Jurnal Agroekoteknologi Tropika Lembab
Volume 5, Nomor 2, Februari 2023
Halaman:129-135

ISSN: 2622-3570
E-ISSN:2621-394X
DOI.210.35941/JATL

Tanah Berkembang dari Batuan Lumpur dan Pasir untuk Pelapisan Timbunan Bekas Tambang Batubara di Teluk Dalam, Kalimantan Timur

Soil Development on Mudstone and Sandstone as Topsoiling Overburden Materials Coal Mine Waste Dump at Teluk Dalam, East Kalimantan

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Manuscript received: 16 September 2022 Revision accepted: 14 November 2022

ABSTRACT

The process of moving regolith from the coal mine site to the dump site (disposal) resulted in changes in soil forming materials and reconstruction which also affected changes in soil body and soil properties of coal mine reclamation. This research aimed to understand soil development in mudstone and shale as overburden materials on age less than two years old, two to five years old and more than fifteen years old. Soil profiles are made based on the age of disposal and then the soil is observed in each layer on each profile. Soil samples were taken based on the soil layer profile description results. The result showed that morphological characteristic and physico-chemical properties at disposal age less than 5 years were relatively irregular due to the large influence of mining activities, while those aged more than 15 years soil-forming factors such as time and climate showed pedogenetic process.

Keywords: development, mudstone, overburden, shale, top soiling.

ABSTRAK

Proses pemindahan regolith dari lokasi tambang batubara ke lokasi pembuangan (disposal) mengakibatkan perubahan bahan pembentuk tanah dan rekonstruksi yang juga mempengaruhi perubahan tubuh tanah dan sifat tanah reklamasi tambang batubara. Penelitian ini bertujuan untuk mengetahui perkembangan tanah pada batulempung dan serpih sebagai material penutup pada umur kurang dari dua tahun, dua sampai lima tahun dan lebih dari lima belas tahun. Profil tanah dibuat berdasarkan umur pembuangan kemudian tanah diamati pada setiap lapisan pada setiap profil. Sampel tanah diambil berdasarkan hasil deskripsi profil lapisan tanah. Hasil penelitian menunjukkan bahwa karakteristik morfologi dan sifat fisiko-kimiawi pada umur buangan kurang dari 5 tahun relatif tidak teratur karena besarnya pengaruh kegiatan penambangan, sedangkan yang berumur lebih dari 15 tahun faktor pembentuk tanah seperti waktu dan iklim yang menunjukkan telah terjadinya proses pedogenetik.

Kata kunci: Pengembangan, batulumpur, timbunan, serpih, pelapisan tanah.

INTRODUCTION

The system of coal mining in East Kalimantan, Indonesia is a convert the landform due to the change of landscape and regolith structure where the majority of parent materials such as mudstone and shale become to use as an overburden dump area. Environmental consideration requires that overburden materials from coal mines especially mudstone and shale at Teluk Dalam, Tenggarong are landscape to a stable configuration and revegetated with Sengon plant (pioneer) species. Mudstone and shales are made of silt-and clay-sized particles that are small to see. The only differences between mudstone and shales are that mudstone break into blocky pieces, and shales break into thin chips with roughly parallel tops and bottoms (Mandusha 2020), both are made of ancient mud.

Mudstone and shale are sedimentary rocks formed from the consolidation (compacting) process of particle deposits carried by wind and air on the earth's surface (Hanafiah 2014). Coal mine waste often has unfavourable physical and chemical properties and in certain circumstances provide a hostile medium for plant growth. The mining activity by opening forest vegetation areas causes loss of nutrients and soil organic matter content, erosion and sedimentation, and decrease in the number of soil microorganism (Oktorina 2017)

The research aimed to characterize the waste of Teluk Dalam, Tenggarong with respect to the morphological characteristics, physic-chemical properties and genesis of mudstone and shales at certain years applied as overburden materials and that properties which may affect waste dump management and revegetation. (Buol *et al*. 2011) stated that soil development depends on climate (temperature and rainfall), topography, parent materials, biology (livings), and time.

