Mining Science, vol. 00, 2015, 23−30

www.miningscience.pwr.edu.pl

Mining Science
(previously Scientific Papers of the Institute of Mining of the Wroclaw University of Technology. Mining and Geology)

ISSN 2300-9586
previously 0370-0798

Received: March 07, 2015, accepted: May 05, 2015

PROPERTIES OF FLY ASH FROM AGRO-FORESTRY BIOMASS COMBUSTION IN THE ASPECT OF THEIR USE IN MINING TECHNOLOGY

Aleksandra PAWLUK, Piotr KASPRZYK*, Dušan TERPÁK

AGH University of Science and Technology, Mickiewicza 30, 30-059 Krakow, Poland

Abstract: Production of electricity / heat through the use of biomass is one of the possible ways to increase energy production from renewable energy sources and promote sustainable development by reducing direct greenhouse gas emissions chich is associated with the energy sector (Moraisi et al., 2011). In the coming years, biomass will have important role as a natural source of renewable energy, due to the rising cost of fossil fuels, highly questionable safety of nuclear energy and the need of carbon dioxide emissions reduction. (Callejón-Ferre et al., 2014). According to 2009/28/EC Directive about the promotion of use of energy from renewable sources, Biomass is defined as the biodegradable fraction of products, waste and residues from the agricultural industry (including also substances coming from plant and animals), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste. Increasingly frequent use of alternative fuels, including biomass, in different areas of the industry cause a large production of new waste materials. Economic and environmental considerations are the cause of increased interest in the use of the economic potential of ash generated in these processes. In the article possibility of using new waste materials, which are fly ash from the combustion of mixed agricultural and forest biomass as hydraulic backfill material, solidifying and gobs caulking was analyzed.

Keywords: fly ash, biomass, backfill, mining technologies

1. INTRODUCTION

Demand of energy, which grows with development of civilization and implement of the European Union requirements, increase interest in the use of energy from renewable sources. Energy from Renewable Energy Sources (RES) is designed to re-

* Corresponding author: Piotr Kasprzyk, piotr5.kasprzyk@gmail.com

doi: 10.5277/ms150221

duce the depletion of traditional resources in the main fossil fuels (coal, oil, natural gas) and the accompanying increase in their consumption of environmental pollution. As a renewable energy sources is meant solar, hydropower, wind energy, geothermal energy, municipal waste, heat of surrounding environment (using heat pumps), biofuels and biomass (Zimny, 2010). According to the definition in the Directive "on the promotion of the use of energy from renewable sources" (Directive 2009/28/WE), biomass means the biodegradable fraction of products, waste and residues from the agricultural industry (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste (Dz. U. L 140/16 2009). During the combustion process of biomass combustion by-product – ash is formed. Properties of this ash must be well understood, to make it possible using it in a variety of industries. Therefore, analysis and development of management technology of these ashes become essential problem. Evaluation of the usefulness of waste from the of biomass combustion, which is formed in power plant, to convert their mining technologies is carried out in accordance with the guidelines set out in two basic standards (PN-93 / G-11010, PN-G-11011: 1998):

- PN-G-11010: 1993 - applies to materials for hydraulic backfill,
- PN-G-11011: 1998 - applies to materials curable for proppants and sealing of abandoned workings

The possible applications of the method and technology of use of mining waste determine the technical service, which uses the waste according to local conditions in a particular mine. Not every material that is used in mine is the backfilling material. Many of them are used as "filler" of gobs and excavation voids. Depending on this, the corresponding standard is used. Way of using the in mining technology all kinds of waste, including waste energy, requires making experiments and determining their physico-chemical properties (Kępys et al., 2014; Mazurkiewicz et al., 1997).

The standard for hydraulic proppant PN-93 / G-11010, is sufficiently general and refers to the material used itself, and the PN-G-11011 standard is very detailed and apart from the evaluating material and conditions in a particular mine, it describes, among other things, the mixing water used there or characteristics of the underground water (Terakowski and Kwosek, 2011).

2. HARMFULNESS OF POWER PLANT WASTE

According to the Central Statistical Office (Główny Urząd Statystyczny - GUS), the share of renewable energy in the overall total primary energy acquisition in 2011 was 11.2%. Biggest amount of the energy is derived from solid biomass - 85.6%. Combustion of both coal and solid biomass in the power industry produces a large amount of cumbersome industrial waste. In the recent past, the only way to solve the problem of combustion by-products was their storage, thereby taking an annual 1.2 - 1.4 km^2 of surface (Ratajczak et al., 1999).

