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Quality of Land Fertility on Post Cement Mine Areas in South Kalimantan, Indonesia

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Abstract Cement mining activities PT. Indocement Tunggul Prakarsa (PT.ITP) in Tarjun Kotabaru has partly entered the post-operative stage and it is being prepared for revegetation. To restore the level of fertility of land according to the standards required to be revegetated with the species of plants belonging to fast-growing species. In order for successful planting activities it is necessary to know the level of fertility. The types of soil can be found in the study area included; clay, laterite, and lime-stone. This collecting of sample uses a purposive sampling method, in which sample points are placed on each soil type. The result showed that soil fertility level is relatively low with C-organic, P₂O₅, K₂O, CEC, and basic saturation parameters under secondary natural forest condition so that fertilizer addition is needed in each type of land to increase fertility.

Keywords Land, Post Mining, Fertility, Revegetation

1. Introduction

The common problem with ex-mining areas is environmental change. Change chemically primarily impacting groundwater and surface water, continues physically morphological changes and land topography. Furthermore, it is a microclimate change due to changes in wind speed, disturbance of biological habitat in the form of flora and fauna, and decreased productivity of land with the consequences of being barren or bare. Based on the change needs to be done reclamation effort. Besides aiming to prevent erosion or reducing runoff water flow rate, reclamation is done to keep the land unstable and more productive. Reclamation is expected to generate added value for the environment and creating a much better state than the previous situation. [27, 19, 18]

Open pit mining in South Kalimantan causes such

problems as Soil quality will decrease drastically, decline in quality or quality of soil may occur physically, and chemical and biological. The soil will lose the surface of the topsoil and the resultant compaction heavy equipment activity, changes in soil chemical content (pH, chemical components) are extreme, loss some micro elements, the loss of soil organisms (biodiversity) so that the pores of the soil changed [31, 25]. Under natural conditions of nature can repair this damage takes a very long time therefore it is necessary to intervene in the rehabilitation process. A common strategy for restoring land is to improve quality land, choosing the right seeds, seeding, planting and maintenance. Rehabilitation is an integrated and time-consuming process.

The problem is the effort of revegetation in the post-mining land, it is not easy this is constrained by land conditions that are marginal status, causing slow-growing plants, growth languish, dwarf and often become the cause of death. In order for the implementation of revegetation to produce normal plant growth as well as sustainable growth, knowing and understanding the marginal post-mining land conditions and knowing how to improve them is known.

Mining activities of cement for raw materials PT. Indocement Tunggul Prakarsa (PT ITP) in the Tarjun Region of Kotabaru Regency has partially entered the post-mining phase and it is preparing for reclamation and revegetation. Plants are important components of ecosystems, they are the primary food producers and therefore it is important to identify the magnitude of the toxic effects on these organism [7]. Post-mining activities efforts have also been implemented in accordance with the environmental management plan as contained in the Environmental Impact Analysis document, in particular the Environmental Management Plan, approved by the Central AMDAL Appraisal Commission.

The types of land contained in the mining area of PT. ITP included; laterite, clay, and limestone. These soil types are poor nutrients and efforts need to improve their fertility.

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Mining and processing of zinc-lead ores are activities that can enrich surrounding area with heavy metals [21]. The adverse effects of heavy metals in some areas are connected with their transfer in the trophic chain, from soil through plants to animal and human [23]. Metal is associated with contaminated groundwater and soils [1]. The chemical analyses are seldom suited for the evaluation of potential ecology risks [6, 2]. The first stage that needs to be done to determine the level of fertility, namely by testing the soil samples in the laboratory.

This study aims to determine the level of critical land in the area of cement mining PT. ITP as a first step to plan the planting will be done. This method is expected to increase the success rate of the planting. Good planning and environmental management will minimize the impacts of mining on the environment and will help in preserving eco-diversity. This article want to assess the deterioration of physical and chemical soil properties due to surface mining and also their management with a purpose to get productive mine soil.