MATERIALS AND METHODS

Study Area

Soil sample are derived from reclamation sited of soil which have been reconstruction of dumping area PT. BBE at Teluk Dalam, generally, the overburden area (disposal) has top soiling applied, but some do not have top soiling. Coordinately, the researched area at 117° 04' 06" E and 0° 26' 58" S (P_1), 117° 04' 44" E and 0° 26' 13" S (P_2) and 117° 05" 02" E and 0° 26" 40" S. Location for determining the soil pit (P_1, P_2, and P_3) is indicated by the company. Observation of soil profile using guidelines of soil profile description, each soil samples analyzed for routine analysis at soil laboratory (Figure 1 and 2).

Figure 1. Study area of PT. BBE (left side of Samarinda-Tenggarong high way

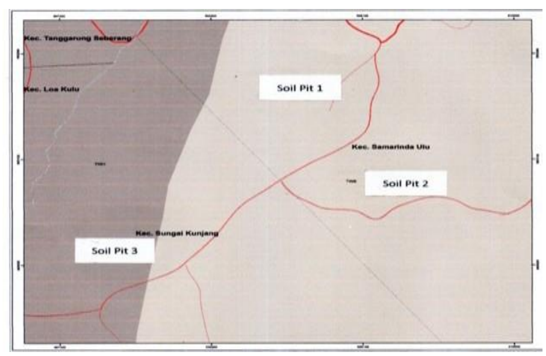

Figure 2. Location of soil profile (pit)

Methods

This research was conducted using soil survey method. As preparation of research, field observation activities were conducted such as determining location of soil sampling/observation point at Teluk Dalam, Kutai Regency, East Kalimantan is an area of about 15 km North-West Samarinda City.

The representative profile is developed on mudstone and shale overburden and is situated on upland at an altitude no more than above 50 m from sea level. Site for a soil profile of age waste dump selected on less than 2 years (P_1), 2–5 years (P_2) and more than 15 years (P_3). Site characteristics studied such as slope. erosion, natural drainage, vegetation and effective soil depth were recorded. Soil colour was determined by munsell soil colour charts. Each observation point (P_1, P_2, and P_3) observed soil properties such as soil layers (topsoil, subsoil, and parent materials) through a mini pit or profile pit. Data collected during field observations included soil horizon layers (A, B, and C), soil color, texture, structure, consistency, coarse fragment > 2 mm), pedogenic properties, effective soil thickness, groundwater depth/class drainage, and parent material.

From the soil profiles, disturb and undisturb soil samples were taken from designated genetic horizons for physic-chemical analysis in the laboratory. Soil sample analysis consisted of: Texture (silt, clay, sand), Bulk

Density (g mL^{-1}), Permeability (cm $second^{-1}$), Soil reaction (pH H_2O and KCl), Organic Carbon, P_2O_5(mg kg^{-1}), Extractable Base (Ca, Mg, K, Na), Cation Exchange Capacity (NH_4OAc), and Base Saturation (%).

RESULTS AND DISCUSSION

The Teluk Dalam, Tenggarong, East Kalimantan, Indonesia is an area of coal mining has a tropical rainy forest climate with characteristic of rainy season whole of the year by mean annual temperature 27.60–28.70^{o}C. The average annual rainfall for Tenggarong is about 2,634 mm. The Teluk Dalam, Tenggarong waste dump is dominated by late tertiary sediment rock, mainly trending South-West to North-East. The rock are weakly lithified and show considerable short range variation in texture, ranging from sandstone to mudstone. Sedimentary rock and the coarser alluvial deposit contain few or very low weatherable minerals and so the soil formed from these materials have low to negligible content of most plant nutrients. Landscape of Teluk Dalam before mining consist of rolling to dissected ridge and low hills which in many places rise abruptly from the river basin. This relief is made up as the results of the considerable folding activity during geological times. Slope greater than 15% is predominate, they generally 150 m in length and the amplitude is typically in the range of 25-50 m.

The reconstruction processes of post-mining soil body with top soil, subsoil, parent materials, and bedrock are the initial stage of formation reclamation land. Generally, the reclamation area has top soiling applied on the overburden of mudstone and shale materials dumping but some do not have top soiling. The top soiling materials for layering upper part of overburden taken by the excavator that is available in the surrounding area from undisturbed soil body. The materials taken without separating in between soil body so that the materials for top soiling are mixing of both soil solum and upper part of weathered parent material (Singh and Chandran 2015) Morphological appearance of coal mines reclamation soil profile is presented in Figure 2 and Table 1.

