

The Application of Good Mining Practice Using Angiospermae Vegetation on Post-Tailing Land at the Mile 21 Research Center, PT. Freeport Indonesia

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ABSTRACT

Sustainable mining requires the implementation of Good Mining Practice (GMP) principles to minimize negative environmental impacts, particularly on tailing disposal sites. One important aspect of GMP is post-mining land rehabilitation, especially on tailing sites that have the potential to cause ecosystem damage. Tailing-affected lands require restoration involving plants capable of adapting to extreme environmental conditions. This study aims to apply GMP by utilizing angiosperm vegetation for land rehabilitation at the Research Center Mile 21, PT. Freeport Indonesia. Tailing-contaminated lands need recovery through plants that can thrive in harsh conditions. Angiosperm plants were selected for their ability to improve soil structure, reduce erosion, and enhance soil fertility. This research evaluates the effectiveness of angiosperm vegetation in accelerating soil recovery and supporting ecosystem sustainability. The findings are expected to provide valuable information and recommendations for more effective tailing site rehabilitation management and serve as a reference for environmentally friendly mining practices in the future.

Keywords: good mining practice; tailing; vegetation Angiospermae; revegetation; PT. Freeport Indonesia.

INTRODUCTION

Environmental pollution due to mining activities, especially on ex-tailings land, is a serious problem that requires special attention. PT Freeport Indonesia, one of the largest mining companies in Indonesia, has implemented the principles of Good Mining Practice (GMP) in its tailings reclamation activities to minimize environmental impacts and improve sustainability. However, the success of implementing GMP in reclaiming ex-tailings land needs to be further evaluated.

This study aims to provide a comprehensive overview of the success of implementing GMP in tailings reclamation, as well as its impact on environmental conditions and the sustainability of the ecosystem around the PT Freeport Indonesia mining area.

Good Mining Practice (GMP) refers to a series of best practices in mining operations that aim to minimize environmental and social impacts, and ensure sustainability at every stage of mining activities [1]. GMP covers aspects such as waste management, the use of environmentally friendly technology, and ecosystem restoration after mining activities [2].

The implementation of gold mining cannot be done carelessly, therefore, the implementation of Good Mining Practice is very necessary. Because all procedures carried out will have a direct and long-term impact on the community living around the mine, the environment where the mine operates, and workers who are in direct contact with mining materials every day. Therefore, gold mining must be carried out referring to operational standards and procedures in accordance with government regulations. This is what was then hatched in Good Mining Practice (GMP), as an effort to maximize the implementation of disciplined and safe gold mining [3].

PT. Freeport Indonesia (PTFI) is a mineral mining company affiliated with Freeport-McMoRan (FCX) and Mining Industry Indonesia (MIND ID). PTFI mines and processes ore to produce concentrates containing copper, gold and silver and then markets the concentrates throughout the world and especially to domestic copper smelters, PT Smelting. Freeport Indonesia has conducted exploration in two places in Papua, namely the Erstberg mine (since 1967) and the Grasberg mine (since 1988), in the Tembagapura area, Mimika Regency, Papua Province [4].

In its operational activities to obtain gold and copper concentrates, PTFI produces tailings or mining waste sand (SIRSAT) which generally have unfavorable physical and chemical properties. Tailings waste is finely ground natural rock dregs, which are left after the concentrate is separated from the ore in the grinding plant. Physical constraints include damaged soil structure, coarse texture (dominated by sand), sensitive to erosion, low water holding capacity. Chemical constraints include low pH values and cation exchange capacity, poor nutrients and organic matter, and high heavy metal content [4].

Tailings reclamation is the process of restoring ex-mining land that has been contaminated by waste from the mining process. According to Tye [5], tailings reclamation involves various techniques such as covering tailings with fertile soil layers, returning vegetation, and controlling erosion to prevent further pollution. PT Freeport Indonesia applies this technique to improve the environmental quality around the tailings area.

Tailings that are not managed properly can result in serious water and soil pollution. Water resources contaminated by heavy metals and other hazardous substances can cause extensive ecosystem damage. According to Dwyer [6], the use of GMP in tailings reclamation can significantly reduce this impact by controlling waste discharge and preventing the spread of pollutants.

