Production of Bio Fertilizer from Blending Coal Fly Ash and Vermicompost

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Abstract

This work focused on the evaluation of the potential to produce a bio fertilizer from the blending of vermicompost and leached coal fly ash. A blended bio fertilizer with nitrogen (3.8-4.8%), phosphorous (3.3-4.5%) and potassium (3.7-6.2%) was produced. The use of vermicompost fertilizer for blending will stabilize fly ash and give it novel properties that make it comparable to the generic chemical fertilizers.

Keywords: Bio fertilizer, bio leaching, coal fly ash, nutrient composition, vermicompost

1. Introduction

The vast amount of waste generated is still far from being fully utilized in its maximum as a product or by-product, making technological alternatives needed in order to reduce its environmental impact (Ahmaruzzaman, 2010). There are many reasons to increase the amount of waste being utilized. Firstly, disposal costs are minimized and secondly less area is reserved for disposal, thus enabling other uses of the land and decreasing disposal permitting requirements thirdly, there are financial returns from the sale of the by-product, lastly the by-products can replace some scarce or expensive natural resources (Santi et al., 2021).

One major by-product is fly ash from combustion of coal, which is unsatisfactory disposed into ash dams or landfills (Das et al., 2013). This method of disposing ash is not the best solution both from the ecological and economic point of view. Therefore, there is continuing interest in establishing suitable processes in which fly ash can be efficiently reused. Fly ash is one of the residues created during the combustion process and comprises the fine particles that rise with flue gases (Seidel et al., 2001). Fly ash is a waste by-product material that must be disposed of or recycled (Bhattacharya et al., 2021). In the past fly ash produced from combustion was simply entrained in flue gases and released into the atmosphere which created environmental concerns that prompted EMA to regulate emissions down to less than 1% of total fly ash produced by ZPC.

Currently the production of fly ash in Zimbabwe is at 50 000 t/year which is 136.89 t/day mainly from the Zimbabwe Power Company (ZPC) (*ZPC Documents, 2016*). This is the fly ash that is not being converted or used in any economic processes and it is causing environmental degradation through acidification of soil around the area where it is dumped. The ZPC yearly production target of fertilizer is at 80 000 tons per year shared by large producers such as ZFC, Windmill, Omnia and other small players against a national requirement of 200 000 t/year. Zimbabwe currently imports over 40 000 tons of AN fertilizer due to Sables which is currently having operational hardships. On the other hand, the production of vermicompost in Zimbabwe can feasibly reach 60 000 t/year based on the current production of biodegradable material. This work focuses on the production of bio-hydro metallurgically treated fly ash and its blending with vermicomposting fertilizer to produce a bio fertilizer.

2. Materials and Methods

The standard experimental procedure of bioleaching of fly ash and media preparation was followed during experimental design.

2.1 Determination of the bio fertilizer particle size distribution

The aim was to determine the size distribution of the blended bio fertilizer. The materials required included: a vibrating shaker and a digital scale. The procedure included weighing a 10kg of the blended bio fertilizer mixed in the ratio 1:2 fly ash and vermicomposting fertilizer respectively and turning on the vibrating shaking machine for 10 minutes. After 10 minutes weigh the respective masses of bio fertilizer collected in each screen and tabulate the results

2.2 Nutrient media for leaching out metal sulphides from fly ash preparation

The objective was to prepare the media required for bacterial growth. The nutrient media was important for providing nutrients while the bacteria was producing enzymes required for leaching out metal sulphides from fly ash. The materials used included an electronic balance, nutrient media, autoclave, spatula, cotton plugs, and glass marking pen and aluminum foil, heating mantle, beakers, measuring cylinder, glass rod and agar plates. The procedure included weighing 4g of the nutrient media using an electronic balance and put in a beaker then 200 mL distilled water was added and stirred. The mouth of the conical flask was closed with a cotton plug and it was covered with aluminium foil. It was labelled and autoclaved at 121 °C for 15 minutes.

2.3 Serial dilution of water containing bacteria

The objective was to dilute the water containing the bacteria to get the optimum number of bacteria in solution for. Serial dilution ensures that the optimum multiplication quantities of the bacteria which is usually found on the fifth and sixth dilution multiplication. The materials required were: fly ash sample 10g, distilled water, pipettes, test tube stand, sewage waste sample 20 mL and 10 test tubes. The experimental procedure included: weighing 10 grams of sewage waste in an electronic balance and transfer the contents were transferred into a clean dry test tube. 10 clean test tubes were taken and marked serially 10⁰, 10⁻¹, 10⁻², 10⁻³, 10⁻⁴, 10⁻⁵, 10⁻⁶, 10⁻⁷, 10⁻⁸, 10⁻⁹ and placed in that order. Oil sample was completely mixed with distilled water. This was the 1st dilution (10⁰). Now the test tube (containing sewage waste) was placed in a test tube stand and allowed to sediment till faddy water settled above. Carefully 1mL of the faddy water was pipetted out from the test tube avoiding the pipette to touch the soil surface. The media was transferred to a new test tube with marking (10⁻¹). 9mL of distilled water was added to it and again it was mixed thoroughly. This was the 2nd dilution. The above steps were repeated similarly, with correct amounts until 10⁻⁹ dilutions. After serial dilution was over the diluted sample of order 10⁻⁴ or 10⁻⁵ dilutions were kept aside for use in culturing and multiplication of bacterial strains present in sewage waste sample on agar plates.

