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River Sludge Potency as Soil Conditioner Material on Post-Mining Critical Land

Ibrahim[1], Soemarno[2], Syekhfani[3]& Sugeng Prijono[4]

[1] *Graduate School of Agriculture, Faculty of Agriculture, Brawijaya University Department of Forest Management, Faculty of Forestry, Mulawarman University, Jl. Kuaro, Kampus Gunung Kelua, Samarinda 75119, Indonesia.*

[2] *Department of Soil Science, Faculty of Agriculture, Brawijaya University, Jl.Veteran, Malang 65145, Indonesia.*

Abstract: *The study aimed to identify the potency of river sludge as conditioner material on post-mining critical land through the alteration of chemical properties and biomass weight of Calopogonium mucunoides cover crop which was cultivated in every treatment. It applied completely randomized design with the treatment of mixing topsoil and sludge put in 1x1x1 m planting hole. The mixing ratios of sludge were 0% (P_0control), 25% (P_1), 50% (P_2), 75% (P_3) and 100% (P_4), in which every treatment consisted of 4 replications. The study was located on coal post-mining land which had not been reclaimed (re-vegetation). The result confirmed that adding sludge affected the increase of soil's chemical properties as follows: Base Saturation, Organic-C, CEC, N total, Available P, available K, exchangeable Ca and Mg (the correlation coefficient was 0.97-0.83). On the other side, there were reductions in the following chemical properties: pH (H_2O) and Al Saturation (the correlation coefficient was -0.79 to -0.90). In general, the best change of chemical characteristics took place in the level of mixing sludge namely 75% (P_3) and 50% (P_2). It was observable from the highest yield of cover crop biomass namely 198.28 gram/m^2 (P_3) and 123.93 gram/m^2(P_2). The main constraint of sludge usage as the main conditioner material for soil's chemical characteristics resulted in the decrease of soil permeability so that puddles occurred on soil surface. It was evident in the decrease of soil permeability rate (measurement I and II) in P_4treatment (100% sludge) from 4.73 cm/h into 0.43 cm/h.*

Keywords - *Sludge, Reclamation, Critical Land, Mine, Cover Crop*

I. Introduction

East Kalimantan is one of Indonesia'sprovinces possesing abundant coal reserve compared to others. Its coal reservepotency is estimated to be 35% of the total maintained in Indonesia namely 105 billion tons [1]. It instigates uncontrolled natural resource depletion resulting in destructive natural disasters [2]. The condition is depicted in the number of coal mining business license issued by the central government namely 67 PKP_2B permits (Coal Mining Agreement), and 1.451 IUP permits (Mining Permit) are issued by district/city governments. Based on all permits, it is estimated that the total area of coal mining in East Kalimantan is approximately 7 million ha [3].

Coal mining activities are those of high risk resource exploitation resulting in environmental damage. It is due to the destructive activities toward landscape as the main component of ecosystem constituent. Damaged landscape affects deforestation, micro climate change, poor water system, and subsided soil productivity. The damage occurs since the volume of soil solum is stripped approximately 3-5 times from the obtained coal. This condition is degraded by the loss of nutrients in mining activities began with topsoil stripping, followed by transporting, accumulating and returning the topsoil [4].Those various stages cause land fill in post-mine area to undergo physical, chemical and biological changes. Regarding soil chemical properties, the changes include: decreased soil's pH and CEC, low soil's organic matter, increased solubility of Al, cation base deficiency and increased solubility of toxic elements [5] [6].Various damages in soil properties cause natural revegetation on post-mining land to barely occur, so that the land can potentially be a critical area.It was stated by Ritung (2010) that the impact of coal mining in East Kalimantan has led to approximately 3 million ha of critical land. It is highlyconcernedsince the critical land in Indonesia has reached 29.9 million ha [7] [8].

As a preventive action, generally a technical reclamation is taken on post-mining land followed by biological reclamation in the form of vegetation planting. However, such measures often fail mainly due to some aspects which are less understood carefully [9]. The main aspect of failure is low soil fertility on post-mining land and lack of soil volume for the land deposit. These cause the soil solum to be shallow and unable to support the vegetation growth on it.

