Scaling Up Soil Conditioner Production Using Bauxite Residue and Oil Palm Wastes

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Abstract

The mining industry is undergoing significant transformation towards greater sustainability, striving to achieve carbon neutrality and "zero waste", in order to reduce its ecological impact. This shift is in alignment with the United Nations' Sustainable Development Goals (SDGs) as the sector endeavors to minimize its environmental footprint. In 2019, Norsk Hydro Brazil and SENAI Innovation Institute for Mineral Technologies (ISI-TM) initiated a project called “Bayer Process Towards the Circular Economy – Metal Recovery and Soil Conditioners from Bauxite Residue”, aiming at bauxite residue (BR) valorization. One of the proposed alternatives to BR disposal was the formulation of a soil conditioner, for soil fertility improvement, using BR and agroindustrial residual biomass, which is also abundantly available in the state of Pará (Brazil). Previous lab scale tests (~9 kg) were conducted evaluating batch composting of 0 % (blank), 25 %, 50 %, and 75 % of BR with raw palm oil mill waste (POMW) and palm oil compost (POC). The results of the study revealed that the formulation of 25 % BR and 75 % POC had a water holding capacity (WHC) ≥ 60 % and a cation exchange capacity (CEC) ≥200 $mmol_c \cdot kg^{-1}$, thus reaching the requirements set by Brazilian legislation for the production and commercialization of soil conditioners while also not differing from the blank control treatment (0 % BR). After establishing the technical foundation, the subsequent phase involved scaling up the production of the soil conditioner. The current paper addresses the scaling up of soil conditioner formulations, consisting of 25 % and 50 % BR, through a 200 kg batch composting process conducted under controlled conditions. After 90 days of composting, all the evaluated formulations fulfilled the minimum guarantees of WHC and CEC for the production and commercialization of soil conditioners, demonstrating the technology’s potential for scale-up.

Keywords: Circular economy, Mining sustainability, Soil fertility, Waste management.

1. Introduction

Aluminium demand is projected to experience significant growth over the next decade, with an estimated increase of 33.3 Mt, reaching approximately 120 Mt by 2030. This growth is primarily driven by the transportation, electrical, construction, and food sectors. [1]. The transition towards a low-carbon economy and the strengthening of decarbonization policies in various countries will have a positive impact on the demand for aluminum, particularly in the production of electric vehicles, solar panels, and conductor cables, among other applications. At the same time, mining companies have their own challenges to become more sustainable, net zero and waste zero, in accordance with the ESG principles claimed by society and investors. This shift is also in alignment with the United Nations' Sustainable Development Goals (SDGs), as the sector endeavors to minimize its environmental footprint.

In 2019, Norsk Hydro Brazil and SENAI Innovation Institute for Mineral Technologies (ISI-TM) initiated a project called "Bayer Process Towards the Circular Economy – Metal Recovery and Soil Conditioners from Bauxite Residue", aiming at bauxite residue (BR) valorization [2-3]. One of the proposed alternatives to BR use was the formulation of a soil conditioner, for soil fertility improvement, using BR and palm oil mill wastes (POMW), which is also abundantly available in the state of Pará (Brazil) [3]. The main advantage is the use of the entire, unfractionated BR and not just a single part (e.g., iron, rare earth elements, etc.), which could result in another side residue stream. The incorporation of organic matter and treatment with organic acids has been suggested to ameliorate BR alkalinity [4] and remove sodium from desilication products [5], despite that the alkaline nature of BR is a desirable characteristic for a soil conditioner to be applied to Brazil's acid soils. We believe that a soil conditioner composed by BR and POMW could be applied for restoring the fertility of weathered acidic soils or as aiding material for rehabilitation of mining sites. Previous lab scale tests (~9 kg) were conducted evaluating the batch composting of 0 % (blank), 25 %, 50 %, and 75 % of BR with POMW and palm oil mature compost (POC) [6]. The outcome of the study revealed that the formulation consisting of 25 % BR and 75 % POC demonstrated a water holding capacity (WHC) ≥ 60 % and a cation exchange capacity (CEC) ≥ 200 $mmol_c.kg^{-1}$, reaching the requirements set by Brazilian legislation for the production and commercialization of soil conditioners [7]. After establishing the technical foundation [6], we decided to scale up the soil conditioners composting to 200 kg batch, testing two formulations containing 25 and 50 % of BR and POMW, under 90 days. Here we compare the results of composting temperature curves, CEC, WHC, and minor and major plant nutrients, assessing potential scaling up effects on soil conditioners formulations.

