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Valorization of wastes from pulp and paper industry: effect of distinct formulations and stabilization conditions in the properties of granules to be used as soil improvers

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INTRODUCTION

The energy sector is responsible for the huge amount of biomass ashes produced worldwide every year (currently over 480 million tons/year) being about 70% of these biomass ashes are disposed in landfills [1]. The pulp and paper industry along with wastes derived from heat and power generation, produces other waste materials including effluents and biological sludge from wastewater treatment. Application to soil for pH correction and fertilization has the potential to allow the recycling of large quantities of the materials. However, in general these waste materials cannot be recycled as such or without the processing or pre-treatment of the materials to allow safe and adequate use. The granulation of the materials followed by open air drying and stabilization (with consequent carbonation of the granules (self-hardening)) was proven to be an adequate strategy to prevent dust formation during transportation and application of biomass ash to soils [2], as well as to reduce the immediate reactivity of these waste materials upon application to soil [3].

OBJECTIVES

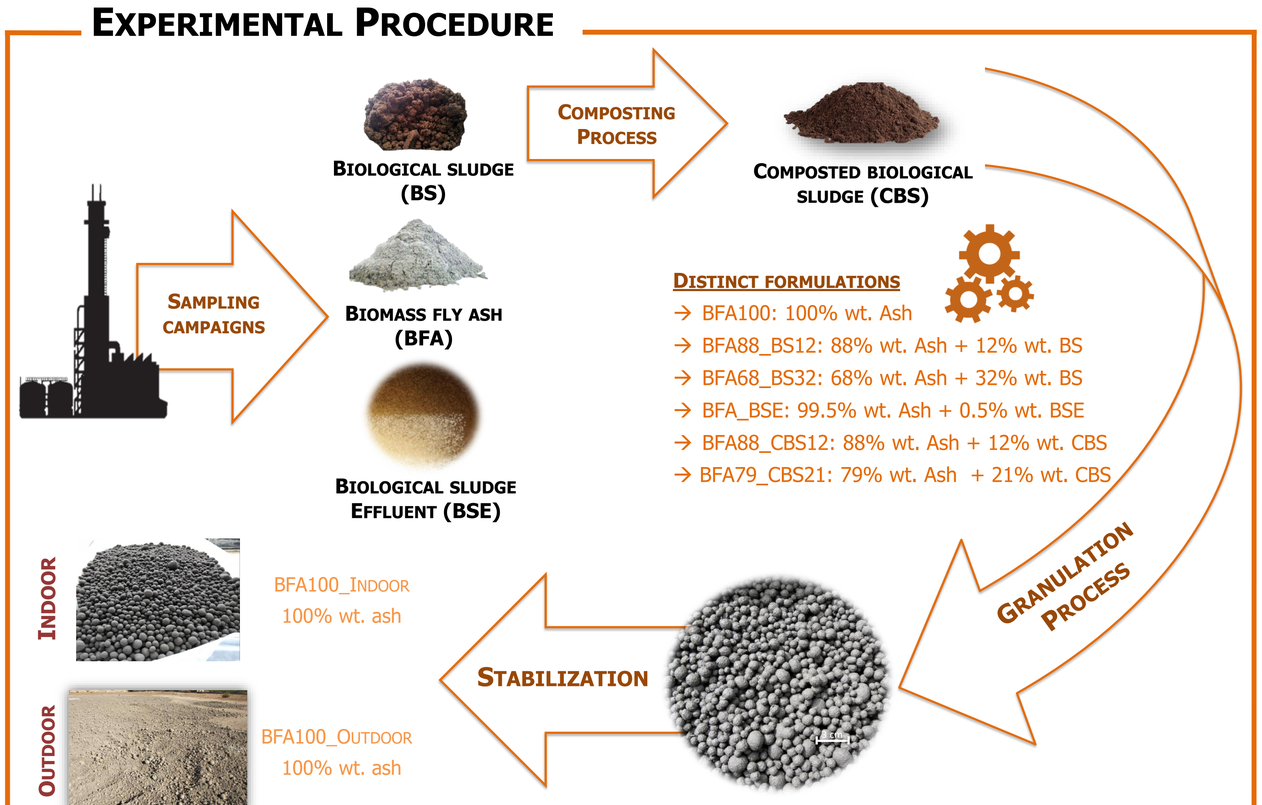
The main objective of this study is to prepare different formulations of granulated materials to be used as soil improvers, testing three different waste materials from pulp and paper industry: biomass fly ash (BFA), composted biological sludge (CBS), and biological sludge effluent with 2% wt. of solids (BSE). Different formulations and stabilization conditions (indoor and outdoor) were tested, in order to evaluate their influence on the physical-chemical properties and elemental composition of the granules produced.

