Treatment by leaching of bottom bed ash from biomass combustion in bubbling fluidized bed

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Abstract

The management of bottom bed ashes from biomass combustion in bubbling fluidized bed combustors (BFBC) is a major issue, namely considering operating problems and environmental aspects.
Bottom bed ashes from combustion of forest biomass residues in BFBC were studied. The ashes were characterized considering particle size distribution, chemical composition, and water leaching.
Compared to the original sand bed, the bottom bed ashes have a wider distribution of particle sizes; the inert material fed mixed with the biomass is responsible for this result.
The bottom bed ashes studied have distinct physical-chemical properties.
The treatment by water leaching and screening improves the quality of the ashes in order to allow its material valorization. After leaching, the concentration of some chemical elements in the ashes decreased in distinct percentages, depending on the chemical element and the origin of the ashes. The higher percentage of concentration decrease was observed for Cl and S.

Keywords: Ash, leaching, combustion, fluidized bed, biomass

INTRODUCTION

Fluidized bed combustion (FBC) technology is recognized as the most appropriate technology for biomass combustion, due to the inherent advantages of low process temperatures, isothermal operating conditions, and fuel flexibility. The existing FBC technology at industrial scale includes the bubbling fluidized bed combustors (BFBC) and the circulating fluidized bed combustors (CFBC). Among other characteristics, these technologies differ in the pattern of gas-solid hydrodynamics in the reactor, the size of the bed particles, the heat and mass transfer rates in the reactor, the temperature and flue gas composition profile along the reactor. This in turns influences the characteristics of the ashes produced during biomass combustion, and thus, flows of ashes with distinct properties will be produced in these installations.
During biomass combustion in BFBC two main types of ashes are produced: the bottom bed ashes and the fly ashes. The bottom bed ashes are composed by the sand particles from the original (mainly quartz) sand bed, the inert material (forest soil and small stones) fed together with the biomass, and the biomass ash. The fly ashes are composed by the smaller size particles from the original sand bed, particles resulting from attrition and abrasion of the original sand bed particles, inert material fed with the biomass, and the biomass ash. In opposition to a grate furnace, where the bottom ashes represent the higher percentage of the total ashes produced in the installation, during BFBC the bottom bed ashes often represent the lower fraction of the total ashes produced in the plant; the bottom bed ash fraction can be of the order 5%wt [1,2], 10%wt [3], 17%wt [4], or as high as 50%wt to 60%wt as often observed in some Portuguese thermal plants with BFBC.
The bottom bed ashes during BFBC result from periodic discharges of the bed, among other reasons, related to: i) the need of bed renovation and replacement in order to avoid bed agglomeration and defluidization, ii) discharge of excess bed solids in order to maintain bed height, iii) the replacement by fresh natural sand with appropriate particle size distribution in order to guarantee proper hydrodynamic conditions of the bubbling bed.
The discharge of bottom bed ashes originates a significant amount of solid wastes to be managed. The ashes from biomass combustion in thermal plants are classified as a waste according to the European List of Wastes [5], and the bottom bed ashes from BFBC are classified with code 100124.
Most of the published research work dealing with bottom bed ashes from BFBC is related with the phenomena of bed agglomeration and defluidization, and less related with the environmental management and material valorization of the bottom bed ashes.
The phenomenon of bed agglomeration and defluidization is an issue of major concern during BFBC. The reasons behind this phenomenon are associated with the formation of an ash coating layer around the bed particles, and are related with the Na and K and their combination with the Si, resulting

in compounds with a relative lower melting point present on those layers, achieved at the low temperatures of BBFC (800ºC to 900ºC), thus promoting the agglomeration of the particles and subsequent defluidization of the bed [6-20]. Nevertheless, in general, the bottom bed ash in a BFBC are composed mostly of silica (mostly quartz) sand particles, with particle size from the few micrometers until some millimeters, often containing a relatively thin (with a few micrometers) coating layer mainly composed of inorganic material that is found in most of the typical biomass fuels [21].
In this work are analyzed some physical-chemical properties of bottom bed ashes from combustion a variety of forest biomass fuels in industrial BFBC existing in Portugal. Are also evaluated some results of the physical-chemical treatment applied to the bottom bed ashes from the BFBC, in order to produce a material that can be used in industrial applications, as for example, in substitution of natural silica sand.

EXPERIMENTAL METHODOLOGY

The experimental work developed in this study is included in a wider research project [22] aimed to study the characteristics of ashes produced in industrial thermal plants in Portugal, and to evaluate solutions for their management. The work includes the characterization of the ash flows in industrial thermal plants using biomass as fuel, the treatment of the ashes considering is material valorization, and the environmental management of the ashes.
In the study presented here are analyzed results about the characteristics of bottom bed ashes sampled in some Portuguese industrial thermal plants with BFBC. The ashes were characterized for particle size distribution, chemical composition and leaching.
It was studied the raw bottom bed ash and the mass fraction of bottom bed ash with particle size in the range 0.3 to 1.0 mm. The interest in this particle size fraction (0.3 to 1.0 mm) is related with the possibility of its recycling, namely to be utilized as: i) substitute of part of the natural sand used for bottom bed replacement in the BFBC, and ii) as aggregate in construction materials.
Figure 1 shows the main flows of ashes in thermal plants with BFBC, and also the proposed bottom bed ash treatment and material valorization approach under evaluation.

