



Stabilization of waste bottom ash generated from hazardous waste incinerators



Lucia Rozumová, Oldřich Motyka*, Kristína Čabanová, Jana Seidlerová

Nanotechnology Centre, VŠB - TU Ostrava, Nanotechnology Centre, 17 listopadu 15/2172, Poruba, Ostrava 708 33, Czech Republic

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ABSTRACT

Stabilization of bottom ash generated from hazardous waste incineration by the means of solidification was assessed by applying three different amounts of cement admixture (10%, 20% and 30%) and four distinct solidification periods (1 day, 4 days, 7 days and 28 days) in order to decrease the amount of harmful elements or compounds in the waste. Complex assessment of all the observed parameters was performed both according to the EU standard 2003/33/EC for waste acceptable at landfills for hazardous waste and by using ecotoxicological test on the freshwater algae *Desmodesmus subspicatus*. Whilst unmodified bottom ash exceeded the permit limit concentrations, after the solidification, most of the elements was immobilized in the admixture. The growth inhibition of *D. subspicatus* was, however, found out to be increasing during the process, possibly because the increase of molybdenum in the leachate with the increased cement addition and prolonged solidification period. From all the combinations tested, 30% cement addition and the standard 28 days solidification period appears to be the ideal one.

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Introduction

Since quantity of hazardous industrial waste increases significantly, it is evident that treatment and disposal of all such materials without causing the environmental harm has become a major concern. The current approach in waste management can be summarized in three principles: waste prevention, recycling and reuse, and final disposal of waste and its monitoring [1].

Incineration of the waste is advantageous because it makes wastes applicable as an energy source whilst rendering both their volume and mass significantly lower. Nevertheless, combustion of wastes produces CO₂, fly ash and bottom ash as a by-product [2–5]. Fly ash is a product of exhaust gases purification collected from the electrostatic precipitators or bag filters; the other product of combustion is solid combustible material – bottom ash. Solid wastes, such as bottom and fly ash (as well as off-gas cleaning), contain residues with high levels of heavy metals, inorganic salts and other, organic, compounds.

Only as recently as in 2003 was bottom ash included on the list of dangerous waste materials according to the Council of the European Union; whilst fly ash had been listed as a dangerous waste material (code 19.01.13) already [6]. Such waste is obliged to

be stabilized as well as evaluated for its toxicity with all the necessary analyses being carried out in order to assess and minimize the leaching of its possibly environmentally harmful components when being disposed of [7].

These waste materials are evaluated according to the applicable waste legislative – usually, once more, as hazardous materials because of the trace concentrations of heavy metals and other substances in their matter known to be detrimental to health. The most commonly produced hazardous wastes include industrial waste and hazardous hospital or medical waste. Hazardous medical waste originates from operations of any sanitary unit, such as public and private infirmaries, municipal surgeries, military hospitals, blood donation centers, diagnostic laboratories, microbiological laboratories, veterinary clinics and veterinary diagnostic laboratories. These wastes need proper collection, transportation and management because of their dangerous properties [8].

Solidification and stabilization (S/S) techniques serve as means of prevention and/or minimization of leaching of potentially harmful compounds or elements from the combustion product. Generally, it is a process of converting a toxic waste to a physically and chemically more stable form. For the immobilization of heavy metals, the most adaptable binder currently available is cement [9]. Such immobilization is performed by production of a solidification product with improved handling characteristics and decreased surface area (hence aggravating the transport of

* Corresponding author. Tel.: +420 59 732 1559; fax: +420 597 321 640.

E-mail address: oldrich.motyka@vsb.cz (O. Motyka).

contaminant by reducing the mobility of the contaminant as well as its bonding into a non-toxic form). Solidification product also acts as a barrier to the migration of ions [10,11].

Solidification of the bottom ash by its blending with cement material was also proved to be an easy and relatively low-cost mean to reduce its toxicity [12]. Recently, the addition of chemical reagents into cement mortar mixed with ash has been considered a viable alternative [13].

The use of cement as a binder is different. In work of Botta et al., cement was used for immobilization of a model liquid organic pollutant into the cement matrix using organoclays as pre-sorbent agents [14]. Lim et al. investigated the suitability of using cement-stabilized sludge products as artificial soils in earthworks [15]. In the study of Zhang et al., the authors studied varying heavy metal fixation effects by applying diverse retention mechanisms of two distinct technologies. Long-term leaching test (160 days), the maximum availability leaching test and modified three-step sequential extraction procedure were applied [16]. The immobilization of Ni(II) in various cement matrices was investigated using the neat Portland cement both in absence and presence of water reducing and water repelling admixtures; cement blended with kaolin was also applied [17]. S/S by cement was applied on fly ashes from a municipal solid waste incinerator that were subjected to mechanochemical treatment in a planetary ball mill. The leachability of lead from the treated fly ashes and from the cement product was investigated [18].

