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IMPACT OF TIN MINING ON SOIL PHYSIO-CHEMICAL PROPERTIES IN BANGKA, INDONESIA

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Abstract

Surface mining, including tin mining, is the most common mining practice in Indonesia. The existence of mining ore or minerals close to the surface soil is the reason for carrying out this mining method. The process of mining surface resulted in the change of land landscape, which may cause soil erosion and even flood. It has caused various ecological and environmental problems, including soil degradation. This study describes soil physio-chemical properties impacted by surface tin mining in Bangka, Indonesia. Soils were collected from three different land use in natural forest, agroforestry, and post tin mining area in Bangka Regency, Province of Bangka Belitung Island. Five-spot soils were sampled from each site. Each site had three replication of the sampling area. The plot size for each site is about 200-500 m^2. Soil texture, pH, total N, available P, exchangeable K, organic carbon, C/N ratio, CEC, Al^{3+}, and H^+ were analyzed. The results showed that mining decreased organic carbon, total N, available P, exchangeable K, and CEC. Mining changed the soil texture to be dominated by quartz sand. These results indicate that mining is significantly deleterious to soil fertility, therefore, it is potential as a limiting factor for plant growth, which could be a hamper for restoration efforts of post tin mining areas.

Keywords*: tin mining, restoration, soil physiochemical properties, soil degradation*

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1. INTRODUCTION

As an important industry, tin mining contributes to economic development in Indonesia. The high world`s demand for tin leads to the increase in tin mining. About 30% of world tin production comes from two Indonesian islands, Bangka and Belitung, which have been mined since 1668 (Irawan et al., 2014). In 2013, Indonesia was the world`s leading tin exporter. Indonesia was the second highest mine production in 2013 (95,200 tons) and 2014 (84,000 tons) after China (110,000 tons in 2013 and 125,000 tons in 2014) (US Geological Survey, 2015).

The process of tin mining by simple washing using a sluice box is a common method in Indonesia. This approach is based on a significant weight differential between tin and gangue minerals, which are primarily quartz. The sluice box will hold the tin ore, while the water flow will carry the gangue minerals (Hutahaean and Yudoko, 2013). There are four main activities of the process of open tin mining that significantly influence environmental quality: (1) stripping the topsoil, (2) disposing of stripped material, (3) making dams (voids), and (4) washing (leaching) and disposal of tailings (Adhiyatama, 2014).

Aside from the substantial economic benefits, this tin mining activity also causes severe damage to the environment, which is a major concern. Post tin mining landscape is typically irregular, with many steep-walled holes, which sand heap of tailing is poor for its physiochemical properties. The small expanse of a lake formed as a result of the dredging process. This converts the productive land into unproductive and potentially prone to landslides (Asmarhansyah, 2016). On steep slopes, erosion is exacerbated by the removal of vegetation and a lack of suitable soil (Haering *et.al.*,2004), destruction of watersheds, and siltation (Clemente *et.al.*, 2004; Ghose, 2001). This process of tin mining may result in a huge quantity of tailings, which is extremely unfertile and contain high toxic metal concentration with low soil pH (Ashraf et al., 2012). Soil chemical properties, such as nutrient content, are frequently classified as extremely low (Sukarman and Husnain, 2016). This condition implies that the soil is incapable of supporting the plant or other organism to grow and live optimally. Information on the characteristics of soil in post-mining areas, including tin mining, is important as a basic knowledge for the future restoration approach.

Land use significantly influences the soil properties. The common land uses in Bangka area are forest, agroforestry, and mining. Agroforestry systems are land management practices that involve growing trees and shrubs alongside agricultural crops or livestock on the same plot of land (Molla, 2019). Agroforestry is a land cultivation usually used by the community after mining is closed. Agroforestry is frequently described as a suitable system for a community's land use needs.

This study aimed to evaluate the impact of tin mining on soil physio-chemical properties in Bangka, Indonesia. We compared the soil`s physical and chemical properties using soil from natural forests, agroforestry, and post tin mining areas. The natural forest represents an undisturbed area, agroforestry represents a cultivated area in the post mining area, and pot tin mining represents a disturbed area.

2. MATERIALS AND METHODS

2.1. Study Site and Soil Sampling

The study site was in Sungailiat, Bangka Regency, Province of Bangka Belitung, Indonesia. Based on statistics Indonesia, this region has 2000 – 3000 mm annual rain. Soils were collected in three different land use types: natural forest, agroforestry, and post tin mining in Bangka District, Indonesia. A representative natural forest was studied as an undisturbed area or control located in Bukit Betung Air Ruai Pemali Bangka Regency, Province of Bangka Belitung Island. Three sites of natural forest within a distance of 7-10 km were studied as replication. Developed agroforestry with cacao and coconut milk plantation cultivated by local people was studied in Rambak Sungailiat Bangka Regency, Province Bangka Belitung Island. Three sites of agroforestry area within a distance of 7-10 km were studied as replication. Left abandoned tin mining was subjected to disturbed- degraded land. The studied was in Rambak Sungailiat Bangka Regency, Province of Bangka Belitung Island. Three sites of post mining areas within a distance of 7-10 km were studied as replication.

Five-spot soils were sampled from each site. Each site had three replications of the sampling area. The plot size for each site is about 200-500 m^2. Totally 45 soils were collected from all sites. The soil was collected at a depth of 0 – 20 cm for about 1- 2 kg per soil for analysis purposes. This depth of soil was decided for sampling because the depth of a plant`s root and

topsoil is reached this depth which means the biological activity is active in this depth and it influences the physiochemical characteristics is influenced. Soil collected in natural forests and agroforestry was prioritized at rhizosphere depth.

