019 BCRC - SEA Minamata Initial Assessment document, data obtained from the 10 highest provinces of mercury use in small-scale gold mining in Indonesia Figure 1 (b).

## Impact of Mercury Use on The Environment

Mercury (Hg) is widely used to extract gold from its ores, both before and after the cyanidation process is used. When Mercury is mixed with the ore, it will form an amalgam with gold or silver. To obtain gold and silver, the amalgam must be burned to evaporate its mercury. Traditional gold miners use mercury to capture and separate the grains of gold from the grains of the rock. These Hg deposits are filtered using cloth to obtain the remaining gold. The filtered precipitate is then kneaded by hand. Mercury-containing mining debris water is allowed to simply flow into rivers or into other waters [5]. Mercury produced from small-scale gold mining waste will enter the aquatic environment and undergo deposition, dilution, dispersion, then be absorbed by living organisms in the water [6]. The ilustration on mercury cycle in the environment is provided in **Figure 2**.

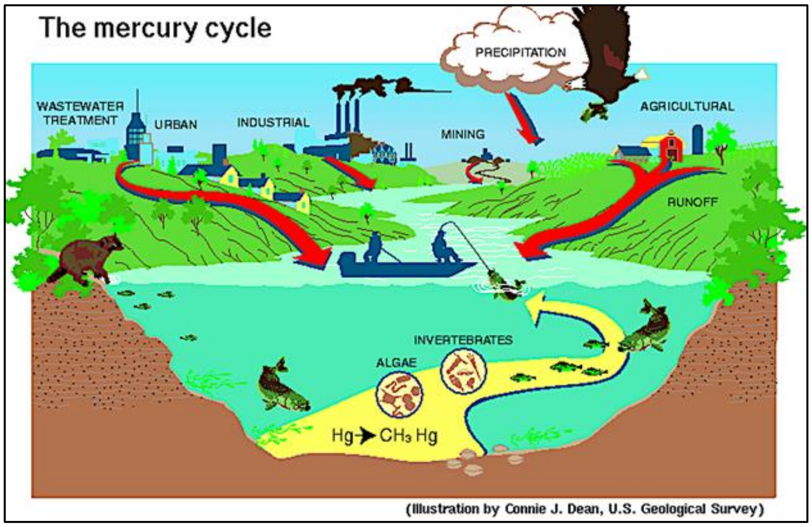



Figure 2. Ilustration on Mercury Cycle in the Environment (Source: U.S *Geological Survey)*

Mercury is persistent in bioaccumulation and biomagnification in the food chain, generally forming methyl mercury in addition to that it is also a transboundary pollutant due to its volatile nature ( *volatile*) in room temperature. The impact of wastewater disposal from gold mining using mercury is very dangerous. The following is the impact of wastewater disposal used for gold mining using mercury in terms of several aspects including impacts on health ; socioeconomic; and socio-ecological aspects. In the process of washing gold using mercury, so that gold and dirt can separate, many miners do not use personal protective equipment so that direct contact occurs. In addition to direct contact, it can also have an impact on the surrounding environment. If gold washing activities using mercury are carried out periodically, it will allow accumulation in the miner's body which gives rise to various types of chronic and acute diseases. The health effects that arise depend on the part and duration of the heavy metal bonded in the human body. If viewed from the socioeconomic aspect, it can be possible to decrease the income of people engaged in agriculture, due to the decline in the quality of the land used, the increase in labor costs due to labor scarcity in the agricultural sector. On the socio-ecological aspect, namely the occurrence of environmental pollution. The gold processing process is in the yards of houses and gardens, allowing the occurrence of mercury pollution to the environment, especially if the tailings storage pond is not handled with well. In addition, the fencing process is simply carried out around the house, it can cause environmental pollution by the mercury vapor it causes [7].

## Phytoremediation

Phytoremediation is a technology that utilizes plants to purify, remove, or reduce pollutants in the soil or water. One ofthe effective plant hiper-akmuulators as a phytoremediation of heavy metals is hyacinth (*Eichornia crassipes*). Hyacinth is a type of aquatic plant that can absorb and accumulate heavy metals, can absorb heavy metals because of heavy metals that accumulate in a short time. Various previous studies have shown the benefits of hyacinths, for example, in a study that explained that as many as 9 hyacinth stems consisting of one type of plant in contact with wastewater for 9 days, resulted in a decrease in Hg levels which were originally 0.22 ppm (control samples) decreased to 0.0037 ppm [8].

Hyacinth plants have a physiology of the root system of fibers with a length ranging from 10-300 cm. The arrangement of long roots in hyacinths serves to absorb heavy metals in waters at a certain depth. The high accumulation of metal elements absorbed by hyacinths occurs in the root part when compared with the stems and leaves. This is because at the root there is a phytocellular compound that functions to bind metal elements so that the phytoremediation mechanism that occurs is rhizofiltration [9]. Phytocrasformation is the change of toxic compounds into simpler compounds such as carbon dioxide, water and methane as a non-toxic form of material. Plants will remodel organic matter by using water as their fuel [10]. Based on the mechanism of plants in remediating heavy metals and other polluting organic compounds, it can be divided into several processes, namely:

a. Phytoexstration includes the absorption of contaminants carried out by the roots and will be translocated or accumulated polluting compounds to other plant parts such as leaves and headers. Rizofiltration is the ability of plant roots to absorb, precipitate and accumulate heavy metals and other compounds from waste streams with the aim of cleaning the surrounding environment.
b. Phytodegradation is an attempt to change or metabolize contaminants in tissues. Dehalogenase is one example in this mechanism where it overhauls oxygenase-depleted compounds or halogens in an overhaul of aromatic compounds.
c. Phytostabilization is a phenomenon of stabilizing polluted soils by producing certain chemical compounds.
d. Phytocollatilization is a phenomenon of plants absorbing contaminants and then releasing them into the atmosphere through the leaves.

## Data Analysis

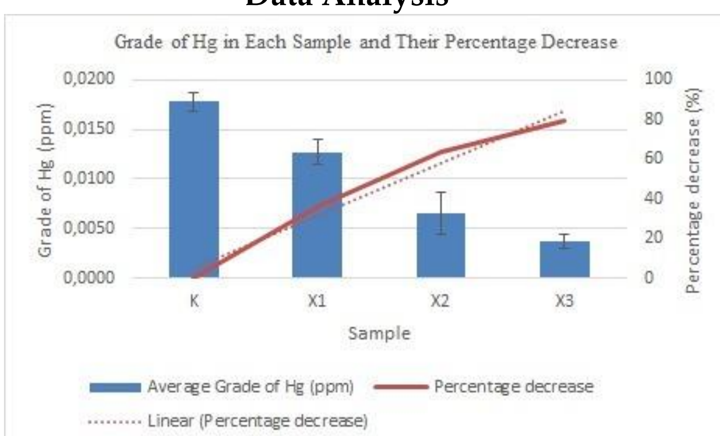



**Figure 4.** Hg levels in each sample and their percentage decrease

Based on the experimental data obtained, the more weight the hyacinth, the greater the percent decrease. The most effective treatment was obtained in sample X3, where the sample used was mercury wastewater which had been added with hyacinth weighing 500 gr / L and allowed to stand for 9 days . From this, mercury levels, which were originally 0.0178 ppm, were reduced to 0.0036 ppm. Where this 0.0036 ppm has met the environmental quality standards that have been set by according to the Decree of the Minister of Environment No. 202 of 2004. The experimental data can be seen in figure 4.

Hyacinth or latin name (*Eichornia crassipes*) physiologically has an important role in overcoming pollutants of waters, because it can survive by forming clumps. If the more or heavier the hyacinth, automatic evaporation will occur frequently, the more frequent evaporation occurs it is this that can speed up the process of salt transportation salts and metals from root to leaf. This is also what causes when added with hyacinth weighing 500 gr / L, it produces the most percent decrease in mercury, which reaches 79.7%.

The mechanism of this experiment is that it begins with small-scale folk gold mining using amalgamation. The amalgamation method is the process of binding gold metal from the ore using mercury (Hg) in a tube called a amalgamator. An amalgamator, in addition to functioning as a place for the amalgamation process also plays a role in reducing the size of gold ore from coarse to fine-grained (80 - 200 mesh) with a scouring medium in the form of iron ingots. The amalgamator can be rotated by the driving force of river water through a pinwheel or electric power (dynamo). The result of this process is in the form of wet amalgam and tailings. Wet amalgam is then accommodated in a place, like a reservoir which is then panned for the separation of mercury with amalgam. The obtained amalgam is processed through burning (bombing) to obtain a gold-silver metal fusion (bullion). Furthermore, the separation between gold metal (Au) from silver metal (Ag) is carried out using a solution of silver nitrate. Water from the results of this treatment, do not immediately discharge into the river water, but are separated first in the reservoir that has been provided, from this reservoir is later hyacinth added. After that, only then can the water from the reservoir be discharged into the river.

