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Compressive strength and heavy metal leaching of concrete containing medical waste incineration ash

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HIGHLIGHTS

- Medical waste incineration bottom ash was studied to investigate the usage of building materials.
- S/S process was studied at different ratios of ash/cement mixture and two different curing times.
- It was considered that the mixing ratio up to 15% was acceptable ratio.
- The heavy metal concentrations was stabilized by solidification/stabilization process.
- Statistical methods was used to investigate the selected range of binders combinations (cement and MWBA) influence on chosen performance characteristics of concrete.

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ABSTRACT

This paper provides the results of the study on solidification/stabilization (S/S) of medical waste incineration bottom ash (MWBA). S/S is a process reducing heavy metals leachability of materials, and so as permitting disposal of them in a sanitary landfill. This process can be also described as a recycling facility because the usability of solidified matrix as a building material according to mechanical characteristics. In this study, S/S process was studied at different ratios of ash/cement mixture (0%, 5%, 10%, 15%, 20%, 25%, 30%, 40% and 50%) and two different curing times (7 days and 28 days).

The results of the study showed that S/S method can able to prevent the heavy metals leachability of MWBA. The concrete compressive strength decreased with increasing MWBA ratio. The compressive strength was 38 MPa for 100% cement with 0% MWBA ratio. The compressive strength reduced to 11.3 MPa when 50% cement was mixed with 50% MWBA. The data obtained from experimental study was also evaluated statistically.

1. Introduction

Medical waste can be defined as any solids wastes generated in diagnosis, treatment or immunization of human beings or animals, in research pertaining thereto, or in the production or testing of biologicals [1].

Because of increasing quantities and inadequate management system, medical waste management and selection of appropriate management systems also are important global problems over all the world. Incineration and disposal of the resultant, such as ash, could be determined as proper application for management of medical waste [2,3]. However, it is possible to obtain %70 mass and %90 volume reduction in medical waste by using incineration process, and considerable amounts of solid residuals, such as bottom and fly ashes containing heavy metals, are produced during this process [3–7].

The most common application for wastes and also by-products produced by human or industrial activities is to determine the alternative processes for exploitation of them to protect air, soil and water resources and also to eliminate the disposal cost. Reuse and recycling of wastes and/or by-products are alternative ways reducing the negative effects of them. Nowadays, such research and/or production is being carried out in several countries where these materials are used as raw material, such as, additives for building materials. In this content, stabilization/solidification (S/S) is used as a pre-landfill waste treatment technology that aims

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to make hazardous wastes, such as ashes, safe for disposal [8]. Solidification/stabilization is a process that involves the mixing of a waste with a binder to reduce the contaminant leachability by both physical and chemical means and to convert the hazardous waste into an environmentally acceptable waste form for land disposal or construction use [9]. The solidification of wastes with cement and the use of these solidified wastes in the production of construction products has become a common way to minimize environmental contamination and to recycle the wastes [10].

In Turkey, in order to prevent medical waste threat, "Regulation Regarding the Control of Medical Wastes" was issued in 1993 and it was amended in 2005 [11]. This regulation declared that health institutions are responsible for collecting and temporarily storing the medical wastes separately from other wastes and municipalities are responsible for taking and destroy them and the Ministry of Environment and Urbanization is responsible for auditing them [12].

In Istanbul, the daily amount of medical waste collecting form 252 health institutions is approximately 35–40 tons. Medical wastes collected separately from health institutions are transported with special vehicles to Medical Waste Incineration Plant located in Kemerburgaz, Istanbul. The capacity of the plant is 24 tons per day. The actual incineration capacity of the plant is approximately 15.000 tons per year. The plant has two stage combustion system consisting of a rotary kiln and secondary combustion chamber, at a temperature between 1000 and 1200 °C. The slag, produced in the rotary kiln, is taken to an ash quench chamber and then it is transferred to landfill sites by a conveyor system. Volume and mass reductions of incineration facility are %95 and % 75 respectively.