2.2. Soil Analysis

Soil chemical properties are analyzed for its soil pH (H_2O and $CaCl_2$), Cation Exchange Capacity (CEC-buffered by NH_4OAc 1.0 N pH 7), organic carbon (Walkey&Black method), available P (Bray I/II method), total N (Kjeldahl method), exchangeable K (buffered by NH_4OAc 1.0 N pH 7), Al and H concentration (extracted by KCl 1N). The class of soil texture was analyzed as well by hydrometer methods. Soils were analyzed in laboratory soil and plant in SEAMEO BIOTROP Bogor, West Java, Indonesia.

2.3. Statistical Analysis

Statistical significance of treatments and variable factor data were analyzed using KaleidaGraph 4.1 software (Synergy Software 2012, USA) for analysis of variance (ANOVA) test. Post-hoc analysis was performed using Tukey HSD test ($P < 0.05$).

3. RESULTS AND DISCUSION

Soil`s physical and chemical properties from natural forest, agroforestry, and tin mining are presented in Table 1. The process of tin mining produced sandy textured soil dominated by quartz sand and leached topsoil and other clay or silt. Quartz is a type of mineral that is highly resistant to weathering (Wilson, 2020). It means there is no addition of minerals into the soil; therefore, it can be the trigger to extremely poor nutrients in the soil. Furthermore, the porous loose characteristics of sand unable to hold water which leads to the leaching nutrient, including its base cation.

Among area, soil in tin mining has lower organic carbon, total nitrogen (N), available phosphate (P), exchangeable potassium (K), and cation exchange capacity (CEC). Corresponds to this study, Pratiwi et.al (2012) reported the impacted area due to tin mining, however, our results are much lower compared to Pratiwi et.al (2012). This difference could be due to the sampling time different, which was five years different. During these five years, environmental factor such as raining may cause high erosion and leaching of the soil physiochemical properties. Furthermore, In addition to this study area has a variety of topography, ranging from flat to hilly, which could

be the trigger for soil erosion and degradation. The high annual rain (2000 – 3000 mm/y) (BPS-Indonesia) in this area leach alkaline cation resulting on the low soil pH. Furthermore, the parent material of Bangka Belitung Island is dominated by igneous granite (Syafrizal, et.al., 2019), which has acid characteristics. Therefore, all areas measured in this study had low pH.

Table 1. Soil chemical and physical properties collected from natural forest, agroforestry, and post tin mining in Bangka District, Indonesia*

No	Area code	pH		OrgC	Total N	C/N Ratio	Av. P
		H_2O	$CaCl_2$	(%)			ppm
1	NF	4.47b	3.37b	2.25a	0.21 a	11.0 a	10 b
2	AF	4.49b	4.43a	2.35a	0.20 a	12.33a	124.93 a
3	PM	4.97a	4.1b	0.08b	0.02 b	3.67 b	2.43 b

Table 1 (continued)

No	Area code	Exchangeable K	CEC	Al^{3+}	H^+	Texture Class (%)		
		me/100g				Sand	Silt	Clay
1	NF	1.40 a	11.18 a	1.01 a	1.31 a	61.97b	13.15a	24.87a
2	AF	2.48 a	10.34 a	0 b	0.10 b	67.67a	10.43a	21.9a
3	PM	0.95 a	0.79 b	0.14 b	0.24 b	87.83a	1.93 a	10.23a

*Different letters within column of each plant species indicate significant difference ($P < 0.05$) by Tukey HSD test (n=5).

NF: Natural Forest, AF: Agroforestry, PM: Post Tin Mining, C-Org.: Organic Carbon, N Total: Total Nitrogen, Av. P: Available Phosphate, Ex. K: Exchangeable Potassium, CEC: Cation Exchange Capacity, Al^{3+}: Aluminum, H^+: Hydrogen

High organic carbon in natural forest and agroforestry is from vegetation growing in both areas. While in post tin mining, organic carbon was extremely low due to the absent input of organic matter and the process of mining. The lack of organic matter is also responsible for the low total nitrogen (N) concentration as well in the tailing of the tin mining area. This organic carbon value and N concentration are even still much lower compared to the tailing of tin mining in Nigeria (Jibiri et al., 2011) and in Spain (Valverde et al., 2011). Available P and exchangeable K were

found to be deficient in the tailing of post tin mining areas. This lack of nutrition is due to the process of tin mining by washing increased leaching of macro and micronutrients in post tin mining areas. The high available P and K in agroforestry could be due to compost and fertilizer application during cultivation in this area. In contrast, the sufficiency of available P and K in natural forests is from a close cycle of organic matter resulting from vegetation growing and dying in this area.

The very low CEC value in tailing of tin mining is related to the low value of organic carbon and clay portion. The texture of the soil in the post mining soil is dominated by sand. This condition is opposite to CEC, organic matter, and sand texture from tailing of tin mining in Spain (Valverde et al., 2011) which had a higher value of those elements. High rainfall and erosion are responsible for the low CEC in Bangka Island.

4. CONCLUSION

Mining severely decreased the quality of soil`s physical and chemical properties. Chemical analysis of tailings soil in tin mining indicates that available P, exchangeable K, total N, total organic carbon, and CEC are extremely deficient. Organic matter may become an important keyword to the fulfillment and improvement of land properties in tin mining. The result of this research may become a basic information for the restoration approach of post tin mining areas.

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