CONTRIBUTIONS OF THE ASH FROM FOREST BIOMASS COMBUSTION IN THE RECYCLING OF NUTRIENTS TO THE SOIL

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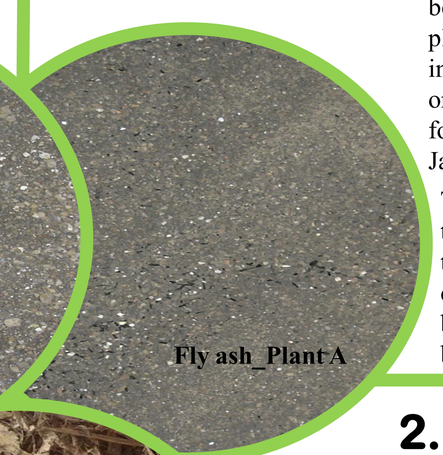
BACKGROUND

The management of the ash resulting from the thermochemical conversion of forest biomass to energy it is an issue with relevance at the environmental, economic and public health level. The ash produced in industrial thermal units, using eucalyptus bark and branches and other forest residues as solid fuel, has different final destinations, including the landfill. In recent years, new environmental directives strongly penalize this management option. Therefore, it is urgent to study sustainable alternatives, such as the valorisation of the biomass ash on the agricultural and forestry soils.

The recycling of ashes to the soil is an important alternative for ash management, because when the biomass is extracted from the forest, the nutrients and acid-buffering capacity are also removed from the soil. Thus, this valorization of the ashes contributes to minimize some negative impacts of these industrial practices, which include the acidity correction of the agricultural and forest soils (as liming agent, the ashes have high pH) and the reintroduction of the exported nutrients with the biomass to energy, like P, K and Ca, thus contributing to the recycling of nutrients in the ecosystems..

The phosphorus (P) and nitrogen (N) are the most important nutrients for plants growing. When the biomass is removed from the forest or agriculture lands, the P is also extracted from the soil in lower quantity than N. However, the ashes from biomass combustion are poor in N content, because the N is mostly converted to the gas phase during the thermochemical conversion of biomass to energy, but the ashes can have some P content.



TOPICS

Research Objective:

Create a background of physical and chemical characteristics from biomass, and its ashes, produced by Portuguese thermoelectric plants. In order to investigate the possible environmental impacts, treatment and valorization to contribute the sustainability in the value chain of the biomass to energy, giving priority to the study of the management operations that concerning the application of biomass ashes to the soil, contributing to the nutrients recycling, like P, K, Mg and Ca, to the forest ecosystem.

Keywords:

biomass ash, combustion, nutrients recycling, ashes management

METHODOLOGY

	Description	Methods
Soil	Sampling and preparation of the samples	Sampling from 38 points in 950 m² area till 30 cm of depth in typical sandy land of the littoral Center of Portugal on March 2012. The soil was air dried and sieve below 2 mm
	Determination of major and minor elements	X-ray fluorescence with Panalytical Axios spectrometer, using 10 g of ash sample
Ashes	Sampling and preparation of the samples	Sampling of about 30 to 50 kg dry ashes from thermoelectric plants; Bottom ashes milled and sieved below 2 mm
	Determination of major and minor elements	X-ray fluorescence with Panalytical Axios spectrometer, using 10 g of ash sample
	Determination of loss on ignition (LOI)	1.5 g of dried and sieved samples was introduced, using ceramic crucibles, in a carbolite muffle at ambient temperature and heated to 1100 ºC over 3 hours

The fly (from the electrostatic precipitator) and bottom (from the bottom bed) ash samples were collected in a sampling campaign in two industrial plants (referenced as A and B) located in Portuguese pulp and paper industries. In plant A, the ashes were sampling over one year (2011), i.e., one sampling per month. In the another plant B, the ashes were collected four times, i.e., one sampling on March, July and October of 2011 and January of 2012.

The thermal plants A and B have BFB (Bubbling Fluidized Bed) technology with nominal thermal capacity around 50 MW_{th}, the temperature in the furnace was in the range 800 to 900 ºC. Both BFB combustors use forest residues as fuel, like eucalyptus bark and branches, from activities of wood processing, wood chips, pine branches, pine needles and eucalyptus leaves from logging activities.