RESEARCH METHODS

Research Design

This study was conducted in the Research Mile 21 area of PT Freeport Indonesia, which is a location affected by tailings accumulation. This study uses qualitative and quantitative approaches to evaluate the implementation of GMP in PT Freeport Indonesia's tailings reclamation. Several methods used in this study include:

1. Field study: Direct observation of the condition of ex-mining land before and after the implementation of GMP.
2. Secondary data analysis: Using data from the company's annual report and previous studies on tailings reclamation.
3. Interviews: Conducting interviews with related parties at PT Freeport Indonesia, including the reclamation team and environmental management.

Population and Sample

Population is a generalization area consisting of objects/subjects that have certain qualities and characteristics determined by researchers to be studied and then conclusions drawn [7]. The population in this study were field supervisors who implemented good mining practices on mile 21 land, almost all of which were used.

The sample is part or representative of the population to be studied. Sampling for research, if the subjects are less than 100 people, all should be taken, if the subjects are large or more than 100 people, 10-15% or 20-25% or more can be taken. The sampling method in this study is using purposive sampling with inclusion and exclusion criteria.

Data Processing and Analysis

At the data processing stage, researchers collect data for the application of good mining practices on mining waste land, and questionnaires for assessment or score calculations to conclude the results of the data collected. At this stage, researchers also analyze the data that has been obtained by collecting data using questionnaires, documentation, interviews, and field surveys.

RESULTS AND DISCUSSION

This research was conducted at PT Freeport Indonesia, Mimika Regency, Central Papua Province at the Grasberg open pit mine in 2024. The location of this research is at mile 21 of PT Freeport Indonesia.

Before the implementation of GMP, the tailings area of PT Freeport Indonesia was severely damaged due to the accumulation of mining waste containing heavy metals. After the implementation of GMP, land conditions showed significant improvements with a decrease in heavy metal concentrations and improvements in soil and water quality around the tailings area [8]-[11].

Reclamation activities using Good Mining Practice on PT Freeport Indonesia Tailings are dominated by grasslands enriched by shrubs and herbs, so the reclamation activities begin with planting of *dyscamsia cloisi* grass seeds. In addition to planting forest plant species to restore the ecosystem function as before, the tailings area is also converted into productive land by cultivating seasonal agricultural crops and plantation crops.



Figure 1. Land area before GMP implementation **Figure 2.** Land area after GMP implementation

The existence of mining activities in our country is unavoidable. This is a consequence of the abundant natural wealth in our country. Good mining practices must prioritize the preservation and restoration of the natural environment. This involves protecting natural habitats, conserving biodiversity, and restoring disturbed land.

The damage caused by mining, both open and closed mining, inherits extraordinary environmental impacts. Good and proper mining management (Good Mining Practice) needs to be continuously studied and developed in current mining business activities. All activities that can disturb the community, including environmental damage, should be prevented or at least mitigated.

PT Freeport Indonesia's mining operations are carried out in Mimika Regency, Central Papua Province at the Grasberg open mine. PT Freeport Indonesia's mining activities have two important impacts, namely the placement of cover rock in the alvin ecosystem above an altitude of 4000 meters above sea level and the placement of tailings in the lowlands to the mouth of the Aikwa River. Efforts to manage both of these important impacts are carried out through a reclamation program. Reclamation in Grasberg is unique because it is carried out in an alvin ecosystem that has high endemism so that the source of plant seeds is taken from the surrounding area in the special mining business permit area in the IUPK that is still undisturbed.

In implementing reclamation activities using Good Mining Practice, PT Freeport Indonesia focuses reclamation activities on the Grasberg open pit mine area where the area will be used as a plantation area [12].

Reclamation activities carried out on a 5-hectare site using coffee and cocoa vegetation have been carried out well, although they have only reached the planting stage on 2.5 hectares of land or half of the total planned area. Coffee is planted with a planting distance of 2.5 meters x 2.5 meters, while cocoa plants are planted with a distance of 3 meters x 3 meters. This planting technique is designed to provide enough space for each plant to grow optimally and reduce competition

between plants in absorbing water and nutrients. Although the newly planted land has only reached half of the initial plan, the growth of coffee and cocoa plants in the area that has been passed shows promising results, with plants growing well and stably. The application of coffee and cocoa vegetation is expected to help restore the ecosystem, reduce erosion, and increase soil fertility in reclamation areas in the long term.

Indicators of success found in this evaluation include good tailings waste management, with the application of technology that minimizes water and soil pollution, strict supervision and monitoring of water and air quality around the reclamation site to ensure that waste does not pollute the surrounding environment, effective revegetation where the plants planted have a high success rate in growing and developing, helping to restore disturbed soil ecosystems [13]-[15].

