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Bioremediation of Iron on Diamond Post Mining Soil Using Compost Made from Cow Manure and Traditional Market Organic Waste

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ABSTRACT

The purpose of this research was to improve the diamond post-mining soil quality using a bioremediation composting method based on the cow manure and organic waste from a traditional market. This research was conducted for: 1) identifying the conditions for temperature, pH and moisture during the composting process; 2) analyzing the difference of variations in composition and the best composting durations. The bioremediation method used is open windrow composting, divided into four composition variations, namely variation A (100% soil); B (75% soil: 25% compost); C (50% soil: 50% compost); D (25% soil: 75% compost). The variations of composting duration are 15th and 30th days. From the result of two-way ANOVA test, it can be concluded that there is no significant difference in the decrease of Fe value due to the variations in composition ratio and duration of composting.

Keywords: bioremediation, composting, cow manure, Fe, market organic waste.

INTRODUCTION

The environmental damage is caused by mining activities. This is because the mining activities such as coal, metal, gold or diamond mining produces hazardous and toxic waste that contain heavy metals. The content of heavy metals is what makes the environment damaged. In order to minimize the environmental damage, it is necessary to manage the mining waste products to mitigate environmental damage that will occur (Sidabutar, 2013). However, repairing the soil damaged by heavy metal waste requires a long time. Besides, the recovery of soil damage can be accelerated by adding bacteria into the polluted soil, which is also called bioremediation (Sudaryono, 2007).

The diamond mining in Banjarbaru in Cempaka District is a form of community mining. Community mining involves small-scale mining operations that are carried out by local communities. These mining activities affect the chemical, physical, and biological properties of the soil. The physical constraints include, e.g. damaged soil

structure, while the chemical constraints – a low pH and high iron (Fe) levels.

On the basis of the author's preliminary study in February 2019, the diamond mining in the Tiung River village, Cempaka sub-district, contributed to a high Fe heavy metal content in the soil, namely 1755.83 mg/kg. If the concentration of Fe in the soil that is 30 ppm it can poison the plants (Tadano and Yoshida, 1978; Yoshida, 1981), so it is not good for the agricultural soil. Because Fe is an essential metal that often is toxic to humans in large doses, eventually causing death (Hakiki, 2018).

One method of bioremediation is composting, which is a technique of removing the harmful pollutants from the environment. The main principle of bioremediation process involves increasing the microbial activity through controlling temperature, pH, and humidity. The bioremediation techniques using compost made from organic waste can be employed to overcome the damage to soil affected by pollutants (Mizwar, 2014). The compost addition can thus be considered as a 'super-bioaugmentation' with a complex natural mixture

of degrading microorganisms, combined with a 'biostimulation' by nutrient containing readily to hardly degradable organic substrates. It also improves the abiotic soil conditions, thus enhancing the microbial activity in general (Kästner and Miltner, 2016). An organic fertilizer or compost has several advantages compared to an inorganic fertilizer. These advantages include complete micro and macro nutrients, even though the amount is small and can improve the soil structure by loosening and increasing the soil availability. Compost is a fertilizer that comes from the weathering process of materials in the form of leaves, straw, reeds, grass, animal waste, organic waste and others. Compost has the advantage of being able to improve the soil physical properties, as well as the chemical and biological ones.

MATERIAL AND METHOD

This research was conducted from April to July 2019. The soil sampling was done in ex-diamond mining soil in Cempaka District. Bioremediation with the composting method was conducted at the Education Techno Park (ETP) of the Engineering Faculty Lambung Mangkurat University. Compost fertilizer and soil sample testing are carried out at the Banjarbaru Center for Environmental Health and Disease Control (BBTKLPP) Laboratory.

The materials used in this research were 300 kg of ex-mining soil, 180 kg of cow manure compost and 180 kg of half processed organic waste. The used tools included shovels, hoes, analytical scales, gunny sacks, tarps, trash bags, soil survey instruments, soil testers, cameras as research documentation tools, and other tools that supported this research.

The research design used is Complete Random Design with 4 variations of composition and 3 replications. The variations of soil and compost ratio namely: 100% soil as a control, A (75% soil: 25% compost), B (50% soil: 50% compost), C (25% soil: 75% compost). Each pile contained 40 kg soil and compost mixture. The height of each pile is 30th cm and the distance from each pile is 30th cm.