One of promisingalternatives to resolve the issues is the sludge usage as soil conditionermaterial. The sludge is generally easy to find in river or lake. Its use as a medium of soil conditioner on degraded land is considered very beneficial sinceitis able to improve the solubility of base cations, soil CEC and soil's organic matter content [10]. Sludge administration is considered a quite practical method to overcome revegetation problems on degraded land.Besides, to some extent it can be considered safe for the environment [11] [12]. Applying cover crops is another thing considered in the post-mining land reclamation activities. The plants can be used to transform degraded and poor nutrient lands into productive ones [13]. It is feasible sincetheyare able to protect the land from erosion, to increase water infiltration, to maintain soil moisture and to increase soil organic matter [14]. Increasing soil organic matter is an important primary step toremediate soil's physical and chemical properties [15].

The study was designed to determine the extent of post-mining land productivity improvement through the method of mixing topsoil and river sludge as a soil conditioner. The parameters applied as indicators to identify them were soil's characteristic (fertility) and biomass weight of cover crop grown on the land.

II. Methods

2.1 Study Site and Experiment Design

The study was conducted on coal post-mining land of PT Panca Prima Mining (00°31'49,26" and 00°31'49,44" South Latitude, 117° 11'52,44"and 11'52,62"East Longitude) located in Sambutan Village (14 asl), 25 km from the capital city of Samarinda, East Kalimantan Province. Its climate type, according to the classification of Schmidt and Fergusson is Type A (very wet) with annual rainfall average namely 2127.51 mm (the number of rainy days in the average annual rainfall is 221 days). The average daily temperature is 32.79ºC at maximum and 22.81ºC at minimum. The air humidity is the average of 77.26%. The average amount of annual solar exposure intensity on the study site is approximately 43.76%. The use of sludge in this study was originated from Sambutan River which was approximately 5 km from the study site. The topsoil was derived from the remaining coal mining activities in the location of study. Several characteristics of sludge and topsoil in this study were presented as follows:

Table 1. Several Chemical and Physical Properties of Sludge (precipitating in river) and Topsoil

Characteristics			Media			
	Parameters		Sludge	Criteria	Topsoil	Criteria
chemical	pH	H_2O	4.10	Very acid	4,52	Acid
	CEC	-	12.25	Low	5,75	Very low
	Saturity (%)	Base	48.60	Medium	29,80	Low
		Al	18.56	low	68,54	High
	Organic matter (%)	C Organic	4.21	high	0,68	Very low
		N Total	0.12	Low	0,03	Very low
	Availability (ppm)	K_2O	78.92	Very high	34,45	Medium
		P_2O_5	11.25	Medium	2,58	Very low
Physical	Texture	Clay	52.30	-	20,90	-
		Silt	25.10	-	4,90	-
		Sand	22.60	-	74,20	-
		Class	Clay		SCL	

Note: Assessment criteria based on Research Center of Soil, Bogor in Sondari (2011)

The research was conducted on a 7x11 m plot. Next, on the plot 1x1x1 m, holes were made at a distance of 1m for each hole (20 holes). They were filled by planting medium obtained from mixing sludge and topsoil (The process of mixing needed a mixer (molen machine). Then, Calopogonium mucunoides cover crop was planted on the medium. The planted cover crop seeds were those of one month ageand had been sown in a wicker basket. The amount of seeds in each basket was twenty-five plants with 20 cm average height. The position of planting was precise in the middle of growing media (the planting space was 2 m from one another).

The study was designed by Completely Randomized Design with a single factor, five treatments and repeated four times. The treatment consisted of five levels of mixing sludge with topsoil, namely: 0% (without sludge), 25%, 50%, 75% and 100% (full of sludge). The analysis of variance was conducted to investigate the effect of treatment on the data result. When the analysis results revealed a significant effect, it would be continued by Least Significant Different (LSD) test. To identify the effect of treatment on the obtained data, a correlation test was administered. All obtained data were proceeded by SPSS-20.

2.2. Soil Sampling, Soil Analysis and Biomass Weight Measurement

Soil sampling was conducted before planting (Phase I) and post-harvesting (stage II) in each treatment and replication (0-20 cm depth). Next, the sample was dried, crushed and sieved with the 2- mesh-size hole. Measuring soil's pH H2O applied a ratio of 1:1 (water and soil). N-Total applied macro-Kjeldahl method [16]. The Organic-C applied Walkley Black method [17]. The available P and K used Bray P1 (Jackson, 1958). K +, Na +, Ca ++ and Mg ++ cations used Ammonium Acetate (1 M NH4OAc buffered at pH 7). Al3 + saturation used titrimetric method. The soil was extracted by 1 M of KCl, then titrated by 0.05 M of NaOH [18]. The dry weight of cover crop biomass (after yield) was observed after drying (45^0C) and weighed to reach the constant weight.