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2. Materials and Methods

Study Location

The study was conducted in the cement mining area of PT. ITP in Tarjun Sub-district, Kotabaru Regency, South Kalimantan Province. Types of soil found in this area consist of laterite, clay, and lime-stone. These materials used as source for making cement. These areas are quite open, so erosion and leaching as well are very high.



Picture 1. Location of research

Soil Analyses

As an assessment standard for soil fertility degree, ie soil texture (sand, dust and clay), soil permeability, bulk density, density particles, porosity, soil acidity (pH), soil nutrients N, P, K, C-org, Ca, Mg, Na, Al, KB, and Cation Exchange Capacity (CEC).

This research begins with preparation. The method used in this research is descriptive survey method with sampling by purposive sampling according to soil type (laterite, clay and limestone). In general, research conducted on 4 (four) stages, namely: (1) preparation, (2) field implementation,

(3) laboratory analysis, and (4) data analysis / discussion.

The preparation stage includes the preparation of field survey equipment. Required equipment such as a ground drill, sample ring and equipment and other materials. Field implementation stage is the activity of soil sampling. Soil sampling is carried out in PT. ITP, there are three types of soil studied in this research, namely on Lateritic land, clay / clay and Lime stone. In each land area two composite soil samples were taken at a depth of 0-20 cm. At each sample point, soil samples were taken in a disturbed condition using a soil drill and which were not disturbed using the sample ring.



Picture 2. Secondary forest land (control)



Picture 3. Laterite land



Picture 4. Clay land



Picture 5. Lime-stone land

The stage of laboratory analysis is carried out in Soil Fertility laboratory Faculty of Agriculture Universitas Lambung Mangkurat. The disturbed soil samples were dried and sieved using a 2mm sieve, while the undisturbed soil samples were directly weighed for soil weight [13] then partially filled with water to analyze some soil physical properties. The [13] physical properties variables analyzed are as follows: Soil texture (fraction of dust, sand and clay) using pipette method, Porosity determined from Bulk Density determination using ring sample and Particle Density using pycnometer with gravimetric method, and soil permeability using Constant Head Permeameter. The calculation of the porosity value of the soil follows the formula: Porosity = $(1 - BD / PD) \times 100\%$. Furthermore, the soil chemical properties analyzed were P and K total using the method of degradation with 25% HCl extract, total N using Kjeldhal macro method, C-organic extracted K-Chromate using Walkley and Black method, P-available using Bray I extract spectrophotometer method, pH H₂O (1: 2,5), interchangeable cations and Soil Cation Exchange Capacity extracted extract with NH₄OAc 1M pH 7.0 and interchangeable Al is extracted with 1N KCl using titrimetric method.

The last step is to analyze the physical and chemical properties of the soil and discuss it descriptively to know and study the soil chemical status and soil fertility. Assessment of soil chemical status using criterion of soil chemical properties based on criteria issued by Soil

Research Institute in 1983. While soil fertility status was determined using soil fertility criterion assessment of fertility status based on criteria of Soil Research Center in 1995.

3. Results

3.1. Assessment of Soil Physical Properties

Some of the physical properties of the soil have a role in forming the land, such as texture, permeability and porosity. Relative amount of sand (2.0-0.05 mm), silt (0.05-0.002), and clay (< 0.002) sized particles determine the texture of soil. Mine soils with sandy textures can not hold as much water or nutrients as finer textured soils like loams and silts [26]. The result of measurement of soil physical properties is presented in Table 1.

Soil fertility is strongly influenced by soil texture. Most pores in sandy soils are large and drain rapidly and sand particles have low cation exchange capacity compared than the others, therefore sandy soils have low nutrient and water retention capacity [29]. The texture of the soil found in post-cement mine of PT. ITP land on laterite soil is silt clay loam, clay ranges from clay loam to clay, while in lime stone clay ranges from sandy clay loam to clay. Clay particles have a high cation exchange capacity can therefore hold nutrients and organic matter [10]. Organic matter accumulates in clay-rich soils because it is poorly accessible to decomposing microbes by binding to clay particles and occlusion within aggregates [3, 23]. This condition is supported by the rapid difference of permeability of the three types of land present in PT. ITP, in quick succession of Laterite, clay to lime stone soil. However, in contrast to the permeability, the porosity of the three soil types decreases from laterite, clay to lime stone. Porosity in Laterite soils is higher than clay and lime stone soils, but permeability is lower when compared to both types of soil. This condition indicates that the high porosity in the laterite soil is thought to contain more micro space when compared to other soil types.