In the absorption process, of course hyacinths are also influenced by other factors, such as temperature, pH and time, To obtain effective results, a good temperature is around 25oC – 30oC. Then a good pH is in the range of 7 – 7.5. If the pH is too low or too high, then the growth of hyacinths will be inhibited, so later absorption will also be maximized. For the time factor, a good time for the hyacinth absorption process is about 5-9 days, only then can wastewater be discharged into the river.

## CONCLUSION

Mercury undergoes bioaccumulation and biomagnification within the food chain, generally forming methyl mercury in addition to that mercury is persistent and as a *transboundary pollutant* due to its volatile properties (*volatile*) at room temperature. Phytoremediation is a technology that utilizes plants to purify, remove, or reduce pollutants in the soil or water. One of the hyperaccumulator plants that is effective as a phytoremediation of heavy metals is hyacinth (*Eichornia crassipes*). Hyacinths were proven to be able to absorb wastewater from mercury gold mining, so that the water becomes clearer. The addition of hyacinth weighing 500 gr / L to mercury wastewater is the most appropriate step, because it gets the highest percentage of decrease, which is 79.7% The heavier or more hyacinths, the more mercury levels will be absorbed. Community of gold miners who are still mining gold in a home industry are suggested to treat their wastewater using hyacinths to absorb the mercury, thus mercury gold mining will become relatively safer. Considering the temperature and pH factors, the hyacinths take roughly 5-9 days to react with the mercury before the wastewater can be discharged into the river.

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# Study on Digging and Loading Equipment Requirement for the Reclamation Plan in the Coal Mining Area of PT. Timah in Paku Village, Payung District, South Bangka Regency, Province of Bangka Belitung Islands

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ABSTRACT

Reclamation activity is one of the activities carried out in mining planning. This reclamation activity needs to be well planned. One of the reclamation activities is land arrangement. This land arrangement activity can be carried out by backfilling in ex-mining holes. This back filling activity is carried out by PT. Timah in carrying out reclamations related to land management. Former mining pit at PT. Timah will be back-filled in 2026 or the third year in the life of the mine. The back filling that will be carried out starts from RL 10 to RL 59. RL 59 is the target because the altitude is the same as the surrounding conditions. To carry out back filling on the plan, a material volume of 2,623,400 m3 is required. The age of the mine is only until 2029, so with the material requirements divided by 4 years of reclamation, 655,850 m3 per year is obtained. The equipment used to meet annual needs is 1 Dozer Komatsu D85 A, 1 Excavator CAT 320 D, and 5 dump trucks Scania P410.

## INTRODUCTION

Tin is one of the natural resources found in Indonesia. The tin reserves in Indonesia cover the islands of Karimun, Singkep, and parts of the mainland of Sumatra (Bangkinang) in the north and south, namely the islands of Bangka and Belitung. The region that produces the largest tin is the island of Bangka. PT. Timah Tbk is one of the companies that carry out tin mining activities on the island of Bangka. Mining activities carried out by PT. Timah Tbk using the open pit mining method. It consists of several stages, namely starting from prospecting. Each stage in mining activities has its own function and can have an impact on the environment. Therefore the company is expected to be able to carry out supervision of mining activities in order to minimize the impact that occurs while still having economic value.

One of the impacts that can occur from mining activities using the open pit mining method is the emergence of a former mine opening. The impact of the formation of the former opening hole needs special handling. One form of handling the negative impacts of mining activities is carrying out planned

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reclamation. Reclamation is an integral part of mining activities. This reclamation activity is intended to return ex-mining land to its designation. This research was conducted at PT Timah. Tbk which is located in Paku Village, Payung District, South Bangka Regency, Bangka Belitung Islands Province. The area of PT Timah.Tbk's Mining Business Permit (IUP) which is planned for mining from the 2024-2029 period is 5,199 hectares.

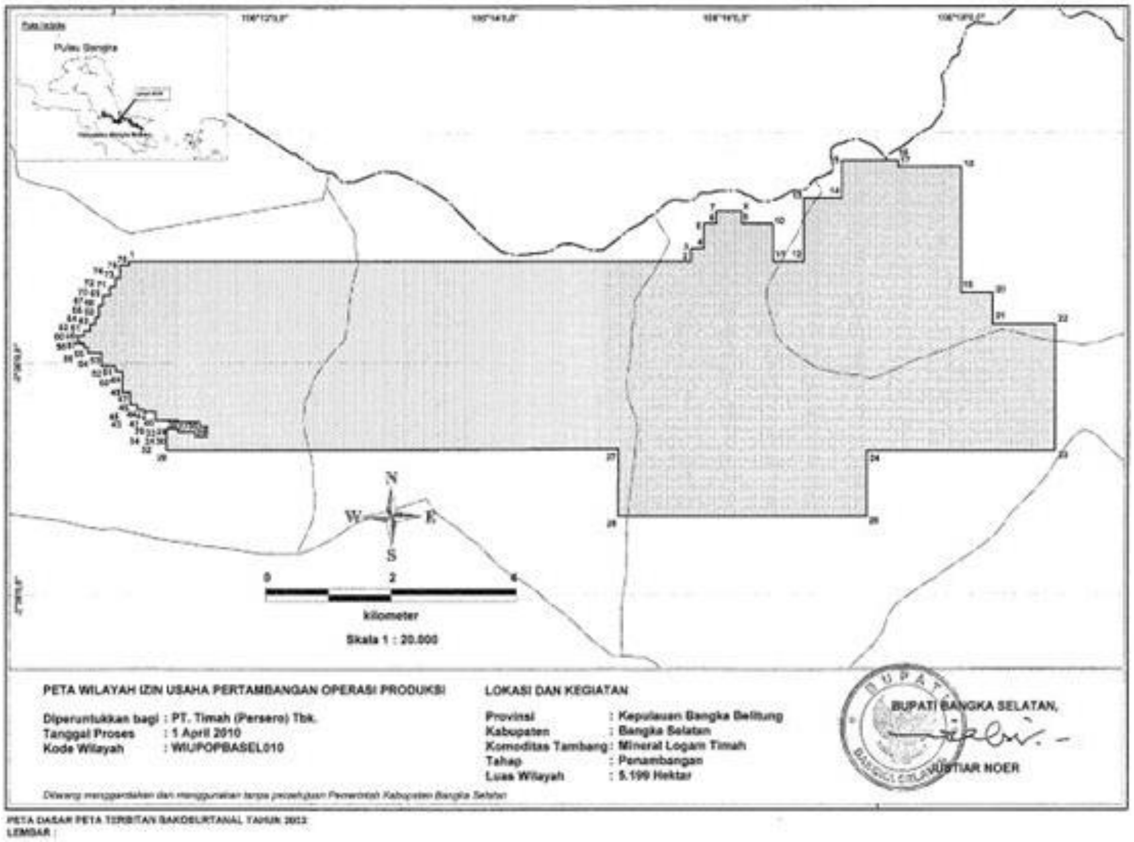



**Figure 1.** (a) (a) Map of  PT. Timah.Tbk. Mining Business Permit (IUP) Area

## METHODOLOGY

Minister of Energy and Mineral Resources regulation no 1827 of 2018 states that every IUP holder must carry out reclamation. Reclamation activities are activities carried out to restore land according to its designation. Reclamation activities need to do reclamation planning. Reclamation activities include land use management activities, land clearing plans, reclamation programs for disturbed land which includes temporary and/or permanent ex-mining land and non-ex-mining land. In planning, it is necessary to calculate costs for reclamation activities. This fee will be used for reclamation guarantees. Reclamation guarantees can later be taken by companies whose amount is calculated based on success criteria. Success criteria include success standards for land management, revegetation, civil works, and final completion.