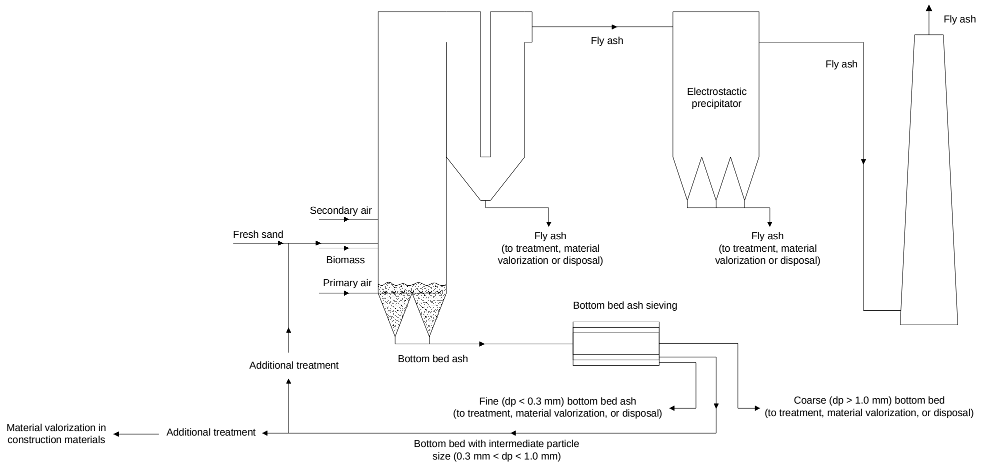

Figure 1 – Schematic of the main flows of ashes in a thermal plant with BFBC, and bottom bed ash treatment for further material valorization.

Thermal Plant Characteristics

The bottom bed ashes studied were sampled in five BFBC, with nominal thermal capacity in the range 50 MW_{th} to 100 MW_{th}, using forest biomass residues as solid fuel. Among the biomass fuels used, the eucalyptus bark and the residues from logging activities are the major component. The typical operating conditions of the industrial BFBC include temperature of the bubbling bed in the range 800ºC to 900ºC, and O_2 concentration in the flue gas in the range 4%v(dry gases) to 7%v(dry gases).
The ash samples were collected at the discharge location of the bottom bed ash in the industrial BFBC plants. Each bottom bed ash sample had a mass of about 30 kg.

Bottom Bed Ash Characterization

The bottom bed ashes samples collected were characterized for particle size distribution by sieving.

For chemical characterization, it was selected the bottom bed ash fraction with particle size in the range 0.3 to 1.0 mm from three BFBC installations, considering the applications to be studied, as stated before. The mass fraction of the bottom bed with particle size in this range 0.3 to 1.0 mm can represent from 40%wt to 60%wt of the bottom bed ash discharged in the BFBC analyzed. It was also characterized the raw bottom bed ashes (with particle size below 2 mm) from one industrial BFBC.
The chemical characterization of the bottom bed ash was performed for major and minor chemical elements by X-Ray Fluorescence (XRF), using a Panalytical Axios spectrometer. Prior to analysis, the bottom bed ash samples were subjected to a grinding process in an Agatha mill, followed by drying at 101 ºC ± 1 ºC for 12 h. The chemical analysis was performed considering: i) Loss on ignition (LOI), and ii) XRF analysis on a pressed pellet previously prepared. For LOI determination, approximately 1.5 grams of the sample, milled and dried, were heated to 1100 ºC for 3 hours in a Carbolite furnace; the LOI was obtained based on the loss of weight after the heating at 1100 ºC. The pressed pellet for XRF analysis was prepared with about 10 grams of milled and dried ash sample. The ash sample was mixed with 4 or 5 drops of polyvinyl alcohol and homogenized in a plastic recipient, and further pressed in a standardized form. After drying the pressed pellet is then submitted to X-Ray analysis.
Some particles from the raw bottom bed ash of one BFBC and the respective particles resulting from its industrial leaching with water were prepared for further analysis of their cross section by Scanning Electron Microscopy - Energy Dispersive Spectroscopy (SEM-EDS), using an ultra-high resolution analytical scanning electron microscope HR-FESEM Hitachi SU-70.

