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Research Article

Clay and organic matter applications on the coarse quartzy tailing material and the sorghum growth on the post tin mining at Bangka Island

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Abstract : Artisanal mining on the island of Bangka leaves a lot of damaged land surface covered by coarse-sized tailings that are dominated by the quartz mineral and it causes soil to be extremely unfertile. The objective of the present research was to understand the impact of the clay and organic matter (OM) applications on the tailings for supporting the growth of an adaptive plant which is used in the present study is sorghum. The study was conducted on the artisanal mine closure land at Pangkalpinang, the clay material and cow dung were collected from locally near location. Land was prepared by constructing four treatments, i.e.: control, OM + NPK, clay + OM, and clay + OM + NPK. The amendment materials were applied by mixing the tailing on the 30 cm wide and depth on each planting strip with a distance of 70 cm. Sorghum seeds were planted with a spacing of 20 cm. Watering plants was done by utilizing the water pit at the beginning of germination and plant growth. The results showed that sorghum grown and survived only one month in the control treatment. Sorghum growth is very good on the treatment of clay + OM+ NPK, while the other two treatments result in stunted growth of sorghum.

Keywords: *artisanal mining, Bangka Island, clay*

Introduction

Land in the area of Bangka Island, Indonesia, was formerly as land cover of forest and farmland. Many of tin mining activities in artisanal and small scale mining (ASM) resulted in the formation of land having an uneven surface and formed puddles and pits or *kolong*. In addition, after the mining activity is completed many of lands are left without a good reclamation process. In addition, many of top soils were disposed of during the mining process took place. Top soils should be separated and stored in the protected area along the overburden excavation prior the tin extraction, and then these would be used as material for post-mining land reclamation.

There is severely ruined environment in Bangka and Belitung islands due to uncontrolled tin mining (Aspinal, 2001 and Nurtjahya et al., 2009). Field observation on many areas of the tin mined-land on both islands showed that there were huge holes with standing turbid water, termed as *kolong*, mounds of dirt resembling barren land, and also white coloured land surface of quartz sand-tailing. But with the loss of tip soil during the mining process, then the land is abandoned after the mining process in the form of coarse-sized piles of tailings and dominated by quartz.

Generally, artisanal and small-scale mining (ASM) in Indonesia is undertaken with little or no environmental care (McMahon et al., 2000). They added that until the 1980s ASM was quite small with limited damage. However, steady growth in the decade before the crisis and a substantial increase in ASM in Indonesia have significantly changed that situation.

Another problem that can also be generated is the presence of pyrite material. At the time before the mining process, this material was under the soil surface, so that this material was in the reduction. With the mining activities, this material can be exposed to the surface of the soil and then this material can be oxidized to sulfuric acid.

The impact of mining that do not comply with the provisions of the right may leave the land with a surface without vegetation, uneven and irregular micro-relief and the lack of a functioning soil layer supporting biophysical environment and it cannot produces economically. Most ASM areas have a short productive life, usually less than ten years (McMahon et al., 2000). While small-scale mining may increase rural incomes in the short term, increased reliance on mining relative to agriculture combined with significant environmental damage during the mining phase may have lasting impact on the potential for a more balanced rural development in mined-over areas.

Land reclamation at the site of ASM that has been done much constrained by images of the people that it has no experts that successfully reclaimed the post tin mining area in Bangka Island. Community and policy makers claim that the reclamation process is not economical and it requires expensive and difficult to apply high technology in society. Rehabilitating the environment caused by ASM of tin mining in Bangka requires a huge amount of money (Aspinall, 2001). In this report, he also referred the statement of governor that "Even if *timah* (tin) assets were sold, it still would not be enough to repair the extensive damage". Sustainable land management needs a selection of appropriate adaptive management (Zhao et al., 2005), especially on degraded lands (Cowie et al., 2011). Although the climate in Bangka island is not classified as dry climate, there are six months in average dry season annually. In this season, it is very difficult to grow the seasonal crops, such as main food and vegetable crops, without irrigation practice. Many kinds of crop were tried to be grown in this degraded post mining land, however there were not good result. There were not available of soil as plants growth medium, nutrients and water at dry season on the coarse tailing materials that dominated with quartz mineral.