The cost of carrying out the reclamation consists of two parts, namely direct costs and indirect costs. Direct costs consist of land use stewardship, revegetation, prevention and control of acid mine drainage, civil works according to land use, & management and utilization of ex-mining pits. Indirect costs consist of equipment mobilization and demobilization, reclamation planning, administration and benefits of third parties as executors of reclamation at the production operation stage, and supervision. In the research conducted by case study, the calculation of the cost of implementing the reclamation plan was carried out.

## RESULT

Land reclamation for mining activities at TB Paku PT. Timah. Tbk during the period from 2026 to 2029. Reclamation activities carried out are land structuring by backfilling in ex-mining pits. The ex-mining openings/pits that are being carried out are the east pit (pit A) and the middle east pit (pit B) which are pits that will no longer be active in 2026. (**Figure 1**). From the picture above, incision A is made in pit A and incision B is in pit B. The side view of the incision will be drawn so that you can get an idea of how much material will be backfilled in the pit. From the incision it appears that the ground floor of the mine is at RL 10 and back filling activities are carried out up to RL 59. At RL 59 is the target height to be achieved adjusted to the surrounding altitude (**Figure 2**).

(a)

(b)

(c)

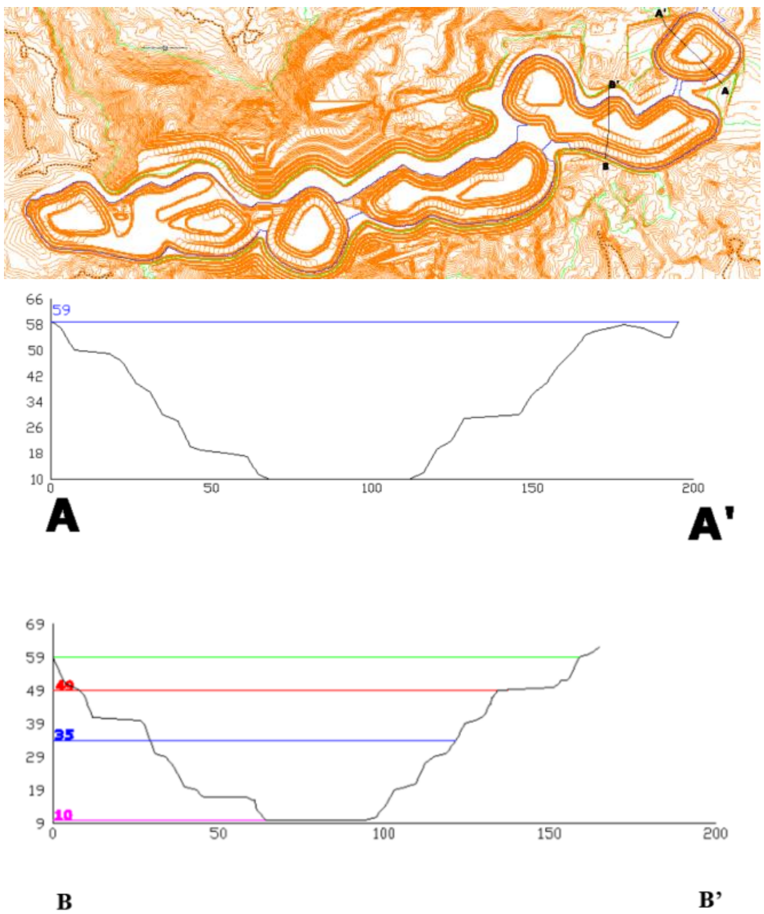
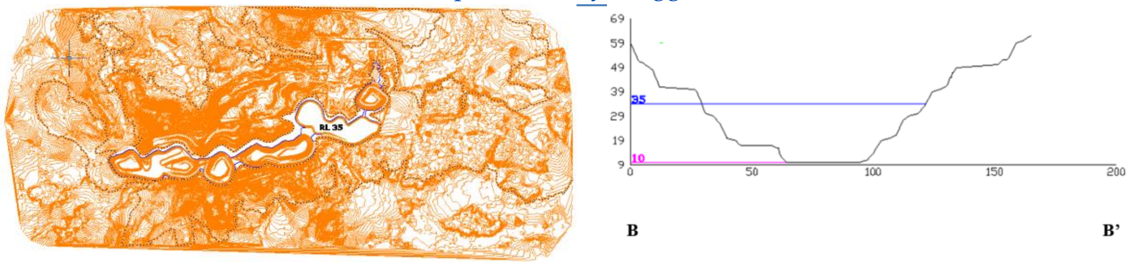



**Figure 2.** Pit TB Paku PT Timah.Tbk Topographic map (a) showing locations ofsection A - A′ (b) and B - B′ (c)

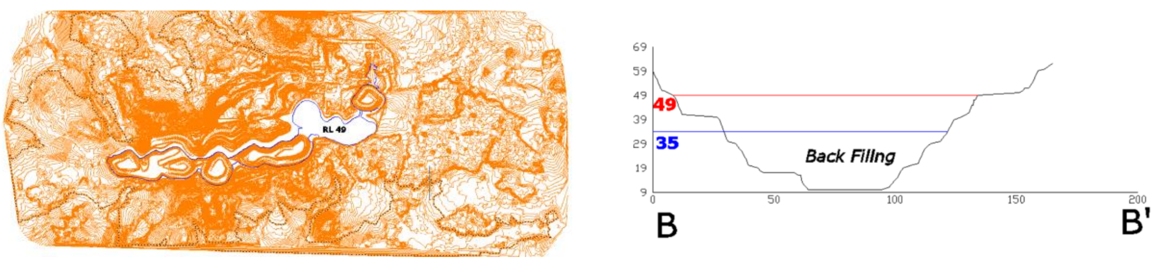
From the sections A and B, a total volume of 2,623,400 m3 was obtained for backfilling with an area of 100,584 m2 or 10 ha of land being stockpiled. The reclamation plan is planned for 4 years so that the volume to be stockpiled per year is 655,850 m3. Stage 1 reclamation will be carried out in 2026 in the former mining area B. According to the productivity target of 655,850 m3 per year, then backfilling will be carried out from RL 10 to RL 35 with a land area of 4.3 ha. This phase one activity is carried out in 2026 because it is waiting for the Middle East pit or pit B to be inactive (Figure 3).




(a) (b)

**Figure 3.** Location of Line and Section B of the Reclamation Phase 1

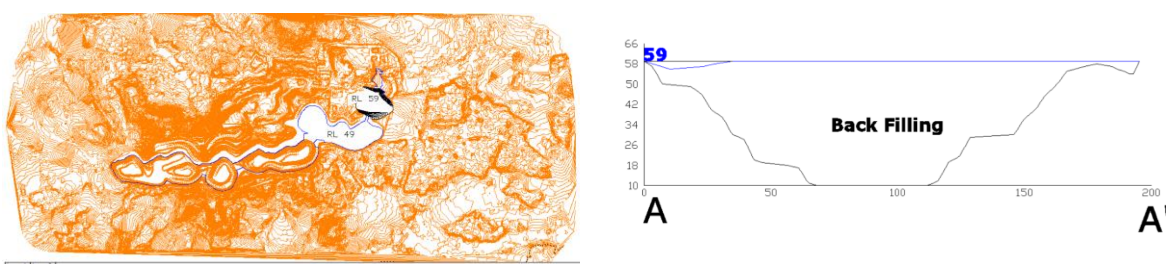
The second stage will be carried out in 2027 by continuing to carry out back filling at the same location from RL 35 to RL 49. Elevation 49 makes the pit level with the mine road to the west pit. With the average elevation of the location, it will be easier to do back filling in the pit at the east end which has not been done back filling. The area of the second stage of reclamation is 5.73 ha and has a volume of 706,776 m3 for stockpiling. (**Figure 4**).




(a) (b)

**Figure 4.** Location of Line and Section B of Reclamation Phase 2

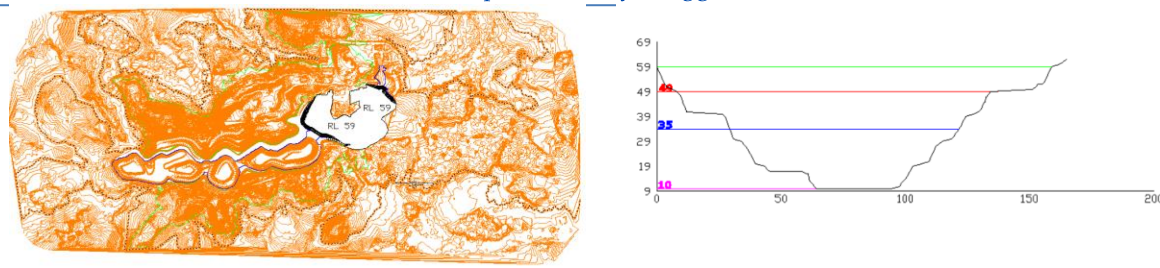
The third stage will be carried out in 2028 by backfilling the pit at the east end (Pit A) from RL 10 to RL 59. At RL 59 the pit has the same elevation as the surrounding conditions. The area of the second stage of reclamation is 2.5 ha and has a volume of 548420 m3 for stockpiling. (**Figure 5**).