The composting process was carried out for 15th and 30th days. The measurement of temperature, pH and humidity was done every day at 13.00 – 14.00 AM at three points of the pile (top, middle, bottom) using a soil survey instrument and soil tester. The research data were presented

in graphical form to identify the pH, temperature and humidity conditions.

The analysis of temperature, pH, humidity data, and Fe value were described in a graphic form. Two-way ANOVA test was conducted to analyze the difference of Fe value from the treatment, followed by an LSD test using SPSS 17.1 for Windows to see the best variation in composition variations and composting durations in the open windrow composting system.

RESULT AND DISCUSSION

Bioremediation composting conditions

The graphs of the changes in the compost temperature in each variation namely 100% soil treatment, 75% soil: 25% compost, 50% soil: 50% compost, and 25% soil: 75% compost, as can be seen in Figures 1 and 2. Figure 1 indicated that in the beginning of the of composting bioremediation, the highest temperature is 35.33°C (in 25% soil : 75% compost ratio). While the lowest temperature is in 100% soil variation. Figure 2 shows that the changes in composting bioremediation temperature made from organic waste is higher than the cow manure compost. The highest temperature found on the 5th day at variation of 50% soil: 50% compost ratio.

The graphs of the changes in the compost temperature shows that the bacteria in the open windrow composting process are classified as mesophilic because such bacteria lived in the temperature range 10-40 °C. The mesophilic bacteria play a role in reducing the particle size of organic matter so that the surface area increases and accelerates the composting process (Widyawati et al., 2015). The mesophilic condition is more effective because the activity of microorganisms is dominated by bacteria and fungi. The temperature in each treatment does not reach the thermophilic phase (45-60°C) because the height of the pile is too low that has an impact the compost pile lose heat faster, so that high temperatures cannot be reached (Widarti, 2015).

The temperature at the top of the pile is higher than the middle and bottom point. In turn, the lowest temperature was obtained on the 25th day in variation of 100% soil, 50% soil: 50% compost, and 75% soil: 25% compost ratio.

The graphs of pH changes of compost pile can be seen in Figures 3 and 4. Figure 3 shows the results of the analysis on the pH value of

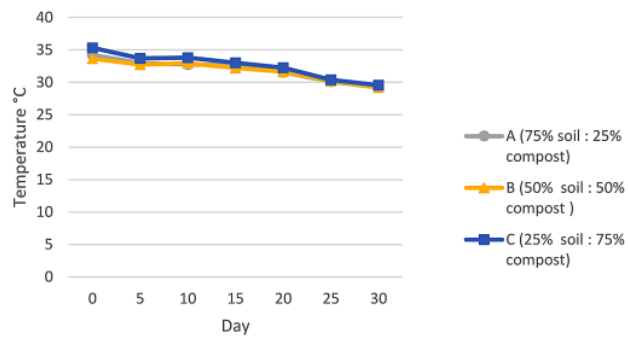


Figure 1. Temperature changes of bioremediation of cow manure made compost

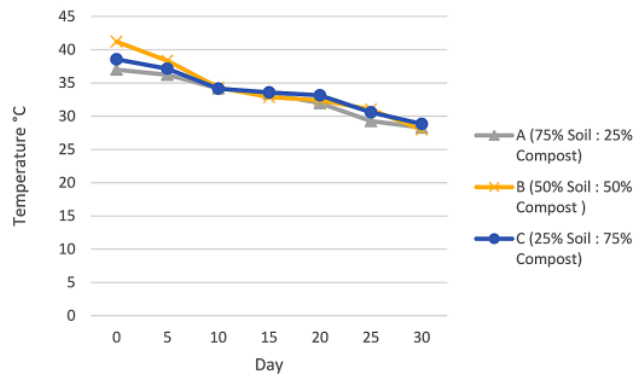


Figure 2. Temperature changes of bioremediation of market organic waste compost

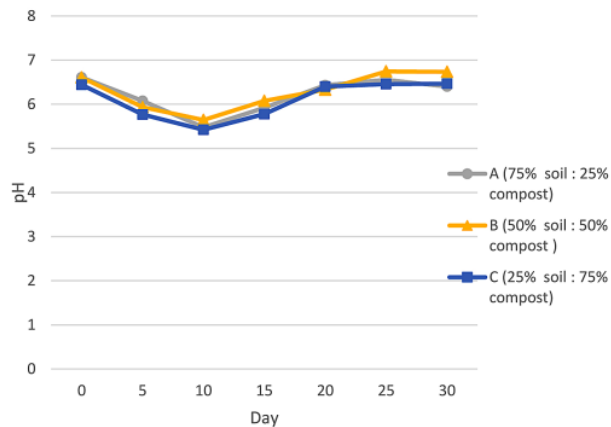


Figure 3. pH changes of bioremediation of cow manure compost

composting bioremediation based on the cow manure. It was observed that during the composting bioremediation process, there was a fluctuation in the pH value. In the composting process, the pH value needs to be considered because it could affect the microorganism activity in it. The pH

value during the composting bioremediation with the values range from 5.1 to 7.00.