Bottom Bed Ash Leaching

The bottom bed ash leaching was evaluated using two procedures: i) water leaching in laboratory, and ii) industrial water leaching. The leaching in laboratory was applied to three bottom bed ashes with particle size in the range 0.3 to 1.0 mm. The industrial leaching was applied to the raw bottom bed ashes from one industrial BFBC.
The laboratorial leaching tests were performed according to the European Norm EN 12457-2 [23]. Before leaching, the solid samples were pre-dried for 12 h at 105ºC ± 5ºC. According to this procedure, 100 grams of dry bottom bed ash sample were transferred to a polypropylene stopper flask and then 1 L distilled water was added; that is, leaching with an L/S ratio (liquid to solid ratio) equal to 10 was used. It was a batch leaching test with duration of 24 hours under continuous stirring in an orbital shaker (250 rpm).
The industrial leaching was performed in continuous and under typical conditions used in an industry that makes treatment of natural sand for the construction industry. The leaching includes a continuous shower like process using a L/S (liquid to solid) ratio equal to 2, and a processing capacity of 10 ton/h; the process includes treatment of the leaching solution by sedimentation in order to reuse the liquid solution on the leaching process.

RESULTS

The results presented here include: i) the particle size distribution of the original sand bed of the BFBC (OB_1, OB_4, OB_6), and the particle size distribution of the raw bottom bed ashes (BA_1_R, BA_2_R, BA_4_R, BA_5_R, BA_6_R) from five industrial BFBC, ii) the chemical composition (determined by XRF) of the original natural sand bed (OB_4, OB_6), of the bottom bed particles with particle size in the range 0.3 to 1.0 mm before (BA_4, BA_5, BA_6) and after (BA_4_L, BA_5_L, BA_6_L) laboratorial leaching with water, of a raw bottom bed ash (BA_6_R) and the respective bottom bed ash after industrial leaching and screening (BA_6_IL).
After industrial leaching and screening the material (BA_6_IL) to be valorized in industrial applications has the following particle size cumulative (lower) mass distribution: 100%wt<2.0 mm, 94.9%wt<1.0, 18.9%wt<0.50 mm, 0.027%wt<0.25 mm, 0%wt<0.063 mm, and the chemical analysis by XRF was made on samples prepared from this particle size distribution.
It is presented information about the SEM-EDS analysis of the cross section of some bottom bed ash particles before (BA_6_R) and after industrial leaching (BA_6_IL).

Bottom Bed Ash Characteristics

From the macroscopic point of view, the bottom bed ashes from BFBC that use (mainly) eucalyptus bark as biomass fuel are dark in color, whereas the bottom bed ash from BFBC that use a variety of forest biomass residues (e.g., from logging activities) are brown in color. The bottom bed ashes from the BFBC analyzed showed no agglomerated particles.
The particle size distribution of the natural sand utilized as original bed and the bottom bed ashes discharged is shown in Figure 2, for the industrial BFBC installations studied. It is observed that the bottom bed ashes show a particle size distribution that is enriched with fine and coarse particles

when compared with the original natural sand bed. Other studies in industrial BBFC [1,2,3,4] do not show this pattern characterized by a wide particle size distribution. The enrichment in fine and coarse particles relative to the original sand bed, observed in these Portuguese BFBC installations, can be explained by the quality of the forest biomass residues used as fuel. The biomass used can have considerable amounts of inert material (forest soil particles and small stones) as has been shown in a study conducted in a Portuguese industrial thermal plant using similar biomass fuel [24]; this contamination of the biomass fuel by inert material results from bad practices during the biomass residues collection and management before delivering to the BFBC installation. In fact, the increasing mass fraction of coarse particles in the bottom bed ashes observed here is not related with agglomeration phenomena, because no signs of agglomeration were observed in the samples studied.
From the operating perspective, there are some negative implications from the bottom bed enrichment in lower particle size material. For example, the lower particle size material fed with the biomass is composed mostly of particles from the forest soil, and its lower terminal velocity enhances the entrainment along the freeboard and the corresponding erosion of the heat exchange equipment (e.g. super-heaters). The higher particle size material is composed of coarse soil particles and small stones from the forest, that have much higher fluidization velocities than that of the particles from the original sand bed. This enrichment in coarse particle size influences the quality of bed fluidization, affecting negatively the heat and mass transfer inside the bed, and the whole performance of the BFBC.
The high level of inert material (soil and small stones from the forest) fed mixed with the biomass in the Portuguese BFBC plants [24] implies a relatively high frequency of bottom bed discharge, and consequently these bottom bed ashes have low residence time (<3 days) in the BFBC when compared with other practices in industrial installations using BFBC [1,2].
The composition of bottom bed ashes samples is shown in Figure 3, considering the loss on ignition (LOI) and major chemical elements, and in Figure 4 considering some minor chemical elements.
The characteristic low value of LOI reveals the low content of organic matter in the bottom bed ashes, as it is usual in BFBC due to the relatively efficient combustion inside the bed and the low solid carbon content inside the bed during the combustion of high volatile matter content solid fuels as the biomass. For the bottom bed particles BA_4 and BA_5, the unburned material determined at 550ºC [25] was found to be lower than 0.40%wt (dry basis) and 0.09%wt (dry basis), respectively.
The major chemical element present in the bottom bed ashes is Si; Oxygen not considered. The Si expressed as SiO_2 represent about 74%wt, 72%wt, 83%wt and 85%wt of the bottom bed ashes with reference BA_6_R, BA_6, BA_4 and BA_5. This abundance of Si it is related with the natural (mostly quartz) sand (>98.5%wt SiO_2) used as original bottom bed in the BFBC.
The bottom bed ashes are enriched in chemical elements (Figures 3 and 4) that can be found in the inorganic content of biomass [21], when compared to the original (quartz) sand bed. Considering the relatively high content of inert material (forest soil particles and small stones) fed mixed with the biomass [24], it is expected also that the bottom bed ash composition is influenced by the composition of that inert material.