III. Result And Discussion

3.1. Characterization of Sludge and Topsoil

The result of chemical analysis (Table 1) indicated that the obtained sludge (still fresh) had very acidic pH, CEC, Al saturation and low concentration of total N, medium base saturation and P_2O_5, high Organic-C and very high K_2O.Meanwhile, the chemical analysis results of topsoil confirmed that pH was categorized acid, CEC, Organic-C, N total and P2O5 were very low, base saturation was low, Al saturation was high and K2O was medium. Based on the comparison of two analysis results, it could be seen that the sludge obtained from Sambutan River had a relatively good nutrient when compared with the topsoil resulted by stripping pre-mining activities. Thus, the sludge was highly potential as soil's conditioner material.

3.2. Changes in Properties of Growing Media (Topsoil and Sludge Mixing) Before Planting and After Yield

Various changes in the properties of growing media before planting and after yield were summarized in the following table:

Table 2 Effects of Mixing River's Sludgeon Soil's Chemical Properties (pH, H2O, KB, Al Saturation and Organic-C)

Sludge (%)	Parameter											
	pH (H_2O)			Base Saturation (%)			Al. Saturation (%)			C Organic (%)		
	Sample taken and Observation		Changes	Sample taken and Observation		Changes	Sample taken and Observation		Changes	Sample taken and Observation		Changes
	I	II		I	II		I	II		I	II	
P_0- 0	4.59 [a]	4.61 [a]	0.02	27.80[a]	25.73 [a]	-2.07	55.41 [a]	63.88[a]	8.47	0.54 [a]	0.50 [a]	-0.04
P_1-25	4.60 [a]	4.64 [a]	0.04	34.61[a]	36.37 [b]	1.76	44.70[ab]	41.40[b]	-3.30	1.26 [b]	1.03 [b]	-0.23
P_2- 50	4.15 [b]	4.26 [b]	0.11	44.75[b]	51.19 [c]	6.44	41.99[b]	37.67[b]	-4.32	1.59 [c]	1.30 [c]	-0.29
P_3- 75	4.19 [b]	4.31 [b]	0.12	46.80[bc]	53.16 [c]	6.36	35.48[bc]	28.01[c]	-7.47	2.12 [d]	1.58 [d]	-0.54
P_4-100	4.16 [b]	4.08 [c]	-0.08	54.40[c]	55.85 [c]	1.45	24.28[c]	22.79[c]	-1.49	2.70 [e]	2.52 [e]	-0.18
R	-0.79**	-0.89**		0.88**	0.88**		-0.81**	-0.90**		0.97**	0.95**	
Qualitative	high	Very height		Very height	Very height		Very height	Very height		Very height	Very height	

Note:figures followed by the same letter in the same column indicated no significant difference at the α level of 5% based on LSD

Table 3. Impact of sludge mixing to the chemical characteristic of soil for CEC, N Total, P_2O_5 and K_2O)

Sludge (%)	Parameter											
	CEC (cmol.kg^{-1})			N Total (%)			Available P_2O_5 (mg kg^{-1})			Available K_2O (mg kg^{-1})		
	Sample taken and Observation		Changes	Sample taken and Observation		Changes	Sample taken and Observation		Changes	Sample taken and Observation		Changes
	I	II		I	II		I	II		I	II	
P_0- 0	4.03 [a]	3.01 [a]	-1.02	0.03 [a]	0.04 [a]	0.01	1.28[a]	1.48[a]	0.20	31.28 [a]	36.13 [a]	4.84
P_1-25	6.95 [b]	4.52 [a]	-2.43	0.05 [a]	0.07 [a]	0.02	1.78[a]	2.54[a]	0.76	30.62 [a]	34.18 [a]	3.56
P_2- 50	11.15 [c]	13.79 [b]	2.64	0.09 [b]	0.12 [b]	0.03	8.77[b]	10.96[b]	2.19	48.05 [b]	56.87 [b]	8.83
P_3- 75	13.47 [cd]	15,16 [bc]	1.69	0.10 [b]	0.12 [b]	0.02	10.46[c]	12.32[b]	1.86	49.49 [b]	60.92 [b]	11.44
P_4-100	15.88 [d]	16.62 [c]	0.74	0.17 [c]	0.14 [b]	-0.03	11.50[c]	11.26[b]	-0.24	65.51 [c]	74.17 [c]	8.65
R	0.93**	0.93**		0.94**	0.83**		0.93**	0.86**		0.91**	0.92**	
Qualitative	Very high	Very high		Very high	Very high		Very high	Very high		Very high	Very high	