In Figure 4, the observation of the changes in pH shows that on 1st day and 2nd day the pH value is low, the pH value becomes relatively stable starts on the 3rd day until the 30th day.

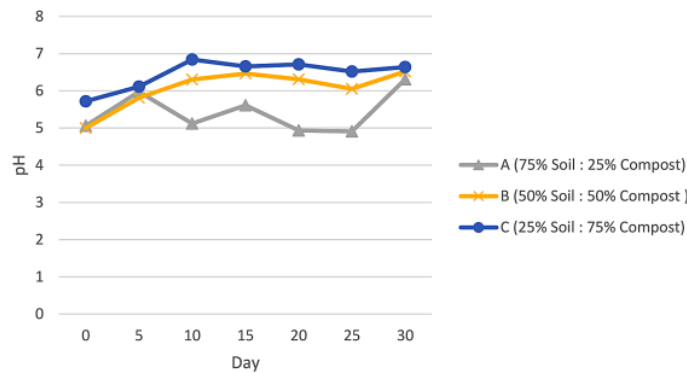


Figure 4. pH changes of bioremediation of market organic waste compost

The composting process causes changes in the organic material and the pH itself. The pH value during the composting period greatly influences the growth of the microorganisms. At the beginning of the composting process on the 1st day to the 2nd day, the pH shows a value ranging from 5.5-5; then there was an increase in pH on the 14th day with a pH value of 7. However, on the 15th day, the pH decreased again to 5.9.

A good stirring during the composting process can maintain the pH value under neutral pH conditions. The composting process causes changes in the organic material and the pH itself. For example, the acid release process causes a decrease in pH (acidification), while the production of ammonia from nitrogen-containing compounds increases the pH in the early phases of the composting process.

The graph of the changes in compost humidity can be seen in Figures 5 and 6. Figure 5 shows that in 75% soil: 25% compost ratio, the compost humidity is in between 31-60%. In 50% of soil

50% compost ratio, the pile has a humidity between 51-60% (the optimum conditions), whereas in 25% of soil: 75% of compost the humidity reaches 53-80%.

In Figure 6 on 75% soil: 25%, the compost humidity 54.44-65.56%. In 50% of soil: 50% compost has a humidity of 56.00-68.33%, while in 25% of soil: 75% of compost the humidity reaches 63.33-70%. On the basis of the graph above, it is known that on the first day of the composting process, variations in 100% of the soil have a normal moisture content (47%), while in other variations it has a moisture content in the range of 60-70%. However, on the third day, the water content in the 100% variation of soil has decreased below 40%, while other variations have remained stable in the range of 60-70%. Therefore, on the 5th day of stirring, water is added to keep the pile moist and not too dry.

If the compost pile is too moist, the decomposition process will be disturbed. This happens because the water content will cover the air cavity