Figure 3. Disposal < 2 years

Figure 4. Disposal 2–5 years

Figure 5. Disposal > 15 years

Morphlogical Characteristics of Disposal (Waste Dump) Area

The disposal morphology in the study area based on the thru soil profile description, has differences characteristic. The upper part of soil about two centimetre has litter as a source of organic material grass and dead leaf. Grass is commonly found in this area due to fluctuated ground water table up to the surface at disposal dump area (< 2 years old). The amount of rainfall in East Kalimantan with a tropical humid climate that can reach 2000 mm per year with a Potential Evapotranspiration (PET) of about 1,017 mm per year, provides an annual effective rainfall of about 983 mm which results in fluctuations in groundwater to reach the ground surface and when it is less rain will bring the results of weathering to a deeper part (Mulyadi 1999). Quenardet *et al.* (2011), states that the occurrence of clay leaching (lessivage) caused by the annual effective rainfall (rainfall minus PET) of more than 150 mm to 200 mm and increases significantly when the annual effective rainfall is more than 400 mm.

Table 1. Morphological characterized of waste dump(< 2 years, 2-5 years and > 15 years old)

Disposal Age	Bulk Density	Thickness (cm)	Horizon Layer	Soil Colour	Texture	Structure	Consis-tency	Roots
< 2 years	1.48	0-10	Ao	10 YR 5/4	Si Clay	SAB	Friable	Many
	1.51	10-37	A/C	10 YR 5/6 and 10 YR 5/1	Si Clay	SAB	Slightly Firm Firm	Common
	1.78	37-55	OB	10 YR 5/2	PM	Massive	Very Firm	-
	1.69	>55	OB	10 YR 5/1	Mudstone	Massive		-
2 – 5 years	1.34	0-16	A/B	7.5 YR 6/6) 10 YR 7/3	Mudstone Si Clay	SAB	Friable to Slightly firm	Common
	1.56	16-54	BC1	10 YR 6/4 10 YR 6/2	Mudstone Si Clay	SAB	Slightly Firm To Firm	Common
	1.51	54-100	BC2	10 YR 6/2	Silty Clay	Massive	Firm	Few
	1.58	>100	OB	5 YR 5/1 10 YR 5/2	Si Clay Mudstone	Massive Platy	Slightly firm	
> 15 years	1.22	0-3/22	A	10 YR 4/2	Mudstone	SAB	Friable to Slightly firm	Many
	1.36	3/22-38	BC1	10 YR 6/2	C Loam	SAB	Slightly Firm	Common
	1.54	38-82	BC2	10 YR 5/3 10 YR 8/4	Si Clay	R Structure	- -	Few
	1.58	>82 > 100	C/OB	10 YR 5/2	Si Clay	-		Very Few

The mineral soil materials beneath this layer come from surrounding area as a top soiling which have been spread and levelling by dozer. Brownish yellow (10 YR 5/6) soil colour mixing gray colour (10 YR 5/1) about 25% by volume and yellowish red (5 YR 6/8) about 4% by volume as a mixing between soil and parent materials. The Clay Loam soil texture of this disposal area with sub angular blocky structure break to small and weak grade, firm (moist) and sticky (wet) consistency, low organic matter content, common root and smooth, clear soil boundary. Reyes (2017) suggested to observe the soil profile according to horizon boundary, horizon thickness, texture, structure, consistency, effective depth, type and number of pores, and other characteristics. Overburden layer have founded more than 37 cm where developed dominantly by gray mudstone and shale parent material, which more than 90% the material could be drilling and hoe by hand auger or hand hoe (37–55 cm), but difficult to drilled or hoe at more than 55 cm thick.

The upper layer of disposal area age more than 2–5 years has litter horizon from leaf and dead roots about 2 cm thick. Thick of top soling applied come from surrounding area of soil materials no more than 16 cm with reddish yellow (7.5 YR 6/6) and very pale brown (10 YR 7/3) of weathered parent materials. Silty Clay texture with friable (moist) or sticky (wet), low organic matter content, common roots, clear smooth soil boundary.

