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The effect of rice husk biochar on heavy metal content in compost derived from municipal waste

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Abstract

The heavy metals contained in the municipal wastes has been an issue when it comes to re-using of wastes. This study objectively studied the effect of rice husk biochar on lead and copper content of compost derived from municipal waste. Different waste materials comprising of municipal waste: 8kg, rice husk biochar: 2kg, Rice straw: 0.2kg, Eucalyptus green leaves: 0.5kg, decaying tomatoes: 1.5kg, Vegetable leaves (spinach): 0.5kg were composted. Three replications were made, one set with biochar and one set without biochar. The result showed that copper content only increased from 85.47 mg kg^{-1} to 99.60 mg kg^{-1} in the biochar pile, unlike the non-biochar pile, which increased to 105.43 mg kg^{-1}. The reduction of lead was not as effective as that of copper as it is from 86.00 mg kg^{-1} to 138.35 mg kg^{-1} for non-biochar and with biochar is 111.33 mg kg^{-1}. The non-effectiveness in reducing lead as compared to cupper is because of the inherent content in the biochar used. It was therefore concluded that rice husk biochar was more effective in removing Cu compared to Pb.

Keywords: Biochar, nutrient uptake, soil properties.

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1.0 Introduction

Compost is decomposed organic material (E. Khater, 2015). The process of compost making is termed composting. Composting is the controlled aerobic (oxygen-using) biological decomposition of moist organic matter, producing a soil conditioner. This organic matter that undergoes the biological decomposition process may include biodegradable municipal wastes (undergo biological changes) such as poultry manure, pig manure, sewage sludge etc. These organic constituents record the right content level of nitrogen, phosphorus, potassium and other essential nutrients. Therefore, compost provides virtually all of the essential nutrients for healthy plant growth, and it almost always releases those nutrients overtime to give plants a slow intake of the elements. Over the years composting has grown to become a more acceptable method of managing municipal wastes, treating sewage sludge, pig manure, tannery waste, poultry manure, etc. its acceptability is based on its ability to convert and divert organic wastes from useful products of relatively low cost that are useful for agricultural purposes.

Composts that are formed by the decomposition of organic materials such as poultry manure, pig manure, sewage sludge etc. can be applied to soils as a soil conditioner, although research has it that composts also contain heavy metals. Therefore the presence of these heavy metals can restrict the use of compost as a soil conditioner (Singh and Kalamdhad, 2012). Heavy metals are metallic elements with high atomic weight and density with examples like Cadmium (Cd), copper (Cu), lead (Pb), Nickel (Ni) and Zinc (Zn) are found in all composts in toxic levels. Heavy metals do not degrade throughout the composting process because they are compounds that do not decompose (Farrell, and Jones, 2018). They can be absorbed by plants and animals to be introduced into the food chain, and subsequently, they become concentrated due to loss of carbon and water from the compost due to microbial respiration (Farrell and Jones, 2018). Recent studies indicate how pertinent the heavy metal content is to composting. Therefore, it can be considered "irresponsible" to neglect this subject matter, hence the need to deduce possible means of absorbing them into the compost heap, biochar has high absorption potential that can absorb these heavy metals (Chimuka and Manungufala, 2009).

Biochar is pyrogenic black carbon, derived from the pyrolysis of biomass such as wood or grass under nitrogen-limited condition (Lehmann *et al*., 2006; Rutigliano *et al*., 2014). It is a solid product of thermal decomposition of organic matter at a temperature below 900 ^{0}C under conditions of oxygen deficit (Jindo, Mizumoto, Sawada, and Sonoki, 2014) produced for environmental or agricultural application. With the increase in pyrolysis temperature range within a range of 400^{0}C to 700^{0}C will lead to higher aromaticity and hydrophobicity of biochar as well as higher specific surface area and pore volume. Higher specific surface area connotes increased ability for physical adsorption of solids, liquids or gases. Therefore, composts with biochar content is expected to affect the heavy metal content of the pile positively. Plants growth inhibition, lower biomass production and heavy metal accumulation result in the reduction of grain yield and cause severe economic losses on account of plants growing in polluted agricultural soils (Farooq, Abbas, Hannan, Rinklebe, and Sik, 2017)

Heavy metals, unlike organic contaminants, cannot be degraded by microorganisms. Thus the use of compost as soil amendments, i.e. as corrective measures to soil degradation and toxicity problem. It may be a convenient and low-cost approach to remediate soils by changing the mobility and bioavailability of heavy metals (Udeigwe *et al*., 2011).