Based on this phenomenon post-tin mining land in the island of Bangka, it would require technology that is simple and readily available materials as an amendment material and does not require an expensive cost. In addition, a selected plant from dry climate is needed, so the plant can grow well especially during the dry season. So this study was aimed to study the application of local materials that can be used to reclaim the post-mining land which is covered by coarse tailing materials and dominated by the mineral quartz, and then growing the adaptive food crop to initiate foodstuff supply in this region.

Materials and Methods

The experimental site was located at the complex of the offices area of the Kepulauan Bangka Belitung province, located in Pangkalpinang city. This land was as a post artisanal tin mining, and the land use was as forest before the mining activity. Mining activity was done by manual tools that people had. To reach the tin ore layer, firstly they removed the overburden and also the topsoil. Unfortunately, the top soil was not stored at the save area, so that it lost by the erosion. By process of back filling, the pit as result from tin extraction was filled with tailing. This method resulted in piled of tailing which was containing coarse materials that dominated by quartz and it was white in colour.

The reclamation experiment was done on the area of thousand square meters, and it was begun at the end of September 2011. The land was leveled prior to use as the area of experiment. There were three samples collected from the tailing materials, and they would be analyzed to understand the physical and chemical properties of the tailing. There was also a material layer showing soft, fine in size, and gray in colour. This material was also collected and it was also analyzed like the tailing materials. The tailing and clay materials were then air dried and sieved passing 2 mm in size for physical and chemical analysis. Texture of these materials was analyzed by the mechanical method. Cation exchange capacity was analyzed by the extraction using NH4OAc pH 7, the extractable cations of Ca, Mg, K and Na were then measured using AAS. Sn and Pb were analyzed in order to understand potential of the content of the metals in the residual materials. The pH(H_2O), pH(KCl), electrical conductivity (EC), total-N, organic-C, available P were also analyzed. Chemical properties of water at pit (*kolong*) were also determined to understand the environmental quality of the post mining area.

In this study, the concept of reclamation was designed by constructing the tailing materials to be close to an artificial soil. It was thought because the tailing was a coarse material, and extremely low content of both silt and clay fractions. As the tailing was originally from the layers of overburden and the waste of the tin extraction, it was also containing an extremely low of organic matter. By applying the clay material and cow dung that were already available in this area, it would be easily used to ameliorate the coarse tailing. Also, it did not need cost for transportation as these materials were collected in the area of the experiment. It was thought to encounter that reclamation is not identically expensive work.

The experiment was set by constructing the planting strips with distance of 70 cm. In order to minimize the requirements of the amelioration materials, the amelioration was done by mixing it with the tailing only on the strips of the planting at 30 cm in width and depth.

The experiment was prepared by constructing four treatments, i.e.: control, OM + NPK, clay + OM, and clay + OM + NPK. After the land preparation was completely done, the seed of sorghum was planted with distance of 20 cm. Sorghum was chosen to be planted because it had a potential to grow well although at marginal environment, although it was already categorized as lost crops of Africa (National Research Council, 1996).

During the two weeks after planting, watering was done for everyday because there was a dry season. Also the seed absolutely needed a moist condition in order to get a germination stage. From the middle October 2011, the rainy season was come and the watering was then stopped. Measurement of plant height was periodically done for every week.