The horizon formed in the A/B layer is a transition between the A horizon which tends to turn into a B horizon. This characterizes the process of the formation of the pre Cambic horizon. The pedogenesis process has occurred since the soil developed in its original place (forest vegetation). When the soil is spread in the disposal area, mechanical processes such as excavation, hauling and spreading cause the soil material to become more tenuous than the original (disturbed). Rainfall and high temperatures result in increased significantly soil formation processes being spread.

Morphological characteristics shows that the soil structure has developed. Inceptisols appear to be the result of two major situatiossoil developing on geologically young sediment or landscape, and soil developing on areas where environmental inhibit soil-forming process. The physical processes may consist of destruction of the original rock or sediment structure and subsequent development of soil structure units (Wilding *et al.* 1983). The BC1 horizon layer, the soil colour is light yellowish brown (10 YR 6/4) and light gray brown (10 YR 6/2) mottles which is a rather massive OB gray mudstone material, silty clay texture, sub angular blocky to massive structure, firm, common roots, clear smooth soil boundary. The next layer (BC2) has a is is light gray brown (10 YR 6/2), namely the OB layer which has been weathered so that it is relatively crumbly to an angular blocky structure, commonly roots developed. The soil used as a topsoiling come from surrounding area by natural forest vegetation where the soil has been developed such as Ultisols topsoiling. (Fatai *et al.* 2017), stated that the color of Ultisols in the top soil has a yellowish-brown color and will get reddish with the increase of depth. In a deeper layer that is more than 100 cm deep, the soil is gray (10 YR 5/1) and grayish brown colour (10 YR 5/2) mottles with a rocky-platy structure of about 50-70% by volume and the structure easily destroyed in the presence of water. Disposal areas that are more than 15 years old, all of which are derived from gray mudstone parent material that are not covered with soil, have an O layer of about 2 cm in the form of litter from rotting roots, leaves, and twigs.

In the deepest layer (> 100 cm) i.e. C horizon shows that colour, structure, consistency and texture are typical materials in this disposal dump area. The presence of a diagnostic horizon in the layer above is an indication of the process of degradation and gradation of parent materials in the form of leaching and flocculated from weathering results. The development of the horizon from C/OB layer that have a grayish brown (10 YR 5/2) soil color of the lowest layer to brown (10 YR 5/3) in BC layer, Light brownish gray (10 YR 6/2) in BC1 layer and dark grayish brown (10 YR 4/ 2) in the upper layer shows that there is an oxidation-reduction process in the soil profile, as well as the effect of increasing organic matter content, especially in the top layer. Although there has not been an increase in clay content from the elluvial layer to the illuvial layer with a relatively homogeneous texture, namely clay loam on the surface and silty clay in the layer below, this does not indicate an indication of the formation of an argillic horizon. However, the soil structure has shown development in the form of angular blocky, common class and moderate in grade, of which (20-25%) are still in rock-structure form in the BC1 layer and about 40% in the BC2 layer. Likewise, the density of the soil tends to be lighter with a bulk density of around 1.22 g mL^{-1} in the surface layer, increasing by about 1.35-1.54 g mL^{-1} at a depth of 20-50 cm and quite heavy at 1.58 g mL^{-1} on the bottom layer (>80 cm).

Rainfall and air temperature are the most dominant climatic factors on soil formation in addition to other soil-forming factors such as living things, parent material, topography and time. The physicochemical properties in the disposal dumping area, Teluk Dalam are also influenced by the factors mentioned above, but the human being factor plays an important role in accelerating the process of soil formation. Processes such as land clearing and excavation at the origin site, then transporting the material to the disposal area, spreading to leveling are the steps taken.