From an environmental aspect, the success of PT. Freeport Indonesia's tailings reclamation can be seen from the ecosystem restoration efforts implemented in the former mining area. Some of the results recorded are: Improvement in the quality of soil that was previously contaminated with heavy metals to be more suitable for planting, reduction in pollutant levels in water and soil due to gradual reclamation, Success of the revegetation program, where plants successfully grow in the reclamation area, improving soil stability and preventing erosion.

Table 1. Stages of coffee and cocoa growth

Growth Stages	Coffee (<i>Coffea spp.</i>)	Chocolate (<i>Theobroma cacao</i>)
Seedbed Period	2-3 weeks	5-7 days
Seedling Stage	6-12 months	6-12 months
Initial Growth	2-3 years	1-2 years
Beginning of Fruiting	3-5 years	3-5 years
Productive Age	20-30 years	25-30 years

From the table data above, it can be concluded that cocoa plants tend to grow faster than coffee, with a shorter time to start bearing fruit and reaching peak productivity.

Good Mining Practice requires responsible and efficient waste management to prevent environmental pollution. This includes the management of plants that can be used as plant fertilizer in the reclamation process.

Based on this, revegetation is needed by utilizing pioneer plant species such as grass groups. Plant species from the Brassicaceae group can also function as bioremediation. Local plant species will be very helpful and can minimize changes in the ecosystem in the local location.

Implementation of Good Mining Practice using pistia plants taken from the PT Freeport Indonesia area and managed to be used as natural fertilizer. Pistia plants are one of the aquatic weeds that have the potential to be used as organic fertilizer for plants. Continuous use of organic fertilizers over a certain period of time will make the soil quality better compared to inorganic fertilizers. For soil, organic matter has the function of binding soil particles so that it can improve soil structure. In addition to the benefits of pistia plants which are good as organic fertilizer, we can also make the PT Freeport Indonesia yard clean, especially in the Gorong - Gorong area.



Figure 3. Taking Pistia Plants in the Gorong-Gorong area

After the pistia plants are taken from PT Freeport Indonesia in the Gorong-Gorong area, they are then transported to mile 21, then dried for 5-7 days. The plants will disintegrate by themselves, and are ready to be used as organic fertilizer for plants.



Figure 4. Pistia Storage and Drying at Mile 21

Organic pistia material is more easily decomposed in the soil and its mineral content is more quickly available for plant growth. Utilization of organic pitsia material can provide good nutritional intake in the form of fertilizer or fresh plants because it can increase nutrients in the soil, fast vegetative reproduction, easy to obtain, and can also improve the physical, chemical, and biological properties of the soil. So that the pitsia plant which was originally only a weed can be used as one of the organic materials that are useful for soil and plants.

The types of soil in the remaining tailings land of PT Freeport Indonesia include:

1. Whole sand without any soil mixture. Plants planted in whole sand areas can make plants fertile, but without fertilizer, plants cannot be stimulated to grow because they do not get nutrients. The presence of a mixture of pistia fertilizer can help stimulate plants to grow well.
2. Soil mixed with sand. Plants planted in a mixed sand soil area can make plants more fertile and grow faster. If added with fertilizer, the plants will be more fertile and grow faster, because the soil mixed with sand will remain loose and there will be no blockage of fibrous roots.
3. Soil without a mixture of sand. This soil makes plants unable to grow well because the hard and not always loose soil texture can cause blockage of the roots so that plants do not get oxygen and nutrients that make plants infertile or die.

Table 2. Analysis of soil texture on former gold mining land

Fraction	Mark (%)
Sand	49,86
Silt	20,52
Clay	29,62

From the table above, it can be seen that the percentage value of the sand fraction is higher when compared to dust and clay and when viewed from the soil texture triangle, this ex-mining land is included in the sandy clay loam texture. The high sand content in this soil is caused by the soil material used in the filling at the beginning of mining activities.

The characteristics of the physical and chemical properties of tailings soil are different from the soil structure in general. The characteristics of the physical properties of tailings are often found in sandy soil structures with high soil surface temperatures. For the chemical properties of tailings, several excessive heavy metal elements and soil pH are found to be too high or low, while other nutrients needed for plant growth are less available. Therefore, land like this is classified as infertile.

Soil such as the character of tailings land cannot be used directly for agricultural land, plantations or the like. The stability of contaminated land is important for all components of life in the habitat, so land rehabilitation is the main thing.