Table 1. The physical properties of soil in post-cement mine areas

Physical properties		Laterite		Clay		Lime-stone	
Texture	Sand (%)	14,28	7,98	19,09	34,37	45,77	33,40
	Silt (%)	52,37	61,32	37,35	33,34	27,08	41,14
	Clay (%)	33,35	30,71	43,56	32,28	27,15	25,46
	Class	Silt clay loam	Silt clay loam	clay	Clay loam	Sandy clay loam	loam
Permeability (cm/hour)		0,34	0,40	1,16	1,53	4,83	3,82
Porosity (%)		48,08	47,07	44,89	33,45	22,54	23,55

Lime stone has higher sand included sandy clay loam which it is high permeability (cm/hour) compared than both soil types. Sandy soils have a low capacity to store C. Water infiltration into sandy soil may be reduced by water repellency [16, 21].

3.2. Soil Chemistry

3.2.1. Soil pH

Soil pH is a measure of active soil acidity and is the most commonly used indicator of mine soil quality. The pH of a given mine soil can change rapidly as the rock fragments weather and oxidize. Pyritic minerals (FeS_2), when present, oxidized to sulfuric acid and drastically lower the pH, while carbonate (Ca/MgCO_3) bearing minerals and rocks tend to increase the pH as they weather and dissolve. Unweathered (or unoxidized) mine soils those contain a significant amount of pyritic-S in excess of their neutralizers (carbonates) will rapidly drop the pH to a range of 2.2-3.5 after exposure to water and oxygen [26].

Land in secondary forest has a pH of 5.46 while soil pH on cement land of PT. ITP ranges from 3.23-8.05 (Table 2), where the soil pH value is acid to neutral. The soils show acid in clay and alkaline, and alkaline in limestone. If a mine soil pH range in the range of 6.0 to 7.5 is ideal for forages and other agronomic and horticultural uses [12, 14]. According to Hakim et al. (1986) [8], soil reactions (pH) outside the 6-7 range may result in a decrease in the availability of certain nutrients and sometimes lead to other nutrient availability. This can result in disruption of nutrient uptake by plants thus inhibiting growth and decreasing plant productivity [30]. At neutral pH (6-7) nutrient availability becomes optimal in terms of nutrient quantity and equilibrium in soil solution [29].

3.2.2. C-organic and N-total

The C-organic values in the study area ranged from 0.07% to 0.87% (very low-low). The lowest content of organic carbon was found in a soil sampled collected from sampling laterite and the highest from sampling in limestone. A level of organic carbon greater than 0.75% indicates good fertility [13]. Organic carbon is positively correlated with available N and K and negatively correlated with Fe, Mn, Cu, and Zn [20].

Nitrogen is needed by plants in large quantities, generally becoming a limiting factor on non-fertilized soils

[29]. The three major macronutrients, namely nitrogen, phosphorus and potassium are generally found to be deficient in overburden dumps [7, 25]. N is taken root in inorganic form, ie NH_4^+ (ammonium) and NO_3^- (nitrate) [15]. NH_4^+ absorption is more prevalent in neutral soil pH, whereas NO_3^- at low pH. The NO_3^- compound generally moves toward the root due to mass flow, the NH_4^+ compound is not car, the movement is caused by the diffusion also the mass flow [24]. The nitrogen content in the study area can be described as low (0.04-0.20%). The lowest content of nitrogen was found in a soil sampled collected from sampling in laterite and the highest from sampling in secondary forest (Table 2).

3.2.3. Content of P_2O_5 and K_2O

Organic matter is the major source of nutrients such as nitrogen, and available P and K in unfertilized soils [9]. All newly created mine soils, and many older ones, will require significant fertilizer element applications for the establishment and maintenance of any plants community.