Note:figures followed by the same letter in the same column indicated no significant difference at the α level of 5% based on LSD

Table 4. Effect of Mixing River Sludge toward nutrient solubility (Ca++ and Mg++), permeability rate and Cover Crop Biomass Dry Weight of Calopo Gonium

Sludge (%)	Parameter									
	Ca (cmol.kg^{-1})			Mg (cmol.kg^{-1})			Laju Permeabilitas (cm/jam)			Biomass Dry Weight (gram/m^2)
	Stage of Sampling		Changes	Stage of Sampling		Changes	Stage of Sampling		Changes	
	I	II		I	II		I	II		
P_0- 0	0,02	0,05	0,03	0,14	0,12	-0,02	15,15[a]	15,90[a]	0,74	36,60[a]
P_1-25	0,46	1,09	0,63	0,71	1,05	0,34	18,48[a]	17,75[a]	-0,73	30,18[a]
P_2- 50	0,69	1,80	1,11	1,14	1,43	0,28	7,95[b]	2,06[b]	-5,89	123,93[b]
P_3- 75	0,90	2,48	1,59	1,57	2,55	0,98	6,80[b]	2,38[b]	-4,43	198,28[c]

P_4-100	1,41	2,82	1,41	2,05	2,66	0,61	4,73^b	0,43^b	-4,30	116,10^b
R	0,95**	0,92**		0,93**	0,97**		-0,80**	-0,86**		0,67**
Qualitative	Very high	Very high		Very high	Very high		Very high	Very high		high

Note: figures followed by the same letter in the same column indicated no significant difference at the α level of 5% based on LSD test

3.2.1 Soil Reaction (pH of H2O)

The results confirmed a strong correlation between the increasing concentration of sludge administration and a decrease in pH of growing media before planting and after yield (R = -0.79 and R = -0.89). It is presumed that the organic matter within the sludge decomposed to produce organic acids [19].The decomposition process was inhibited when the sludge was logged in the river (anaerobic). Another cause of low pH is due to the release of H + ions by the process of N denitrification derived from the sludge [10].The lowest pH value was before planting and after yield which was found in P4 treatment (100% sludge) and the highest was at P0 treatment (control). Applying sludge at the level of 50 to 100% (P2, P3, P4) led to significant differences in pH of the control treatment (before planting and after yield).The study results also revealed the addition of sludge dose by 50 and 75% (P2 and P3) did not show significant differences on changes of soil's pH values (before and after planting). From Table 2, it presented an increase in soil's pH value after 40 days of planting. The increase occurred in treatments of P1 (25%), P2 (50%) and P3 (75%). It is presumed that organic matters in the sludge have been mineralized and they release base cations (K, Ca and Mg) which can increase soil pH [20]. The increasing pH did not occur in P4 (100%), it was because the decomposition process of organic material was hampered by the existence of puddles on the plot.

3.2.2 Base and Al saturations

Based on Table 2, it showed that adding sludge concentration caused an intense impact on the increased value of planting medium's Base saturation (R = 0.88 before planting and R = 0.88 after yield). Also, the correlations were similar for Al saturation value, but it decreased Al saturation values in line with the increase of sludge concentration (R = -0.81 before planting and R = -0.90 after yield). It was presumably caused by the deposition of alkaline elements (mainly Ca and Mg) contained in the sludge used in this study. The base element was derived from leaching process by runoff which dissolved the base cations into the river water. These cations reacted with the detergent waste water and then they settled as calcium and magnesium salts with river sludge. Based on chemical reactions, the process was described in the following reaction [21] [22]:

$$\underset{\text{(Water Soluble)}}{2C_{17}H_{35}COO^{-}Na^{+}} + Ca^{2+} \rightarrow \underset{\text{(ppt)}}{\mathbf{Ca(C_{17}H_{35}CO_2)_2}} + \mathbf{2Na^{+}}$$

$$\underset{\text{(Water Soluble)}}{2C_{17}H_{35}COO^{-}Na^{+}} + Mg^{2+} \rightarrow \underset{\text{(ppt)}}{\mathbf{Mg(C_{17}H_{35}CO_2)_2}} + \mathbf{2Na^{+}}$$