Stored power plant waste affect both atmospheric air and aquatic environment. Secondary dusting, which occurs at a wind speed of more than 3 m/s can cause elevation of more than 30 kg of material per year from an area of 1 m^2 (Mazurkiewicz et al., 1997). Rainwater filtering through the landfill elute the pollutant loads and moving them into the groundwater. In addition, the deposited waste results in deterioration of aesthetics of terrain around them.

In addition to the inconvenience of power plant waste in ecological aspect, there is also an aspect of their hazard to humans commonly determined as an aspect of health and safety. The most important parameter in this regard is an alkaline pH of the aqueous extract. Instructions and descriptions of technological processes of use this type of waste should include information that waste is (or may be) alkaline. Instructions also should have an appropriate guidelines. These guidelines should specify the use of appropriate personal protective equipment (goggles, shields, gloves, etc.) as well as appropriate procedure in the case of direct contact with the material. These wastes are not so strong corrosive alkalis such as: caustic soda, calx or cement, but still the basic health and safety conditions in contact with the ashes must be respected. Although fly ash from the biomass combustion are not as potent skin irritant, workstations where people work with these materials, the safety conditions should be maintained to prevent their direct contact with the skin (Terakowski and Kwosek, 2011). Moves of settling of the area are caused by the underground mining activity. The output has a significant environmental impact. Systemic filling in mining holes and excavations are needed, an influence on increasing is applicable backfill in the underground mining. For putting excavations materials of different kind are being used in order to increase the technical safety i.e. the prevention for fires and explosions and to the purpose of the improvement in the ventilation. Materials for backfill come from the mining industry and the mining. The technology of giving a leg up enables
a wide range of technical solutions for different mining areas. Efficient functioning of systems backfill, is increasing the amount of mining operations. Badly the designed system influences the safety in the mine. Nowadays ashes with binder are being used by the hole for the emptiness in order to support the roof (Masniyom, 2011).

3. THE SUBJECT AND THE RESEARCH METHODOLOGY

The subject of research was fly ash derived from the combustion of agro-forestry biomass in the fluidized bed boiler. The following tests were performed to find its physicochemical properties:

- size distribution by laser diffraction using a Analysette 22 Fritsch,

- density of material by pycnometry using a helium pycnometer,
- chemical composition by emissional spectroscopy with inductively coupled plasma (ICP-AES) and mass spectrometry was determined with inductively coupled plasma (ICPMS)
- leachability of chemical pollutants were carried out in accordance with Polish norm PN-EN 12457-2 (EN 12457-2). Distilled water was mixed with waste in 1/10 ratio. The material was shaken in a plastic container for 24 hours, and then filtered. The pH of the aqueous extract was determined by potentiometry. Chloride content was determined using the titration method.

4. RESULTS OF EXPERIMENTS

Fly ash from the combustion of agro-forestry biomass used in research has silt texture and light gray color (Fig. 1). Particle size was measured using laser analyzer Analysette 22 Fritsch, the results of the analysis are shown in Figs. 2 and 3.

The largest dimension of particle of tested ash is 200 micrometers. In the analyzed ash, particles with diameter of 5.0 - 80.0 micrometers are dominating. Their content is close to 75% of the total weight of the material, while the grain content of less than 0.1 mm was 87%.

Density of ash as determined by helium pycnometry was 2.65 g/cm^3. The results of the study of the chemical composition is shown in Table 1. The main components of tested ash SiO_2, P_2O_5, K_2O and CaO.