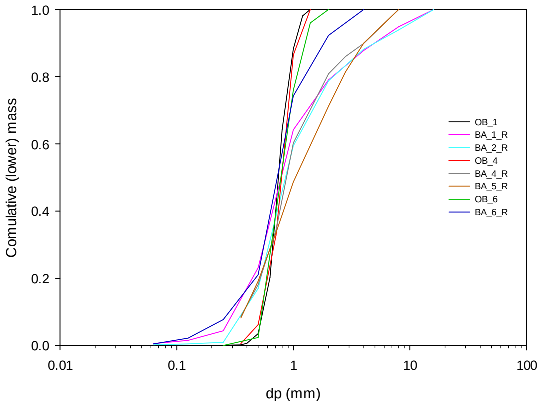

Figure 2 – Cumulative (lower) mass size distribution of particles from: original sand bed of plants 1 and 2 (OB_1), original sand bed of plants 4 and 5 (OB_4), original sand bed of plant 6 (OB_6), and raw bottom bed ashes from plants 1, 2, 4, 5 and 6 (BA_1_R, BA_2_R, BA_4_R, BA_5_R, BA_6_R).

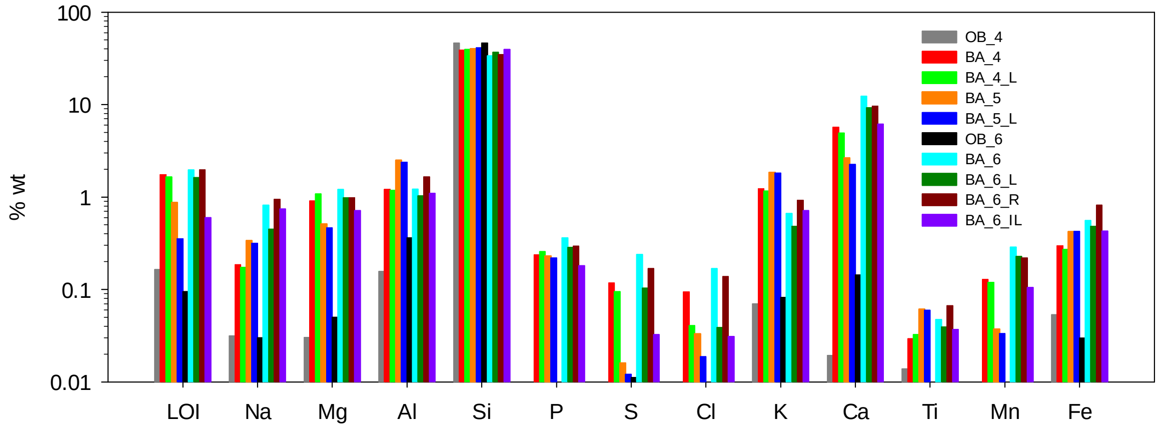

Figure 3 – Chemical composition (LOI and major elements determined by XRF, except Oxygen) of the original sand bed from three BFBC (OB_4=OB_5, OB_6), bottom bed ashes (0.3 to 1.0 mm) from three BFBC (BA_4, BA_5, BA_6) and the respective bottom bed ashes after laboratory leaching (BA_4_L, BA_5_L, BA_6_L), raw bottom bed ashes from a BFBC (BA_6_R) and the respective bottom bed ashes after industrial leaching (BA_6_IL). Chemical elements without value in the figure mean that the concentration it is below the detection level of the XRF. Y-axis in logarithmic scale.