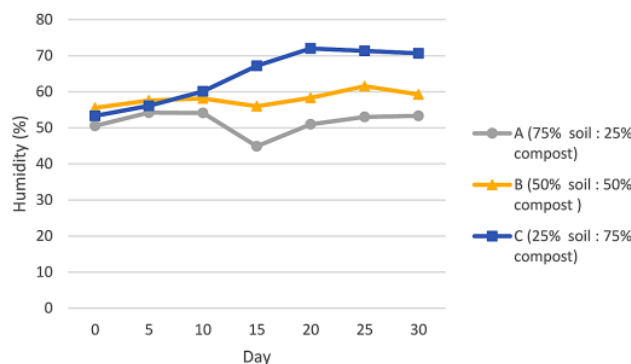


Figure 5. Moisture changes of bioremediation of cow manure compost

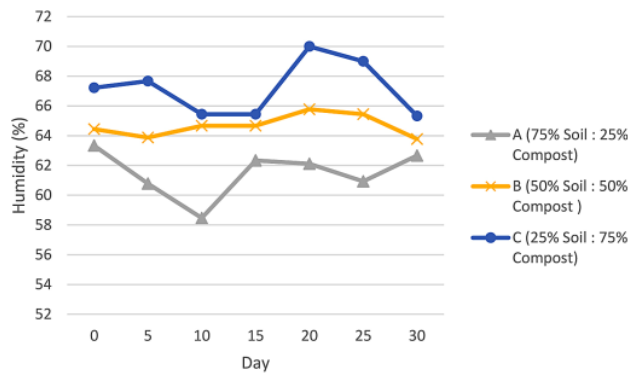


Figure 6. Humidity changes of bioremediation of market organic waste compost

in the pile. This condition will cause the composting process will take longer. If the humidity is too low, the efficiency of degradation will decrease due to the lack of water to dissolve the organic material that will be degraded by microorganisms as a source of energy (Widarti, 2015).

Fe value in composition variations

The comparison of the Fe value in the composition of 75% soil: 25% compost, 50% soil: 50% compost, 25% soil: 75% compost made from the cow manure and market organic waste with bioremediation duration of composting day can be seen in Figures 7, 8, 9.

Figure 7 shows that Fe value in the compost (75% soil: 25% compost) made from the cow manure on first day is higher (788.68 mg/kg) than the compost made from organic waste (696.86 mg/kg). On the 15th day, Fe value of the compost made from the cow manure increased, while Fe value of the compost made from organic waste

decreased. On the 30th day, Fe value of the compost pile made from the cow manure decreased significantly as much as 822.31 mg/kg. Fe value of the compost pile made from organic waste decreased as much as 182.72 mg/kg.

Figure 8 (50% soil: 50% compost ratio) shows that Fe value of compost made from cow manure on first day is lower (885.68 mg/kg) than the compost made from organic waste (955.31 mg/kg). On the 15th day, the compost made from the cow manure and that made from organic waste decreased by 39.9 mg/kg and 206.66 mg/kg, respectively while on the 30th day the cow manure based compost decreased by 287.65 mg/kg so that the value of Fe became 528.13 mg/kg and the compost based on organic waste decreased by 335.5 mg/kg so that the value of Fe became 413.15 mg/kg.

Figure 9 (25% soil: 75% compost ratio) shows that bioremediation of the iron (Fe) value using the compost made from the cow manure on 1st day is lower (825.17 mg/kg) than using