The objectives of this study are directly aligned with two goals of 2030 Agenda for sustainable development:

Goal 12.5 – By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

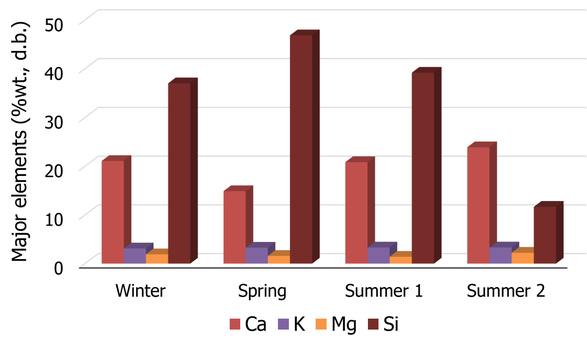
Goal 15.3 – By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation neutral world.

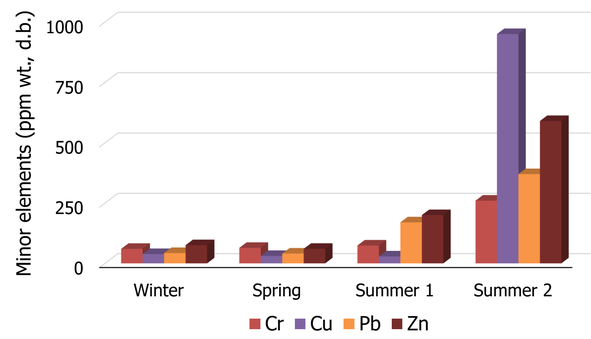
EXPERIMENTAL PROCEDURE



EFFECT OF DISTINCT FORMULATIONS

VARIABILITY IN COMPOSITION OF BIOMASS ASH USED IN GRANULATION PROCESS (COLLECTED IN DIFFERENT PERIODS OF THE YEAR)





GRANULES WITH BIOLOGICAL SLUDGE (BS) *vs.* COMPOSTED BIOLOGICAL SLUDGE (CBS)

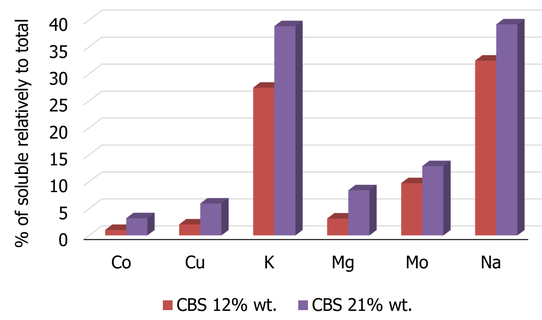
- Granules with similar %wt. of organic material presented higher pH and LOI for the mixtures with CBS. Additionally, granules with CBS show a lower dissolution of chloride than granules with BS. The composting process turns the chloride present in the mixture in less soluble forms.

SOIL IMPROVER	GRANULES WITH 10%wt. ORGANIC MATERIAL				
	Moisture (%wt.)	LOI at 550ºC (%wt.)	pH	EC (mS cm^{-1})	Soluble Cl (% to total)
BS	1.5	10.0	7.9	3.9	99.2
CBS	4.4	14.4	9.6	6.6	32.7

CBS at 12%wt. *vs.* 21%wt

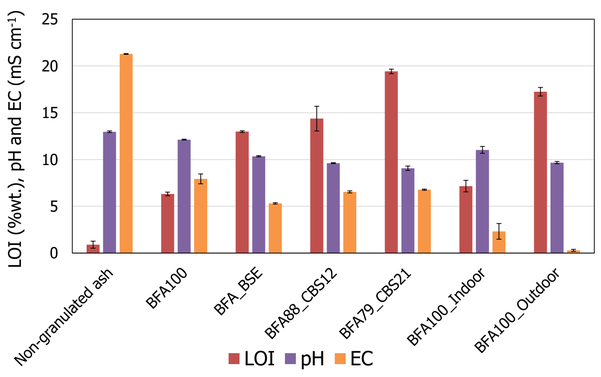
SOIL IMPROVER	Moisture (%wt.)	LOI at 550ºC (%wt.)	pH	EC (mS cm^{-1})	Soluble Cl (% to total)
CBS12	4.4	14.4	9.6	6.6	32.7
CBS21	5.6	19.4	9.1	6.8	18.1