2.4 Bioleaching of fly ash (*Thyobacillus ferrooxidans*) for nutrient recovery

The objective was to leach fly ash off metal sulphides and to determine the period of time required to carry out complete leaching. The materials required included: fly ash samples from ZPC, *Thyobacillus ferrooxidans* inoculums (from sewage sample), filter paper, filter funnel, conical flasks, beaker and glass rod, distilled water and electronic balance. Initially fly ash was sieved in 200 meshes sized sieve and 500 grams of it was weighed in an electronic balance and the contents were transferred into a clean dry beaker. A filter funnel was taken, cleaned thoroughly, dried and placed on a conical flask containing 200 mL *Thyobacillus ferrooxidans* inoculums. The mouth of the conical flask was closed with cotton plug and covered with aluminum foil. It was labelled with appropriate names and dates and incubated in a

shaker incubator at 60 $^{\circ}$ C for 1 week. The smell and color change were checked every two days after incubation. After 7 days, the water was separated from the fly ash by using a funnel placing a filter paper over it. The leached water was kept aside for characterization and analysis. pH was checked three times a day every day on leached solution and the fly ash to determine the extent of leaching. The experiment is important to check the extent of leaching that can be achieved and which can be translated to industrial scale. The pH of the leached water can be used to determine the interior design of leaching vessel and other parameters.

2.5 Determination of the nutrient composition of the bio fertilizer

The experiment is important to check the applicability of the blending innovation. The materials required were a *PRV1X* nutrient analyzer.

2.6 Determination of the calorific value

The aim was to find the calorific value of blended fertilizer, untreated fly ash and fly ash. The results of the experiments were essential for establishing the calorific values of the products for use when conducting stream energy balances. The reagents and apparatus used in the experiment included: a digital bomb calorimeter, digital scale, plastic spoon, cooling water and oxygen tank (to be used for combustion by the bomb calorimeter). The procedure included: weighing 4 grams and divide into 5 sets of samples for the sample of fly ash, blended fertilizer, vermicomposting and treated fly ash. Adding 1g of each sample into a bomb metal container and place the igniting string (of known calorific value) and put into the bomb calorimeter. After putting the sample into the bomb and calorific value is calculated and displayed.

3. Results and Analyses

The block flow diagram for the production of the blended bio fertilizer from both metallurgical fly ash and vermicompost is shown in Figure 1. The focus was on the production of bio-hydro metallurgically treated fly ash and its blending with vermicomposting fertilizer. The target metal sulphides recovery of at least 95% is to be achieved before blending with the vermicomposting fertilizer.



Figure 1. Block flow diagram for production process of the bio fertilizer

3.1 pH results for leaching experiment

From the results (Table 1), it is clear that the effective leaching occurred on the days 5, 6 and with day 7 having the highest average fly ash pH of 7.6. It can be thus concluded that in order to provide a continuous production of blended fertilizer, several leaching vessels at different stages of leaching should be installed in the plant. The overall pH of the leached solution was found to be 5.3, which is very acidic. The fly ash found at ZPC relatively is more acidic compared

to that of coal found in other regions of the world because the coal used for power generation in Zimbabwe is a low grade of coal high in impurities and low in carbon content.

Experiment	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	4.8	5.4	6.1	6.4	6.9	7.2	7.6
2	4.8	5.6	6.3	6.5	7.0	7.2	7.6
3	4.9	5.1	6.3	6.8	7.1	7.4	7.7
Average	4.5	5.4	6.2	6.6	7.0	7.3	7.6

Table 1. pH that was measured three times daily for the weekly leaching process

3.2 Bio fertilizer size distribution

The size distribution of between 1.18 mm and 75 μ m is going to be considered as factors in the design of a wet granulator. The selection was made because of the fact that the given size range constitute of the most abundant retained weight as presented in Figure 2.



Figure 2. Blended bio fertilizer particle size distribution

3.3 Bio fertilizer calorific value

The blended bio fertilizer had calorific values ranging from 3470-3475 KJ/kg as indicated in Table 2.

Sample no	Vermicompost (KJ/kg)	Fly ash (KJ/kg)	Blended bio fertilizer
			(KJ/Kg)
1	2125	4199	3472
2	2127	4199	3470
3	2130	4200	3475
4	2122	4200	3472
5	2166	4200	3475
Average	2134	4200	3473

 Table 2. The calorific value of vermicomposting fertilizer

3.4 Nutrient composition of the blended fertilizer

The nutrient composition of the blended bio fertilizer is given in Table 3. The N: P: K value was not constant but it's a ratio 4:6:4 by average that fluctuates based on ash and vermicompost composition and quality.

Nutrient	Range (%)
Organic carbon	13.5-17.4
Nitrogen	3.8-4.8
Potassium	3.7-6.2
Metals	3.0-5.1
Zinc	4.3-5.7
Nickel	3.8-6.2
Metalloids	2.7-3.2
Phosphorous	3.3-4.5

4. Conclusion

The utilization of fly ash to produce a blended bio fertilizer with vermicompost is a sustainable and environmentally friendly technology. The blended bio fertilizer from fly ash and vermicompost gives a chemical composition that is comparable to chemical fertilizers with an N: P: K ratio of 4:6:4.

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