Phosphorus is a macro element which is very important for plant growth but its level is lower than N, K and Ca. As a growth factor, phosphorus is considered more important than Ca and K [24]. P_2O_5 and K_2O values were used to assess soil fertility status according to PPT criteria (1983). The result of soil analysis also shows that the content of P_2O_5 and K_2O on the land of cement area of PT. ITP of all soil samples was described very low (1.02- 2.71 mg P_2O_5 / 100g), while the K_2O content in the sample was described as low to moderate (2.95-3.49 mg K_2O / 100 g) (Table 2).

3.2.4. Exchange Bases (K, Na, Ca, Mg)

In general, K is usually absorbed by plants in the form of K^+ . Usually K is found in large quantities in the soil, but only a small part of the plant is used, that is water soluble or interchangeable (in soil colloids) [29]. The exchangeable bases/cations (K, Na, Ca, Mg) are the equivalent milligrams of each cation in the exchange complex and are cationic forms which can be absorbed by the plant.

The results showed that the Ca-exchange values in all samples ranged from very low to moderate (2.32-2.93 me /100g); Mg-exchange values range from 0.11-0.13 me/organic 100g (very low to low), Na-exchange values range from 0.01-0.03 me / 100g (very low), whereas the value of K- exchange rates ranging from 0.01 to 0.03 me /100g (relatively low) (Table 2).

Table 2. Soil chemical properties on cement land of PT. ITP

Type of soil	pH H_2O	SO_4 (ppm)	C N		P-total mg/100 g	K-total mg/100 g	Ca-dd Mg-dd Na-dd K-dd				CEC	P Bray (ppm)	V (%)
			----- % -----				----- me/100 g tanah -----						
Soil in Secondary Forest	5.46	0.58	0.56	0.20	13.75	36.81	9.04	1.70	0.10	0.64	34.40	2.33	33.37
Laterite	5.84	0.69	0.07	0.04	1.48	3.40	2.32	0.12	0.03	0.01	18.93	1.05	13.02
Clay	3.23	0.66	0.16	0.06	1.41	3.23	2.50	0.12	0.02	0.02	20.84	0.82	12.72
Limestone	8.05	0.66	0.87	0.06	2.08	2.96	9.23	0.11	0.02	0.02	21.01	0.75	44.03

3.2.5. Cation Exchange Capacity

CEC ground depends on the type and amount of clay content, organic matter content and soil pH. Therefore, the size of CEC is very determining the level of soil fertility [5]. The reclamation activity of the former cement mine does not cause changes in the soil CEC compared to the CEC in the non-reclaimed land (secondary forest). The CEC in all soil samples ranged from 18.93 to 34.40 me/100g of soil (Table 2), which can be explained from low to very high. The soil conditions are acidic that the soil loses the cation exchange capacity and the ability to store cation nutrients in exchangeable form due to the development of positive charges [29].

3.2.6. Base Saturation (V-value)

Basic saturation (KB) is the ratio between the number of exchange cations with cation exchange capacity (CEC). Similar to soil CEC, the saturation of the soil base on non-reclaimed land is not unlike the reclaimed mining land. The V-values in all soil samples ranged from very low (12.25%) to moderate (50.41%).

3.2.7. Status of Soil Fertility

Table 3. Soil fertility status in three soil types in cement mining area compared with secondary forest

No.	Type of soil	C organic	P-total	K-total	CEC	V	Soil fertility
	Soil in secondary forest	L	L	M	H	L	L
	Laterit	L-VL	L	VL	L	L	L
	Clay	VL	L	VL	M	L	L
	Limestone	L-VL	L	VL	M	M	L

Source: primary data that is processed (2017). VL = very low; L = low; M = medium; H = high; VH = very high

Soil fertility is the ability of the soil to provide nutrients in a sufficient and balanced condition without any toxic substances supported by water and air systems that support the growth of plants. Based on the soil fertility criteria of Soil Research Center (1983) with key parameters of soil fertility (C-organic, P₂O₅, K₂O, KTK, and saturation), fertility status in the study area is lower than non-reclaimed land (secondary forest). All soil types have the same fertility level, that is low-medium (Table 3).

