Coal is still one of the main sources of energy for producing electricity. The environmental impact of the solid products resulting from coal combustion (fly ashes) is mitigated by employing them as secondary raw materials. Their chemical and physical properties are strongly dependent upon the type of coal and the burning plant technology, making their characterization an essential prerequisite for recycling. In recent years, there has been also a concomitant increase in the amount of ashes produced from biomass combustion. Structurally and chemically different, they pose different problems in terms of ecological impact: one of the most relevant is the concentration of heavy metals. In this work, two samples from the combustion of coal and lignite, and two samples from the combustion of biomass, namely straw and hay, have been investigated by means of scanning electron microscopy (SEM) with energy dispersive spectrometry (EDS) and micro-Raman spectroscopy (with laser wavelength 532 nm). Raman spectroscopy, with the aid of the optical microscope, allowed for addressing the laser beam on specific crystals for phase identification at the micrometric scale [1]. X-ray diffraction (XRD) was employed for bulk qualitative analysis of the crystalline fraction. Due to the operating temperatures above 1400 °C, fly ashes from coal combustion showed the presence of partly glassy spherical bodies (around 10 μm in diameter) with alumino-silicate composition. Crystallization of mullite (ideal \( \text{Al}_2\text{Si}_2\text{O}_5 \)) from the mass was documented. Euhedral to pseudoeuhedral iron oxide crystals were found as a ‘coating’ on some of these particles, suggesting ‘condensation’ at the grain surface. Their presence in the mass is also an indication of their crystallization from the glass during cooling. These findings are in agreement with XRD results, showing mainly mullite, hematite (\( \text{Fe}_2\text{O}_3 \)) and quartz. Ashes from the combustion of biomass consist mainly of unburned fuel residues, that represent up to 25% in weight. Silica is about 40% in weight and is mainly concentrated in spherical glassy-like particles from nanometric to micrometric in size. Both types of ashes from biomass are high in potassium and phosphates. Typical phases detected by XRD are Arcanite (\( \text{K}_2\text{SO}_4 \)) and Monetite (\( \text{Ca(HPO}_4 \)). Implications for the use of these by-product as secondary raw materials will be discussed.


Acknowledgement: Research supported by the project CZ 1.05/1.1.00/02.0060 from the European Regional Development Fund and the Czech Ministry for Education, Youth and Sports.
Fig. 1: SEM micrograph from the sample of lignite fly ash depicting a spherule with iron oxide crystals emerging from the matrix.

Fig. 2: SEM micrograph from the sample of biomass fly ash depicting an unburnt hay fragment. In the surrounding material, glassy nanometric sized spherules can be recognised.

Fig. 3: Micro-Raman spectrum of a spherical body in fly ash from the combustion of lignite (shown in the inset picture). Hematite (Fe₂O₃) Raman bands are indicated.