Results and Discussion

Characteristics of studied tailing

Table 1 shows the tailing was dominated by the coarse fraction that was more than 90% sand and clay content of only around 4-7%. Reaction or pH(H_2O) tailings ranged from 4.3 to 4.5, while pH(KCl) ranged from 4.1 to 4.3. The difference between pH(H_2O) with pH(KCl) of less than 0.5 indicated that the tailing was dominated by variable charge minerals. Organic content ranged from 0.22 to 0.32%, which was as remain of the decomposition of organic material from vegetation that growing in the past prior to mining. Total N content was very low, about 0.02% with C/N ratio was low at 11-12%. P availability was also very low at 4.6 to 5.8 ppm. Tailings material had a very low CEC value with a range of 1.39 to 1.59 cmol (+)/kg and exchangeable base cations (Ca^{+2}, Mg^{+2}, K^+ and Na^+) was also very low. Base saturation ranged from a low to moderate. With this need to be aware that the tailings that had been examined, the availability of Pb ranged from 0.03 to 0.10 ppm, which have the potential contamination of crops grown.

Table 1. characteristics of the tailings and clay

Parameter	Tailing				Clay
	1	2	3	4	
pH H_2O	4.5	4.4	4.3	4.3	3.7
pH KCl	4.3	4.3	4.2	4.1	3.4
C-organic (%)	0.24	0.32	0.24	0.22	0.64
N-total (%)	0.02	0.03	0.02	0.02	0.06
C/N ratio	12	11	12	11	11
Available P-Bray (ppm)	4.6	5.2	5,0	5,8	9.9
Exchangable cations					
Ca (cmol(+)/kg)	0.52	0.29	0.18	0.18	0.71
Mg (cmol(+)/kg)	0.15	0.19	0.13	0.11	0.36
K (cmol(+)/kg)	0.02	0.02	0.02	0.02	0.05
Na (cmol(+)/kg)	0.00	0.08	0.05	0.03	0.22
Al (cmol(+)/kg)	0,04	0,06	0,04	0,00	2,07
H (cmol(+)/kg)	0,10	0,12	0,08	0,06	1,3
CEC (cmol/kg)	1.59	1.56	1.51	1.39	7.69
Fractions					
Sand (%)	92	92	92	94	37
Silt (%)	3	3	1	2	48
clay (%)	5	5	7	4	15
Texture	Sand	sand	sand	sand	loam

Clay material which used as amendment had pH(H_2O) 3.7, which was lower than the pH of which reclaimed tailings. In addition, the clay also had value difference between pH(H_2O) with a pH(KCl) of less than 0.5 also meant as variable charge clay. The content of organic C, total N and P availability at the clay showed higher than that tailings, but the C/N ratio between both tailing and clay were relatively similar. CEC of the clay material was also low at 7.69 cmol (+)/kg with a content of the base cations and base saturation which low only 10.40%. Al saturation in the clay material was high at 26.92%, which had potential toxicity for plant roots which sensitive to Al toxicity.

Characteristics of the pit water

In the process of extraction tin with a spray method can leave a coarse material deposited directly on the site. Then the fine-sized material is slowly deposited gradually in accordance with the size of the material. With the size of very fine material, forming a layer which sediment is impermeable to water. In the advance of small basin land as a result of excavation until the tin ore is found then the basin becomes water reserve a place called the pit water (Figure 1). The presence of the pit water could potentially be used as irrigation water in reclamation by re-vegetation when the plant needs water.

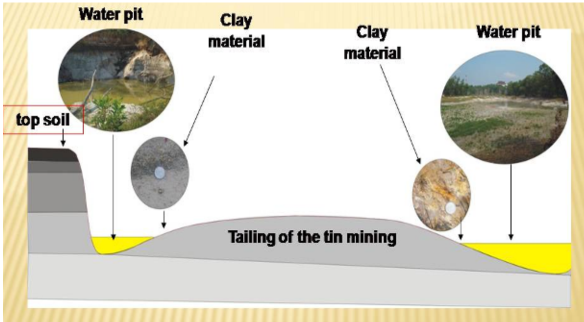

Figure 1. The land surface on the post tin-mining activity

Table 2 shows the results of chemical analysis of the pit water. Based on the pH value of the pit water it can be said that the water reacted acid. Acidity of the pit water can be generated by mineral oxidation processes that occur in the process of excavation of overburden and extraction of tin. Field observations indicated the presence of sulfide minerals in the mining location. These minerals were then underwent oxidation and produced free sulfuric acid. Based on water analysis also obtained a Pb element of 0.01mg/L as for Sn was not detected in the pit water.

