Research article

Fly ash vitrification as the effective physico-chemical waste stabilization method

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Abstract: *In this paper, the physico-chemical stabilization method of electrical power plant fly ash of the Province of Lodz in central Poland was studied. The chemical composition and leachability of metals were determined in the investigated samples. The ashes were vitrified in a thermal plasma process and their chemical stability was tested to determine whether the ashes can be disposed safely into the environment, specifically onto surface soil. The heavy metal leachability tests proved that the products after vitrification were more stable than non-vitrified waste making it more suitable for disposal into the environment.*

Keywords: *electrical power plant waste, fly ash, vitrification, solidification/ stabilization*

Introduction

The used of a coal as the source of classic energy has created the pollution problems of gas emission to the atmosphere as well as the fly ash appearance after the process of heat production from power electrical plant. Fly ashes and their disposal is a current issue affecting the global environment.

The Lodz Province in central Poland, as the big agglomeration with a population of 2.6 million inhabitants, was not aware of this problem. In 2009, 13732.4 tons of wastes were created in this region where 5074.8 tons came from the thermal processes of power plants [1]. The most popular method of their utilization (almost 90%) is a landfill storage.

The fly ash as the final product of a hard coal and a lignite combustion, contains various elements (also heavy metals) which cause the harmful effect to the human health and the environment. Coal is the most popular type of the classic source energy in Poland which means that after the burning processes the fly ashes appeared in a huge amount. It causes that fly ash requires a special treated as the hazardous waste listed with the code 10.01.02 [2]. This type of waste cannot be storage as the raw material directly on the land. It is important to find the effective method which transforms the fly ashes to the inert or less toxic products.

One of the solidification/stabilization (S/S) method used for the fly ash utilization is a thermal plasma stabilization [3,4]. This process is an effective method that provides to the environmental neutrally glassy product called vitrificate [5-9]. This technology is more effective than classic combustion because it guarantees a complete decomposition of organic substances, also pathogens and a significant reduction of the material volume about 75% of the incinerated waste.

The aim of the study was to demonstrate the advantage of electric power plant fly ash vitrification process as the one of the most effective physico-chemical method of waste stabilization.

Experimental

Materials

The fly ash samples came from an electrical power plant Belchatow of the Lodz Province. The samples were collected after two months of the mixture chimney filter fly ashes.

Methods

Chemical composition of fly ash

The ash chemical composition was determined by the Atomic Absorption Spectrometry – Graphite Furnace AAS-GF (air-acetylene flame) according to the BS DD CEN/TS 14429 concerning the leachability tests of wastes [10]. The ash composition of particular radicals was shown as the oxides.

Metal leachability

Ash. Metal leachability analyses were done according to the procedure which was described previously by Cedzynska *et al.* [11]. The chosen metals (Cd, Cr, Cu, Ni, Pb, Zn, Fe, Al, Mn) concentrations in water extracts were measured by Atomic Absorption Spectrometry Graphite Furnace AAS-GF (air-acetylene flame). The GBC 932 Plus spectrometer with a GF 3000 graphite furnace was used.

Vitificates. Metal leachability analyses of vitrificates (stabilised ash forms) were done according to the EN 12457-2:2000 [12] concerned granulated wastes and sludge leaching tests analyses.

Vitrification

The plasma vitrification process was used for stabilisation of fly ashes. Plasma „Little JetArc" device, designed and constructed in the Institute of Electrical Apparatus Technical University of Lodz, was used for the vitrification [13]. In this device plasma was generated directly in a DC arc forming between the graphite crucible melting chamber acting as the anode and a graphite rod cathode. The processes of ash stabilization were run in the atmosphere of argon during 300s with a delivered power of 1400 W.

Results and Discussion

The results of the chemical analyses of fly ash (Table 1) indicated that silica, calcium, and aluminium are the primary constituents found in the waste samples under investigation. These three components in the forms of oxides, make up approximately 88% of the total mass of the ash sample, which is enough to melt the waste ash and form a glassy product (vitrificate).

Table 1. Chemical composition of fly ash

Compound	[wt %]
SiO_2	42.97
CaO	28.08
Al_2O_3	16.96
Fe_2O_3	4.97
SO_3	3.61
TiO_2	0.99
MgO	0.83
K_2O	0.28
Na_2O	0.14
P_2O_5	0.13
MnO_2	0.02

In Table 2 some significant differences were observed between the fly ash samples leachability of chosen metals and their vitrificates. After the stabilization process the metals leachability decreased in a range of 27.27% for Cu to almost 100% for Cr.

Table 2. Heavy metals leachability from ash and vitrificates [g·/kg d.m.]

	Product	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Al	Mn
1	Fly ash	10.22	15.29	0.22	2.37	8.17	0.22	0.57	36.43	0.91
2	Vitrificate	0.22	0.01	0.16	1.12	3.32	0.13	0.20	7.56	0.24
3	% reduction of leachability	97.80	99.93	27.3	52.6	59.3	40.9	64.3	79.24	73.0
4	CD 2003/33/EC	1.00	10.00	50.0	10.0	10.0	50.0	n.l.*	n.l.	n.l.

*n.l. – no information concerning limited value was established in the Council Decision

The landfill storage of waste has been regulated by the Council Directive 86/278/ECC [14] concerning the sludge disposal on the land. Sludge contained heavy metals and toxic organic compounds can be stored only when the concentrations of hazardous substances do not exceed the settled values. The Council Decision CD/2003/33/EU [15] established the criteria and procedures for the acceptance of waste at landfills. The landfill storage of transformed dangerous waste in the places destined for non-toxic waste (Table 2) and hazardous waste must respect the European regulations. The leachability tests analyses of our experiments showed that only two elements (Cd and Cr) concentrations exceeded the minimum value of metals concentration in fly ash samples. The obtained results for Pb were near the maximum acceptable value. Nevertheless, the huge amount of electrical power plants waste makes the problem very serious for human and environmental being. The low leachability of heavy metals from vitrificates qualifies this physico-chemical method of stabilization to the one of the most effective process of waste utilization. Finally the environmental friendly products have appeared and in such form the wastes could be stored on a land without any harmful effects to the soil.

The European regulations are very strict regarding heavy metals concentrations of storage wastes. The high temperature plasma technology utilization as one of the stabilization methods is a proper tool in a waste hierarchy requirements of Council Directive ED/2008/98/EC [16]. The vitrification process used in stabilization of fly ash creates a good alternative methods of hazardous wastes utilization and their disposal among the available offers.

The fly ash wastes management is an important issue in the worldwide environment, therefore their proper collection and disposal are important as they can directly impact the health risks. The electrical power plant waste management plan should also include the special technologies which are required for their utilization.

Thermal plasma vitrification is an effective method of neutralizing fly ashes from electrical power plants which makes a possibility to obtain the environmentally harmless products with a significant reduction of volume.

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