Research Article

Soil characteristics of post-mining reclamation land and natural soil without top soil

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Abstract: Generally, Nickel mining was conducted by the open-pit mining method which caused change of soil physical, chemical and biological properties. Reclamation land often experienced various obstacles, including microclimate conditions that were not yet suitable, overburden chemical, physical and biological properties, difficulty in obtained ameliorant, and lack of top soil. Top soil that was used for post-mining reclamation land activities was obtained from the soil is not yet mined locations (natural soil). This study was aimed to determine differences in soil characteristics (soil physical, chemical and biological properties) on post-mining reclamation land with natural soil without top soil. The research used survey methods conducted on post-mining land of PT. INCO. Soil samples were taken at 2 locations, namely, the location of post-mining reclamation (Harapan) and location that had not mined but the top soil had peeled to a depth of ± 1 meter (Shelly). The results showed that the soil physical and biological properties at Shelly location were relatively better than those at Harapan location. The soil at Harapan and Shelly locations had available P content and exchangeable-Na was low, and exchangeable-Ca was very low. Exchangeable-Mg was high at Harapan, while at Shelly was low-moderate. The exchangeable-K content of the soil in the Harapan location was moderate than Shelly location. The soil at Harapan location had a very high Base Saturation (BS) with a pH of 6.7 than Shelly location had high BS with a pH of 5.8. It is necessary to improve post-mining reclamation land management.

Keywords: natural soil, nickel, post-mining reclamation, soil characteristics, top soil

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Introduction

Mining is a vital industry that was economical for some countries and provides great economic benefits so that sustainable development needs to be done because it relates to national and regional income and provides benefits to communities around the mine area (Sumantri et al., 2008). Indonesia is known as a country with high mineral potential. Indonesian mineral resources can be divided into 3 major groups, namely are energy minerals (oil and gas), metal minerals (nickel, lead, gold, silver, copper, etc.), and non-metallic minerals (limestone, clay, quartz sand, and etc). In the utilization of metal mineral resources, mining was conducted in locations that have metal mineral content such as Nickel mining at PT. INCO, Sorowako, which was scattered almost along the Verbeek mountains in South Sulawesi in a very large number. Nickel ore was obtained by applying the open-pit mining method. This method was conducted by stripping the soil and nickel overburden. This stripping activity causes land degradation which includes changes in the soil physical, chemical and biological properties, such as the opening of forest vegetation areas, loss of nutrients and soil organic matter content, soil compaction, topographic changes, pollution, changing soil composition, erosion, and sedimentation, and decrease in the number of soil microorganisms (Sariwahyuni, 2012; Oktorina, 2017). In terms of restoring the capability of the environment, the rehabilitation of sustainable post-mining land was the most important part, so that...
the land can function again as a medium for growing crops. Efforts to rehabilitate land conducted by the Nickel mining were focused on land reclamation (Ambodo, 2008). This was because every company that carries out mining activities was required to carry out reclamation of post-mining land (Patiung et al., 2011). Reclamation is the process by which derelict or highly degraded lands are returned to productivity, and by which some measures of biotic function and productivity is restored (Singh et al., 2002; Lone et al., 2008; Kavamura and Esposito, 2010). Reclamation strategies must address soil structure, soil fertility, microbe populations, top soil management, and nutrient cycling in order to return the land as closely as possible to its pristine condition and continue as a self-sustaining ecosystem (Sheoran et al., 2010). Top soil has a soil depth of ± 10-20 cm. This layer also contains the main nutrients for the growth of roots, and many contain nutrients and the air is available for plants so that top soil is an essential component of land reclamation in mining areas (Ghose, 2001). Top soil that was used for post-mining reclamation land activities was obtained from the soil is not yet mined locations (natural soil). Revegetation on post-mining reclamation land has not been shown optimal plant growth. Therefore, it is necessary to assess the soil physical, chemical and biological properties on post-mining reclamation land with a purpose to get productive soil for its sustainable and beneficial use. Natural soil without top soil affects soil solum as a growing medium for plants that cannot support normal plant growth so that the soil is unproductive. This study was aimed to determine differences in soil characteristics (soil physical, chemical and biological properties) on post-mining reclamation land with natural soil without top soil. This information can be used as consideration for companies in an effort to the success of post-mining land reclamation.

