Natural revegetation of tailing deposited on agricultural area in Buru, Maluku

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Abstract. Tailing deposited on rice field in Buru District Indonesia poses a severe environment problem since rice does not grow on tailing with low fertility. The aim of this study was to verify the natural vegetation grown naturally on mercury contaminated tailing which covered the top soil of rice field, as well as the development of legume tree, Trembesi, Rain Tree (Albizia saman F. Muell) grown in purpose between the pioneer plants. Plant succession observations were carried out for 2.5 years on 524 m² of rice fields. As presumed, the succession was similar to the general pattern of primary revegetation. The study area increased diversity of weed as primary vegetation which influenced the better growth of Trembesi. A total of 17 natural plants were recorded as pioneer weed as well as late colonizer. Weed grazing by livestock, mainly cow, promoted the diversity of plants due to their role as seed dispersal agents.

1. Introduction
Gold mine tailing of Buru Island, Maluku contains high mercury concentration from the ore extraction process. Mercury-contaminated tailing was disposed into nearby rice fields after the mine was closed. Residual mercury in the tailing may leach into subsoil and eventually reaches the ground water. This poses a serious environmental problem, considering the toxic nature of mercury in plant and animal cell.

Tailings are characterized by very fine grinding rocks dominated by silt or clay, high concentrations of trace elements but low concentration in organic matter as well as nutrient for plant growth [1,2,3], low in organic matter (<1%), sandy texture (>50%) and high permeability [4]. Mercury level in gold tailings are generally higher than other tailings and has become a long ecological issue. In extreme cases such as tailing disposition in Mandzoro River in South Africa, Hg concentration ranged between 161.8 to 1999.1 µg/g dry weight [5]. The average mercury content in the tailing from Mount Botak, Buru Island was between 13.7 to 166.1 µg/g dry weight [6].

One of the impacts of mercury deposit in tailing is the elimination of native vegetation. Soil rehabilitation based on vegetation is a good method to remediate contaminated agricultural soils. Reclamation of tailings can be achieved through the establishment of permanent vegetation or...
Revegetation by natural succession is an important factor in ecological and aesthetic function restoration of post-mining landscapes [8]. Generally, disturbed ecosystem may undergo natural revegetation through spontaneous plant succession. Tailing deposit creates a new soil order without clear horizon, Entisols [9]. Community of early vegetation grown on unformed soil is called primary succession. Pioneer plants that grew through primary succession may contribute to better soil physical and chemical characteristics through rhizosphere effect. This condition increase soil carrying capacity to support plant growth. Field study to examine pioneer plant species that grew as primary succession in Buru Island tailings is necessary for ecological purposes. In this study naturally grown vegetation on mercury tailing contaminated rice field and the development of Trembesi (*Albizia saman* F. Muell) planted between the pioneer plants were examined.

2. Materials and Methods

2.1. Site description

Gold mine was located in Botak Mountain, Wamsait Village, Waeapo Subdistrict, Buru District, Maluku Province, Indonesia (Figure 1). The 125 hectares mining operation started in 2012 and closed officially by government of Maluku on 2015. At this moment, some local inhabitants still utilize the mine as main living source. Underground hard rock mining techniques was used by the illegal miner to excavate gold from the site.

![Figure 1. Botak Mountain in Buru district, an intensive legal mining location circa 2012-2016](image1)

Figure 2. Local plants at February 2017 dominated by grass and sedges (left) that protect Trembesi (circled) grown among the grasses (right).

Some mined ore was transported into agricultural field in Waelo village, Waelata Subdistrict where gold was extracted using mercury. A Waste-dumping area covers approximately 524 m² tailing dump
area with the average depth of 5 meter. This location is next to agricultural area, specifically rice field. From 2016 analysis, mercury concentration in tailing was 566.8 mg/kg with the additional of 46.38 mg/kg of arsenic. Naturally, mercury and arsen concentration in soils are between 0.008-7.45 mg/kg [10] and 0.1 to 67 mg/kg respectively [11].

