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

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The subject

- The Portuguese policy for the energetic sector defines as priority the renewable resources, among them the forest biomass residues

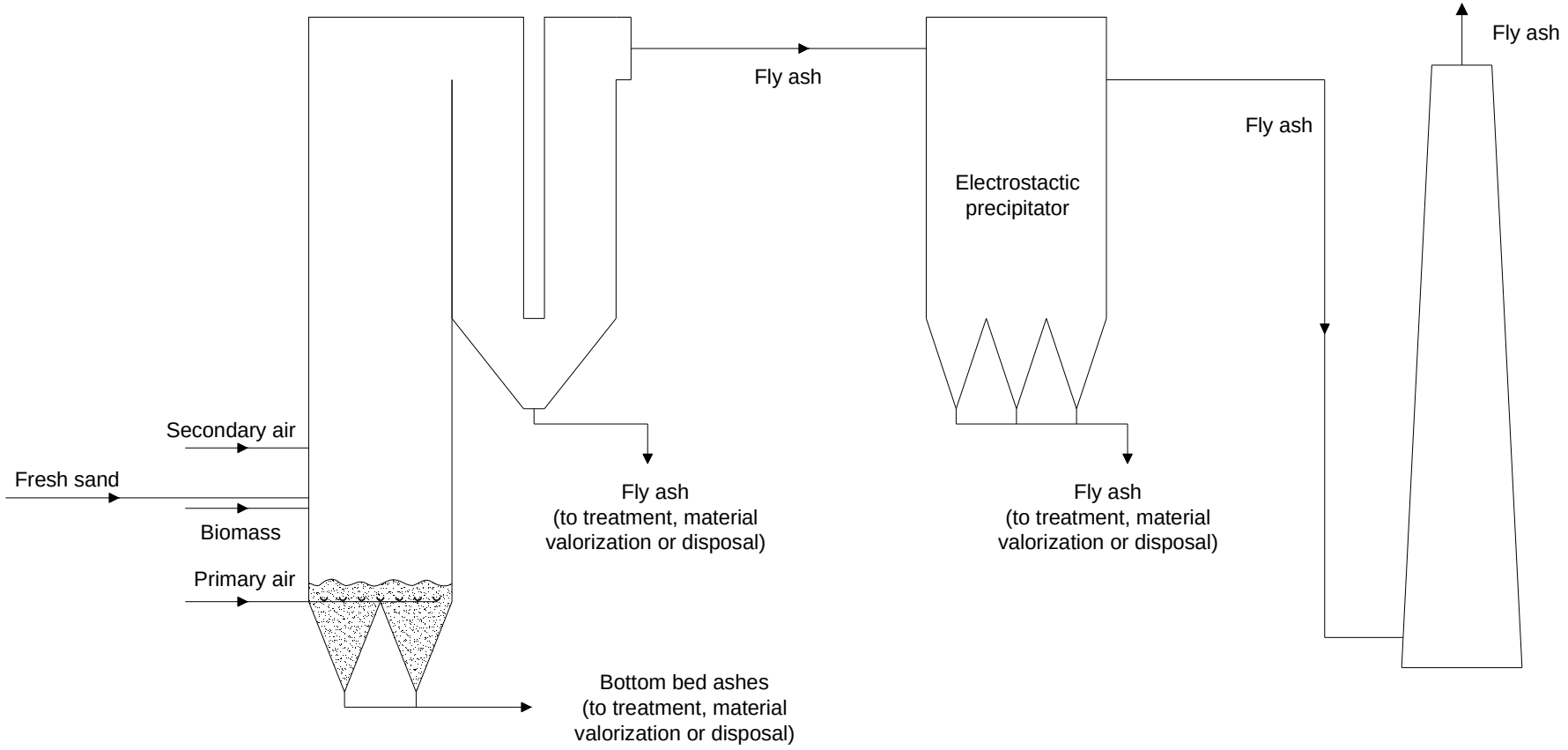
- A considerable amount of biomass ashes will be produced and needs to be managed considering environmental compatible solutions

- No national (Portuguese) guidelines for biomass ash management

Industry is trying to manage the ash in a sustainable manner

Need to define appropriate management options for biomass ashes considering the sustainability of biomass to energy policies

Typical ashes flows in the Portuguese thermal plants with BFBC



Experimental work : Industrial installations

The bottom bed ashes studied were sampled in:

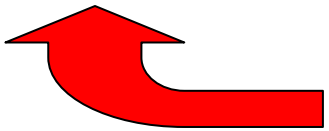
- Industrial thermal plants with BFBC
  - Thermal capacity in the range 50 MW_{th} to 100 MW_{th}
  - Forest biomass residues (FBR) as solid fuel
    - Eucalyptus bark
    - Residues from logging activities

- Typical operating conditions of the BFBC
  - Temperature in the bubbling bed: 800ºC to 900ºC
  - O_2 in the exit flue gas: 4%v to 7%v (dry gases)

- Ash samples collected at the discharge location of the bottom bed ash

Bottom bed ashes

- Mass fraction of bottom bed ashes on the total amount of ashes produced in thermal plants with BFBC:
  - Of the order 5%wt to 20%wt (literature information)
  - As high as 50%wt to 60%wt as often observed in Portugal in some thermal plants with BFBC