In general, soil fertility in post-mining land is relatively low compared to secondary forest. The fields are generally open so that erosion and nutrient leaching occur.

4. Discussion

Soil texture greatly determines the water system in the soil, in the form of infiltration speed, penetration and ability to bind water by soil. Soil texture is also very strong influence on soil fertility, especially the ability to bind nutrients and affect the CEC [32]. Clay particles tend to have high CEC and have nutrient binding ability, compared to sand and dust particles.

The soil in the post-mine area of PT ITP has a fairly high variation between one sample point and the other sample points. On laterite soils have sand content of 14.28% and 7.98%, silt of 52.37% and 61.32% and clay 33.35% and 30.71%, from these data indicate that between the sample points there is a high enough difference for each soil texture, sand. Similarly, on clay soil with 19.09% sand and 34.37%, and limestone soil with sand 45.77% and 33.40%. A considerable difference between one point and another is thought to be caused by the high erosion rate, since the land in the post cement mine is generally open and tends. This

condition resulted in sand washed by rain water so dissolved. In lime-stone soils the content of sand tends to be high compared to laterite and clay soil. Soil with high sand content tends to have low nutrient and CEC [32]. But in reality lime-stone has nutrient content and CEC is not too much different from laterite and clay soil. CEC soils may vary with pH change. The soil conditions are so acidic that the soil loses the cation exchange capacity and the ability to store cation nutrients in the form of cation exchange due to the development of positive charges [29]. Because lime-stone soil has a pH of 8 it tends to bind high cation and CEC cations than the other two types of soil.

In the laterite soil contains the highest silt 52.37% and 61.32% compared to clay and lime-stone. High dust content tends to have a lower soil nutrient binding ability when compared to clay soils containing higher clay. The lower clay has a low CEC. Clay particles have high CEC and can hold nutrients and organic matter [10, 17]. Organic matter accumulates in clay-rich soils because it is poorly accessible to decomposes in aggregates [4, 23].

Clay soil certainly has a high clay content compared to the other two laterite and lime-stone land. High clay content of course has the ability to bind high soil nutrients and CEC are also high. However, when compared with lime-stone, the soil nutrient content on the clay is mostly lower. This is because lime-stone has a relatively neutral pH 8 to make optimal soil in regulating nutrient balance in soil solution. According to [15] soils with a low pH or less than 6 result in a decrease in the availability of certain nutrients and sometimes even the advantages and availability of other nutrients. This resulted in disruption of nutrient uptake by plants thus inhibiting growth and decreasing plant productivity [30].

In general, land in the post-mining area of cement PT. ITP has a much lower nutrient content than secondary forest that is still covered by vegetation and has not been disturbed once. Although the fertility of soils in secondary forests is much higher than the three types of land present in post-mining areas of PT. ITP, but in general soil fertility in secondary forest in South Kalimantan is still relatively low according to the criteria of Soil Research Center (1983).

After knowing the low nutrient content in the three types of soil in post mining area of PT. ITP, it is necessary to determine the type of plant capable of living in the area, as well as the necessity of adding nutrients especially in the first year until the third year of planting, until the plant is able to adapt well with poor soil nutrients and low pH for laterite and clay soil.

Normally low 10^4 H was caused high content of metal in the soil. Metal concentrations in soil exert an enormous influence on the diversity, composition, and activity of soil microorganisms that carry out essential ecosystem services. At low concentrations, microorganisms can affect plant growth and disease through the production of metal chelators [8].

5. Conclusions

From the result of study on post-mining area of PT. ITP summed up as follows:

- (1) Based on the soil fertility criteria of Soil Research Center (1983) with key parameters of soil fertility (C-organic, P_2O_5 , K_2O , KTK, and saturation bases, soil fertility status of post-mining land of PT ITP cement is very low to low compared to land of secondary forest.
- (2) Low nutrient content in the three types of soil at the post-mining area of PT. ITP is necessary to determine the type of plant capable of living in the area, as well as the necessity of adding nutrients especially in the first year until the third year of planting.

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