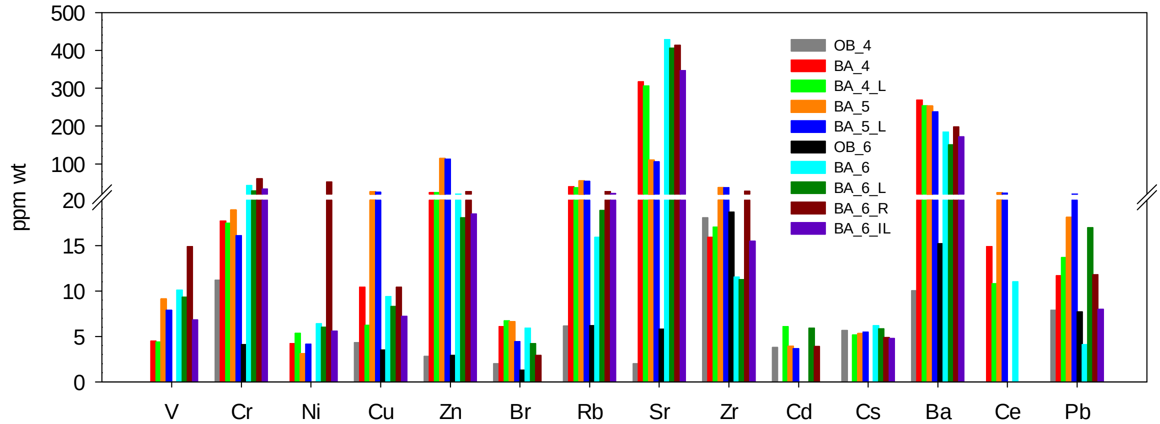

Figure 4 – Chemical composition (some minor elements, with concentration > 5 ppm wt, determined by XRF) of the original sand bed from three BFBC (OB_4=OB_5, OB_6), bottom bed ashes (0.3 to 1.0 mm) from three BFBC (BA_4, BA_5, BA_6) and the respective bottom bed ashes after laboratory leaching (BA_4_L, BA_5_L, BA_6_L), raw bottom bed ashes from a BFBC (BA_6_R) and the respective bottom bed ashes after industrial leaching (BA_6_IL). Chemical elements without value in the figure mean that the concentration it is below the detection level of the XRF.

Nevertheless, each bottom bed ash analyzed has its own particular chemical composition, among other factors, influenced by: i) the biomass fuel characteristics, ii) the operating conditions, namely the stoichiometry and temperature, and iii) the residence time of the bottom bed ashes. With exception of Ca, present in concentrations in the range 2.5%wt to 10%wt, the other chemical elements are present in concentrations lower than 2%wt. By a descending order in concentration, the general pattern of abundance of major chemical elements in the bottom bed ashes is:

Si>Ca>Al≈K>Mg>Fe>P>Na>Mn≈S>Cl>Ti, for BA_4;

Si>Ca≈Al>K>Mg>Fe>Na>P>Ti>Mn>Cl>S, for BA_5;

Si>Ca>Al≈Mg>Na≈K>Fe>P>Mn>S>Cl>Ti, for BA_6;

Si>Ca>Al>Mg≈Na≈K>Fe>P>Mn>Ti>S≈Cl, for BA_6-R.

Three bottom bed ashes samples (BA_4, BA_6, and BA_6_R) show Sr followed by Ba as the most abundant minor chemical elements; the bottom bed ashes BA_5 show Ba as the most abundant minor chemical element, followed by Zn, Sr and Rb. By a descending order in concentration, the general pattern of abundance of minor chemical elements in the bottom bed ashes is:

Sr>Ba>Rb>Zn>Cr>Zr>Ce>Pb>Cu>Br>V≈Ni, for BA_4;

Ba>Zn>Sr>Rb>Zr>Cu Ce>Cr≈Pb>V>Br>Cs>Cd>Ni, for BA_5;

Sr>Ba>Cr>Zn>Rb>V≈Ce>Zr≈Cu>Br≈Ni>Cs>Pb, for BA_6;

Sr>Ba>Cr>Ni>Zr>Rb≈Zn>V>Pb>Cu>Cs>Cd>Br, for BA_6-R.

During biomass combustion the original (mostly quartz) sand bed particles become enriched in chemical compounds typical of the inorganic content of the biomass. This enrichment occurs as a coating layer of the sand particles. This process is shown in Figures 5 and 6, where the SEM-EDS of the cross-section of a particle from the original sand bed (OB_6), a particle from the raw bottom bed ashes discharged (BA_6_R), and from the leached (industrial procedure) bottom bed ashes (BA_6_IL) are presented. The coating layer was measured as to have less than 50 μm thickness in particles with equivalent diameter higher than 0.4 mm. Some of the chemical elements typical of the inorganic content of the biomass [21] were found in that coating layer in distinct amounts, namely the Si, Ca, Mg, P, Na, Al, S. In Figure 6 it is presented the location and qualitative abundance of some of those chemical elements in that layer, namely the Ca, K, Mg and Na. This enrichment in the outer layer of the bottom bed particles has been documented in the literature and it is related with the bed agglomeration and defluidization phenomena [6,7,8,9,11,12,13]. The relative amount of some of these chemical elements, namely Si, Ca, K, Na and Al, and it relation to the melting temperatures of some inorganic compounds present in that layer has been used to explain the agglomeration and defluidization phenomena during BFBC [6,7,17,18], and to develop measures for its prevention, as for example the use of additives [7,14,16,17,18].