Furthermore, when the sediment sludge was used as a growing medium, the base elements (Ca and Mg) within the sludge was dry and reacted with rain water to form Ca2+ and Mg2+cations. The cations would be absorbed by soil colloids dominated by negative charges. It resulted in soil's high Base Saturation value. On the other side, the base cations could neutralize the dissolved Al elements in order to lower the saturation value of Al in the growing media. From Table 2,it showed that applying sludge 75% (P3) and 100% (P4) did not result in a significant difference, but those two treatments provided a significant difference with the treatment without sludge (P0) (before planting and after yield). Similar conditions were also found in the value of Al saturation. The value of base saturation on sludge administration treatment (P1, P2, P3 and P4) tended to increase after harvesting. The opposite condition occurred in Al saturation value, possibly due to longer process of releasing Ca and Mg bound by the increasing of detergent's active ingredient. Thus, the solubility of Ca2+ and Mg2+ increased (Table 4). This presumption was supported by the significant difference in P0 treatment (control) with P1 (25% sludge) toward the Base and Al saturation values (before planting). The condition changed after 40 days of planting in which those two treatments (P0 and P1) showed significant differences.

3.2.3 Organic-C

Organic-C value in growing media showed an intense correlation affected by the concentration of sludge and topsoil mixture. It was confirmed by the increase ofOrganic-C valuein line with the increase of sludge concentration (R = 0.97 before planting and R = 0.95after yield). Besides, all treatments showed significant differences oneanother (before planting and after yield). The effect of sawage sludge (concentrations of 0, 25, 75, 100, 125 tons ha-1) shows a highly significant difference in the improvement of soil organic matter content [10]. These conditions are due to sawage sludge's basic characteristics namely rich in organic material derived from organic waste, vegetation and aquatic organisms [23]. The highest organic matter content ofgrowing media was found in P4 treatment (100% sludge) with the approximate value 5 times higher than P0 treatment (control). This condition occurred before planting and after yield. The percentage of organic matter in the growing medium tended to decrease after 40 days of planting. It was presumably that the fresh organic material in sludge underwent the process of decomposition due to the change of anaerobic (waterlogged) into aerobic condition (dry).

3.2.4 N Total

Based on Table 2, itpresented a very strong positive correlation between adding concentrations of sludge and N total percentage in the planting medium (R = 0.94 before planting and R = 0.83after yield).Itrevealed that N was the primary source of organic matter in sludge. Based on the study, NTotal content of P4 treatment (100% sludge) was the highest and significantly different from the other treatments (before planting). Different conditions occurred after 40 days of planting (after yield),where N total value of P4 treatment did not show significant differences toward P2 treatment (50% sludge) and P3 (75% sludge).It wasbecause the organic matter decomposition and cover crop litter were hampered by the (anaerobic conditions) temporary puddles on the surface of P4 treatment plots. Puddlesalso loweredN total content (after yield) in the treatment (0.03%). It was supported by Indriyati, et al. (2007), who stated that the flooding caused N deficiency as a result of changes in nitrate ion (NO_3^-) to be N2O and then becameN2 (denitrification process) [24]. From Table 2, it showed that the percentage of N total in 25% of sludge concentration (P1) did not show significant differences with control treatment (P0) (before planting or after yield). It wasbecause the growth process of cover crop in P1treatment plots was quite hampered so that there was not too much N supply for the growing media.

3.2.5 Available P

The results of correlation test showed that the effect inadding sludge concentration had a very strong influence and resultedthe increased solubility of P Available in the planting medium (R = 0.92 before planting and R = 0.86 after yield). The highest content was found in P4 treatment (100% sludge) and significantly different from other treatments except P3 treatment (75% sludge). The content of Available P in P4 treatment was approximately eight times higher than P0 treatment (topsoil). It was found in the pre-planting condition and after yield. The data illustrated that the content of Available P on topsoil which was used as a growing medium was very low. It was presumably because Ultisol parent materialwas poor in minerals as the source of P element like Apatite [25]. On the other hand, the available high P content of sludgewas supposedly derived from organic matter contained in sludge and deposition of sludge detergent waste having $Na_5P_3O_{10}$ (sodium tripolyphosphate). From Table 3, it showed that the concentration of Available P afteryield (40 days) tended to increase in all treatments, except P4 treatment (100% sludge). It was supposed thatthe reformation process of organic-P into inorganic-P was hampered due to anaerobic conditions (the presence of waterlog). Similarly, it was reported by Sulistiyanto, et al. (2005), who stated that the low availability of P in forest soils with high ground water (stagnant) was due to the inhibition of inorganic material decomposition (litter) by soil micro-organisms [26]. Another assumption was due to low pH of the growing media so that some of H2PO4- ions were precipitated in the form of FePO4. 2H2O. The chemical reaction could be written as follows:
The reactionwas reversible and caused P availability to increasewhen the solubility of H+ ions in the soil solution decreased [27] [28].