Materials and Methods

The research was conducted in the mining concession area of PT. INCO Sorowako South Sulawesi. Soil analysis was conducted at the Laboratory in the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University.

Materials

Soil samples derived from natural soil which had been peeled top soil of ± 1 meter in 2004 years and had been begun naturally grow local plants such as Bonu (Thricospermum buretii) and Trema orientalis which were ± 4 years old (Shelly), while the soil on reclaimed land was revegetated ± 4 months (Harapan).

Methods

This research was conducted using a survey method. As preparation for research, field observation activities were conducted such as determining slopes and determining the location of soil sampling. Taking soil samples for soil chemical and biological properties was conducted randomly and composite while soil physical properties at certain points in each research location.

Soil sampling for analysis of soil physical properties

Soil sampling in each location was conducted by using a ring sampler at a depth of 0-30 cm and 30-60 cm as many as 3 replications in each location. Undisturbed soil samples on the ring were wrapped in aluminium foil so that the water content remains as the first condition. The aggregate soil samples were taken at a depth of 0-30 cm and 30-60 cm.
The soil aggregate was air-dried first before being analyzed.

**Soil sampling for analysis of soil chemical properties**

Collecting soil samples in each location for analysis of soil chemical properties were taken randomly and composited at a depth of 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, and 50-60 cm.

**Soil sampling for analysis of soil biological properties**

Soil sampling for analysis of soil biological properties at the research locations was taken randomly and composited at a depth of 0-10 cm. The composite soil before analysis was put in a closed plastic and then stored in an icebox.

**Soil Analysis**

The physical properties analysis consisted of Bulk Density (BD) using the ring sampler method, aggregate stability using the dry and wet sieving method, and texture using the pipets method. The soil was air-dried after collection and sieved through a 2.00 mm and 0.5 mm, thus producing air-dried fine soil. The soil that has been air-dried was used for the analysis of the soil chemical and biological properties. The chemical properties analysis consisted of pH in H$_2$O and KCl, organic C, total N, available P, Cation Exchange Capacity (CEC) and Base Saturation (BS), bases that exchanged (Ca, Mg, K, and Na), and micronutrients available (Fe, Cu, Zn, Mn). The pH in H$_2$O and KCl (1:1 weight) was determined by the glass electrode method. The organic C content was determined by Walkley and Black method. The total N content was determined by the Kjeldahl method. The available P content was determined by the Bray-I method. The CEC and quantification of the bases that exchanged (Ca, Mg, K, and Na) extracted with 1 N NH$_4$Ac pH 7.0, K and Na by flame photometry, and Ca and Mg by Atomic Absorption Spectrophotometer. Micronutrients available (Fe, Cu, Zn, Mn) extracted with DTPA. Soil biological properties analysis consisted of total microorganisms, Fungi, carbon biomass of microorganisms, and soil respiration. Total microorganism and Fungi were measured by the plate count method, carbon biomass of microorganisms was determined by the sonification method and soil respiration by CO$_2$ Evolution method.

**Results and Discussion**

**Soil physical properties on post-mining land and natural soil without top soil**

The soil physical properties at Shelly were better than Harapan (Table 2). This was based on bulk density in the depth soil of 0-30 cm at Harapan was higher than Shelly. The soil at Harapan has silty loam texture which belongs to the medium texture class, while at Shelly it varies in the depth soil of 0-10 cm (silt) with medium texture class, 10-20 cm (silty clay) with slightly fine texture class and 20-30 cm (silty clay loam) with a class of fine textures. Thus, at the depth layer of 0-30 cm at Harapan, it has a lower porosity than the soil at Shelly. The position of porosity is very important because it greatly affects the physical properties (soil structure and aeration), soil chemical (nutrient movement) and biology (the activity of soil microorganisms) that affect plant growth.

| Physical properties | Harapan | Location | Shelly |
|---------------------|----------|----------|--------|
| Bulk density (g/cm$^3$) | 1.50 | 0.65 | 1.03 | 1.46 |
| Porosity (%) | 43.38 | 75.38 | 61.09 | 44.92 |
| Aggregate stability class | Slightly stable | Stable | Less stable | Stable |