In this paper, the treatment and recycling of medical waste incineration bottom ash (MWBA) via solidification/stabilization process was evaluated. MWBS sampled from İSTAÇ A.Ş. Medical Waste Incineration Plant in İstanbul of Turkey used as material in this study. This issue was worked in there stages. In the first stage, MWBA was characterized. In the second stage, solidification/stabilization process was applied. The third and the last stage, solidified material evaluated in respect of environmental impacts. As a results of the study, S/S process was evaluated for recycling of MWBA as construction material.

Although there are many studies on solidification/solidification about many different materials in the literature, there is so limited studies about medical incineration bottom ashes. Therefore, the quality of our work is an original work.

2. Experimental

2.1. Material analysis

2.1.1. Medical waste bottom ash

In this experimental study, medical waste bottom ash (MWBA) collected from the combustion chamber of İSTAÇ A.Ş. Medical Waste Incineration Plant in İstanbul of Turkey was used. Physical properties, chemical composition (XRF analysis), morphology and mineralogical determination (XRD pattern) and radioactivity analysis were carried out to characterize the MWBA.

X-ray fluoresce (XRF) spectrometer analysis was made to determine the major elements and oxides of these elements of MWBA. X-ray diffraction (XRD) analysis was made to determine the mineralogical properties of MWBA. XRF and XRD analyses, density, pore volume and specific surface area measurements were made in Materials Institute Laboratory of TUBITAK-MAM. Scanning electron microscope measurement made in Gebze Institute of Advanced Technology Laboratories, using SFEG Philips XL30 Scanning Electron Microscope (SEM) with gold coating proses. Gamma radioactivity analysis was performed in Turkey Atomic Energy Agency. TOC analysis was made in Water and Wastewater Laboratory in Environment and Cleaner Production Institute of TUBİTAK-MAM. Conductivity (WTW Cond. 330 Kit) and pH (WTW 330) measurements were made measurements of the eluate prepared 1:10.

2.1.2. Cement

Cement (CEM I 42.5 R) was supplied from Akçansa, in Turkey. It complied with the requirement of European Standards EN 197-1 (2002). The physical, chemical and mechanical properties of the cement and the chemical composition of cement obtained from cement supplying company, are given in Tables 1 and 2.

2.1.3. Aggregates

A maximum 22 mm nominal size of the crushed aggregate was used. The coarse aggregates were calcareous stone: crushed stone I (6–12 mm), crushed stone II (12–22 mm), natural sand (0–3 mm) and crushed dusty stone dusty (0–6 mm). The specific gravities of the raw materials, obtained from cement supplying company, are listed in Table 3.

2.2. Mix proportion and concrete mix design

Sample of the MWBA was mixed with the Portland cement to solidify the ash and immobilize the pollutants in the ash. Solidified material prepared with the different portion of ash, cement and also aggregates and water according to C30/37 class of concrete of Turkish standard (TS EN 206-1) [13]. Nine different mixing ratios of ash: 0%, 5%, 10%, 15%, 20%, 25%, 30%, 40% and 50% were chosen. The mixtures were placed into cubic molds (150 × 150 × 150 mm) for concretion period. After that period, concreted solidified materials cured for 7 and 28 days. Mixes were design to achieve workability between 60 and 150 mm. The 28 day cube strengths sought were 40 N/mm^2. Mix proportion used are given in Table 4. The initial mix (0) was a control mix with Portland cement only specified as CEM I.

2.3. Test procedures

2.3.1. Compressive strength

The physical strength of the solidified matrix is significant since it determines the suitability of the materials using as construction material [14]. After the curing procedure, compression tests were conducted in accordance with EN 12390-3 on triplicated solidified materials (2002) [15].

Table 1
The physical, chemical and mechanical properties of the cement.

	Properties	Unite	CEM I
Chemical properties	Insoluble residue	%	0.5200
	SO_3	%	3.1100
	Loss of ignition	%	1.2500
	Cl^-	%	0.0385
Physical properties	Specific gravity	g/cm^3	3.14
	Initial setting time	min	317
	Final setting time	min	194
	Volume expansion	mm	1
	Specific surface area	cm^2/g	3700
	Fineness 45 μm	%	8.6
	Fineness 90 μm	%	0.3
Mechanic properties	Compressive Strength, 2 days	MPa	26.6
	Compressive Strength, 7 days	MPa	40.8
	Compressive strength, 28 days	MPa	55.8