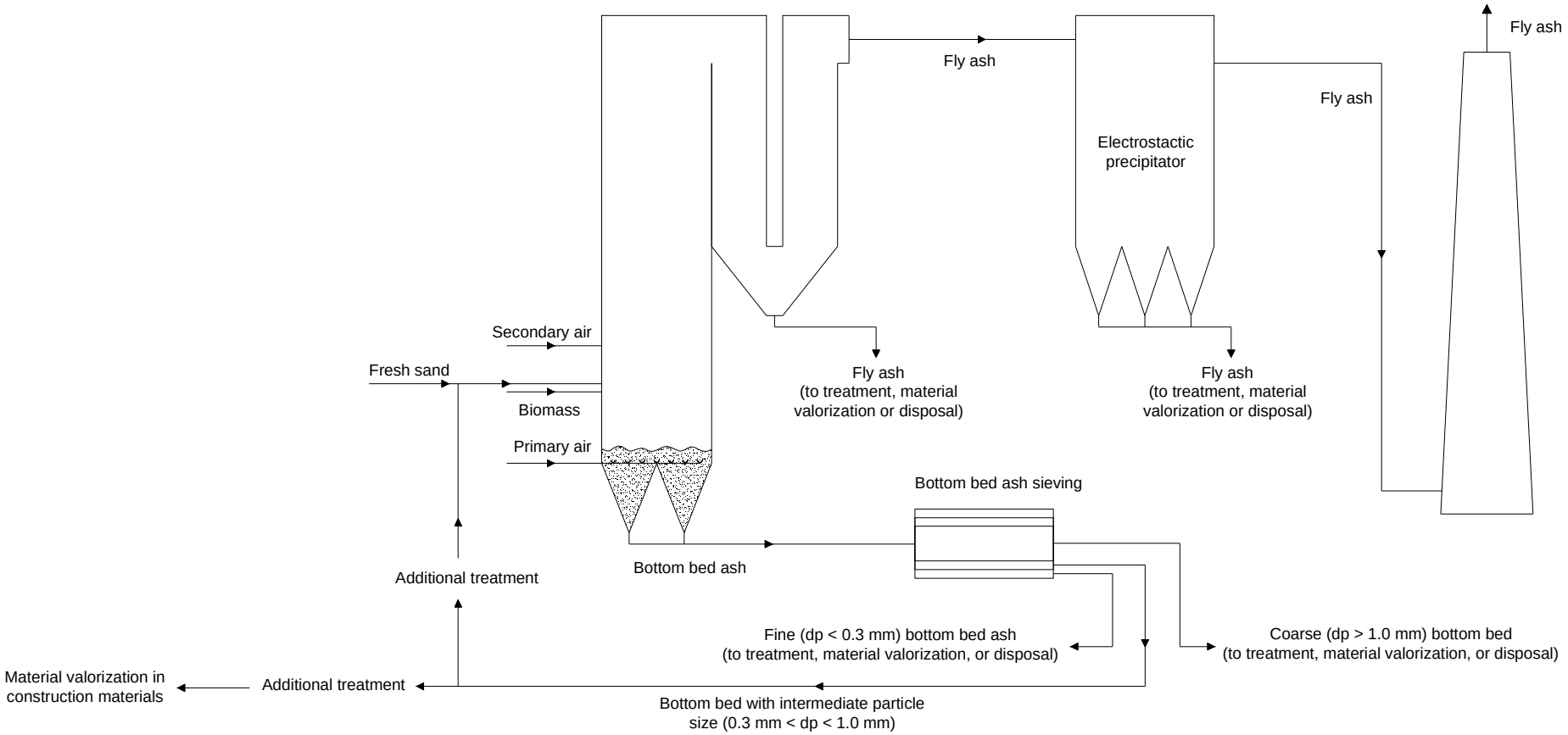
Quality of forest biomass residues used as fuel in the plants.

- High content of inert material (soil and small stones from the forest)
  - Biomass fuel available at competitive costs
    - Distinct subsidies to energy from biomass in distinct European countries

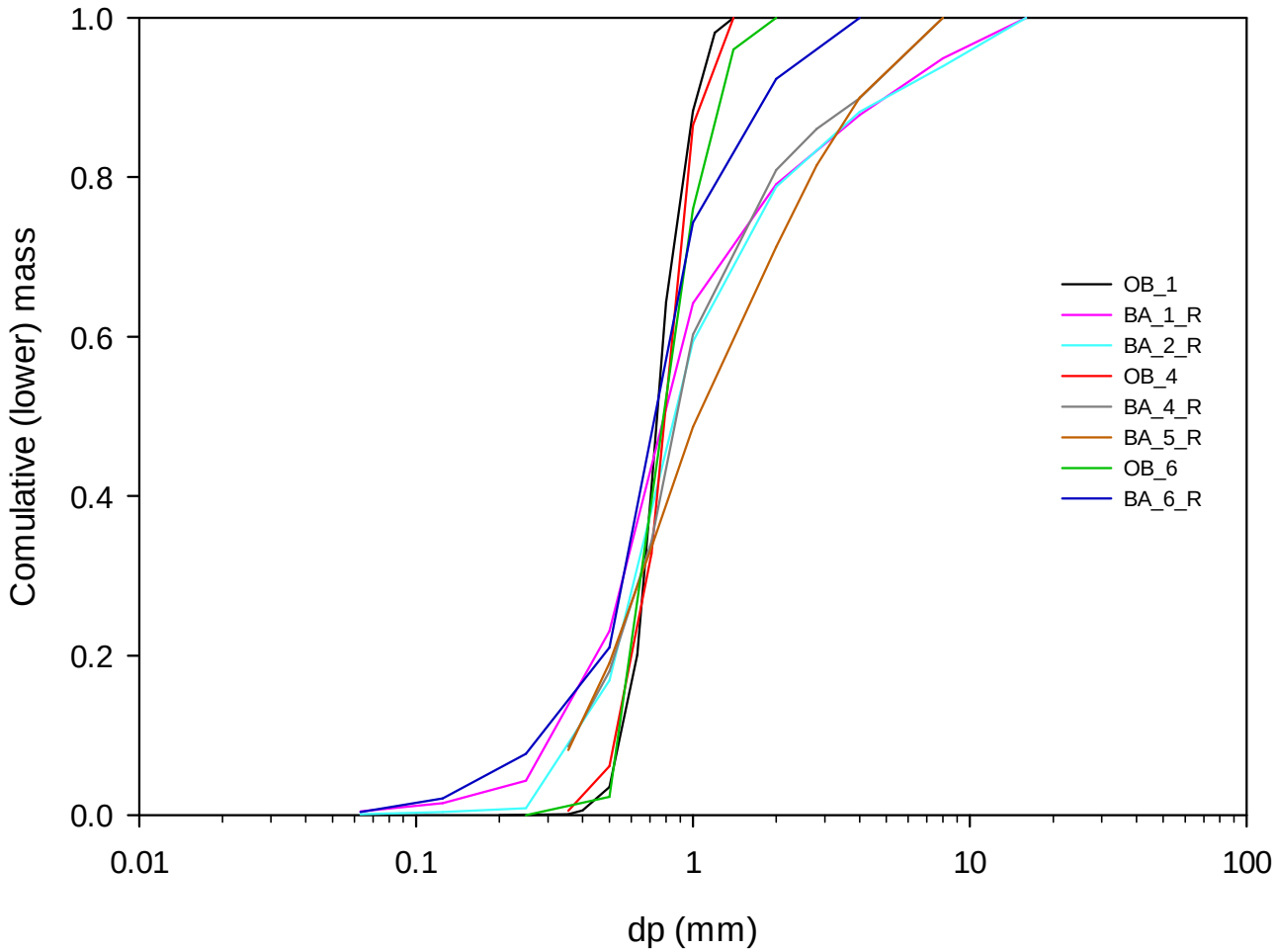
High inert (soil and small stones) content of forest biomass residues used as fuel