Substantial portion of the produced ash is being reused in the construction works in several European countries (contrary to the situation in USA and Canada); ash is applied in pavements, bridges, as a sub-layer in motorways and as a daily cover for landfills, as stated by Anastasiadou et al. [19]. Same author states that the percentage of produced ash used in road construction is 50% in Germany, 60% in Netherlands (with the aim of using 80%) and over 72% in Denmark. Bottom ash and its product after the cementing are suitable for various applications, mainly in road construction [20] or as an aggregate in concrete [21].

Technologies for bottom ash treatment are continuously scrutinized and controlled in order to minimize the potential for environmental pollution. In the research presented hereby, as the process of stabilization/ solidification, cementation was used [13].

Materials and methods

Materials

The studied material is a bottom ash from medical waste incineration; the incineration plant in question processes industrial chemicals as well.

According to EU standard 2000/532/EC do list of hazardous waste, this waste belongs to the category of waste from

incineration or pyrolysis of waste; in the European Waste List, it is listed as 190111 – bottom ash and slag containing dangerous substances [22].

For the stabilization, cement Georoc Dorosol C50 was used; this cement was used because it was specifically designed for the stabilization and solidification of contaminated soils and it is utilized in stabilization on a regular basis. Dorosol C50 cement is made from hydraulic components, Portland cement and quick lime (50%) [23] and was provided by HOLCIM, a.s. company (Prachovice, Czech Republic).

Preparation of stabilized sample of bottom ash

Sample of bottom ash was mixed with the Georoc Dorosol C50 cement so that the amount was 10%, 20% and 30% in the resulting product; resulting product was then 50 g in weight. Water was added to form a sludgy mixture (25 ml). This mixture was then intensively mixed for 10 min and placed into plastic forms to solidify. Solidification periods were 1 day, 4 days, 7 days and 28 days under laboratory conditions.

Preparation of the leachate

From the bottom ash and stabilization products, water leachate was prepared according to EN 12457-4 [24] in two parallels. Solid and liquid phase ratio was 1:10, demineralized water was applied. After 24 h of shaking using flap shaker, solid phase was separated by vacuum filtration by a membrane filter with 0.45 µm pore size. Parameters of the water leachate were set according to EU standard 2003/33/EC for waste acceptable at landfills of hazardous waste [22] which sets the criteria for waste acceptable at landfills of hazardous waste.

Methods of analysis

Chemical composition of the studied samples was determined using X-ray fluorescence spectrometry (XRFS) in the SPECTRO XEPOS equipped apparatus with 50 W Pd X-ray tube. Content and concentration of Hg in solid samples and leachates were determined by atomic absorption spectrometer (AMA 254). Since the contents of some of the elements (Ca, Cd, K, Mg, Na and Zn) were not determinable by the calibration range of the mentioned apparatus, their total contents were – after total acid decomposition of the solid sample in a mixture HF+HNO₃+HClO₄ – determined by AES-ICP (Yvon Jobin 24) or AAS-FA (UNICAM 969). The concentrations of As, Cd, Mo, Pb, Sb and Se in aqueous leachates were determined by AAS-FA or AAS-GF (UNICAM 989QZ). AES-ICP was used for analysis of Al, Ba, Ca, Cr, Cu, K, Mg, Na, Ni, and Zn – in the sequence apparatus with argon plasma (Yvon Jobin 24). Anion content was determined using ion

Table 1
Chemical composition of bottom ash and cement.

Components	Unit	Bottom ash	Cement	Components	Unit	Bottom ash	Cement
Na ₂ O	[%]	14.8	<6	As	[mg kg ⁻¹]	40	0.2
MgO	[%]	2.3	0.8	Ba	[mg kg ⁻¹]	1890	3.29
Al ₂ O ₃	[%]	4.1	4.1	Cd	[mg kg ⁻¹]	1300	1.54
SiO ₂	[%]	19.1	8.8	Cr	[mg kg ⁻¹]	2020	0
P ₂ O ₅	[%]	0.94	<0.07	Cu	[mg kg ⁻¹]	7500	1.12
SO ₃	[%]	9.4	3.9	Hg	[mg kg ⁻¹]	330	0.05
Cl	[%]	7.3	11	Mo	[mg kg ⁻¹]	561	0.13
K ₂ O	[%]	2.84	11.9	Ni	[mg kg ⁻¹]	990	0.43
CaO	[%]	8.0	39.4	Pb	[mg kg ⁻¹]	4000	2.9
TiO ₂	[%]	1.89	0.45	Sb	[mg kg ⁻¹]	588	0.09
MnO	[%]	0.105	0.023	Se	[mg kg ⁻¹]	8.8	0.87
Fe ₂ O ₃	[%]	3.79	14.0	Zn	[mg kg ⁻¹]	10,400	1.9
Lost on ignition	[%]	20.2	14.0	V	[mg kg ⁻¹]	<50	0.94

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