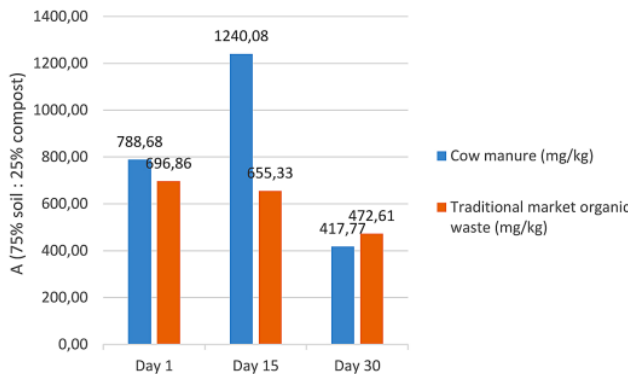


Figure 7. Fe value in the composition: 75% of soil and 25% of compost

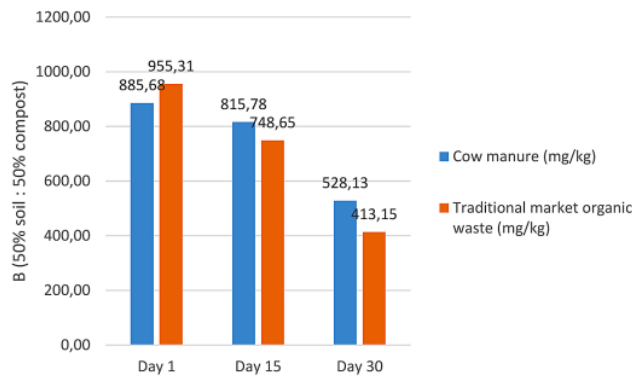


Figure 8. Fe value in the composition: 50% of soil and 50% of compost

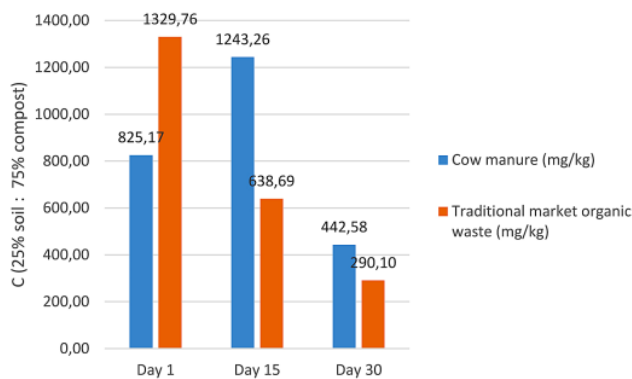


Figure 9. Fe value in the composition: 25% of soil and 75% of compost

the compost made from organic waste (1329.76 mg/kg). On the 30th day, Fe value were decreased from both materials compost. On the 30th day the compost made from the cow manure decreased by 800.68 mg/kg so that the value of Fe became 442.58 mg/kg and that made from organic waste decreased 348.59 mg/kg so that the value of Fe became 290.10 mg/kg.

On the basis of these three compositions, there are advantages and disadvantages during the bioremediation composting process based on the cow manure and organic market waste. The increase occurred on the 15th day based on the cow manure, but on the 15th day the compost based on cow manure with a composition of 50 soil: 50% compost experienced a decrease while on the 15th day the organic waste based compost of the third composition decreased. An increase on the 15th day in the compost made from cow manure occurred because the bacteria experienced a point of saturation, so that the tendency of bacteria to bind heavy metals was reduced

even tended to remove the heavy metal that has been absorbed (Khoiroh, 2014). Because there is still a process of reshuffle and release of Fe, it moves freely; thus, the soil is dominated by Fe (Ariyadi, 2018). The Fe decrease occurred on the market organic waste based compost on the 15th day and 30th day while on the cow based waste compost it decreased on the 15th day with 50% soil composition: 50% compost and 30th day all composition. The decrease occurred during the composting bioremediation process due to the presence of the bacteria that are able to adsorb heavy metals in their cell walls (Khoiroh, 2014). The decrease in Fe is due to the activity of microorganisms and the absorption of Fe by organic fertilizers that form chelate bonds. Thus, the presence of the organic material from the compost based on cow manure is able to absorb the Fe value in the soil. The chelate bond binds the other Fe³⁺ ions, the chelation takes the free Fe ions from the soil causing the Fe level in the solution to decrease (Yowono, 2010). The

organic fertilizer adsorbs and binds the heavy metals by cation exchange, forming electrostatic bonds, complex bonds (Prasetyono, 2015).

This is in accordance with Widyawati's research (2015). Bioremediation is a process of pollutant recovery by utilizing the services of living things such as microbes (bacteria, fungi, yeast) produced in their metabolic processes. As soil dwellers, microbial life is always directly affected by the changes that occur in the soil. In ex-mining soil, the soil changes (physical, chemical, and biological) occur drastically, so that in these ecosystems the microbes must adapt to the new environment, or become extinct. One mechanism of adaptation is to change the expression of genes so that the activity of enzymes and proteins allows them to continue living in the environment. Some microbial mechanisms adapt to the mined soil contaminated with metals, including the microbes capable of using metals as an energy source and presenting metal in the form of reducing metals to non-toxic forms. This microbial ability can be used in the process of metal detoxification, i.e. bioremediation.

Analysis of Fe value using two way ANOVA test

The results of the analysis of composting bioremediation research based on the cow manure, the smallest Fe value during the composting bioremediation process based on the cow manure is 417.77 mg/kg with a composition variation of 75% Soil: 25% compost with a period of 30th days. On the basis of the two-way ANOVA test, it can be concluded that there is no significant difference in the decrease in the Fe value due to the variations in composition and the length of composting bioremediation based on the cow manure.

The results of the composting bioremediation process analysis based on organic waste indicate that the smallest Fe value is 290.10 mg/kg with a variation of the composition of 25% soil: 75% Compost. The Fe value of 290.10 mg/kg is below the threshold value of agricultural soil, according to Yoshida (1978).

CONCLUSION

1. The temperature conditions of the four compositions during the composting process decreased until the 30th day. The pH value in 100% of the soil remained stable at neutral

values (5.5-7). The humidity in the control of 100% of the soil was below 40%, low enough for humidity because the optimal value for composting is 50-60%.

2. Based on two-way ANOVA test, it can be concluded that there is no significant difference in the decrease in Fe value due to the variations in the composition and duration of day composting bioremediation based on the cow manure and organic market waste. The composting bioremediation made from organic market waste composition shows the best result (75% compost: 25% of soil on the 30th day, with a value of Fe of 290.10 and removal amount of Fe decrease of 78.18%).

Acknowledgements

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