RESULTS

1. ASH CHARACTERISTICS

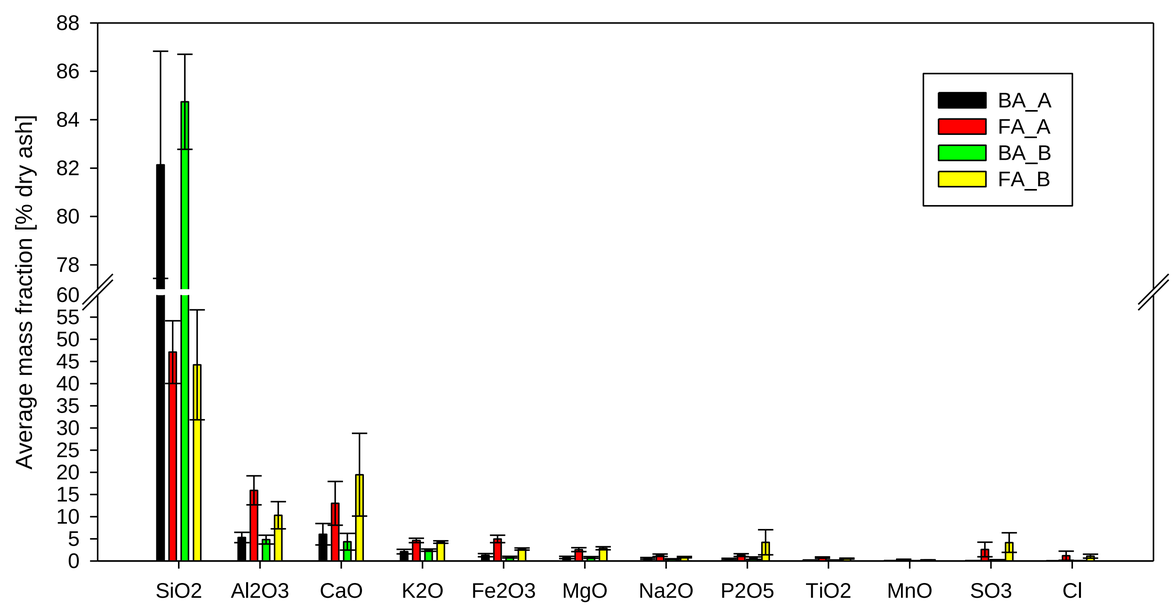


Fig.1 - Major chemical elements (average mass fraction in % of dry ash) in the bottom and fly ashes at industrial thermoelectric plants A – BA_A and FA_A, respectively, and B – BA_B and FA_B.

2. UNBURNED CONTENT IN THE ASHES

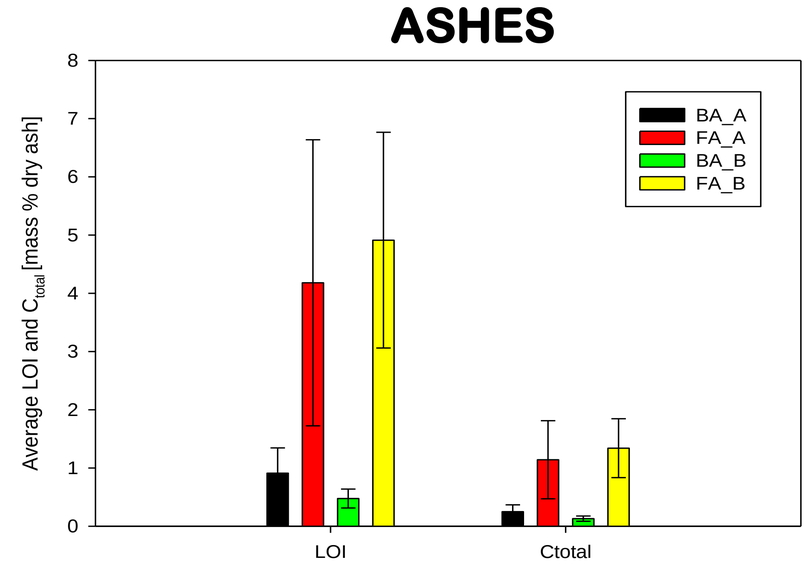


Fig.2 – Loss on ignition (LOI) and the corresponding value expressed as total carbon (as CO_2) content in the bottom ashes from plant A (BA_A) and (BA_B), and in the fly ashes from plant A (FA_A) and B (FA_B).