Revegetation is a planting activity where the main purpose of the revegetation activity is to restore the function of the forest as before mining with native or local plants (native species) which are natural vegetation in the PT Freeport Indonesia area and to restore land conditions as close as possible to their original conditions so that environmental stability can be maintained for the future. revegetation activities in the mile 21 area of PT Freeport Indonesia are by planting coffee and cocoa tree seedlings. Planting coffee and cocoa tree seedlings in the remaining tailings area using organic pistia fertilizer can improve soil structure and stimulate plant growth.



Figure 5. Coffee and Cocoa Tree Seedling Planting Activities

The reclamation area in Grasberg is dominated by grasslands enriched by shrubs and herbs, so the reclamation activity begins with planting coffee and cocoa tree seedlings, the provision of seedlings is carried out using seedlings that come from direct uprooting from the nursery or the use of seeds in the reclamation method using sowing - spraying or hydroseeding.

Nursery facilities are used to grow seedlings of shrub and herb species collected using natural uprooting from the nursery. Reclamation of the tailings sedimentation area in the lowlands is carried out in the double embankment area, namely between the old west embankment and the new west embankment to the Aikwa River estuary where very fine tailings settle and form new land. Tailings reclamation at the Aikwa River estuary uses propagules of the *Rhizophora mucronate* species which do not require nursery facilities.



Figure 6. Planting *Rhizophora Mucronate*

Based on the experience of reclamation using mangrove plants since 2004, the use of propagules guarantees greater growth success compared to using seedlings developed using luxury. Propagule is collected from natural mangrove forests and planted directly in the reclamation area, nursery facilities are needed for tailings reclamation in double embankments. In addition to planting forest plant species to restore ecosystem functions to their original state, the tailings area is also converted into productive land by cultivating seasonal agricultural crops and plantation crops.

The role of luxury is very important in providing quality seedlings that guarantee that plants become productive and produce good harvests, seedlings produced from luxury facilities or PT Freeport Indonesia nurseries are not only used for reclamation programs, but are also provided for social functions or investments where plant seedlings are donated to environmental care community groups that carry out city greening programs and areas around rivers and plantation seedlings such as cocoa and coffee are given to the community for the economic development of the Fujisuko community in and around the PT Freeport Indonesia IUPK area.

PT Freeport Indonesia has implemented Good Mining Practice from the aspect of environmental conservation and social welfare. PT Freeport Indonesia can minimize its negative impacts, strengthen relationships with local communities, and ensure long-term sustainability of operations, one of which is the implementation of Good Mining Practice (GMP) using pistia plants around PT Freeport Indonesia to be used as natural fertilizer to maximize the reclamation process and work together with the community which is a positive step in strengthening the relationship between the company and the local community while providing a positive impact on the environment and the local economy.

PT Freeport Indonesia understands the importance of sustainable mining operations to preserve the environment in the long term. PT Freeport's success in changing the tailings deposition area into productive land for agricultural and forestry cultivation activities is one proof of the success of PT Freeport Indonesia's environmental program, which is certainly inseparable from the role of the best sons and daughters of Papua in continuing environmental management efforts.

Planting coffee, cocoa, and mangrove seedlings shows PT Freeport Indonesia's commitment to maintaining the sustainability of the environment around the mining area. In addition, the use of surrounding plants as organic fertilizer is very beneficial for increasing production in both quality and quantity, reducing environmental pollution, and improving land quality sustainably in mining environments.

The implementation of GMP in tailings reclamation at PT Freeport Indonesia shows a positive impact on the environment. The use of environmentally friendly management techniques has succeeded in reducing the impact of erosion and contamination, and increasing the sustainability of local ecosystems [16]. In addition, the existence of a continuous monitoring program ensures that environmental conditions are maintained in the long term.

CONCLUSION

Based on the results of this study, it can be concluded that the implementation of Good Mining Practice in PT Freeport Indonesia's tailings reclamation activities has shown significant success. Although challenges remain, especially in terms of land recovery in a short time, the implementation of GMP has succeeded in improving the quality of soil, water, and biodiversity in the tailings area. The area of remaining tailings land before reclamation using Good Mining Practice shows barren/open land, while the area of land after reclamation using Good Mining Practice throughout the Mile 21 area has seen many green plants that grow well. The impact of using the application of Good Mining Practice on ex-mining land shows success because reclamation activities that already have good planning will provide a maximum level of success and reduce the level of community unrest.

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