Demonstration of a Composting Plant for Soil Conditioner Incorporating Bauxite Residue

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https://doi.org/10.71659/icsoba2025-br018

Abstract

The proof of concept for producing a soil conditioner (SC) using a composting process with bauxite residue and oil palm waste had been successfully conducted at laboratory scale producing 200 kg of SC per batch at Technology Readiness Level (TRL) of 1–5 in previous feasibility studies. The study covered by this paper represents the continuation of the project "Bayer's Process Towards the Circular Economy: Recovery of Metals and Production of Soil Conditioners from Bauxite Residues", by progressing to prototype stage a soil conditioner demonstration plant (TRL 6) which will be installed at Norsk Hydro Bauxite & Alumina, in Barcarena (Pará State, Brazil). The objective is to scale up SC production using composting heaps at a pilot scale (tonnes) to validate the process efficiency and quality parameters within a simulated operational environment. Additionally, this phase aims to produce a sufficient volume of material for agronomic trials involving various plant species. This innovative product has the potential to aid the rehabilitation of degraded or low-productivity areas, recovery of post-mining sites, and even the cultivation of bioenergy-producing plant species.

Keywords: Circular economy, Sustainability, Industrial residues valorisation, Soil fertility.

1. Introduction

A soil conditioner is a product whose purpose is to improve the physical, physicochemical, and/or biological properties of the soil. It can be produced with raw materials from industrial processing like Bauxite Residue (BR) and/or agro-industry wastes (Class B). During the project "Bayer's Process Towards the Circular Economy: Recovery of Metals and Production of Soil Conditioners from Bauxite Residues" [1–3], the process of composting BR, together with the residual biomass from oil palm processing (Palm Oil Mill Waste – POMW), was evaluated on a laboratory scale (TRL 3). Batches of around 200 kg of Class B SC were produced, containing 25 % BR, in compliance with current legislation [4] and showing promising results in the recovery of soil fertility and brachiaria grass growth, when compared to control treatments [1–3]. The product from this new technology has the potential to be applied in the recovery of abandoned and/or low productivity anthropized areas, rehabilitation of post-mining areas, or even in the cultivation of species with the potential to produce bioenergy.

Brazil has around 109 million hectares (ha) of degraded areas or pastures with low fertility, of which 27 million ha are in the Amazon biome, an area equivalent to 27 million soccer fields [5]. Studies suggest that recovering the fertility of these soils would cost more than 600 billion BRL if the same fertilizers used in agriculture were applied to replace nutrients. Given this scenario, alternatives fertilizers are economically necessary for recovering the fertility of anthropized soils.

Regarding the recovery of mining areas, Norsk Hydro Brazil (Hydro) is a pioneer with the Tailings Dry Backfill (TDB) waste management system, which returns bauxite tailings to already mined areas after dehydration, without any risk to the environment and eliminating the need for tailings dams [6, 7]. Hydro also manages the Brazil-Norway Biodiversity Research Consortium (BRC) with a pillar on the "Restoration of tropical forests, including restoration of biodiversity and forest soils". Hydro also has partnerships with the Brazilian Agricultural Research Corporation (EMBRAPA) and the Vale Institute of Technology to apply innovative techniques to reforestation and biodiversity studies in the areas of Mineração Paragominas. Since plant operation began in 2006, around 2905 hectares of the Amazon biome have already been reforested, with 259 hectares in 2022 alone [8, 9]. The SC has the potential to be applied mine rehabilitation areas as a strategy to accelerate soil fertility and capture carbon. This approach can be beneficial in enhancing soil quality, where the natural recovery is limited. By improving soil characteristics, the use of SC can support faster ecosystem recovery and contribute to more sustainable and efficient rehabilitation practices in post-mining landscapes.

In addition to the benefits from revegetation and recovery of biodiversity in the mined areas, the recovered anthropized soils or conventional agricultural areas could be used for the production of plant species with potential for bioenergy production, for example: oil palm (biodiesel), agave (ethane 1G and 2G) or biomass (grasses/shrubs), further contributing to the sustainability of the Brazilian energy matrix.

As a continuation of the project, this proposal aims to scale up production to the level of tonnes of SC, using the composting process in heaps, under controlled conditions in a prototype demonstrator installed in the company itself (TRL 6). The product obtained will be extensively evaluated in terms of its composition, environmental safety, improvement of soil fertility and agronomic potential in key species for revegetation of mining areas and crops destined for energy conversion. One of the selection criteria for the plant species will be the bioeconomic potential for generating income in communities around the mining area.

The project directly addresses the United Nations (UN) Sustainable Development Goals (SDGs): 2- Zero hunger and sustainable agriculture; 7-Clean and affordable energy; 9-Industry, innovation and infrastructure; and 13-Action against global climate change, among other goals indirectly.

2. Methodology

Technology Readiness Level (TRL) methodology provides a systematic framework for assessing the maturity of a technology. The TRL scale is composed of nine levels, which are grouped into three main stages: Basic Research (TRL 1–3), where fundamental principles are observed and technologies are conceptually formulated; Development (TRL 4–6), which encompasses laboratory validation, process optimization and pilot-scale testing, and Demonstration (TRL 7–9), which includes prototype validation in operational environments, pre-commercial scaling and full industrial application [10].

E. H. Conrow [11] defined this methodology as a "logical measurement system that simplifies the evaluation of the readiness of a given technology and cohesive maturity analogy across various types of the technology". In this context, the TRL scale reflets the evolution of technology from initial concept and early laboratory studies to real word testing and demonstration.

3. Conclusions

The project represents a significant advancement in the sustainability of industrial and agro-industrial residues contributing with economic circularity in aluminium sector. By scaling up from laboratory to pilot production with the aim of reaching TRL 6, this initiative might demonstrate the strong potential for environmental restoration, particularly in degraded and post-mining areas in Amazon region. The pilot composting plant to be installed at Hydro Alunorte, in Brazil, will not only validate the operational feasibility and safety of SC production at scale, but also ensure its compliance with Brazilian regulations and suitability for agronomic application through rigorous physical, chemical, microbiological, and ecotoxicological assessments. The SC has the potential to enhance soil fertility, support revegetation efforts, and serve as a foundation for the cultivation of bioenergy crops, contributing both to environmental rehabilitation and socio-economic development in surrounding communities.

4. References

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