3. SOIL, ASHES AND NUTRIENT CONTENTS

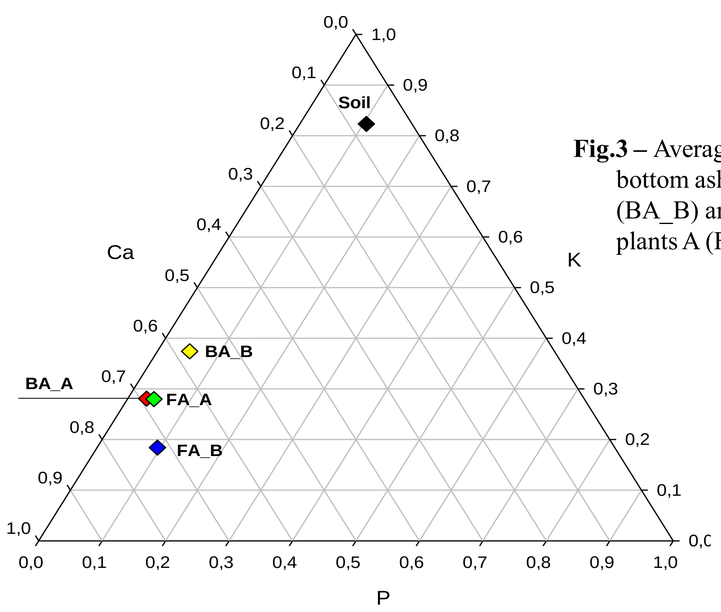


Fig.3 – Average P, K and Ca contents in the soil, in the bottom ashes from thermal plants A (BA_A) and B (BA_B) and in the fly ashes from the thermal plants A (FA_A) and B (FA_B).

4. ASH APPLICATION ON THE SOIL AND LEGISLATION

Table 1 - The limit value (LV) for heavy metals in sewage sludge for application in agriculture soils [Decreto-Lei n.º 276/2009, de 2 de Outubro], the LV for the dosages applied in Portugal, and the average heavy metals concentration (at mg of element·kg^{-1} of dry ash) with its standard deviation, in the ashes (bottom ash – BA, and fly ash – FA) at the two thermal plants (A and B).

	LV in sludge [mg·kg^{-1}]	LV introduced in soil [kg·ha^{-1}·year^{-1}]	BA_A [mg·kg^{-1} dry ash]	FA_A [mg·kg^{-1} dry ash]	BA_B [mg·kg^{-1} dry ash]	FA_B [mg·kg^{-1} dry ash]
Cd	20	0.15	< 5.4	< 7.1	< 4.4	7 ± 3
Cr	1000	4.5	36 ± 8	139 ± 34	52 ± 15	108 ± 49
Cu	1000	12	19 ± 8	68 ± 12	84 ± 123	111 ± 68
Ni	300	3	6 ± 1	37 ± 18	5 ± 2	25 ± 3
Pb	750	15	19 ± 10	115 ± 44	22 ± 12	119 ± 56
Zn	2500	30	115 ± 31	212 ± 21	98 ± 74	221 ± 144

NOTE: In Portugal there is no specific legislation for application of the ashes from thermochemical conversion of biomass on the forest or agricultural soil. The European Council Directive 86/278/EC, transposed for Portuguese law by DL 276/2009 is the reference legislation often used as guide for ash application on soil (Table 1), although this legislation is relative to the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture.

CONCLUSIONS

The results permit to verify the existence of differences between fly and bottom ashes for the several chemical elements. It was observed that the fly ashes have higher heavy metal concentrations than the bottom ashes, for both thermal plants. The fly ashes have more potential (more nutrients: P, K and Ca, and high pH) to be used as soil amendment and recycling of nutrients, compensating the forest biomass extracted to energy conversion.

When comparing the heavy metal content (for Cd, Cr, Cu, Ni, Pb and Zn) on the ashes from the thermal plants A and B with the values from Portuguese legislation, it is observed (Table 1) that the content of this metals on the ashes is below the limit values. These results are indicative of the potential of these ashes to be recycled to the soil, without causing negative impacts for the environment (soil, water and biodiversity).

Considering the LOI as approached by CO_2, as stated before, the percentage of carbon in the bottom ashes is very low (< 0.25%wt), and in the fly ashes the content can be in average around 1.3%wt. This quantity of carbon is important in the context of carbon sequestration on soil, considering the recycling of ashes to the soil. The soil used here in the experiments has a LOI of 3.48% and 0.94% of total carbon. So, the recycling of FA to the soil can be important to the carbon content of the soil.

ACKNOWLEDGEMENTS

This work was financially supported by *Fundação para a Ciência e a Tecnologia* (FCT), Portugal, through the project PTDC/AAC-AMB/098112/2008 (BIAS-TO-SOIL - Biomass ash: Characteristics in relation to its origin, treatment and application to soil), and PhD grant SFRH/BD/71088/2010. This work was also financed by FEDER through the Operational Program Competitiveness Factor (COMPETE).

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