Table 2. Chemical properties of the pit water used as irrigation water

Parameter	Value
pH	4.8
K (mg/L)	0.9
Na (mg/L)	4.64
Ca (mg/L)	3,24
Mg (mg/L)	0.41
Sn (mg/L)	nd
Pb (mg/L)	0.01
EC (mS/cm)	0.049

Amendement of the tailing

To improve the quality of the growing medium of the tailing in this research had been thought as follows. The tailing had a very high permeability and very good aeration for plant growth, but it had retention and nutrient content that was very low as also reported by Nurtjahya et al. (2008). Even sandy soils in northeast Thailand are also characterized as low fertility in nature and they are needed to be ameliorated to become productive soils (Wada, 2005). The tailing with a very bad nature was then ameliorated by clay material from around the site as the insertion of clay that has been exposed during the mining process. This was to facilitate the reclamation process and did not require an expensive cost. But the clay also had chemical properties that were very bad. So it needed materials that play a role in improving the quality of the growing medium for plants, and that was organic matter (Table 3).

Table 3. Chemical properties of the cow dung used in the study

Parameter	Value
Organic C (%)	9.96
Total N (%)	0.8
C/N ratio	12
Available P (%)	5.32
Exchangeable K(%)	1,46

The clay also had a sufficiently high Al saturation value, so it had to be bound by the organic compounds that Al to be not active, and the degree of Al toxicity could be suppressed.

The combination of materials that are dominated by sand with clay material can form a good soil structure and increase the nutrient retention. Fertilizer is then added as additional nutrients can be bound by these combination materials as exchangeable elements. However, the only combination of organic matter and coarse material is not able to form a good structure and also fertilizers that are added are not bounded by such materials, and then they easily leached and they are not able to be utilized by plants.

The combination of tailings, clay and organic matter alone could not suffice and provided good conditions for plant growth. This was because the clay used did not have enough nutrients, and this was shown by the growth of sorghum plants were stunted. In this study the application of amendments made in the form of strip so that the costs used to improve tailing were low (Figure 2).

Growth of sorghum

The present study showed that sorghum plants can grow well in media with acidity levels and also a high percentage of exchangeable Al. This was shown by morphological roots that grow well (Figure 3), so that plant roots can grow well without showing any symptoms of Al toxicity and with very low fertility media. Based on these results it can be said that sorghum has a tolerance of fertility and low pH and Al toxicity.

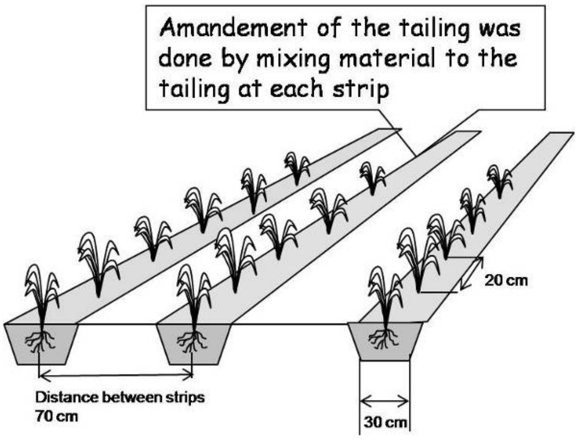

Figure 2. Model of the reclamation on the tailing of the post tin-mined land

Figure 3 also showed that root growth was in the zone of tailing that had been improved by the additions of clay and organic matter. This treatment could enhance the media's ability to absorb water and provide adequately for sorghum plants, especially when the media did not receiving water supply. Management of sandy soils was based on the soil characteristics and crop suitability to achieve sustainable (Zhao et al., 2005). In addition, nutrients were added in this study, that were nitrogen, phosphorus and potassium, could be stored and then available in the exchange complex. As for that was not added clay could be made possible many of these elements were leached. This was indicated by stunted growth in other two treatments of NPK + OM and clay + OM, and moreover those without treatment (control) plants can only survive within a month.