(a) (b)

**Figure 5.** Location of Line and Section B of Reclamation Phase 3.

The fourth stage will be carried out in 2029 by back filling the pit which is in the middle east continuing from RL 49 to RL 59. At RL 59 the pit has the same elevation as the position of the surrounding conditions, especially with the back filling pit at the east end. The area of the second phase of the reclamation is 7.8 ha and has a volume to stockpile of 679545 m3. (**Figure 6**).




(a) (b)

**Figure 6.** Location of Line and Section B of Reclamation Phase 4

The fourth stage is the last stage in the reclamation process at PT. Timah Tbk because 2029 is the last year of PT. Timah.tbk performs production operations according to the age of the mine. After all mining activities have been completed PT. Timah will also carry out backfilling of ex-mining mines in the middle and west as a post-mining activity. Considering the safety factor in stockpiling overburden based on Minister of Energy and Mineral Resources Regulation No. 1827 of 2018, slopes are made with a horizontal: vertical ratio of 2: 1. The position and dimensions of the slopes can be seen in Figure 7. Meanwhile, to minimize erosion, a cover crop is planted on the embankment surface. This revegetation or replanting activity is carried out on piles of waste in former mine openings that have been backfilled. After arranging the area, it is filled with topsoil and sprinkled with cover crops, namely: the legume family or legume cover crop (LCC).


(a) (b)

**Figure 7.** Situation (a) and dimension of disposal area (b)

To carry out back filling activities, it is necessary to carry out calculations to find out the number of loading and transport equipment needed. The equipment used is the same as the equipment used for mining activities. The planned annual stockpiling volume target is obtained from the total volume of the pits to be filled divided by the reclamation time. The total volume to be stockpiled is 2,623,400 m3 divided by the planned duration of the reclamation activity for 4 years. So the target volume of landfilling per year is 655,849 m3. This data can be used as a basis for determining the amount of equipment used. The types of equipment used are Dozers, Excavators, and Dump trucks. The types of equipment used are the Komatsu D85 A Dozer, the CAT 320 D Excavator, and the Scania P410 dump truk.

## Dozer Productivity & Unit Requirement

The dozer used is Komatsu D85A (Figure 8 a) with the required specifications. Heavy Equipment Brand : Komatsu D85 A; Blade Capacity : 3.4 m$^3$; Blade width (L) : 4.26 meters; Blade height (H): 1.74 meters; Working distance: 100 meters; Forward speed (F): 113 m/min; Reverse speed (R): 143 m/min; Time to change gears (z) : 0.05 minutes; Angle factor (a) : 0.7; Override distance ( D ) : 100 m; Work efficiency (E): 0.71.

Dozer Productivity (Q)
Q = q x 60/cm x E
= 9,02 x 60/1,63 x 0,71
= 235,737 m3/ jam
= 1.332.730 m3/ tahun
q = L x H2 x a
= 4,26 x (1,74)2 x 0,7
=9,02
Cm = D/F + D/R + Z
= 100/113 + 100/143 + 0,05
= 1,63
Number of dozers = (Production Target)/(Dozer Productivity) = 655,850/(1,332,730 ) = 0.49 ~ 1 unit

(a) (b)

**Figure 7.** Dozer Komatsu D85 A (a) and Excavator CAT 320 D (b)

## Excavator Productivity & Unit Requirement

The excavator used is CAT 320 D (Figure 8 b) with the required specifications. Heavy Equipment Brand: CAT 320D; Bucket Capacity : 1.19 $m^3$; Bucket Fill Factor : 0.08; Track Length: 4450 mm; Machine type : Net Power ISO-9249 117 KW; Working weight: 22,000 kg; Tank capacity: 345 liters; Work efficiency (E): 0.71; Digging time: 14 seconds; Payload swing time: 7 seconds; Dumping time: 6 seconds; Empty swing time: 7 seconds

Production target = amount of material to be back filled per year = 655,850 m3
Working time = 5,663 hours/ year
Total circulation time = 34 seconds
q = 1.9 m3 x 0.80
= 1.52 m3
Q = (1.52 x 3600x 71.2)/34
= 120.70 m3/ hour
Q per year = 120.70 m3/hour x 5663 hours/year
= 683,524.1 m3/ year

Need for excavators $= \frac{Anual\ Production\ Target}{Anual\ excavator\ productivity}$
$= \frac{655.850}{683.524,1}$ = 0.95 ~ 1 excavator / year.

## Dump Truck Productivity & Unit Requirement

The dump truck used is Scania P410 with the following specifications. Vessel Capacity : 20 $m^3$; Vessel Length : 6 m; Vessel Width : 2.5 m; Vessel Height : 1.5 m; Working time : 5663 hours/year; Work efficiency (E): 0.71.

Dump truck productivity (Q)

Q = ((C x 60 x E))/CM
= ((20 x 60 x 0,71))/28,64
= 29,74 m3/ hour
= 168.428,517 m3/ year

C : Average dump truck capacity (m3)
Cm : Distribution time
E : Work Efficiency

CM = n x cms x D/V1 x D/V2 x t1 x t2
= 13,15 x 0,56 x 1540/333,33 x 1540/666,66 x 1,2 x 0,3
= 28,64
n = c/((q^' x k))
= 20/((1,9 x 0,8))
= 13,15

n : the number of cycles required by the loader to load the truck
c : average dump truck capacity (m3)
q' : loading bucket capacity (loader / excavator, minutes) (m3)
k : bucket fill factor
Cms : Load cycle
D : Dump truck hauling distance
v1 : average speed of loaded dump trucks (m/min)
V2 : average speed of empty dump truck (m/min)
T1 : dump time, standby until discharge start (minutes)
T2 : time for filling and loading positions to start filling (minutes)

Number of dump trucks needed = (yearly production target)/(dump truck productivity) = (655,850) / (168,428,517) = 3.89 ~ 4.

# CONCLUSION

PT Timah Tbk in the implementation of reclamation is carried out for 4 years from 2026 - 2029. In implementing this reclamation, one of the activities carried out is to backfill the ex-mining pits. The total material to be used for backfilling is 2,623,400 m3. The required equipment used for backfilling the material is 1 Dozer type Komatsu D85A, 1 type excavator CAT 320, and 4 dump trucks type scania P410.

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# Review On The Effect Of Vegetation On Waste Treatment In Mining Wetlands

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ARTICLE INFO | ABSTRACT

**Keywords:** mining vegetation, wastewater treatment, wetlands

This study discusses the influence of vegetation growth on waste treatment in mining wetlands. Mining wetlands are wastewater treatment systems that use plants as treatment agents. The aim of this research is to provide information on the impact of vegetation growth in mining wetlands on the effectiveness of waste treatment. The method used is a literature review by searching for articles and scientific journals related to the influence of vegetation growth in mining wetlands. The research results indicate that vegetation growth in mining wetlands has a positive effect on the effectiveness of waste treatment. The more plant species that grow, the better the waste treatment. The pH and TSS levels of the water in the wetlands also increase with the presence of vegetation. Moreover, the levels of Fe, Mn, Pb, and decreased with the presence of vegetation. Additionally, the vegetation with the best productivity while maintaining its condition is Typha sp. This plant can also survive in wetland areas with high water levels. In conclusion, the presence of vegetation has a positive impact on waste treatment in mining wetlands and can be an effective solution to address water pollution in mining areas.

## INTRODUCTION

Open mining activities will have an impact on subsequent environmental degradation processes. Open mining areas have the potential to expose pyrite minerals to the surface. This can trigger the oxidation of pyrite minerals and the formation of SO42-. The oxidation reaction is biologically mediated by *Thiobacillus thiooxidans* bacteria, which produce soil acidity by generating sulfuric acid (Munawar, 2011; as cited in Sandrawati et al., 2019).