- High rate of bottom bed solids discharge to maintain bed solids level
  - High amount of bottom bed ashes to be managed
  - Relatively low residence time of bed solids in the BFBC
- Change of the particle size distribution of the bottom bed
  - Influences the hydrodynamic conditions of the bed, and consequently the reactor performance
- High rate of entrainment of bed particles that have negative impact on the energy recovery equipment (e.g. super-heaters)

Treatment of bottom bed ashes for material valorization



Particle size distribution of the original natural sand bed and discharged bottom bed ashes



Bottom bed ashes treatment by sieving and water leaching

- The treatment applied was made considering the valorization of the bottom bed ashes:
  - Construction materials
  - Substitute of a faction of natural sand in bed renovation

- Two treatments were applied:
  - Industrial

    Raw bottom bed ash
    Continuous sieving and leaching: L/S=2, 10 ton/h
  - Laboratorial

    Sieving to recover the particle size in range 0.3 mm to 1.0 mm
    Batch leaching: L/S=10, 24 h, European Norm EN 12457-2

Bottom bed ashes: Major chemical elements and LOI

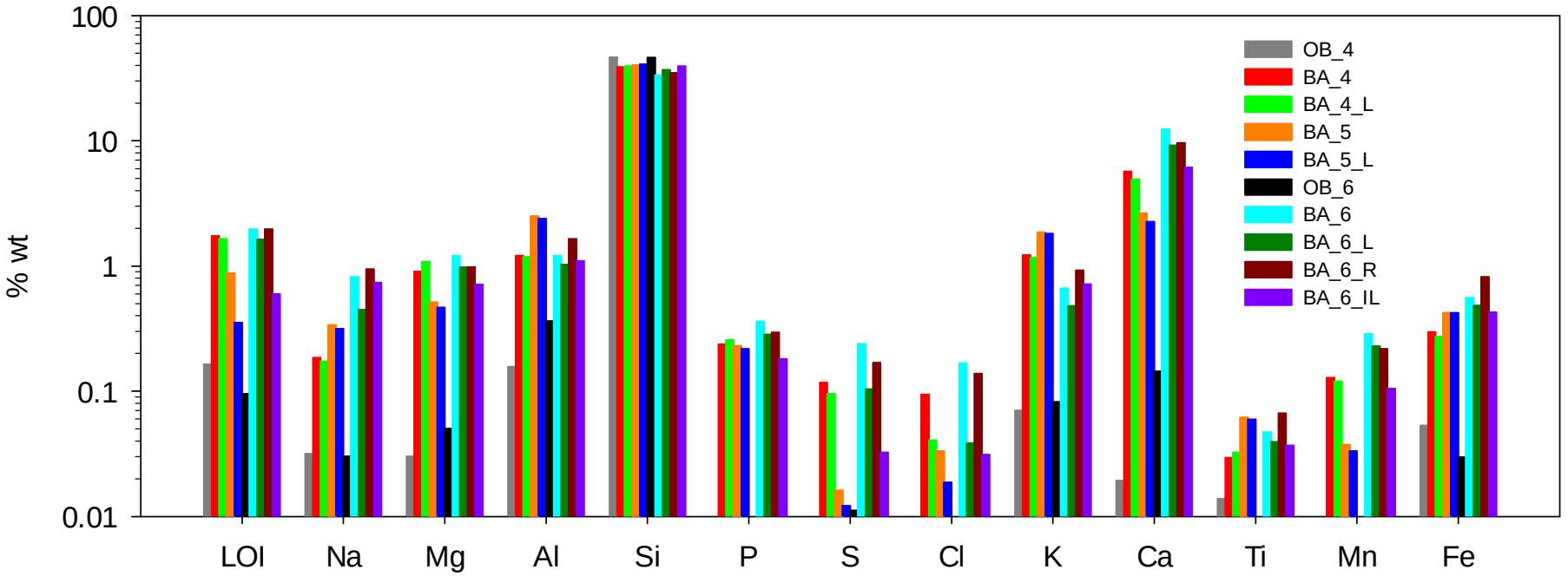
Chemical elements analysis by X-Ray Fluorescence (XRF)