Objectives

- To determine the effect of the biochar on lead (Pb) and Copper (Cu) availability in the compost mix.
- Compare the availability of the heavy metals in the biochar and non-biochar compost.

2.0. **Materials and Method**

This research lasted for 2 months, running from July 2019 through to September 2019. This chapter deals with the location, materials and methods that were used in conducting the research.

2.1. Study Location

The research work was in two (3) phases. The first phase, which will include the practical composting aspect, i.e. the composting process was conducted at the crop production and soil science screen house located at the federal university of technology teaching and research farm. The second phase which will involve the extraction of the heavy metals from the samples obtained in solution form was carried out at the soil science and land management laboratory, and the third (3rd) phase will involve the determination of the heavy metals present, and this was done in the Center for Genetic Engineering and Biotechnology. The three locations are situated in the Federal University of Technology Minna, Niger State of a latitude 9°32'844" N, and a longitude 6°27'808" E, on an elevation of 228 meters above sea level, located in southern Guinea Savannah Agro-ecological zones of Nigeria.

2.2. Source of Municipal Solid Waste

The municipal solid waste was collected from the school's hostel dumpsite. It is a municipal dumpsite where the students dispose of their home and kitchen wastes. A spade was used to turn over the waste pile to open up the inner materials that are considered biodegradable. The wastes were collected into two (2) bucket size of 14 Liters for easier transport back to the experimental site. The biochar was sourced from the previous undergraduate students who produced the biochar from rice husk, using local pyrolysis method. Other compost materials, including the rice straw and Eucalyptus, was sourced from the school environs.

2.3. Experimental Set up

The different compost materials were weighed using a weighing scale to determine the weight of each material in other to obtain a ratio of the compost mix. The compost was composed of 1kg of Rice Husk Biochar, 0.2 kg of straw, 0.4 kg of Eucalyptus green leaves and 4kg of municipal waste.

2.4. Compost Preparation

2.4.1. Municipal Solid Waste (MSW) Separation

The Municipal solid waste was separated using a manual separation method. This method was employed because the Municipal solid wastes consist of materials of uniform sizes as a result of the site the materials were sourced from which is the school hostel. Therefore, it was practical to handpick the unwanted materials like recyclables (polyethenes, paper, tins, etc.) and some tangible contaminants like (batteries).

2.4.2. The Compost Mix

A total of six (6) compost piles was made; the piles were in three replications of the two (2) treatments. The Piles in which biochar was added to was designated as 'PB' (i.e. PB 1,2 and 3). the piles contained all the various materials including the biochar treatment while the other piles 'PNB' (PNB 1,2 and 3) will contain all the various materials except for biochar as a control. This variance in biochar addition is to determine the relative effect of the biochar treatment on the individual heavy metals that were considered, i.e. Lead (Pb) and Copper (Cu) and compare with the results that were obtained from both the treatment and the control.

2.4.3. Composting Practices

The materials to be composted were adequately mixed with the MSW in ratio 1:2 for the greens and the browns, respectively. Water was added daily to moisten the piles to maintain the relative humidity at about 50% and then to maintain an aerobic condition for the decomposition process, and the piles were turned every day to ensure even supply of oxygen to the piles for the respiration of the microorganisms present. The piles were covered by polyethenes (plastic) to prevent excessive loss of water and to maintain adequate temperature needed for the optimum performance of the microorganisms.