The impact of acid mine drainage is not limited to the mining site itself; what is of greater concern is the contamination of water sources outside the mining area, which poses a significant danger to the environment, especially for living organisms. The management of acid mine drainage should be carried out by every mining company in accordance with the obligations stipulated in Ministerial Regulation No.

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7 of 2014 concerning the Implementation of Reclamation and Post-Mining Activities in Mineral and Coal Mining Businesses (Hengen, 2014; as cited in Andrawina et al., 2020).

Passive methods have also become a preferred choice and are frequently employed in acid mine drainage treatment. Constructed wetlands, including their low cost and simple mechanisms, are one of the methods used. Constructed wetlands for treating acid mine drainage resulting from coal mining waste can apply various types of active or passive treatments using wetland plant species that function in reducing heavy metal content in mining wastewater (Shoeran, 2005; as cited in Andrawina et al., 2020).

Wetlands are also implemented in arid regions for clean water supply (Dzikus, 2008; as cited in Sucahyo et al., 2018). Furthermore, their further development is used for natural ecosystem processes in water quality neutralization, such as pH adjustment and the reduction of dissolved metal content in water (Coulton, 2003; as cited in Sucahyo et al., 2018). The acidity level of acid mine drainage ranges from 2 to 4 (Garcia, 2001; as cited in Sucahyo et al., 2018).

This study aims to analyze the influence of vegetation on waste treatment in wetlands in mining areas. The analyzed vegetation's influence includes its effects on pH levels, TSS values, and the levels of Fe, Mn, Pb, and As.

## METHODOLOGY

The research method employed in this study is a literature review, which aims to analyze relevant literature including articles and scientific journals regarding the influence of vegetation growth on waste treatment in mining wetlands. In the field of research, particularly in the creation of scientific works, literature review is commonly known as a literature survey. Therefore, it can be said that literature review is an analytical activity that involves critiquing existing research on a specific topic within a particular field of knowledge. The process begins by collecting data from various articles and scientific journals that discuss vegetation in mining wetlands. Searches are conducted using academic search engines such as Google Scholar, ScienceDirect, and Scopus. The keywords used in the search include "mining wetland," "vegetation," "waste treatment," and "influence." Article selection is carried out by considering relevance to the topic, research quality, and publication year. The collected data consists of secondary data regarding the discussion on the influence of vegetation growth on mining wetlands as well as the discussion on the influence of vegetation on mining waste management.

## RESULT

### The Influence of Aquatic Plants on Ph Value

Based on Aryanto's study (2015), it is explained that by implementing the aerobic wetland method in the treatment of acidic mine water, the pH of the AMD can increase. The passive AMD treatment method used in this research employs the SAPS (Successive Alkalinity Producing Systems) and AW (Aerobic Wetland) methods.

The SAPS method is a passive AMD treatment method using organic matter and limestone in a vertical arrangement. The SAPS pond consists of water (0.3 – 1.8 m), organic matter (0.15 – 0.60 m), and limestone layer (0.60 – 1.5 m). In this pond system, organic matter will deplete oxygen and convert Fe3+ to Fe2+. This condition leads to the breakdown of limestone to produce bicarbonate, thereby increasing the solubility of limestone. The increase in solubility is due to the rise in CO2 pressure, resulting in the decomposition of the organic layer, which subsequently neutralizes the acidity in the AMD.

On the other hand, the AW method is a passive AMD treatment method using aquatic plant vegetation and organic matter planting media with a specific area. This method employs the Typha angustifolia water plant on organic matter (compost, sawdust, dry grass, or animal waste) and water at a height of around 0.1 – 0.5 m. Organic matter will consume oxygen and create an oxygen-free environment known as anoxic conditions. Typically, before entering the AW pond, the AMD will pass through a settling pond with a depth of 1.5 – 2.5 m to reduce Fe(OH)3 content. In the settling pond, the AMD will stay for 8 – 24 hours. The AW pond system operates by treating water that is net alkaline (water that is basic and has a high iron concentration) through oxidation reactions, causing metals to precipitate. The AW Pond functions efficiently when the pH is > 5.5.

In Aryanto's study (2015), five ponds were used, employing both methods. The ponds were arranged alternately: SAPS 1 – AW 1 – SAPS 2 – AW 2 - Outlet. The limestone used in SAPS 1 and SAPS 2 ponds amounted to 128.075 for each pond with an 80% concentration. Furthermore, the number of Typha Angustifolia plants in AW 1 and AW 2 ponds was 702 plants for each pond. The pond system is depicted in Figure 1, and the pond function specifications are provided in **Table 1**.


**Figure 1.** Ilustration on pond system

**Table 1.** Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

| Pond | Media | Function |
|---|---|---|
| SAPS | Limestone and organic matter | 1. Increasing alkalinity through the release of bicarbonate ions from limestone.<br>2. Increasing alkalinity and precipitating metals. |
| AW | Organic matter and Typha Angustifolia water plant | 1. Increasing alkalinity and precipitating metals.<br>2. Absorbing Fe and Mn metals. |

Sampling in this research was conducted monthly over a period of 4 months, and pH data collection was performed using a spectrometer. Throughout the course of the testing, the pH of each pond was obtained as follows: The AMD at the inlet of SAPS 1 pond had a pH range of 3.02 – 3.32. The AMD at the inlet of AW 1 pond had a pH range of 3.06 – 3.35. The AMD at the inlet of SAPS 2 pond had a pH range of 3.13 – 3.36. The AMD at the inlet of AW 2 pond had a pH range of 6.57 – 6.9. The AMD at the outlet pond had a pH range of 6.59 – 6.73. The pH parameter before and after AMD treatment using the SAPS and AW methods is shown in **Table 2.**

**Table 2.** Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

| Parameters | Before | After | Kepmen LH Number 113 of 2013 Criteria |
|---|---|---|---|
| pH | 3,13 | 6,63 | 6 - 9 |

## The Influence of Aquatic Plants and Water Flow Rate on Total Suspended Solid Levels and pH Value

Total Suspended Solids (TSS) are particles that are insoluble in water and have smaller size and weight compared to sediment. The decrease in TSS levels in the pond is related to the presence of plant roots. The positive charge of the plant root hairs can attract colloidal particles with opposite charges, such as suspended solids. This can cause these particles to adhere to the plant roots and be absorbed and assimilated by plants and microorganisms over time. Therefore, if the plants have long roots, the TSS levels will decrease.

Based on the research conducted by Prabowo et al. (2019), constructed wetlands can reduce the concentration of TSS in AMD. This study was carried out in the wetland area of PT. Bukit Asam, South Sumatra, with sampling conducted once per week for a duration of 3 weeks at both the inlet and outlet points. The results of TSS sampling are presented in **Table 3**.

**Table 3.** Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

| Comparison | Research Output | | |
|---|---|---|---|
| | Week 1 | Week 2 | Week 3 |
| TSS in the inlet (mg/l) | 405 | 443 | 621 |
| TSS in the outlet (mg/l) | 6 | 3 | 2 |
| Flow rate ($m^3/s$) | 0,21 | 0,14 | 0,08 |

The concentration of TSS in AMD decreases upon entering the wetland and exiting to the outlet pond. From the first week to the third week, all TSS concentrations decrease, reaching levels of 2-6 mg/l. According to Arroyo et al. (2010); cited in Prabowo et al. (2019), the reduction in TSS concentration is due to plants being able to attract oppositely charged colloidal particles from the positively charged root hairs, such as suspended solids. Consequently, these particles adhere to the roots, are absorbed, and assimilated by the plants and microorganisms.

In addition to the influence of plants, water flow also affects the rate of TSS reduction. From Table 3, it can be observed that slower water flow leads to a greater decrease in TSS concentration. This phenomenon occurs because slower water flow provides more time for plants to perform the particle absorption process. As a result, the quantity of absorbed particles increases, leading to a more substantial reduction in TSS concentration.

## The Effect of Aquatic Plants on Fe Level

The iron (Fe) content plays a role in plant photosynthesis, chlorophyll formation, and respiration. However, if the Fe level accumulates excessively, it can cause deficiencies in other nutrients such as Mn, P, K, Ca, and Mg. Based on the research conducted by Yunus et al. (2018), it is stated that plants play a crucial role in the remediation processes in wetland environments. The functions of plants in wetlands include oxygen release from their roots, providing attachment sites for microbes, and supplying a source of organic material for heterotrophic microorganisms. Reduction and oxidation processes primarily occur around the root zones due to the abundant presence of reducing microorganisms in this region of the plants. The results of the Fe concentration measurements accumulated in the Water Hyacinth and Nutgrass plants were converted into Bioconcentration Factors (BCFs). The measured results of the accumulated Fe concentration in Water Hyacinth and Nutgrass plants are presented in **Table 4**.