Leaching of Bottom Bed Ash

When comparing the chemical composition of the bottom bed ash samples not leached (BA_4, BA_5, BA_6, and BA_6_R) and leached (BA_4_L, BA_5_L, BA_6_L, and BA_6_R_L) it is observed that the concentration of some chemical elements, among them the Cl, S, Na and K, is lower in the leached samples (Figures 3 and 4); this result is important in the context of material valorization of the bottom bed ashes. It was calculated the percentage of variation in the concentration of chemical elements present in the bottom bed ashes samples in result of leaching; for that purpose it was used the ratio between the difference in concentration of (major) chemical elements in the samples not leached and in the leached samples, and (relative to) their concentration in the samples not leached. That percentage of variation reflects a decrease in concentration of some chemical elements present in the bottom bed ashes after leaching. The percentage of decrease in concentration of some chemical elements in the bottom bed ashes in result of leaching is shown in Figure 7. This decrease in concentration can also be regarded as an indicator of the chemical elements removal in result of leaching. It is observed that the percentage of decrease in concentration is different for the distinct bottom bed ashes studied. In general, the percentage of decrease in concentration of (major) chemical elements in the bottom bed ashes with reference BA_6_L is higher than that observed for the bottom bed ashes BA_4_L and BA_5_L. As well, differences in the percentage of decrease in concentration of some chemical elements between the laboratorial (BA_6_L) and industrial (BA_6_IL) leaching of bottom bed ashes were observed; the industrial leaching shows higher percentages of decrease in concentration, except for Na and K. However, it is important to refer that the laboratorial and industrial leaching procedures had differences on: i) the particle size distribution of the bottom bed ashes leached, ii) the L/S ratio, iii) the pattern of solid-liquid contact, and iv) the leaching time.

The chemical elements removal by leaching is influenced by the form according which the elements are bonded in the ashes, including the coating layer around the sand bed particles, and by the physical-chemical properties of the leaching solution, among them, the pH [26,27,28]. Distinct chemical compounds have distinct solubility.

The chemical (major) elements that show higher percentage of decrease in concentration are the Cl and S (Figure 7), despite these elements are present in low concentration (<0.25%wt) in the bottom bed ashes. A concentration decrease in the range 20% to 80% is observed for S, and in the range 40% to 80% for Cl. The presence of these chemical elements bound in soluble salts in the bottom bed ashes can explain the high removal level by leaching [26].

The decrease in concentration of other (major) chemical elements important considering the material valorization of the bottom bed ashes, as for example the Na and K, was relatively low (<7%wt) for the samples BA_4_L and BA_5_L, and in the range 20% to 50% for BA_6_L and BA_6_IL, respectively. The samples resulting from laboratorial leaching showed a higher percentage of decrease in concentration of Na and K when compared with the industrial leaching; when analyzing the laboratorial and industrial leaching it is important to refer that the experimental conditions are distinct.

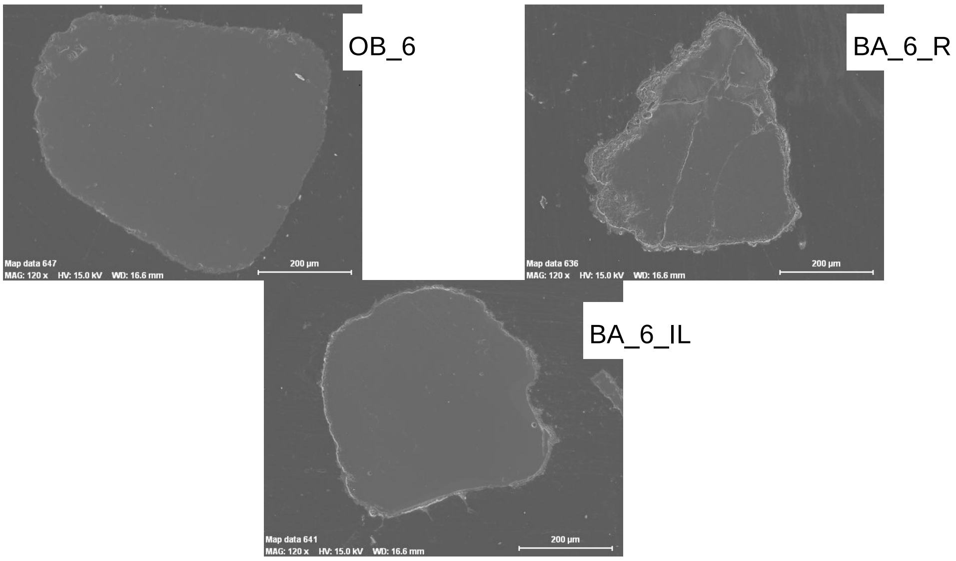

Figure 5 – Microscopic view of cross section of bed particles: original sand bed (OB_6), raw bottom bed (sand) particle (BA_6_R), bottom bed (sand) particle after industrial water leaching (BA_6_IL).