2.5. Laboratory Studies

2.5.1. Compost Sampling

Samples were collected by a systematic collection method, where each compost pile was cut through different diagonals and samples collected from each unit. About 10-15 subsamples were collected throughout the compost pile. Samples were collected from different depths within each pile. Wet areas and the surface of the compost pile were avoided. The samples collected from each unit were then mixed to obtain a uniform representation of the compost. After collecting the samples, they were bagged in labelled polyethenes bags for easy transport from the field to the laboratory.

2.6. Sample Preparation

The collected samples were then transferred in moisture cans and then placed into the oven set at 78°C for three days. The collected compost samples were oven-dried at 72°C for 2 days, then they were crushed gently using a porcelain mortar and sieved using 0.5mm sieve.

2.7. Heavy Metal extraction

The heavy metals were extracted in solution form by open digestion method.1g of each 0.5mm sieved compost samples was weighed with an electronic sensitive weighing balance into six (6) labelled 50ml beakers that were rinsed adequately with distilled water. 25ml of already prepared aqua-regia of ratio 1:3 was added into the beakers, and they were digested at 105^{0}C for 2hours. The samples were fully digested when they were clear, and the fumes had disappeared. Then they were filtered into 100ml volumetric flask using No.42 Whatman filter paper. The filtrate was then made up to the 100ml mark using distilled water. The extract was then transferred into already labelled sample bottles.

2.8. Determination of Heavy Metals (Cu and Pb)

The extracts were transferred to the Center for Genetic Engineering and Biotechnology where the heavy metals were tested for using Bulk Scientific AAS; Model: Accusys 211: Manufacturer: USA. A series of calibrated solutions (standards) containing known amounts of analyte elements were prepared and used to calibrate the Atomic absorption spectrophotometer (Model: Accusys 211, manufacturer USA). Blanks were atomized followed by the standards showing the response from the AAS. The response of standards was then used to establish the accurate performance of the machine and the accurate concentration values of the element. The machine was calibrated after any two analyses. Using the AAS, the light was generated from a hollow cathode lamp at a wavelength characteristic to each analyte. Each analyte was then atomized using an atomizer to create free atoms from the samples. Air-acetylene gas was used as the source energy for the production of free atoms for the elements copper(Cu) and lead (Pb). The samples were then introduced as an aerosol into the flame and the burner aligned in the optical path to allow the light beam to pass through the flame where the light was absorbed. The light was then directed into a monochromator which then isolates the specific analytical wavelength of the light emitted by the hollow cathode lamp from the non-analytical. The sensitive light detector then measured the light and translated the response into the analytical measurement.

The results were presented in (mg/L), therefore to convert the results obtained to mg/kg, the below formula was used:

Concentration (mg/kg): $\frac{\text{Concentration (mg/L) x}}{\text{W}}$

V= final volume (100ml) of solution

W= Initial weight of the sample (1g)

3.0. Results and Discussion

3.1. Copper (Cu) and Lead (Pb)

The effect of Rice Husk Biochar on Cu and Pb at both the initial and final sampling periods of the compost heaps is shown in Table 4.1. Rice Husk Biochar had no significant effect ($p \leq 0.05$) on Cu both at the initial and final sampling periods. However, Rice Husk Biochar only had a significant effect ($p \leq 0.05$) on Pb at the final stage but not ($p \leq 0.05$) at the initial stage of the sampling period.

3.2. Copper (Cu)

The study showed that there was no significant effect of Rice Husk Biochar treatment on Cu both at the initial and final sampling periods of the experiment. The initial samples were collected two (2) weeks after the compost heaps had been set-up while the final samples were collected eight (8) weeks later. The initial results showed that the Cu content of the heap with biochar was higher than that of the heap without Rice Husk Biochar. This could be due to the initial Cu content of the Rice Husk Biochar. It was observed by Gondah (2003) that Rice Husk Biochar contains Cu, although considered low and does not pose toxic hazards, it may have added to the compost Cu content. Despite the higher initial Cu content, the compost heap with Rice Husk Biochar had Cu increase by only 9.9% while the compost heap without biochar had an erratic increase by 23.4%, making the final Cu content of the compost heap without biochar greater than the heap with biochar that recorded greater initial.