**Table 4.** Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

| Parameters | Days | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 |
| Temperature (0C) | 37,2 | 37,3 | 37,5 | 37,3 | 37,1 | 37,7 |
| Water pH in the outlet | 3,20 | 3,97 | 4,64 | 4,70 | 4,96 | 5,31 |
| Fe conc. Fe in water hyacinth | 1.946,79 | 10.263,00 | 5.468,77 | 39.329,83 | 7.734,46 | 5.986,11 |
| Fe conc. Fe in cattail plant | 3.709,87 | 23.371,00 | 20.071,08 | 18.858,59 | 9.229,45 | 19.935,26 |

The data in the table above is then converted into Biokinetic Concentration Factor (BCF) values. BCF is a parameter used to determine the potential of plants as accumulators of Fe in plant dry weight conditions. BCF can be calculated using the following formula :

$$BCF = \frac{Metal\ concentration\ in\ plants}{The\ concentration\ of\ metals\ in\ acid\ mine\ water}$$

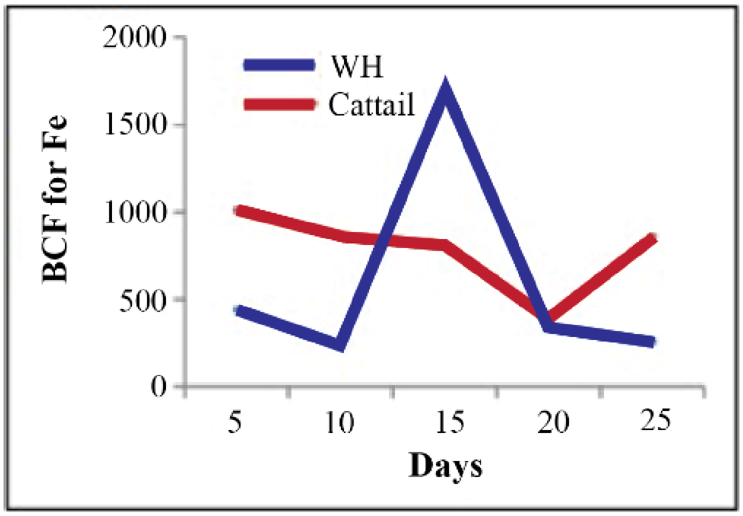


**Figure 2.** BCF for Fe in hyacinth and cattail plants (Yunus et al., 2018).

From the BCF graph for the Fe content, it can be concluded that water hyacinth plants will experience growth inhibition when the water pH is < 4. Water hyacinth exhibits optimal growth at pH levels of 5.5-7. Based on this, water hyacinth will exhibit higher absorption at higher pH conditions and over a longer period of time. On the other hand, reed canary grass can grow well at pH < 4. Although reed canary grass shows better growth compared to water hyacinth, the BCF values for reed canary grass tend to be lower than water hyacinth at pH levels of 5.5-7. Another factor is that at pH < 4, the availability of soluble cations for approaching plant tissue is greatly limited. As pH increases, the binding of metals to plant tissues also increases. At low pH, metal cations are hindered by the repulsive forces from H+ ions on adsorbent sites. Based on Yunus et al. (2018), a study on different metals found that the accumulation of Zn, Pb, As, Fe, and Cd by water hyacinth and reed canary grass increases as pH increases.

## The Effect of Aquatic Plants on Mn Concentration

Manganese (Mn) is a trace element required by plants for chlorophyll synthesis, acting as a coenzyme, serving as an activator for certain respiration enzymes, participating in nitrogen metabolism, and photosynthesis reactions. The distribution and composition of Mn metal in the pond indicates that the Mn metal content is relatively consistent across the surface, middle, and bottom of the pond. Mn metal is not easily precipitated.

The research was conducted on Water Hyacinth and Nutgrass for a duration of 25 days in a 60 m² Constructed Wetland (CW) divided into 2 points. The first point was planted with Water Hyacinth, while the other side was planted with Nutgrass. Data was collected consistently every 5 days, with water samples collected from both the inlet and outlet points, each comprising 100 mL and repeated 3 times. Samples from both plants were also collected at 2 points, near the inlet and near the outlet. Each sampling session commenced with pH and water temperature measurements. Based on Yunus et al. (2018), the results of the accumulated Mn concentration measurements in Water Hyacinth and Nutgrass plants can be observed in **Table 5**. Meanwhile, data in the table **Table 5** was then converted into Bioconcentration Factor (BCF) values as shown in the **Figure 3**.

**Table 5.** Functional Specifications of Aerobic Wetland Ponds (Aryanto, 2015)

| Parameters | Days | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 25 |
| Temperature (0C) | 37,2 | 37,3 | 37,5 | 37,3 | 37,1 | 37,7 |
| Water pH in the outlet | 3,20 | 3,97 | 4,64 | 4,70 | 4,96 | 5,31 |
| Fe conc. Fe in water hyacinth | 4,03 | 10,28 | 7,95 | 23,89 | 26,93 | 28,56 |
| Fe conc. Fe in cattail plant | 5,88 | 27,43 | 7,93 | 3,18 | 36,86 | 29,06 |

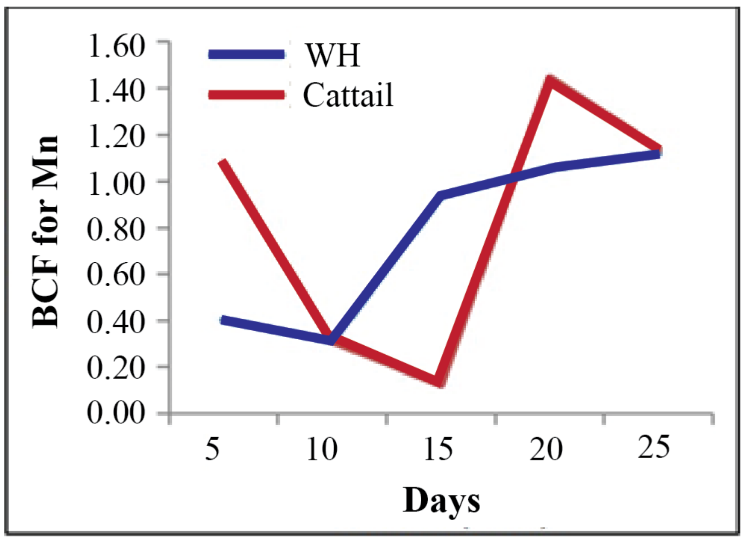


**Figure 3.** BCF for Mn in hyacinth and cattail plants (Yunus et al., 2018)

From the FBK graph for Mn content, it can be concluded that the growth of water hyacinth is inhibited when the water pH is < 4, while it experiences good growth between pH 5.5-7. Water hyacinth shows higher Mn absorption at higher pH conditions and longer duration, as observed from the increasing trend of Mn FBK from day 10 to day 25. On the other hand, water fern shows excellent growth at pH < 4. Although the growth of water fern is better than that of water hyacinth, the Mn FBK values for water fern tend to be lower from day 10 to day 15 and experience a significant increase on day 20.

## Plant Productivity In Wetland

The research conducted by Munawar (2007) is a study of passive treatment, where the main principle is to allow chemical and biological reactions to occur naturally. This involved using 15 types of aquatic plants selected for their health, divided into two groups. One group of plants, each consisting of one sapling, was planted in 10 kg of muddy medium in a plastic bucket and continuously flooded with AMD to a depth of 2-4 cm. Meanwhile, the other group was planted in the same muddy medium and flooded with rainwater to the same height.

The study was divided into several experimental groups : (1) Isolation, identification, and propagation of sulfate-reducing bacteria (SRB), (2) Anaerobic incubation of organic substrate with AMD (pH 3.80 and EC 1090 uS/cm), (3) Selection of acid-tolerant aquatic plant species, and (4) Construction of a small-scale wetland. The research was conducted over a span of two years, starting in June 2004.

According to Munawar (2007), aquatic plants in wetlands have several important benefits, which are as follows:

a. For substrate consolidation, where plant roots hold the substrate together and increase water residence time in the wetland.
b. Stimulating microbial processes, where plants provide surfaces for microbial attachment, release oxygen, and provide a source of organic matter for heterotrophic microbes.
c. Providing habitat for wildlife, where plants can supply food and offer protection for aquatic animals.
d. In terms of aesthetic function, wetlands with abundant aquatic plants are much more visually pleasing compared to wetlands without vegetation.