The depth of soil 30-60 cm at Harapan had a lower bulk density than Shelly because the porosity of the soil at Harapan was higher than at Shelly. This was caused higher of soil organic matter at Harapan than Shelly (Table 3). This condition can occur because the soil on the post-mining reclamation area is not the original soil profile, where there has been a mixture of top soil and overburden. This is thought the layer overburden to be at the top. The stability of soil aggregates at Harapan and Shelly locations at soil depths of 0-30 cm was low. According to the aggregate stability index classification, Harapan soil was classified as slightly stable criteria and Shelly was less stable. This is taken of top soil with heavy equipment that can be destroyed the aggregates that have been
formed, both in top soil and subsoil. Compost spread in top soil as a reclamation effort at Harapan has not been able to improve aggregate stability. However, Shelly was protected by litter leaves from local plants. Therefore, the soil at the Harapan location was easily damaged by rainwater and easily eroded, especially on sloping land so that soil organic matter will be eroded and the soil becomes compact. The movement of water and air is bad and affect the chemical and biological processes of the soil.

**Soil chemical properties on post-mining land and natural soil without top soil**

Soil chemical properties were assessed based on Balai Penelitian Tanah (2005). The soil organic matter at Harapan was relatively lower than Shelly, especially at a soil depth of 0-30 cm (Table 3). Soil organic matter affects the soil ability to provide nitrogen. Therefore, organic C and total N content at Harapan was very low, while at Shelly it was low (soil depth of 0-10 cm). The low content of soil organic matter affects CEC. The organic matter contents at Shelly come from a litter of leaves of local plants such as Bonu (*Thricospermum buretii*) and Trema orientalis decomposed and the fine roots of the plant. In addition, soil organic matter at Shelly is thought to originate from the natural forest around the study site, where the location of Shelly is lower than natural forest. In this case, there was accumulated of forest litter on the soil surface at Shelly. The content of soil organic matter in the location of Shelly come from litter has not been able to supply high levels of organic C and macronutrients. The content of exchangeable Mg at Harapan was classified as high and with increasing depth, exchangeable Mg was higher and higher than the soil at Shelly (Table 4). This is caused by the influence of parent material formed from serpentine ([3MgO.2SiO\(_2\).2H\(_2\)O] rock where Magnesium is higher than Calcium (Foth, 1990).

**Table 3. Organic C, total N, available P in research locations.**

| Depth (cm) | Organic C (%) | Total N (%) | Available P (ppm) |
|-----------|---------------|-------------|------------------|
| Harapan   |               |             |                  |
| 0-10      | 0.09          | 0.017       | 5.67             |
| 10-20     | 0.09          | 0.020       | 5.87             |
| 20-30     | 0.35          | 0.031       | 4.78             |
| 30-40     | 0.55          | 0.025       | 5.94             |
| 40-50     | 0.39          | 0.023       | 4.73             |
| 50-60     | 0.90          | 0.004       | 6.48             |
| Shelly    |               |             |                  |
| 0-10      | 1.11          | 0.154       | 5.31             |
| 10-20     | 0.57          | 0.070       | 6.74             |
| 20-30     | 0.74          | 0.090       | 5.80             |
| 30-40     | 0.55          | 0.075       | 7.22             |
| 40-50     | 0.19          | 0.033       | 7.64             |
| 50-60     | 0.47          | 0.025       | 6.35             |

For the content of exchangeable Mg at Shelly decreases with increasing depth, it is assumed that the parent material does not originate from serpentine rocks. Base saturation was very high at Harapan because the cations absorbed and exchanged were dominated by basic cations, especially Mg. These bases were thought to derive from the addition of compost, top soil, and differences in the bases content from the parent material. However, the CEC at Harapan was very low and Shelly was low.

