Crucial parameters determining efficient use of fly ashes from energy sector as raw materials for dedicated advanced applications

P. Rybowicz[1], A. Kowalczyk[1], A. Łagosz[2], M. Michalik[3], A. Adamski[1]

[1]Faculty of Chemistry, Jagiellonian University, Kraków, 30-387, Poland
[2]Faculty of Materials Science and Ceramics, AGH-UST, Kraków, 30-059, Poland
[3]Faculty of Geography and Geology, Jagiellonian University, Kraków,30-387, Poland
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Presenting author email: pawel.rybowicz@doctoral.uj.edu.pl

Fly ashes from energy sector belong to industrial solid waste stored in mass scale as a consequence of technological solid fuel combustion. Fly ashes as non-flammable fuel residuals of diameters below 500 μm leave the combustion chamber together with exhaust gases. Then they are accumulated with using dust collectors, usually electrostatic precipitators. Currently, around eight hundred million tons of fly ashes are generated annually in the world. The main part of this mass is produced in Asian developing countries such as China and India. Other ash producers are mainly localized in the United States and Europe. The rate of fly ash re-use also varies from region to region. In China and India, only 70% of ashes are re-used, while about 30% of fly ashes is stored in landfills. The total amount of ashes stored in China reaches 3 billion tons (Surabhi, 2017). In the rest of the world (USA, Europe), the level of ash use is higher, around 90-95% (American Coal Ash Association, 2017; European Coal Combustion Products Association, 2016).

In accordance with main principles of circular economy, where waste from one process serves as a raw material in another process, methods of effective fly ash management are constantly sought and developed. The construction industry is currently the main recipient of fly ashes. The ash is mainly used as an additive to concretes and cements. It allows, among others, to reduce carbon dioxide emissions. In addition to environmental issues, fly ash improves cement properties such as compressive strength, workability and water demand. However, due to a remarkable variety of attractive features, fly ashes can be applied as raw materials also in a wide spectrum of more advanced applications (Fig 1).

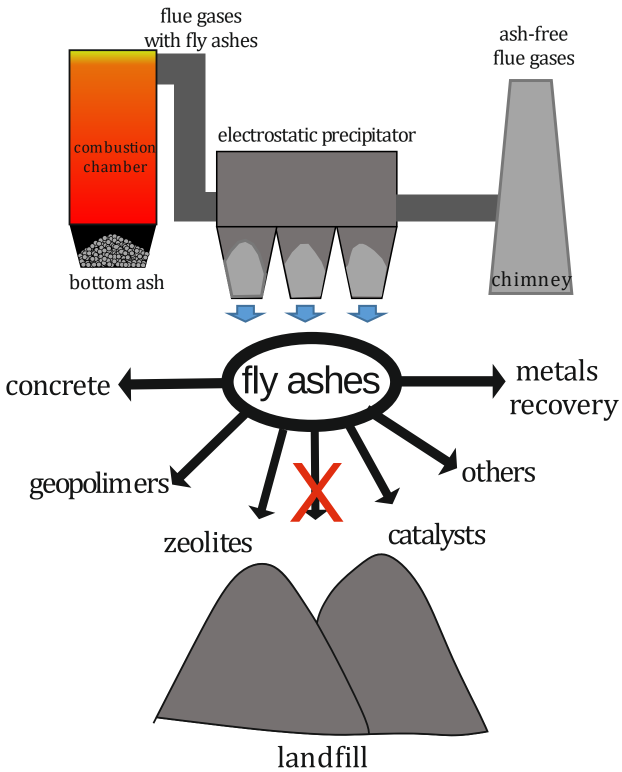

Fig 1. Examples of the use of fly ashes as raw materials.

From both chemical and functional viewpoints, fly ashes are quite complex materials. Their grains are mainly built of silica, alumina and iron oxide of various speciations. Additional components, usually accompanying the latter oxides, are mainly alkali and alkaline earth metals such as sodium, calcium or magnesium.

Very often traces of other metals, like: titanium, vanadium, gallium, selenium, nickel, manganese, copper and zinc etc. could also be found in ashes. The ashes contain certain amounts of unburned fuels too, their content depends on the combustion efficiency. Fly ash particles are mainly in the form of spherical cenospheres, made of silica-alumina glassy phase which additionally contains the previously mentioned additives of metals, i.e. sodium, calcium and magnesium. Among crystalline components such as quartz and aluminosilicates (like mullite) also iron occurs as hematite (Ahmaruzzaman, 2010). All features discussed above clearly confirm that fly ashes can be considered as valuable raw materials. The high content of silicon and aluminum enables, e,g. the synthesis of zeolites and geopolymers. Many authors reported also on the recovery of metals and of the use of fly ashes as catalytic supports.

The current paper presents characterization of fly ashes from the perspective of their pro-ecological use as raw materials. The attention was focused mainly on the role of critical parameters such as a Si/Al ratio, phase composition, content of potentially useful metals and grain morphology as well as a specific surface area of ashes, affecting the usefulness of ashes in catalysis. Chemical composition of investigated ashes from energy sector was determined by X-ray fluorescence, phase composition - by X- ray diffractometry and by Raman spectroscopy measurements. Structural and textural properties, like morphology, grain size distribution and grain chemical composition were determined by SEM-EDS, whereas the specific surface area and pore size distribution were determined by a low temperature nitrogen adsorption. DRIFT spectroscopy was used to describe functional properties of fly ash. The main purpose of our in-depth studies was to identify key parameters of fly ashes to choose an optimal way of their effective chemical valorization. Basing on the obtained results, practical guidelines for an efficient use of fly ashes from energy sector as raw materials have been proposed.

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