Original natural sand bed (OB_4, OB_6)

Bottom bed ashes (BA_4, BA_5, BA_6, BA_6_R)

Leached bottom bed ashes (BA_4_L, BA_5_L, BA_6_L, BA_6_IL)

Logarithmic scale



- The Major chemical element (Oxygen not considered) is Si
  - The Si expressed as SiO_2 represents 72%wt to 85%wt of the bottom bed ashes.
    - Related with the original sand bed (>98.5%wt SiO_2)
  - By a decreasing order in concentration:

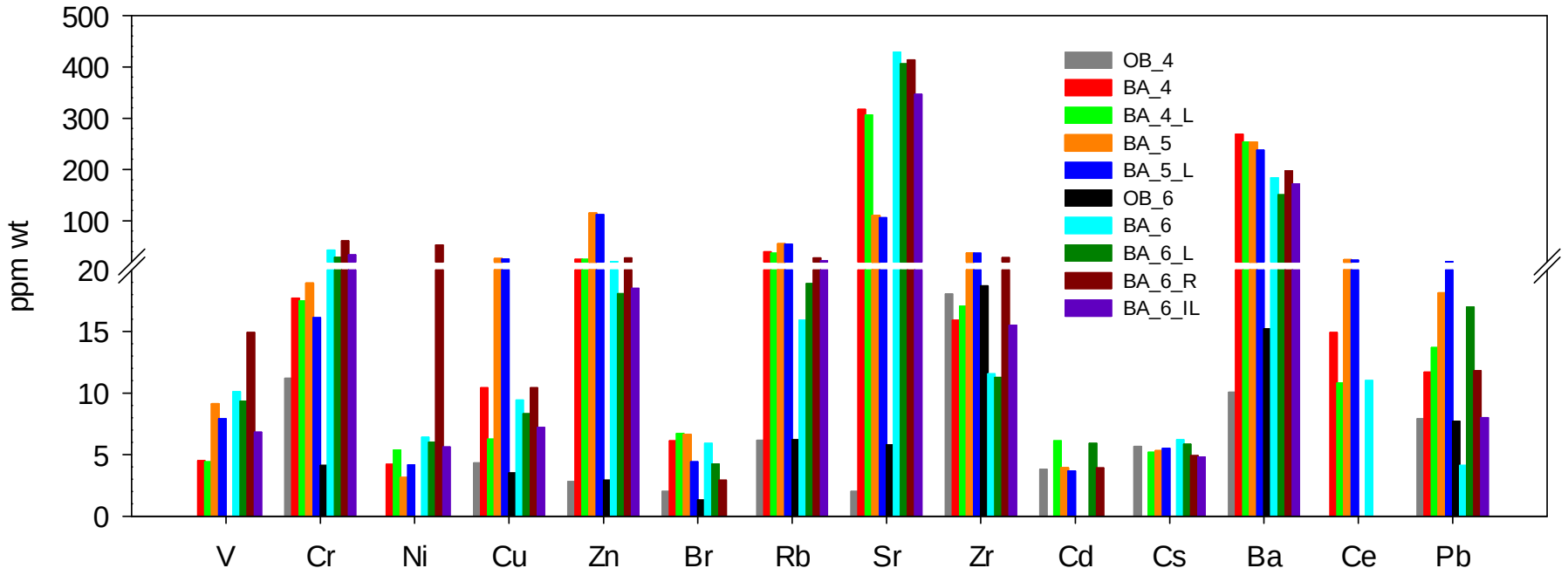
Si>Ca>Al≈K>Mg>Fe>P>Na>Mn≈S>Cl>Ti	BA_4
Si>Ca≈Al>K>Mg>Fe>Na>P>Ti>Mn>Cl>S	BA_5
Si>Ca>Al≈Mg>Na≈K>Fe>P>Mn>S>Cl>Ti	BA_6
Si>Ca>Al>Mg≈Na≈K>Fe>P>Mn>Ti>S≈Cl	BA_6-R

2.5 to 10%wt

< 2%wt

- Low value of LOI
  - Among others, reflects the low content of organic matter in the bottom bed ashes, as it is usual in BFBC in result of the relatively efficient combustion inside the bed

Bottom bed ashes: Minor chemical elements (> 5 ppm wt)

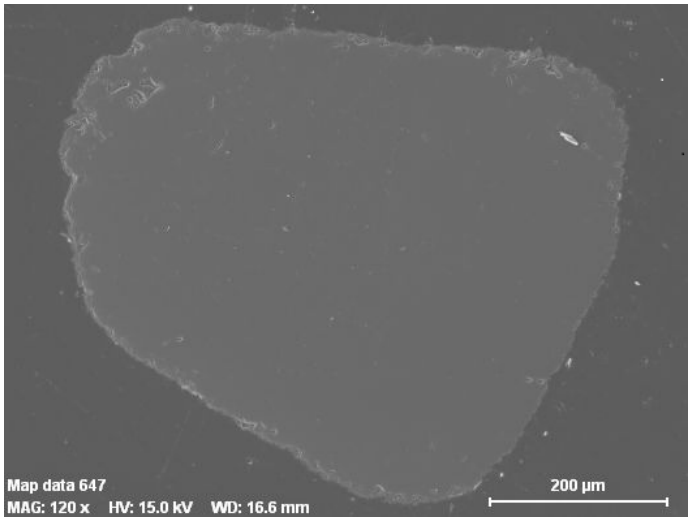


By a descending order in concentration:

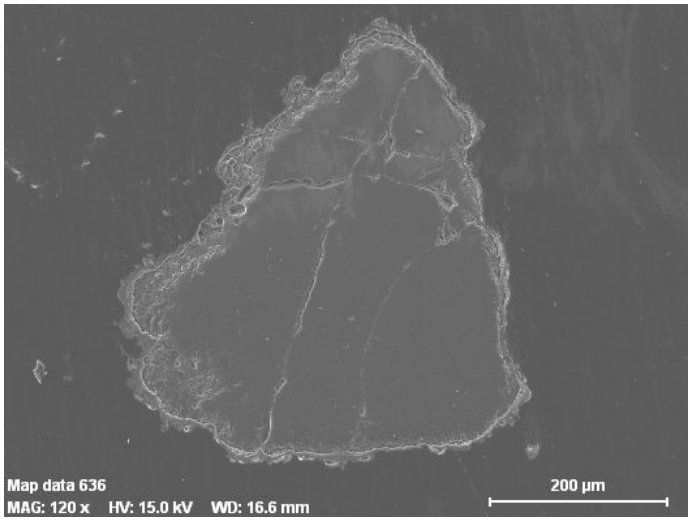
Sr>Ba>Rb>Zn>Cr>Zr>Ce>Pb>Cu>Br>V≈Ni	BA_4
Ba>Zn>Sr>Rb>Zr>Cu Ce>Cr≈Pb>V>Br>Cs>Cd>Ni	BA_5
Sr>Ba>Cr>Zn>Rb>V≈Ce>Zr≈Cu>Br≈Ni>Cs>Pb	BA_6
Sr>Ba>Cr>Ni>Zr>Rb≈Zn>V>Pb>Cu>Cs>Cd>Br	BA_6-R

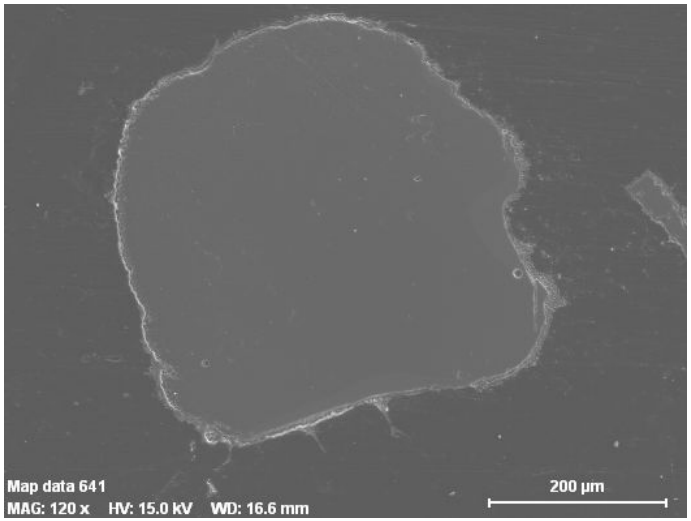
SEM analysis of the cross-section of a bottom bed particles

Natural sand bed (OB_6)



Raw bottom bed (BA_6_R)



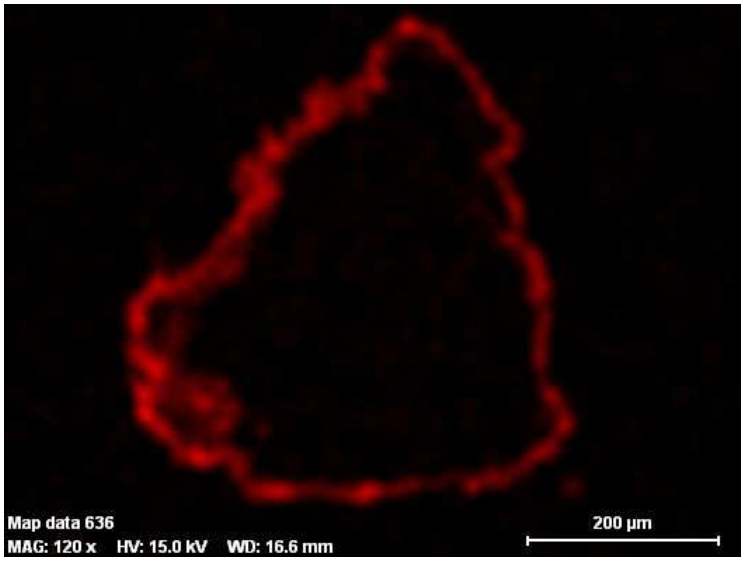


Leached bottom bed (BA_6_IL)

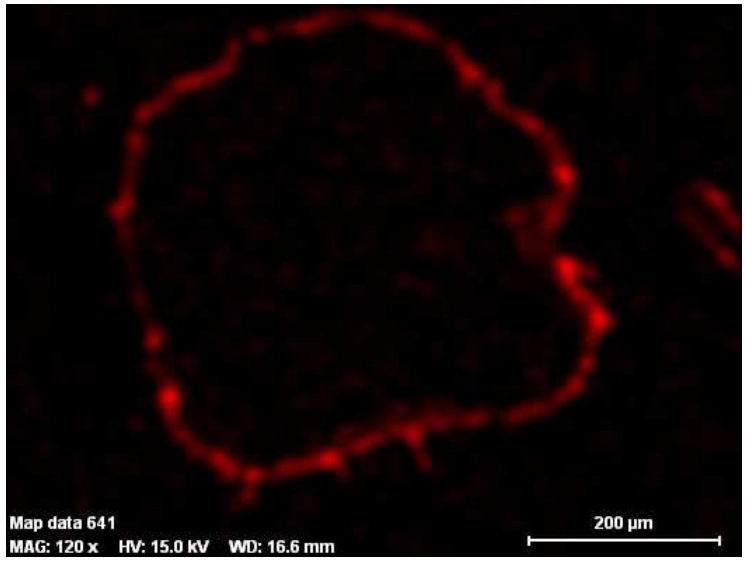
SEM-EDS analysis of the cross-section of a bottom bed particle