**Table 4. pH and bases that exchanged in research locations.**

| Depth (cm) | pH H\(_2\)O | Exchangeable Bases (mg/100g) | CEC (mg/100g) | BS (%) |
|-----------|-------------|-----------------------------|---------------|--------|
|           | Ca          | Mg                          | Na            | K      |                  |
| Harapan   |             |                             |               |        |                  |
| 0-10      | 6.69        | 1.43                        | 2.9           | 0.20   | 0.34             | 2.49 | 100 |
| 10-20     | 6.65        | 1.04                        | 4.12          | 0.15   | 0.28             | 3.20 | 100 |
| 20-30     | 6.58        | 0.73                        | 4.15          | 0.15   | 0.26             | 2.97 | 100 |
| 30-40     | 6.70        | 0.98                        | 12.33         | 0.09   | 0.23             | 3.32 | 100 |
| 40-50     | 6.85        | 1.00                        | 11.50         | 0.13   | 0.22             | 4.25 | 100 |
| 50-60     | 6.75        | 1.02                        | 11.67         | 0.17   | 0.23             | 4.15 | 100 |
| Shelly    |             |                             |               |        |                  |
| 0-10      | 5.81        | 1.04                        | 3.48          | 0.15   | 0.27             | 7.63 | 64.83 |
| 10-20     | 5.61        | 0.85                        | 1.43          | 0.18   | 0.20             | 4.38 | 60.75 |
| 20-30     | 5.50        | 0.82                        | 1.27          | 0.11   | 0.19             | 5.25 | 45.42 |
| 30-40     | 5.28        | 0.76                        | 0.77          | 0.12   | 0.21             | 5.22 | 35.59 |
| 40-50     | 5.72        | 0.55                        | 0.60          | 0.16   | 0.14             | 5.16 | 27.98 |
| 50-60     | 5.77        | 0.74                        | 0.68          | 0.10   | 0.14             | 5.54 | 29.91 |

CEC = Cation Exchange Capacity, BS = Base Saturation
The low CEC is a limiting factor for plant growth. This affects the availability and solubility of basic cations. If CEC is low, the soil will not be able to absorb and provide nutrients for plant growth. Top soil materials require better handling during removal, storage, and application so as to preserve soil physical properties, nutrients, SOC, and CEC (Shrestha and Lal, 2011).

**Soil biological properties on post-mining land and natural soil without top soil**

The organic matter at Shelly was relatively higher than Harapan, where the respiration of soil microorganisms related to the content of soil organic matter. High respiration rates indicate a high total microorganism population. Soil microorganism biomass (C-mic) has a very close correlation with other soil biological properties such as total and soil microorganism activity.

Microbes use carbon as body shape. The activity of soil microorganisms can be seen from the C content derived from soil carbon microorganisms (C-mic). Some natural amendments that can stimulate the microbial activity of the soil, such as wood residues, sewage sludge, sawdust, or animal manures which can provide nutrients especially N and P and organic C to the soil (Papadopoulos et al., 2015). At a slightly acidic soil pH, fungi dominate because bacteria and actinomycetes cannot live well in these conditions. In addition, the fungi population was high in soils with higher organic C content compared to soils with low organic C content. This is because the fungi are heterotrophs that use organic C as their energy source. Fungi are also aerobic so they need oxygen. Thus, the fungi population at Harapan land was lower than Shelly (Table 5).

**Table 5. Differences in respiration rate, C-mic, total fungi, and total microbes.**

| Location | Fungi         | Total microbes | Respiration | C-mic  |
|----------|---------------|----------------|-------------|--------|
| Harapan  | 8.9 x 10^3    | 3.6 x 10^7     | 0.0463      | 838.69 |
| Shelly   | 32.6 x 10^3   | 8.9 x 10^7     | 0.0531      | 916.06 |

**Conclusion**

The soil physical and biological properties at Shelly were relatively better than Harapan. This was based on physical properties at a depth of 0-30 cm at Shelly of bulk density was lower and higher porosity than at Harapan. Biological properties showed total fungi, total soil microorganisms, respiration of soil microorganisms and C-mic on the soil at Shelly location higher than at Harapan. At a depth of 0-10 cm, the soil chemical properties (organic C, total N, and CEC) included very low at Harapan, while at Shelly it was low. The soil at Harapan and Shelly locations had available P content and exchangeable-Na was low, and exchangeable-Ca was very low. Exchangeable-Mg was high at Harapan, while exchangeable-Mg was low until moderate at Shelly. The exchangeable-K content of the soil at Harapan location was moderate than Shelly location. The soil at Harapan location had a very high BS with a pH of 6.7, then Shelly had high BS location with a pH of 5.8. It is necessary to improve post-mining reclamation land management.

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