Table 2. Physicochemical properties of disposal

Disposal Age	Horizon Layer	Thick cm	BD g mL^{-1}	Particle Size Distributin			pH H_2O	OC %	P_2O_5 ppm	CEC Cmol (+)/kg	BS %
				Sand	Silt	Clay					
< 2 years	Ao	0-10	1.48	3	38	58	6.84	1.86	3.36	17.76	85
	A/C	10-37	1.51	33	28	28	4.16	1.27	5.04	19.01	39
2 – 5	OB	37-55	1.78	17	33	50	4.01	1.13	2.94	23.71	30
years	OB	>55	1.69	36	32	31	4.46	0.93	2.52	19.68	39
> 15	A/B	0-16	1.34	40	22	38	4.88	0.57	2.94	16.51	34
years	BC1	16-54	1.56	14	48	38	7.43	2.15	0.84	14.02	71
	BC2	54-100	1.51	31	40	30	8.34	1.44	1.26	18.91	62
	OB	>100	1.58	15	45	40	8.71	1.45	3.36	18.15	77
	Ah	0-3/22	1.22	28	47	25	5.62	1.83	4.20	29.95	49
	BC1	3/22-38	1.36	24	49	27	6.53	0.80	5.46	26.40	62
	BC2	38-82	1.54	50	27	23	7.50	0.51	3.78	24.67	57
	C/OB	82-100	1.58	9	54	37	8.06	0.77	3.36	26.30	70
	OB	> 100	-	14	50	36	8.45	0.79	1.68	29.28	67

The parent material/parent rock is dredged using an excavator so that it is no longer in solid form and forms chunks/fragments because the excavator has crushed it. When it rains, water will easily seep because there is enough pore space in the expanse material (disposal) so that leaching occurs which can dissolve a number of chemical elements contained in mudstone and shale into deeper layers below. Water in soil not only the major agent of rock wetahering and mineral transformation and is necessary to sustain plant growth, but it has major functions within the soil profile (pedon) in redistributing, adding, or removing soil materials (Wilding 1983). The physicochemical properties of the disposal area of less than five years have various soil laboratory analysis results from the samples taken. This is because the time is still relatively short for the pedogenesis process so the properties of the transferred material still affect the physicochemical results obtained. Moreover, the expanse material is taken not based on the composition of the soil so that the material mixes irregularly. This gives results that are not as expected where the content of the analysis results generally decreases with increasing soil depth on chemical properties such as organic matter content, texture, N, P, CEC, and base saturation. (Akhtaruzzaman *et al.* 2014) also state that higher CEC in the surface soil might be due to a higher amount of organic carbon in the surface layer CEC contentmight be related to soil texture, clay mineralogy composition, and accumulation of organic matter and degree of erosion. Disposal over fifteen years old shows the results of more natural physicochemical properties such as soils that develop naturally without much human intervention. High pH in the lower than the upper layer characterizes the accumulation of dissolved bases, this can be seen in the relatively increased dissolved cation (Ca, Mg, K, Na, H, and Al) as well as CEC and base saturation which also increases with increasing depth, This is related to the content of the parent material (shale) which bends so that it releases a number of basic cations. Da Silva *et al* .(2022) state that the parent materials is one of the main factors that influence pedogenesis; soil formed in the different geological context have different physical, chemical and mineralogical properties, and also affect the natural ferility of soil. The content of organic matter decreases with increasing depth, while the density of the soil increases which is indicated by an increase in the bulk density of the soil.

CONCLUSION

The soil profile description and laboratory analysis of physico-chemical at disposal areas that are less than five years old is a description of the process of dredging, moving, and spreading material from the place of origin to the disposal site as a consequence of coal mining activities.

Criteria such as soil layers that are not sequential, such as soil usually formed under forest vegetation, soil extraction using an excavator so that it cannot be distinguished based on the soil horizon, mixing of soil with parent material during collection, and spreading of soil in the disposal area using dump trucks, causes the results of laboratory analysis also varying. In disposal areas that are more than 15 years old, the results of soil profile descriptions and laboratory analysis are more sequenced because there is sufficient time for the pedogenesis process, especially the leaching and flocculation.

ACKNOWLEDGMENTS

I would like to express my deep and sincere gratitude to the Director General of Higher Education Ministry of Education and Culture of the Republic of Indonesia that a part of this work is funded. I am very much thankful to Head of Management of PT. Bukit Baiduri Energy, especially to Mr. Akbar Maulana, S.Si. who have provided the opportunity to conduct research in the company's land reclamation area.

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