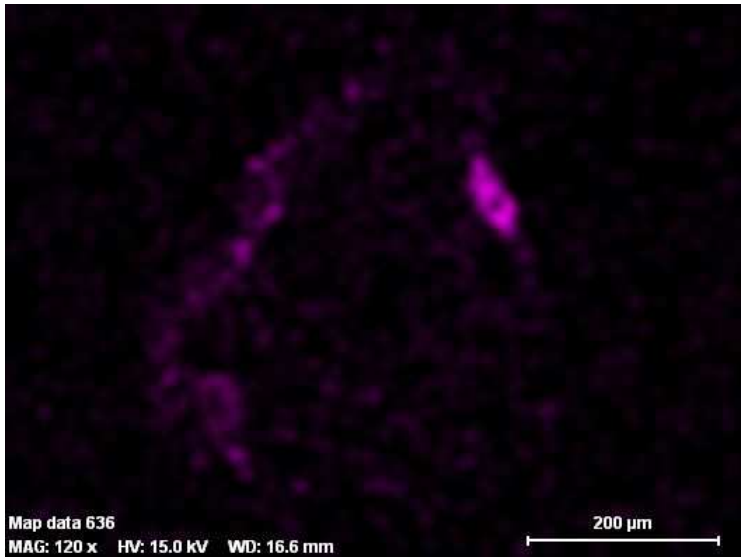
Raw bottom bed (BA_6_R)

Leached bottom bed (BA_6_IL)