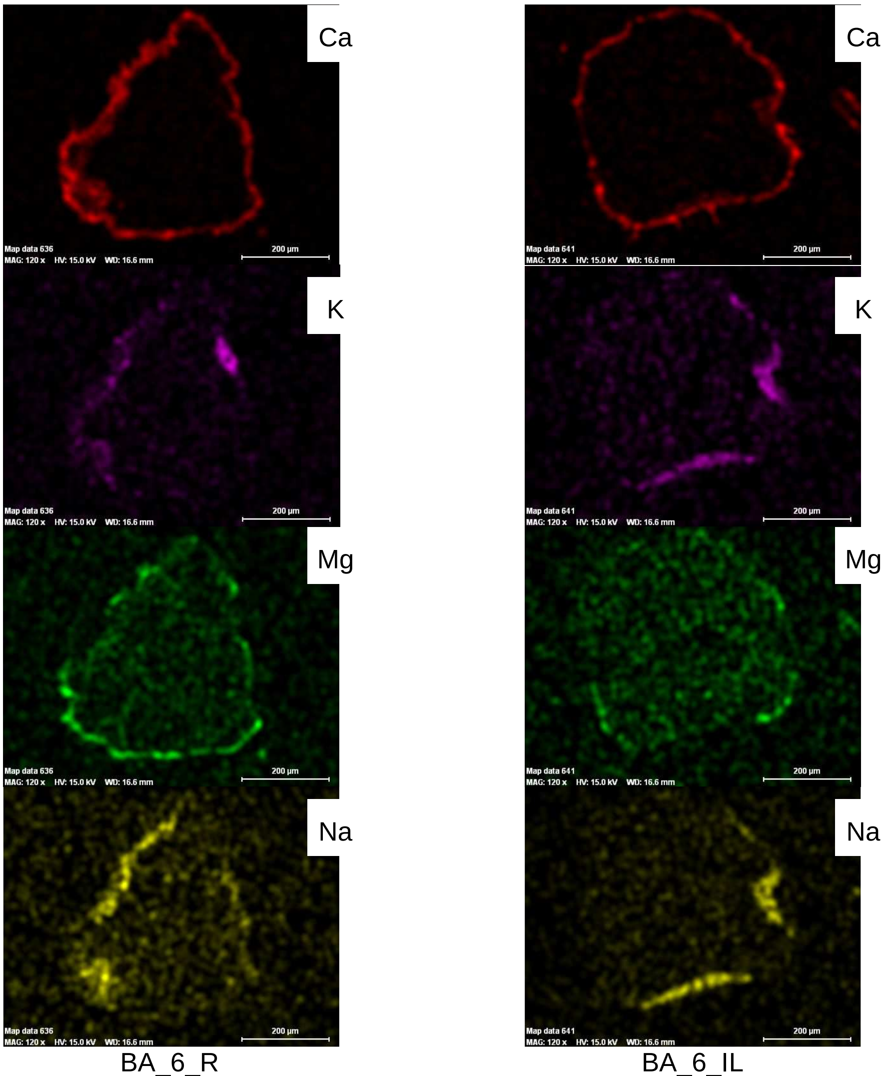

Figure 6 – Composition (Ca, K, Mg, Na) of the coating layer of a bed particle determined by SEM-EDS: bottom bed particle (BA_6_R), bottom bed particle after industrial leaching (BA_6_IL).

The relatively low percentage of decrease in concentration of K and Na could be related with the fact that those compounds are not present mainly in the form of soluble salts, like the KCl or K_2SO_4 [26], but instead should be present as compounds with low solubility as for example the sodium and potassium feldspars [26], also with origin in the inert material (forest soil) fed mixed with the biomass. To a better understanding of this process there is ongoing work dealing with Energy-Dispersive X-Ray spectroscopy (EDX) analysis of the bottom bed ashes.
The concentration of Mg, P and Ti in the leached sample BA_4_L was higher than in the non-leached sample BA_4 (Figure 3). Among other reasons, the relative lower leachability of these chemical elements in comparison to the other chemical elements present in the bottom bed ashes can explain this result; thus, after leaching the sample become enriched in these elements. Considering that sample replicates were used in chemical characterization, before and after leaching, the representativeness of the replicates is another issue to be considered. This subject has to be confirmed with further experiments. The higher concentration of Si in all the leached samples, relative to the non-leached samples, is justified by the lower leachability of this chemical element relative to the other chemical elements present; thus, after leaching the sample become enriched in this element. It was observed that the coating layer around the bottom bed sand particles it is not removed by water leaching, as shown in Figure 5 and 6; nevertheless, by SEM it was observed that the particles show a coating layer with lower thickness after leaching, as shown in the example of Figure 5 for a particle resulting from industrial leaching.

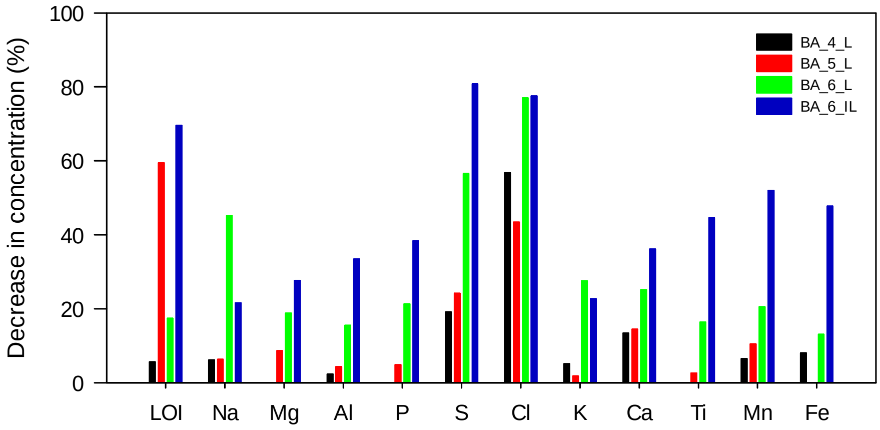

Figure 7 – Percentage of decrease in concentration of (major) chemical elements in the bottom bed ashes in result of leaching. Determined based on the chemical composition (by XRF) of bottom bed ashes before and after water leaching. The percentage of decrease is calculated in relation to the concentration of chemical element in the bottom bed ashes not leached.