3.2.6 Available K

The results showed that the value of Available K was highly correlated with the increase of sludge concentration (R = 0.91 before planting and R = 0.92after yield). From Table 3, it listed that the concentration of Available K in P4 treatment (100% sludge) was the highest and significantly different from other treatments (before planting and after yield). It was presumed that it was caused by colloidal clay of sludge with a very rich K element. The element was derived from the decomposition podsolization process of mica and feldspar primary minerals to form kaolinitic secondary minerals. Based on the table, it also confirmed that after 40 days of planting (after yield) the level of Available K concentration tended to increase in all treatments. It was supposed that the release of K+ bound to the colloidal clay's complex absorption from sludge had increased (due to the change from aerobic to anaerobic conditions). Scholar point out that increase of available K generally occurs close to the rice field drying phase (ripening) [29]. It was presumably related to the soil conditions which were not re-flooded and better soil aeration. This situation led to the oxidation of Fe2+ and Mn2+ by releasing H+. As a result, H+ ions could release the fixated K+ into Available K.

3.2.7 Permeability Rate

From Table 4, it presented that the effect of adding sludge concentration showed an intense correlation resulting in the decrease of planting medium's permeability rate (R = -0.80 before planting and R = -0.86 after yield). Different conditions reported by Usman, et al. (2012) and Hussein (2009) stated that the rate of soil permeability increases with the sludge administration [10] [23]. The difference was presumably because the sludge used in this study contained much organic colloids and colloidal clay. When a mixture of sludge and topsoil took place, both colloids would fill the mesopore and macropore within the topsoil. It delayed the gravitational water to go down to the bottom layer of planting media. From Table 4, it revealed that after 40 days of the growing season, there was a tendency of deterioration in the permeability rate for P1, P2, P3 and P4 treatments (all treatments containing sludge). It was presumably because of the sludge which tended to condense (volume shrinking) and reduce the macropore of growing media. Based on this study, it was observable that administrating mud between 50-100% (P2, P3 and P4) showed no significant difference in the rate of soil permeability (before planting and after yield).

3.3. Land Productivity (Biomass Weight)

The measurement results of cover crop's biomass dry weight showed a strong correlation and tended to increase in line with the raising sludge concentration (R = 0.67). The lowest weight of cover crop biomass was observed in P0 and P1 treatments (both were not significantly different). It was presumably because the nutrient content and the ability to hold water in these treatments (P0 and P1) were very low. The poor ability in water holding was evident from the high rate permeability of planting medium namely: P0 at 15.15 cm/h and P1 at 18.48 cm/h. This condition resulted in the poor growth of cover crop. It was in line with Prijono (2007) who stated that the water requirement for crop is very important since it can affect the plant productivity [30]. The highest weight of cover crop biomass was found in P3 treatment (75% of sludge concentration). It was presumably due to the high nutrient content and good water holding in the treatment of growing media. From this study, it revealed that administrating total sludge (P4) did not provide the highest condition for the cover crop's biomass weight. It was presumably due to low permeability rate (when the rainfall intensity was high) causing puddles on the surface of P4 plot. This situation can lower the gas exchange in soil and air so that it reducesO2 availability (anoxia) for plant roots and soil micro-organisms [31]. The impact of this condition is the mitigation of mineral distribution from roots to other parts of plant. It causes the plants to be dwarf, so it reduces plant's biomass (dry weight) [32].

IV. Conclusion

River sludge used in this study is very potential as a soil conditioner material for critical post-mining land. It was revealed by the increase of soil's chemical properties as follows: Base saturation, Organic-C, CEC, N total, Available P, Available K, exchangeable Ca and Mg. On the other hand, there was a decline in pH (H2O) and Al saturation. In general, the best chemical properties change occurred in the level of 50%(P2) and 75% (P3) sludge mixture. It was also identified in the highest cover crop biomass production at 198.28 g/m^2 (P3) and 123.93 g/m^2 (P2).

Utilizing sludge as a soil conditioner should consider the following things: taking a liming action to prevent the occurrence of pH decrease; making bunds to prevent inundation; pausing several weeks between sludge removal from the river and its application as a soil conditioner. To determine the proper dose of liming, the height of sludge bund and exact pause, a further field research is required.

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