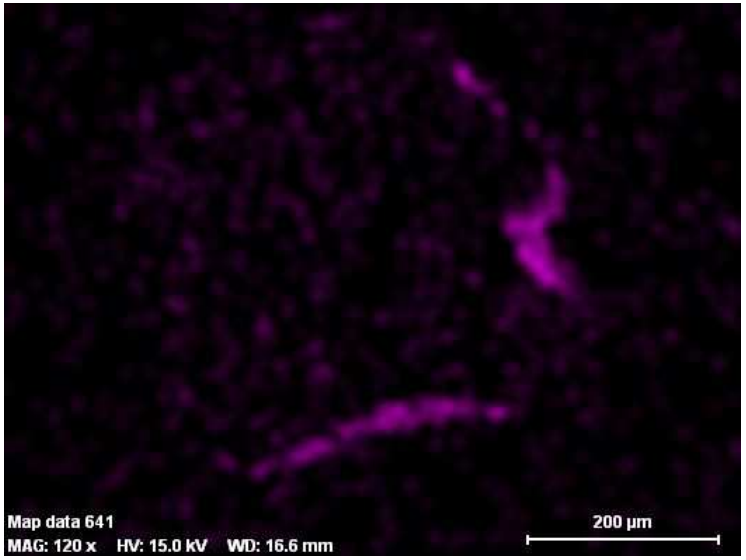


Ca



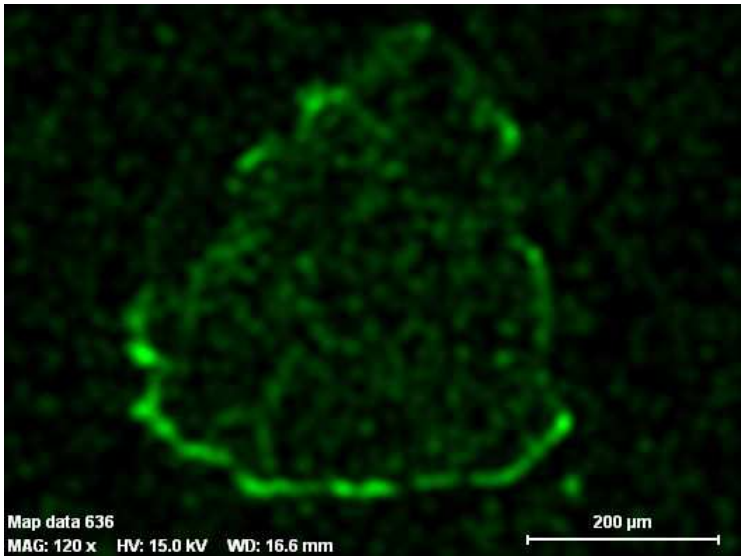


K

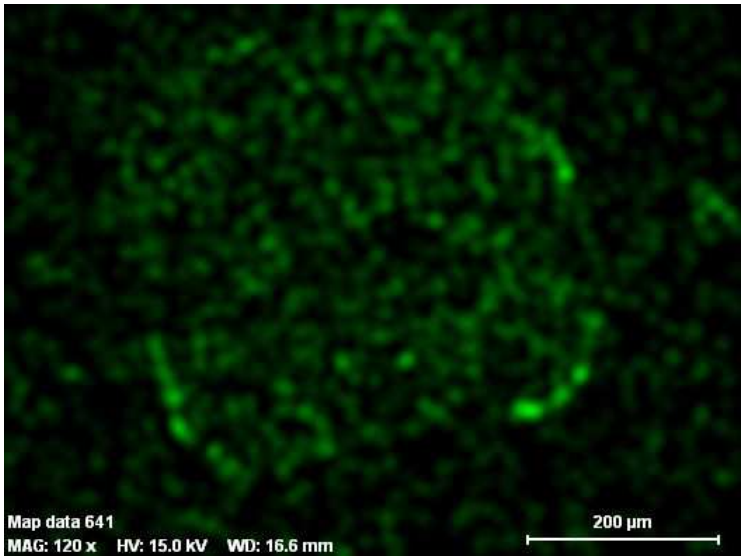


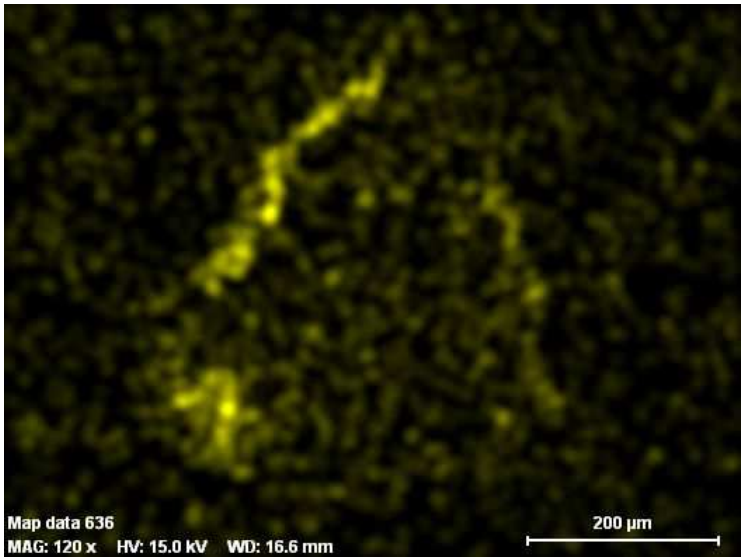
Raw bottom bed (BA_6_R)

Leached bottom bed (BA_6_IL)