2.2. Methods
Descriptive method was applied in the study of land cover (vegetation) within tailing deposit area. Major vegetation survey, mainly weeds exploration and inventory, were carried out based on visual observation. When the study started in May 2016, the main vegetation of the contaminated area are crabgrass (Family Poaceae) and sedges (Family Cyperaceae) grown in several spots. Weeds were classified based on morphology, nature of stem and parasitic characteristic. Vegetation variation and succession observations were conducted three times: on May 2016, February 2017, and August 2018.

On December 2016, a total of 20 Trambesi (Albizia saman F. Muell) from Ambon were planted on purpose on weed-free tailing, and between crabgrass and sedges on contaminated site. Trembesi seedlings were obtained from Ambon city, Maluku province. Each plant hole received one kilogram of composted manure mixed with tailing and 25 g of Nitrogen-Phosphorus-Potassium fertilizer before individual seedling was planted.

Survival rate of trembesi were calculated in 2017 and 2018. Trembesi growth was observed based on some morphological characteristics. Plant height, number of leaf stalk, leaf stalk lengths, stem diameter, canopy diameter, and number of twigs were measured. All parameters except stem diameter were measured by measuring tape. Diameter of stems were measured by using callipers.

3. Results and Discussion
Several dozens of primary successor species were observed in the tailing deposit, and mainly dominated by grass and sedges weeds (Figure 3). We found only two crabgrass, Digitaria ischaemun and Eleusine indica; and four kind of sedges of Cyperus, Fimbristylis and Imperata in 2016 (Table 1). Relatively massive broad leaves weeds development was found at mid-2018 after rainy season at the late 2017 and beginning of 2018. From May 2016 to August 2018, a total of 4 crabgrass, 8 sedges and 5 broadly leaves weeds naturally grown on tailing (Table 1 and Table 2). All grass and sedges were not parasitic and utilize tailings as growth medium. Livestock grazing contributes to seed distribution, resulted vegetation expansion throughout the area. Grass is a good vegetation cover to minimize wind erosion and dust [12], and also can be used as grazing food as long as mercury or other toxic substance is below permissible concentration.

Primary successor plants found in the area were common throughout the region in Buru Island as well as other part of Indonesia. Establishment of native vegetation is important to ensure the progress of land rehabilitation. The growth requirements of this native species were matched to harsh site conditions. Native plants provide essential elements to help other native plant and even introduced plants to grow and to establish their population [13].

Native plants are expected able to be permanent vegetation in soil reclamation. Indigenous plants reconstruct root zone system faster than non-native plants; this ability can improve physical structure and chemical characteristics the root zone [14]. Nutrient cycle in the whole root system, specifically in the rhizosphere, may induce nutrient availability and dependent on the water saturation [15]. In study area, it was clear that growth of Trembesi was supported by root zone system of native plants. It grew better in between creeping grass and tall grass as the result of root zone protection provided by the two weeds.

Observation on 2017 showed that the entire Trambesi seedlings planted on vegetation-free tailing died, but Trambesi grown between grass and sedges were survived. Nine Trambesi were grown good enough, and only one plant exhibited stunted growth based on August 2018 observation (Table 3). Trambesi grew relatively fast and can reach up to 1.5-3 meters in two years. If planted in soil, it can reach up to 15-25 meters in height.
Figure 3. Primary successor in barren tailing on rice field in Buru Island consist of grass of Poaceae family (left) and Sedges of Cyperaceae (right). Numbers is referred for plant genus/species in Table 1.

Root establishment retain water to the plant themselves and for new vegetation which hence create plant ecosystem. This illustrates the rehabilitation process in root zone establishment and development which play an important role in revegetation with sustainable plant communities [16]. Several benefits of pioneer vegetation application includes better soil moisture and provide root protection through rhizosphere effect. This process is important for soil formation with tailing as parent material.