2. Experimental

2.1 Raw Materials

The study was conducted at the SENAI Innovation Institute for Mineral Technologies (ISI-TM), in Belém, Pará, Brazil. The BR was provided by Norsk Hydro Alunorte Refinery, whereas the palm mill wastes (POMW) were provided by Brasil BioFuels (BBF), both located in the state of Pará, Brazil. The POMW were comprised by palm mesocarp fiber (PMF), empty fruit bunch (EFB) and palm oil decanter cake (PODC). Physicochemical characterization of all raw materials was previously described in [6, 8].

2.2 Batch Composting Experiment

The raw materials were filled under alternating layers with 25 % (T25) or 50 % (T50) of BR into 2 000 liters polypropylene containers (Figure 1). A control unit was set by composting only the POMW without BR (Table 1). The final batch weight was approximately 200 kg of soil conditioner. Ammonium sulphate fertilizer was applied to adjust C:N ratio to 30:1 and a commercial bacterial inoculant (*Bacillus subtilis, Bacillus licheniformis and Pseudomonas fluorescens*) was added to the compost piles to accelerate organic matter decomposition. Moisture was adjusted to 60 % of WHC with deionized water and maintained throughout the experiment. The compost was manually turned every 3 days in the first 15 days, and once a week until complete 90 days, for homogenization and aeration. Temperature was checked daily using a compost thermometer (Simpla TE07) [6].

and lower than Control (2.1 mS/cm). Finally, the tapped bulk density in all soil conditioners containing BR showed values around 0.9 g/cm^3. The influence of pH, EC and bulk density will be better addressed in future agronomical tests with different texture soils.

Table 2. Physicochemical attributes of soil conditioners formulations after 90 days composting.

Attribute	Unit	Batch			
		T2*	**Control**	**T25**	**T50**
Total N	%	0.9	1.5	1.4	1.1
TOC	%	18.5	35.9	24.8	21.2
C:N	-	20	23	18	19
P	g kg^{-1}	5.0	4.8	3.7	3.2
K	g kg^{-1}	10.7	21.8	20.4	13.4
Ca	g kg^{-1}	8.2	5.7	3.0	3.0
Mg	g kg^{-1}	2.2	2.1	1.7a	1.3
S	g kg^{-1}	0.1	5.1	7.1	4.0
Al	g kg^{-1}	53	1.1	25.1	32.8
Fe	g kg^{-1}	111.1	4.1	84.5	115.3
Mn	mg kg^{-1}	87.5	14.8	3.1	0.0
B	mg kg^{-1}	-	433	233	633
Cu	mg kg^{-1}	35	8.5	3.6	4.7
Zn	mg kg^{-1}	35	53.6	47.2	42.3
Na	g kg^{-1}	32.3	0.4	30.8	46.9
ESP	%	13.2	0.1	8.7	11.7
Bulk Density	g cm^{-3}	0.90	0.49	0.82	0.89
pH	-	9.8	5.3	7.9	8.9
EC	mS cm^{-1}	3.3	2.7	2.1	2.1

*Data extracted from [6].

4. Conclusions

In general, the Eastern Amazon soils are acidic and nutrient poor, pressuring constant deforestation of new areas for cultivation. Limestone reserves are insufficient for proper agricultural soil pH correction and BR inherent alkalinity could be an alternative for pH improvement in abandoned areas. Here, we showed the success batch composting scaling up to 200 kg of a proposed soil conditioner formulation containing BR and POMW. Even the proposed formulations fulfilling the minimal requirements of CEC and WHC set by Brazilian´s legislation, a complete characterization of the soil/plant/water interactions, under fully controlled conditions, must be done before the soil conditioners production and commercialization.

5. References

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