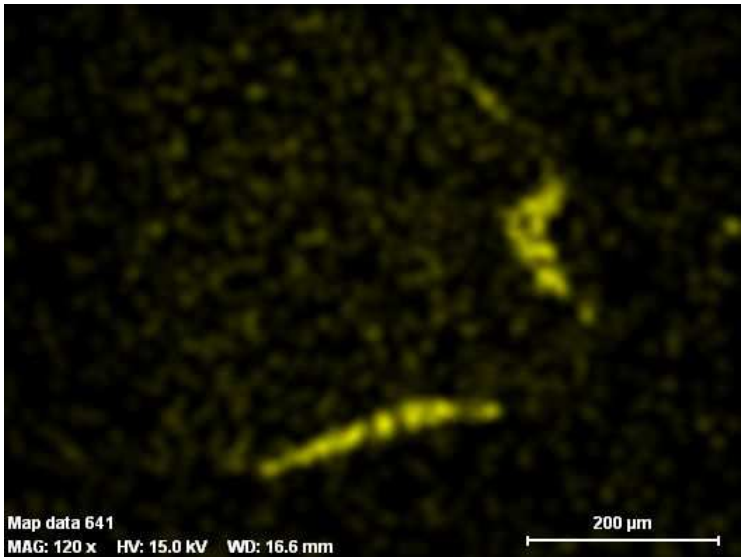


Mg

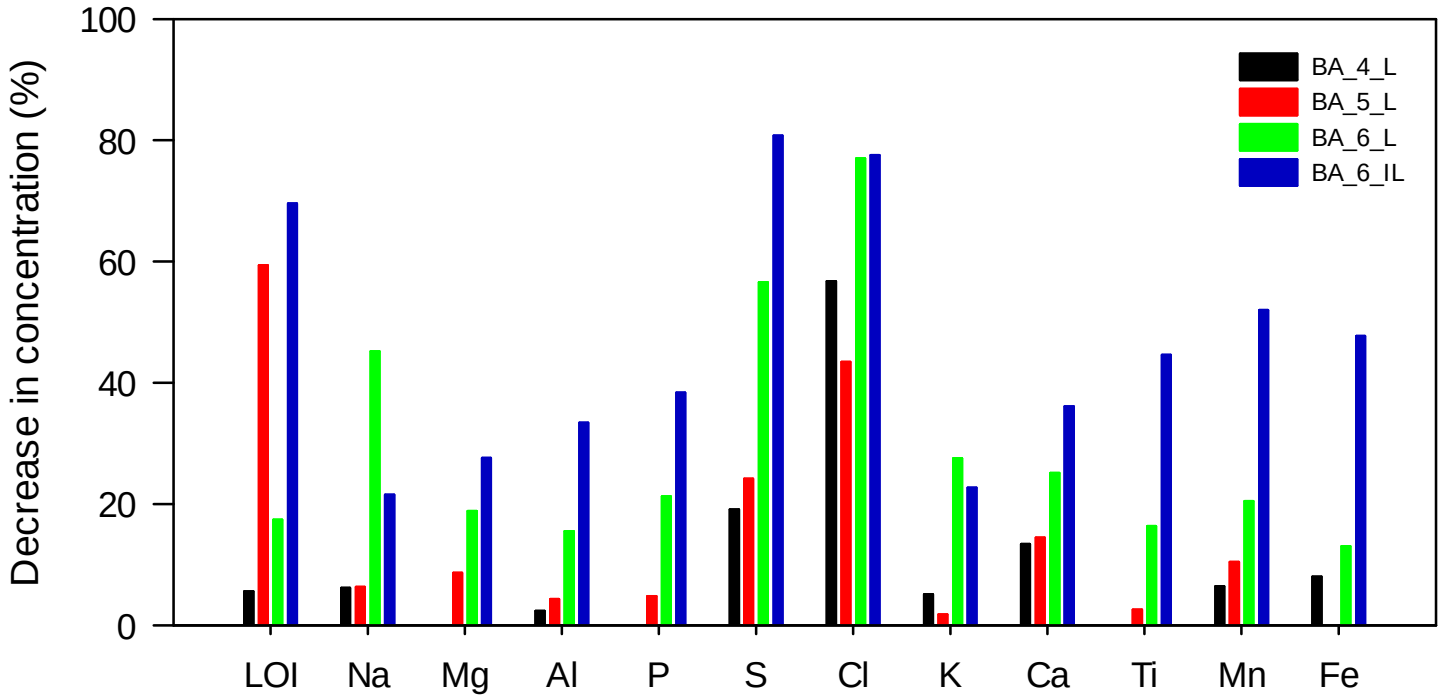




Na

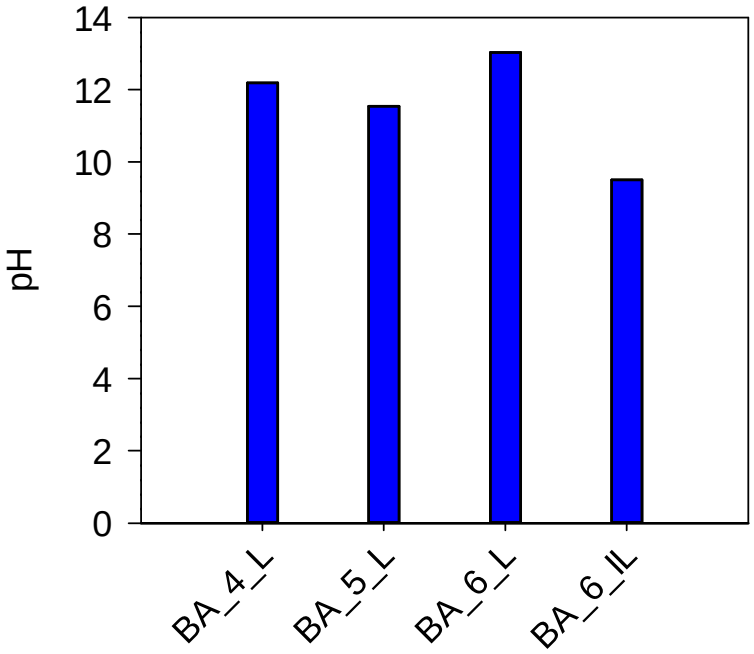


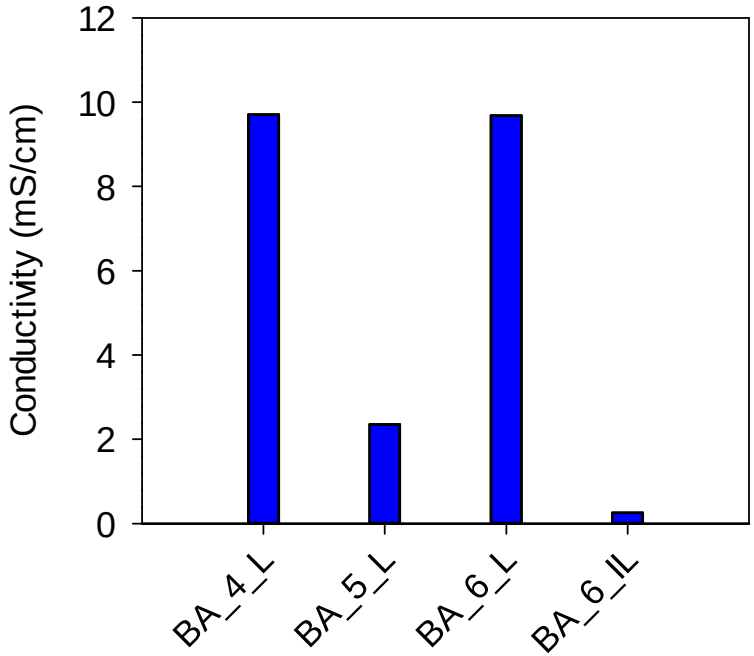
Percentage of decrease in concentration of some chemical elements in the bottom bed ashes after leaching



- The percentage of decrease in concentration after leaching differs among the ashes
  - Influenced by: the solubility of the chemical compounds and physical-chemical characteristics of the leaching solution
- S and Cl show the higher percentage of concentration decrease

pH and conductivity of the leaching solutions





- The high pH values are a result of the alkaline characteristics of the ashes, in result of the content on alkali chemical elements, as for example the Na, K, Ca, that become dissolved in the leaching solutions

- The conductivity reflects 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

Conclusions

- Bottom bed ashes from combustion of forest biomass residues in industrial BFBC were studied
- Compared to the original sand bed, the bottom bed ashes have a wider distribution of particle sizes
  - This has implications on the performance of the bubbling bed
  - The inert material fed mixed with the biomass has a major role in this process
  - The quality of biomass used as fuel has to be improved, namely by removing the inert material (forest soil and small stones)
- The major chemical element (Oxygen not considered) is Si, followed by Ca and Al, in a decreasing order of concentration
  - The Si expressed as SiO_2 represents 72%wt to 85%wt of the bottom bed ashes

- The treatment by sieving and water leaching improves the quality of the bottom bed ashes in order to allow its material valorization in some industrial applications

- After the leaching process the concentration of some chemical elements in the bottom bed ashes decreased in distinct percentages, influenced by:
  - The origin of the ashes
    - The chemical compounds on which the chemical element is bonded, and their solubility
  - The physical-chemical characteristics of the leaching solution, for example the pH, and process (continuous or batch)
  - The higher percentage of concentration decrease was observed for Cl (40%wt to 80%wt) and S (20%wt to 80%wt)
  - The percentage of concentration decrease for Na and K was lower than 7%wt, or in the range 20%wt to 50%wt

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