Characteristics of Leaching Solutions (pH and conductivity)

The pH and conductivity values of the solutions from (laboratorial and industrial) leaching of bottom bed ashes are shown in Figure 8. The laboratorial leaching solutions had pH values in the range 11.5 to 13.0, with the higher value observed in the solution from leaching BA_6 (sample BA_6_L in Figure 8). The pH value of the solution from the industrial leaching has a lower value (pH=9.5) than those observed in the laboratorial leaching solutions. The high pH values are related to the alkaline characteristics of the ashes, and results from its content in alkali chemical elements, as for example the Na, K, Ca, that become dissolved in the leaching solutions. High values of pH are common of bottom bed ashes from industrial BFBC using biomass as fuel [3,4].
The conductivity of the leaching solutions was in the range 0.25 mS/cm to 9.7 mS/cm; the lower value was observed in the solution from industrial leaching of bottom ashes BA_6 (sample BA_6_IL in Figure 8), and the higher values in the solutions from leaching bottom ashes BA_4 and BA_6 (samples BA_4_L and BA_6_L in Figure 8). The conductivity is related with the concentration of dissolved ions, among those, the ions derived from alkali elements like Na, K, Ca, and also ions derived from Cl and S. High conductivity reveals high ionic strength of the solution and this is associated with high concentration of ions, and reflects a higher removal of alkali elements, chlorine and sulphur from the bottom bed ashes.

In the laboratorial leaching experiments, the higher values of pH and conductivity where observed for the solutions from leaching bottom bed ashes from the two BFBC using mainly eucalyptus bark (samples BA_4_L and BA_6_L in Figure 8). For the bottom bed ashes from the BFBC that uses forest residues from several forest management activities a relatively lower value of conductivity was observed (sample with reference BA_5_L in Figure 8).
When analysing the values of pH and conductivity of the solution from industrial leaching with those from laboratorial leaching, BA_6_L and BA_6_IL, it is important to remember that are distinct leaching procedures, as described previously.

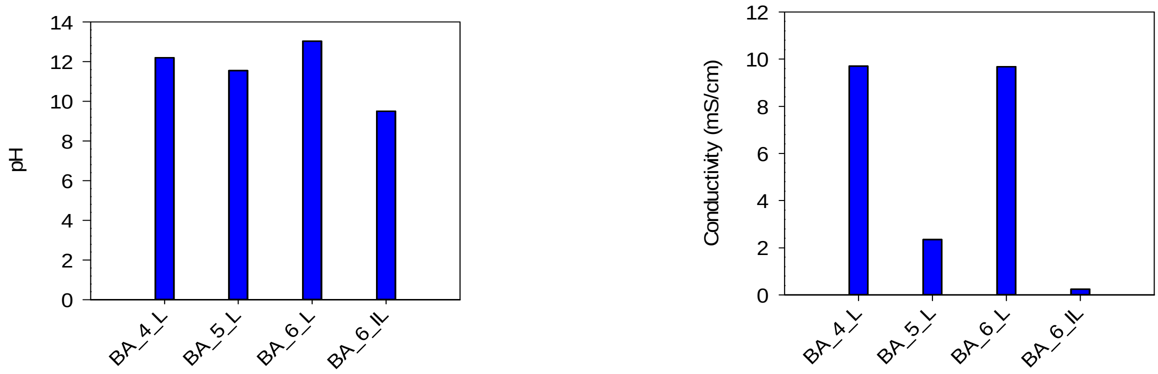

Figure 8 – pH and conductivity of the leaching solutions. Temperature of the solution during measurement: 28ºC for BA_4_L, 25ºC for BA_5_L, 21ºC for BA_6_L, 25ºC for BA_6_IL.

CONCLUSIONS

In this work, bottom bed ashes from combustion of forest biomass residues in industrial BFBC were studied. The bottom bed ashes were characterized considering particle size distribution, chemical composition, and water leaching.
Compared to the original sand bed, the bottom bed ashes have a wider distribution of particle sizes. The inert material fed mixed with the biomass has a major role in this process. In this context, the quality of the forest biomass residues used as fuel has to be improved, namely by removing the inert material (forest soil and small stones) that arrives to the thermal plant mixed with the biomass.
It was observed that the treatment by screening and water leaching can improve the quality of the bottom bed ashes in order to allow its material valorization in some industrial applications, namely as substitute of natural sand, thus saving natural resources.
After the leaching process the concentration of some chemical elements in the bottom bed ashes decreased in distinct percentages, depending on the chemical element and the origin of the ashes. The higher percentage of concentration decrease was observed for Cl and S.

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