Fig. 1. The ash used to research

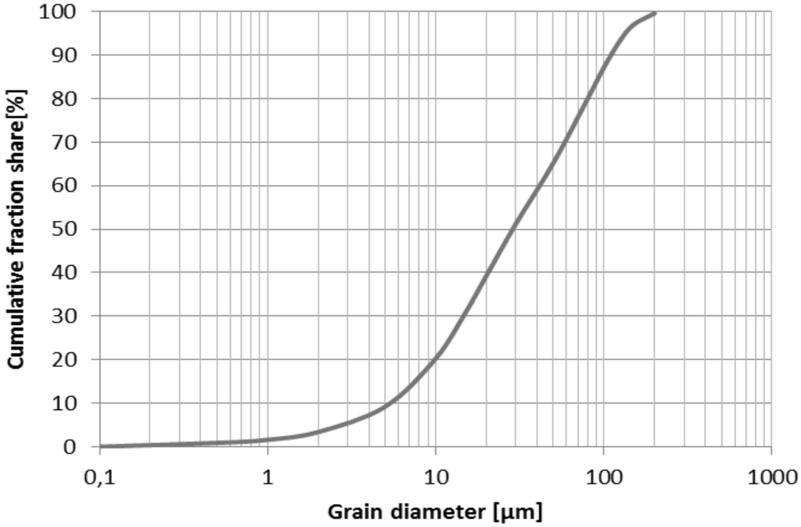

Fig. 2. Grain composition curve for tested Ash

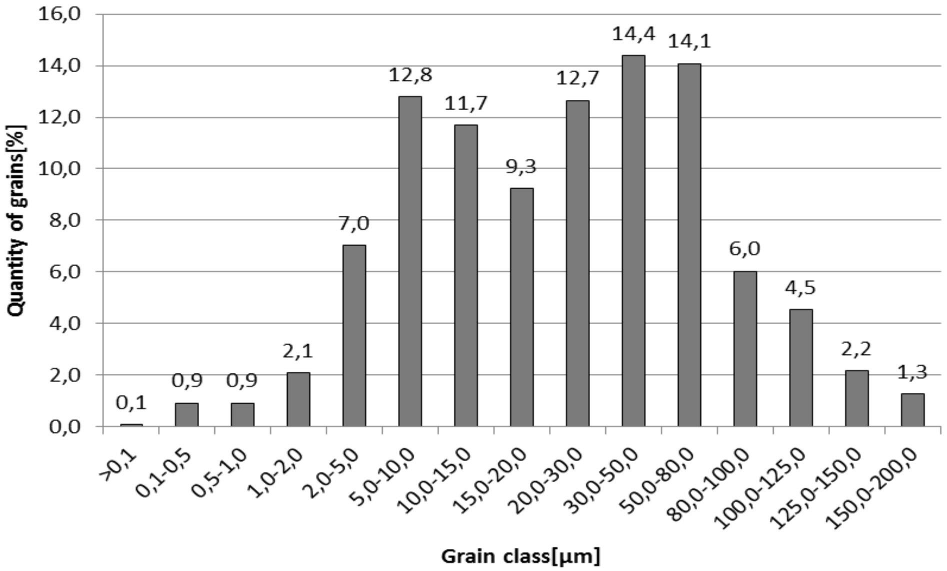

Fig. 3. The percentage of a particular particle size in the sample

A high content of calcium oxide and alkali (especially potassium, phosphorus and also magnesium) in ash, during combustion of the fuel can cause increased corrosion and buildup of deposits in the combustion chamber during combusting of biomass separately. Most of these problems could be eliminated by using technology of co-combusting biomass with coal (Kubica 2003; Ściążko et al., 2007).

Tab. 2 presents the results of research on leaching of chemicals and pH determined in the aqueous solution prepared from the test ash, compared with limit values which are specified in Polish norm PN-G-11011 and PN-G-11010. In the sample of fly ash from the combustion of agro-forestry biomass, exceedance of heavy metals in the water effluent was not observed. In relation to the requirements specified by the above standards, tested waste form biomass combustion complies with these standards except for pH - which is too alkaline. The content of chlorides and sulphates are also too high. pH is not a parameter that would disqualify investigated waste for use as backfill, because the alkaline pH could be easily neutralized. A small amount of substances present in waste may be readily neutralized even in natural conditions by carbon dioxide from the air (Piotrowski, 2011; Kępys et al., 2014). The allowed amount of sulfates associated with flue gas cleaning process, and therefore the presence of desulphurization products in the tested ashes were exceeded. On the other hand sulphate content may be advantageous from the viewpoint of the bonding of barium ions, which are present in mine waters (Pluta et al., 2004).

Determined chloride content in the water extract was also above standard values. It should be emphasized that these numbers, taken based on the standards requirements need to take into account the water conditions prevailing in the relevant area of the mine, where the fly ash is used for the preparation of suspensions (Piotrowski, 2011).

In the sample of fly ash from the agro-forestry biomass combustion, exceedance of heavy metals in the water effluent is not observed.

Table 1. Chemical composition of fly ash (weight percents)

Component	Ash
SiO_2	54.00
Al_2O_3	1.71
Fe_2O_3	1.94
P_2O_5	6.19
CaO	12.83
MgO	4.74
BaO	0.03
K_2O	9.38
Na_2O	0.34
SO_3	4.29

Table 2. Leachability of chemical pollutants and pH of examined ashes

Parameter, component	Unit	Tested fly ash	Standards	
			PN-93/G-11010	PN-G-11011:1998
			Hydraulic backfill	Solidifying backfill and gobs caulking
pH	pH	12.75	6.0-9.0	6.0-12.0
chlorides	mg/dm^3	1538.0	1000	1000
sulphates	mg/ dm^3	4687.00	500	500
sodium	mg/ dm^3	109.30	800	Not determined
potassium	mg/ dm^3	5627.00	80	Not determined
zinc	mg/ dm^3	0.0170	2.0	Not determined
cadmium	mg/ dm^3	0.00020	0.1	0.1
lead	mg/ dm^3	0.0009	0.5	0.5
copper	mg/ dm^3	0.0030	0.5	0.5
chromium(III)	mg/ dm^3	0.21600	0.5	0.5
arsenic	mg/ dm^3	0.0440	Not determined	0.2
mercury	mg/ dm^3	<0.0002	Not determined	0.2