Table 4.1 Effect of Rice Husk Biochar treatment on copper (Cu) and Lead (Pb) at both the initial and final sampling periods

	Copper (Cu) ($mgkg^{-1}$)		Lead (Pb) ($mgkg^{-1}$)	
Treatments	Initial	Final	Initial	Final
PB	90.63^{a}	99.60^{a}	71.00^{a}	111.33^{b}
PNB	85.47^{a}	105.43^{a}	86.00^{a}	138.35^{a}
LSD (0.05)	52.99	32.4	71.68	24.61

Means with the same letter in a column are not significantly different at 5% level of probability using the Least Significant Difference (LSD).

PB:

The final Cu content of the compost heap was compared with maximum permissible limits of European Compost Network, ECN, (2008) given in German compost standards which are considered more stern than those of other countries. It was seen that the Cu was well within the permissible levels of useable composts (Cu<150 mg kg^{-1})

3.3. Lead (Pb)

The study showed that there was no significant effect of Rice Husk Biochar treatment in the compost heaps at the initial sampling period which was collected two (2) after the compost heap has been set-up but showed significant effect at the final sampling period which was done eight (8) weeks after the first sampling period.

The pile without Rice Husk Biochar had more Pb concentrations than the pile with Rice Husk Biochar both at the initial and final stage of the experiment. This could be due to the very high adsorption affinity of Rice Husk Biochar to Pb (Sadegh-zadeh *et al.,* 2014). The compost heap with biochar increased in Pb content by about 56.8% while the compost heap that was without biochar increased by 60.9%.

The final Pb content of the compost was compared with maximum permissible limits of the European Compost Network, ECN, (2008) given in German compost standards which are considered more stern than those of other countries. It was seen that the Pb content was within the permissible levels of useable composts (Pb <200 mg kg^{-1}).

Generally, the adsorption affinity and also maximum adsorption capacities of rice husk biochar is in the order of Pb>Cu (Sadegh-zadeh *et al*., 2014). This is because both Pb and Cu can quickly react with functional groups containing unshared pairs of electrons such as those in oxygen (O), nitrogen (N), phosphorus (P) and sulphur (S). Also, Pb and Cu have a greater affinity for carboxyl groups (Thirumavalavan *et al*., 2011). Therefore, Pb and Cu can easily coordinate with both the carboxyl and hydroxyl groups of the Rice Husk Biochar, as the functional groups have valence shell electrons in the outer orbital. Sadeghzadeh *et al*., (2014), after fitting their isotherm adsorption data into the Freundlich adsorption model, reported that the Freundlich adsorption coefficient values indicated that Cu highest followed the adsorption of Pb. This trend of adsorption was similar to the results of this study, Table 4.1. They explained that fewer electrons found in the outermost valence shell of Pb that can bind with functional groups with donor sites better than Cu. However, in comparison to other biochars of feedstock other than rice husk, the Rice Husk Biochar has considerably higher values for adsorption capacities for heavy metals (Liu and Zhang 2009; Chen *et al*. 2011).

4.0. Conclusion and Recommendation

This study has shown that Rice Husk Biochar is an effective means of controlling heavy metals (Cu and Pb) availability in compost as the control pile that is, piles without biochar recorded the highest Cu and Pb concentrations. Rapid increases in heavy metal concentration in the control piles that recorded initials of 85.47 mg kg^{-1} and 86.00 mg kg^{-1} of Cu and Pb respectively, which increased to 105.43 mg kg^{-1} and 138.35 mg kg^{-1} respectively. Unlike the final heavy metal concentrations of Cu and Pb were 99.60 mg kg^{-1} and 111.33 mg kg^{-1} respectively when Rice Husk Biochar was included in the materials composted. Finally, from the study carried out it can be recommended that further study should be carried out to check other heavy metals that can be trapped and consequently their rates of accumulation reduced to the standard permissible limit of the individual metal in composts.

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