Table 1. Plant succession in tailing during three consecutive year

| Weed/primary successor | Photograph reference number | Year 2016 | Year 2017 | Year 2018 |
|------------------------|-------------------------------|-----------|-----------|-----------|
| Grass (Poacea)         |                               | Digitaria ischaemun | Digitaria ischaemun | Digitaria ischaemun |
|                        | 1                             | Digitaria ischaemun | Digitaria ischaemun | Digitaria ischaemun |
|                        | 2                             | Eleusine indica | Eleusine indica | Eleusine indica |
|                        | 3                             | - | Cynodon dactylon | Cynodon dactylon |
|                        | 4                             | - | Digitaria sp. | Digitaria sp. |
| Sedges (Cyperaceae)    | 5                             | Cyperus compressus | Cyperus compressus | Cyperus compressus |
|                        | 6                             | - | Fimbristylis miliacea | Fimbristylis miliacea |
|                        | 7                             | Fimbristylis ferruginea | Fimbristylis ferruginea | Fimbristylis ferruginea |
|                        | 8                             | - | - | Cyperus iria L. |
|                        | 9                             | - | Cyperus difformis | Cyperus difformis |
|                        | 10                            | Cyperus sp. | Cyperus sp. | Cyperus sp. |
|                        | 11                            | Imperata cylindrica | Imperata cylindrica | Imperata cylindrica |
|                        | 12                            | - | - | Brachiaria purpurascens |
Table 2. Local broad-leaves weeds grown in tailing deposit area in 2018

| Species               | Common name Eng/Ind. | Family       |
|-----------------------|----------------------|--------------|
| Ipomea sp.            | Morning Glory/kangkung liar | Convolvulaceae |
| Hedyotis corymbosa    | Starviolet           | Rubiaceae    |
| Sphagneticola trilobata (L.) Pruski | Wedelia   | Asteraceae   |
| Mimosa pudica L.      | Sleepy plant/Putri Malu | Fabaceae     |
| Blechnum sp.          | Fern/Paku            | Blechnaceae  |

Table 3. Growth of Trembesi planted between plant successor grown naturally in tailing

| Plant Code | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  |
|------------|----|----|----|----|----|----|----|----|----|
| Plant height (m) | 2.55 | 1.54 | 1.32 | 0.76 | 2.49 | 1.97 | 1.13 | 3.75 | 1.20 |
| Number of leaf stalk | 20  | 7   | 5   | 11  | 5   | 8   | 67  | 5   |
| leaf stalk lengths (cm) | 26.2 | 19.3 | 10.4 | 12.5 | 13.5 | 16.2 | 7.3  | 34.8 | 8.4 |
| Stem diameter (cm)  | 5.47 | 2.81 | 19.52 | 7.11 | 4.34 | 2.83 | 1.87 | 6.85 | 2.31 |
| Canopy diameter (m) | 1.16 | 0.22 | 0.21 | 0.25 | 0.54 | 0.17 | 0.16 | 0.29 | 0.15 |
| Number of twigs    | 1   | 2   | 2   | 4   | 7   | 30  | 3   | 11  | 3   |

Different plant development was showed by nine Trembesi tree. Plant growth might be influence by water and nutrient competition from weeds around the tree. However the height of tailing in the area where Trembesi seedlings were planted might also affect their growth.

4. Conclusion
The succession was similar to the general pattern of primary revegetation. After 27 months, a total of 4 crabgrass, 8 sedges and 5 broadly leaves weeds naturally grown on tailing. Grazing the weeds by livestock mainly cow promote the diversity of plants due to their role as seed dispersal agents. A total of 17 natural plants were recorded as pioneer weed as well as late colonizer. Increased diversity of weed as primary vegetation supported Trembesi growth. In weed-free areas, Trembesi seedling planted did not survive. But in weed-covered tailings, nine out of ten Trembesi planted were able to survive.

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