5. SUMMARY

Polish energy industry which is based largely on the use of solid fuels for the production of heat and power is a producer of waste, and fly ash is main component of that waste. Significant amounts of this waste is fly ash from the combustion of coal and lignite. Because in Poland, boilers, where biomass is burned as fuel alone are already working, "new" waste - fly ash from the combustion of biomass is created. Tested waste - fly ash from the combustion of mixed agricultural and forest biomass, have exceeded the value of pH and chloride and sulphate leaching in relation to the PN-93 / G-11010 and PN-G-11011: 1998.

Initially, these materials could be used for in the mine works. However, these materials need to be approved by local hydrogeologists from the region where this waste is intended to be used.

REFERENCES

CALLEJÓN-FERRE AJ, CARREÑO-SÁNCHEZ J, SUÁREZ-MEDINA FJ, PÉREZ-ALONSO J, VELÁZQUEZ-MARTÍ B., 2014. *Prediction models for higher heating value based on the structural analysis of the biomass of plant remains from the greenhouses of Almería (Spain)*, Fuel 2014, 116, pp. 377–87.

Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. Official Journal of the European Union, vol. 140; 2009, pp. 16–2.

KĘPYS W., PIOTROWSKI Z., POMYKAŁA R., GRZYWA A., 2014. *The use of fly ash from biomass in suspension Technologies*, Inżynieria Mineralna, 2(34)/2014, Wyd. Polskiego Towarzystwa Przeróbki Kopalin, Kraków (in Polish).

KUBICA K., 2003. *Biomass combustion and co-combustion with coal part I,* Ecological Bulletin.

PLUTA I., BADURSKI R., GUSTAW SZRETER G., PIOTROWSKI Z., KRAWCZYK P., 2004. *Removing the bar from the „Borynia" mine waters in terms of benefits to the aquatic environment and the protection of collector Olza",* (Materiały konferencyjne: Ochrona środowiska na terenach górniczych, Szczyrk in Polish).

MAZURKIEWICZ M., PIOTROWSKI Z., TAJDUŚ A., 1997. *Placement of waste in underground mines. Part 1: Ecology and Technology*, Wydawnictwo Biblioteki Szkoły Eksploatacji Podziemnej, Kraków (in Polish).

MANOON M., 2009. *Systematic Selection and Application of Backfill in Underground Mines*, Dissertation, Freiberg.

MORAIS J, BARBOSA R, LAPA N, MENDES B, GULYURTLU I., 2011. *Environmental and socioeconomic assessment of co-combustion of coal, biomass and non-hazardous wastes in a power plant*, Resour Conserv Recycl 2011, 55, pp. 1109–18.

Polish Norm PN-93/G-11010 *Mining. Hydraulic backfill materials. Requirements and research*

Polish Norm PN-G-11011:1998 *Mining. Materials for filling and sealing of abandoned workings*

Polish Norm PN-EN 12457-2: *Characterization of waste. Leaching. Examination of compliance in relation to the leaching of granular waste materials and sludges*.

PIOTROWSKI Z., 2011. *Recovery of fine-grained waste in underground mining of coal*, Archiwum Górnictwa, nr 12, Wydawnictwo Instytutu Mechaniki Górotworu PAN, Kraków (in Polish).

RATAJCZAK T., GAWEŁ A., GÓRNIAK K., MUSZYŃSKI M., SZYDŁAK T. WYSZOMIRSKI P., 1999. *Characteristics of fly ash from the combustion of some coals*, Masy popiołowo-mineralne i ich wykorzystanie w górnictwie węglowym, Kraków (in Polish).

ŚCIĄŻKO M., ZUWAŁA J., PRONOBIS M., 2007. *Co-firing of biomass and alternative fuels in power generation*, Wyd. Instytutu Chemicznej Przeróbki Przeróbki Węgla i Politechniki Śląskiej, Zabrze-Gliwice (in Polish).

TERAKOWSKI M. AND KWOSEK M., 2011. *Multi-aspect study of fly ash from Siersza Power Plant in Trzebinia*, Instytut Ekologii Terenów Uprzemysłowionych Katowice (in Polish).