According to Sandrawati et al. (2018), the research estimated plant productivity based on biomass weight and yield. Biomass weight (fresh) was calculated based on the harvested results in the form of tiles, which were then converted to hectares. The measurement results of plant productivity are shown in the table below.

**Table 6.** Plant Productivity (Sandrawati et al., 2018)

| Vegetation | Amount | Biomass Weight (kg) | Productivity (ton/ha) |
|---|---|---|---|
| *Typha sp* | 6 | 3,84 | 17,11 |
| *Cyperus sp* | 2 | 0,58 | 16,67 |
| *Eichornia Crassipes* | 7 | 3,14 | 31,38 |

From the data in the table above, it can be observed that the plant *Eichhornia crassipes* has the highest productivity, which is 31.38 tons/ha. However, the size of this plant decreases over time. This is suspected to be due to the lack of nutrients in *Eichhornia crassipes*, considering that in the last pond, the solubility of nutrients, especially Fe, Mn, and SO4, is very low. This is because *Eichhornia crassipes* plants cannot withstand prolonged exposure to acid mine water, which can lead to nutrient toxicity. It can be concluded that *the Eichhornia crassipes* is not recommended to be grown in constructed wetlands for acid mine water.

The biomass produced by *Typha sp*. is smaller than that of *Eichhornia crassipes*, but it exhibits better growth conditions. *Cyperus sp*. can generate biomass in a similar amount to Typha sp. When using both plants, attention should be given to the growth conditions, as *Cyperus sp.* is more tolerant to severe moisture conditions. Therefore, to achieve high biomass and good plant quality, Typha sp. is preferred as the plant in constructed wetlands compared to *Cyperus sp.* and *Eichhornia crassipes*.

## CONCLUSION

The utilizations of vegetation in wetlands can increase the pH from its initial value of 3.13 to 6.63. It can reduce the TSS (Total Suspended Solids) levels. Additionally, the TSS levels are also influenced by the flow velocity or water discharge. The faster the water flows, the decrease in TSS content caused by vegetation in the wetland would be lower. It also can reduce the Fe (Iron) levels. The concentration of Fe in water hyacinth plants increased up to a maximum concentration of 39,329. The concentration of Fe in sedge plants increased up to a maximum concentration of 23,371. The Mn (Manganese) levels can also be reduced, the concentration of Mn in water hyacinth and sedge plants reached the highest concentration at 28.56 and 36.86, respectively. Different plant species will result in greater biomass. Higher biomass will improve the quality and condition of the plants.

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# Utilization of Reject coal from hauling activities as fertilizer: Coal handling strategies

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**Keywords:** Coal Handling, Reject Coal, Strategies

ABSTRACT

Management of rejected coal in the coal mining industry has become a major concern in efforts to reduce waste and manage resources more sustainably. One approach that has been proposed is the use of rejected coal as an agricultural fertilizer, with the aim of reducing the amount of rejected coal that must be transported and disposed of in active disposal. The research aims to analyze the effect of using reject coal as a fertilizer on the transportation of rejected coal to active disposal. This research will examine the impact of using reject coal as fertilizer on the volume and frequency of transporting rejected coal to active disposal.reject coal.

## INTRODUCTION

Disposal and management of fine coal in the coal mining industry has long been a significant environmental and economic issue. Fine coal, which is often a byproduct of coal mining operations, poses challenges regarding storage, transportation and its potential impact on the environment. One common practice is the dumping of fine coal at active dump sites, which not only uses up valuable land but also raises questions about the environmental sustainability of the method. Proper management of fine coal is essential not only to reduce the environmental impact of coal mining but also to explore potential alternative uses that could reduce the need to transport and dispose of this material in active disposal areas. This research focuses on investigating the impact of transporting fine coal to active disposal sites, aiming to better understand the associated challenges and potential improvement opportunities. Transporting fine coal to active disposal sites requires significant logistical considerations and can have far-reaching impacts. This has an impact on the environment, public health and safety, as well as the sustainability of coal mining operations as a whole. Additionally, the economic costs associated with transporting and disposing of fine coal are enormous, and optimizing these processes can result in cost savings for the coal mining industry.

Fine coal from processing that does not meet the coal specifications that can be sold can still be used for

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fertilizer. In 2021, the total volume of rejected coal disposed of for disposal will be 38,719 tons. Handling rejected coal at PT. Borneo Indobara is stockpiling coal in the coal stockpile area so that this will reduce the capacity of the coal stockpile. Fertilizer resulting from reject coal processing can be used to support reclamation activities. Using this will help conserve and add value to coal resources. One of the wastes produced in large quantities in the coal mining industry is reject coal (rejected coal). Reject coal is formed when the coal separation process produces a fraction that does not meet quality standards for sale as a final product. The main problem that arises is how to manage rejected coal efficiently without causing negative impacts on the surrounding environment, reject coal management has become a major concern among researchers, industry practitioners and environmental regulators. The main option that is often used is to transport rejected coal to active disposal, which is a special area designed to accommodate this waste. however, transporting rejected coal to active disposal is not an ideal solution, considering the various challenges associated with this practice.

Even though active disposal is the main choice for dealing with rejected coal, this approach is not always efficient, especially when the amount of rejected coal produced is very large. In addition, transporting reject coal to active disposal requires high transportation costs, which can affect mining companies' operational costs. In some cases, the distance between the mine and active disposal can be very large, increasing the costs and environmental impact of transportation, on the other hand, the potential for using rejected coal as an organic fertilizer has emerged as an attractive alternative. Processing rejected coal into useful organic fertilizer can reduce the amount of rejected coal that must be transported and disposed of for active disposal. Organic fertilizer produced from rejected coal has the potential to increase agricultural soil fertility and reduce dependence on synthetic chemical fertilizers.

**Figure 1.** Reject Coal

# METHODOLOGY

## Research Time and Location

This research method includes analysis of the chemical composition of rejected coal which will be used as fertilizer. Next, laboratory experiments will be carried out to evaluate the effects of reject coal on plant growth and soil quality. Parameters such as plant height, crop yield, soil nutrient content, and soil properties will be measured and compared with the use of conventional fertilizers.

Apart from that, this research will examine the impact of using reject coal as fertilizer on the volume and frequency of transporting reject coal to active disposal, namely with a transport distance of 23-32 kilometers using more than 10 hauler units for transportation. Data regarding the amount of rejected coal produced and transported will be recorded before and after the use of rejected coal as a fertilizer material.

This research was carried out by taking data from 2021 to 2023, where there is quite a large volume of rejected coal each year which could be used as fertilizer if in this research it could be categorized as organic fertilizer using the method that will be carried out. The location for data collection is in the South Kalimantan area, namely Tanah Spice Regency, in one of the well-known coal companies and with a very large production target, resulting in coal rejects due to the continuous coal processing process.

## Data Collection

This research is also to explore the effect of transporting rejected coal to active disposal on the potential use of rejected coal as an organic fertilizer material. benefits and how these can be integrated into sustainable mining practices. The data collected includes ultimate and proximate laboratory results; volume of rejected coal transported; transport distance and number of haulers used.