There was a very clear distinction between the treatments with complete and control on sorghum leaf colour (Figure 4). In the control treatment, leafs showed yellowish green in colour and then gradually became red and leaf tip showed a purplish red colour. The leaf colour might indicated that the control treatment there was deficiency of macro elements of N, P and K. while for the other three treatments showed the adequacy of the third element of the macro nutrients. Sorghum was reported as very responsive plant to N and P nutrients (Booker et al., 2007). The change of leaf colour is caused by a deficiency of nitrogen element that few of NO3 and NH4 + are transported through the phloem, resulting in discolouration and eventually chlorotic. Sorghum crops are experiencing certain symptoms of nitrogen deficiency are typical.

Figure 3. The roots of the cultivated sorghum at the treatment of the clay + OM + NPK.

Visible symptoms are chlorosis on young leafs which occur starting from the tip of the leaf. Chlorosis begins in young leafs because of nature the nitrogen that is not easily transported from older leafs. Low mobility probably occurs because one of the major protein-containing leaf nitrogen is the Rubisco photosynthetic enzymes. When the enzyme was hydrolyzed by proteinase, photosynthetic activity would go down and this is a process of self-destruction. In case of prolonged deficient, chlorotic leaf also happen to the bones so that all parts of the pale-coloured leaf. Which causes stunted growth of leafs inhibited the ability of photosynthesis.

Figure 4. The colour of sorghum leafs at control (left) and the treatment of clay + OM + NPK (right) after three weeks.

The destruction of chlorophyll due to deficiency of nutrients caused the loss of chloroplast function. Leaf cells did not develop optimally, particularly the palisade and spongy cells shrink and less of chlorophyll. Furthermore, the process of photosynthesis takes place was not perfect so stunted plant growth.

Figure 5 shows a very obvious difference between the height of plants that received the treatment and control. Sorghum plant height increases linearly and significant up to 13-week-old plants on tailings that were given a mixture of clay + NPK + OM. This was supposed due to the addition of clay media structures originally single grain to be structured so might hold water longer to suffice the needs of plants. In addition former tin mine tailing was very poor in nutrients can be improved by the addition of organic matter (OM) and NPK fertilizers so nutrients become available.

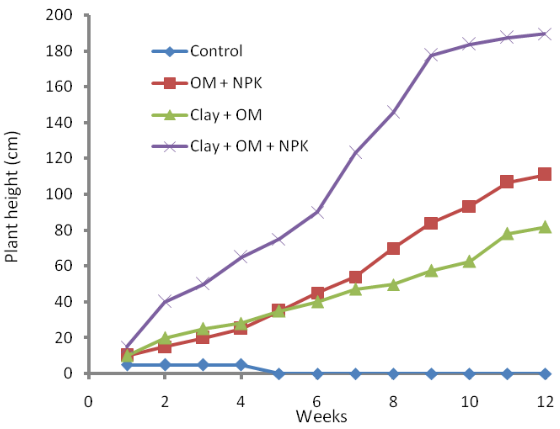

Figure 5. Plant height of the sorghum that cultivated on the tailing after reclamation

Conclussions

According to the present study, it is concluded that sorghum grown and survived only one month in the quartzy coarse tailing or as control treatment. Sorghum growth is very good on the tailing after the treatment of clay + OM+ NPK, while the other two treatments result in stunted growth of sorghum.

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