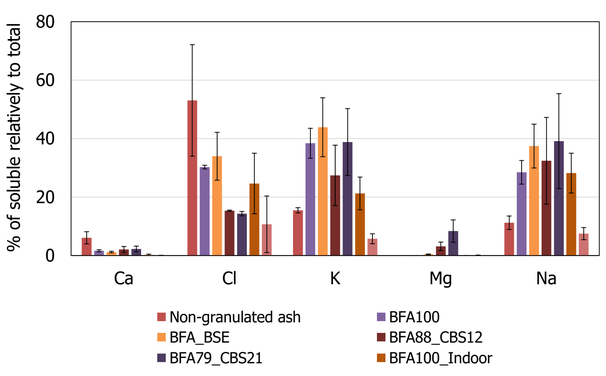
- Granules with higher dosage of CBS presented less bulk density. This is due to the lower bulk density of CBS (500 kg m^{-3}) relatively to the ash (900 kg m^{-3}).
- Chloride content is lower for granules with higher dosage of CBS, indicating that in these mixtures the chloride is mostly derived from ash.



- Soil improvers with high amount of organic material (CBS 21%wt.) presented an higher solubility ratio for some elements (e.g. Co, Cu, K, Mg, Mo and Na) than granules with only 12%wt. of CBS. This could be related to a high desintegration level of these materials during the leaching tests.

PROPERTIES OF GRANULES OF VARIABLE FORMULATIONS



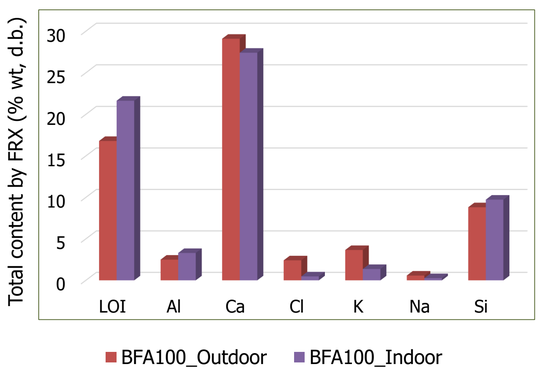


- Granulation process only with water led to a slightly decrease in pH (0.85), and in a subtancial reduction in EC value.
- Increment in organic dosage in granulated materials led to a reduction in pH value, due to the neutral pH of BS and CBS.
- Granules made with BSE and CBS presented higher contents of LOI than the other granules. Materials with higher %wt. of CBS on their formulation add higher LOI value.
- All granulated materials presented similar EC, which was lower than EC in non-granulated ash.
- Chloride, potassium and sodium are the most soluble elements in biomass fly ash and in soil improvers (leaching tests according to EN 12457).
- Stabilization led to a decrease in soluble content of chloride and calcium for the soil improvers.
- Potassium and calcium after stabilization presented a higher solubility than non-granulated fly ash.

STABILIZATION CONDITIONS

SOIL IMPROVER	AFTER 7 MONTHS OF STABILIZATION				
	Moisture (%wt.)	LOI at 550ºC (%wt.)	pH	EC (mS cm^{-1})	Soluble Cl (% to total)
BFA100_Indoor	2.1	7.2	11.1	2.54	25.0
BFA100_Outdoor	11.9	17.3	9.7	0.34	11.8

- Lower values observed for pH, EC and soluble chloride in materials stabilized outdoors are due to the leaching of materials during stabilization process (due to air moisture and raining, thus, promoting a higher carbonation degree), which was further verified by the much higher value of moisture for these granules.



- There was a clear impact of leaching during stabilization, at atmospheric conditions and rain, reflected on the reduction of most soluble salts in ash granules.
- The elemental composition (minor elements) was quite similar for both materials (not shown).

CONCLUSIONS

- Distinct formulations allow to obtain products with variable bulk density, organic matter and elemental composition. Stabilization conditions of the granules determine the physical-chemical properties of the materials produced (pH, EC, chloride content and soluble elements).
- Granules with longer stabilization time and/or stabilized outdoors presented lower pH, EC, chloride content and soluble elements than the materials stabilized indoors. This will influence the reactivity of the granule products when applied to soil and it will affect the impact that the granules will have on soil properties.
- All formulations (BFA 100, BFA_BSE and BFA_CBS) appear to be suitable for the improvement of soils properties, particularly for acidic soils and/ or poor in plant nutrients. Granules that contain higher %wt. of CBS in their formulation can be preferentially used in soils poor in organic matter.
- Materials stabilized outdoors can be preferentially used in agricultural/forest/mining soils with potential salinity problems. The low EC and chloride content of these materials can prevent soil salinization problems and potential plant stress problems due to the toxicity induced by chlorides. However, it is necessary to further assess the fate of salts, soluble ions, and chlorides during the stabilization of granules outdoors as it may be necessary to collect and process the treatment of leachates whenever these are formed during this process.

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