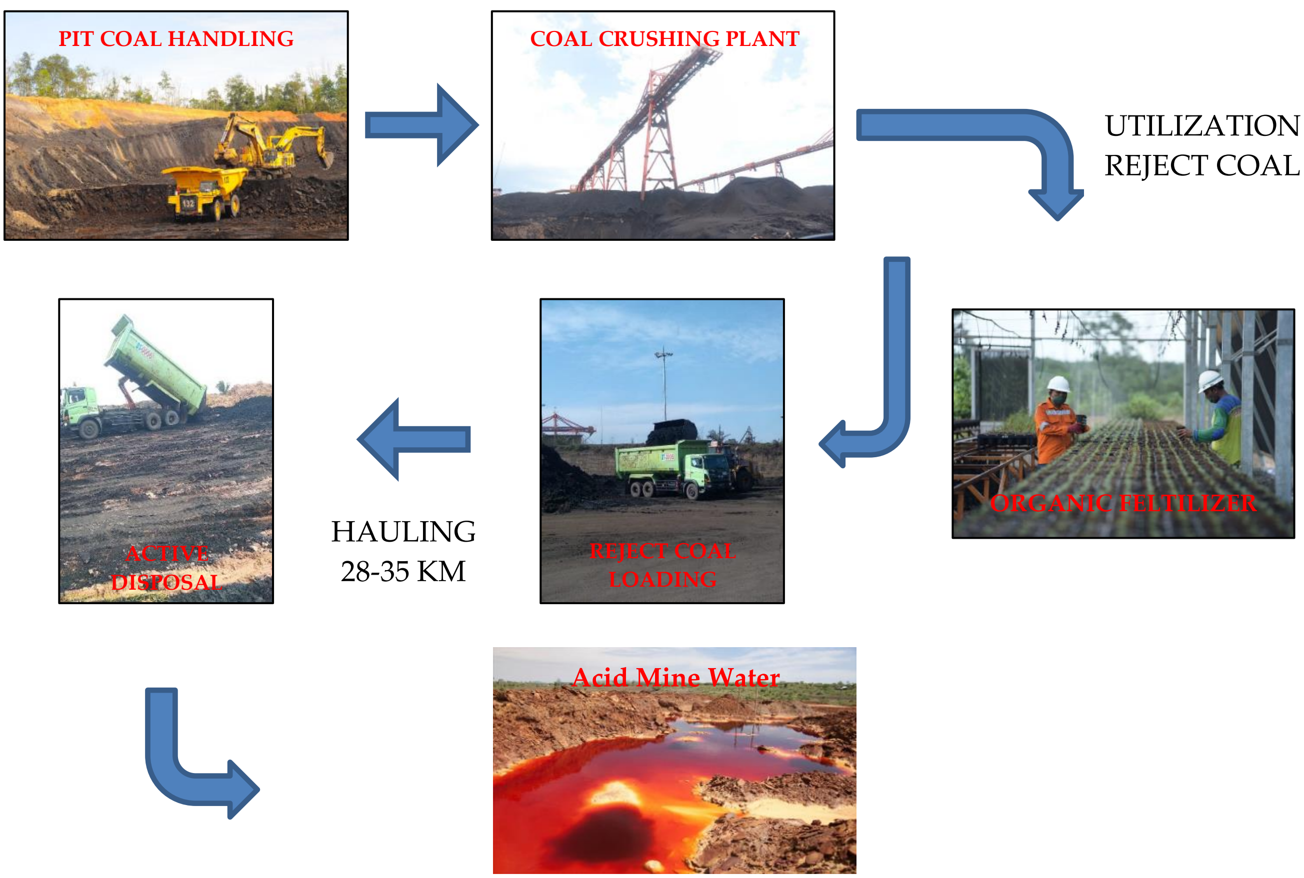


**Figure 2**. Flow Process of The Handling and Utilization of Reject Coal

## Data Processing and Data Analysis

**Table 1.** Ultimate Analysis of Reject Coal

| No | Keterangan | Ph | C organik | N | P | K | Mg | Na | S | Fe |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Soil | 6,2 | 2,72 | 0,11 | 11,73 | 0,13 | 0,30 | 0,22 | TU | TU |
| 2 | Reject coal | 7,41 | 42,25 | 0,67 | TU | 0,01 | 0,05 | 0,07 | 0,06 | 0,32 |

**Table 2.** Test Results for various Organic Fertilizers

| No | Feltilizer Type | N Total (%) | P205 (%) | K20 (%) | C-Organic (%) | C/N Ratio | Water content(%) |
|---|---|---|---|---|---|---|---|
| 1 | Sp Organic | 0.06 | 10.96 | 0.06 | 5.06 | 84 | 13.28 |
| 2 | Chicken manure | 1.17 | 1.87 | 0.38 | 7.16 | 6.1 | 13.01 |
| 3 | Organic Fertilizer KJD | 0.97 | 2.08 | 1.21. | 9.85 | 10.1 | 25.34 |
| 4 | Fertilizer Organic OCP | 9.07 | 8.58 | 6.13 | 15.82 | 1.7 | 16.23 |
| 5 | Compost AU | 2.03 | 0.34 | 3.25 | 17.83 | 8.8 | 13.10 |
| 6 | pellets | 2.69 | 8.25 | 7.02 | 12.25 | 4.7 | 9.23 |
| 7 | Cypramin Miwon | 4.57 | 0.17 | 1.73 | 6.94 | 2.0 | - |
| 8 | Organic Fertilizer Semigrup | 0.53 | 1.86 | 1.08 | 9.21 | 14.26 | 42.98 |
| 9 | Liquid raya fertilizer | 4.07 | 0.18 | 1.03 | 4.80 | 1.2 | - |
| 10 | Alfinase | 0.81 | 4.47 | 1.09 | 19.02 | 23.5 | 22.54 |
| 11 | Fine compost | 0.68 | 1.40 | 1.09 | 5.04 | 7.4 | 46.43 |
| 12 | Solid raya feltilizer | 2.25 | 0.46 | 0.57 | 11.9 | 5.3 | 37.96 |
| 13 | Bokasi | 0.73 | 0.62 | 1.0 | 9.39 | 12.9 | 43.86 |
| 14 | Organic feltilizer Granula 1 | 6.57 | 4.76 | 3.9 | 20.2 | 3.1 | 13.79 |
| 15 | Organic feltilizer Granula 2 | 6.08 | 4.9 | 4.3 | 21.2 | 4.3 | 11.25 |
| 16 | Organic feltilizer Granula 3 | 0.18 | 11.04 | 0.39 | 4.56 | 25 | 31.84 |
| 17 | Organic feltilizer Granula 4 | 1.54 | 7.34 | 0.41 | 10.3 | 7 | 40.9 |
| 18 | Organic feltilizer Granula 5 | 1.89 | 1.9 | 0.27 | 12.89 | 7 | 57.1 |
| 19 | Organic feltilizer Granula 6 | 0.61 | 0.3 | 0.09 | 4.11 | 7 | 26.58 |
| 20 | Organic feltilizer Granula 7 | 1.38 | 0.2 | 0.09 | 6.28 | 5 | 34.24 |
| 21 | Compost | 0.37 | 0.77 | 8.95 | 8.95 | 14 | 62.86 |

**Table 3.** Coal Handling of reject coal 2021-2023

| Date | Volume of Reject Coal transported (tons) | Location of transportation and disposal | Distance From Port to Disposal (kilometers) | Haulers used (units) |
|---|---|---|---|---|
| 2021 | 38.719 | Port Bunati – Disposal Girimulya | 35 | 26 |
| 2022 | 13.972 | Port Bunati – Disposal Kusan bawah dan Girimulya | 9 & 32 | 23 |
| 2023 | 9.490 | Port Bunati – Girimulya | 30 | 20 |

## RESULT

Through a deeper understanding of the potential for using reject coal as organic fertilizer and the impact of transporting rejected coal to active disposal, this research can provide valuable insight for the coal mining industry in an effort to reduce environmental impacts and increase efficiency in managing rejected coal. Apart from that, the potential use of rejected coal as an organic fertilizer material can support more sustainable agricultural practices, reduce dependence on chemical fertilizers, and improve the quality of agricultural soil. The impact of this research is on the Environmental Impact and Sustainability which discusses the environmental impact of transporting rejected coal to active disposal. Reducing the volume of rejected coal transported to active disposal by converting it into organic fertilizer can reduce pressure on active disposal sites and extend their service life. This has the potential to reduce the negative environmental impacts associated with the large-scale disposition of reject coal, and the impact of supporting Sustainable Agriculture where the results of this research provide further support for sustainable agricultural practices by integrating the use of organic fertilizer from reject coal. The use of organic fertilizer can help increase soil fertility and reduce dependence on synthetic chemical fertilizers in agriculture.

## CONCLUSION

Environmental and Sustainability Impact: Using rejected coal as organic fertilizer can reduce the volume of rejected coal transported to active disposal, reduce pressure on active disposal sites, and extend the service life of disposal sites. This has the potential to reduce the environmental impact of large-scale disposition of reject coal. Mining Operational Efficiency: If the use of rejected coal as organic fertilizer is proven to be effective, this can help mining companies reduce transportation and management costs for rejected coal. This can have a positive impact on operational efficiency and financial sustainability of mining companies. Support for Sustainable Agriculture: The use of organic fertilizer from rejected coal can support sustainable agricultural practices by increasing soil fertility and reducing dependence on synthetic chemical fertilizers in agriculture.

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