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Mechanical Pretreatment of Municipal Waste Incineration Ash for Recovering Heavy Metals by the Horizontal Gyration Method

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Abstract

Segregation of binary particle systems in a horizontally gyrated bed has been experimentally studied to recover the heavy metals from municipal waste incineration (MWI) ash. Differences in density and size had less effect on segregation. Effective segregation took place under the centrifugal effect of 1 or less for any particle size ratio. Zn, Cu and Pb were concentrated in the upper side of bed by the horizontal vibration. However, there was less change in concentration for other metals such as Mg, Al and Fe etc. The separation system with the horizontal gyrating separator proved to be an effective method for the pretreatment of recovering Zn, Cu and Pb from incineration residues.

Keywords: segregation, municipal waste incineration, horizontal vibration, heavy metals

Introduction

Ash generated municipal waste incineration (MWI) contains valuable and toxic heavy metals, such as Cu, Zn, Al, Pb and so on, but the greater part of it is filled in the land after the proper treatment, i.e. melting, cementitious stabilization and stabilization with a chemical agent. Incineration reduces the volume of the waste by approximately 90% and the chemical reactivity of hazardous organic compounds. Due to the large amounts of MWI ash generated, it is necessary to recycle metallic elements from it for reserving the resources. Solids from waste incineration such as slag and ash are considered 'artificial ores'. It might become possible to recycle the reached and recovered metals and to reuse them as raw materials by metal-manufacturing industries. In addition, the environmental quality of the residues is improved by the process with respect to a subsequent application of these materials for construction purposes [1,2].

Melting of MWI ash at high temperature in furnace to convert the majority of ash into slag that mainly consists of silica, aluminum, iron, and calcium and immobilizing small portions of heavy metals. This slag is used in road construction. During the melting process, the majority of the heavy metals are vaporized as volatile metal chlorides and concentrated in newly formed fly ash from the furnace (secondary fly ash, SFA). Some of elements, i.e. Zn and Pb, are present in SFA at concentrations that allow an economic recovery. Acid or alkaline leaching followed by solvent extraction would be an alternative recovery process. Separate collection of the residue streams improves the utilization potential of the bottom ash and limits the amount of more contaminated material, which must be managed more restrictively. Available literature on the characterization and treatment of MSW fly ash is not extensive, though there are some recent publications [3].

Mechanical concentration represents a clean technology process with a low cost and low energy level compared with conventional thermal solid waste treatment techniques. A few studies of density segregation have been done to separate particulate materials, but studies on segregation of particles in the horizontally gyrated bed are rare. More recently, the authors reported the separation of lead and aluminum under the horizontally gyratory movement [4-7].

The purpose of this study was to investigate heavy metal concentration from bottom ash using the horizontally gyrated bed.

Experiment

The materials used in segregation experiments were commercial aluminum, copper, lead and YTZ (Yttria-Toughened-Zirconia:95% ZrO_2-5%Y_2O_3, Nikkato) particles. The physical properties of materials are listed in Table 1.

Table 1 Physical properties of used samples

	True density , g/m^3	Apparent density , g/m^3	Average diameter , mm	Shape
Al	2.8	1.1	0.45, 0.55	Nonsphere
Cu	8.9	5.4	0.55, 0.65	Sphere
Pb	11.4	6.8	0.55, 0.65	Sphere
YTZ	5.6	3.9	0.46,0.65 0.75, 1	Sphere

The samples of bottom ash used in this study were collected by the electrostatic precipitator and donated by NKK, Japan. Metal contents were analyzed using a SEICO model SPS3000 ICP/MS after aqua-regia acid digestion. Table 2 shows the composition of MSWI bottom ash.

Particle size distribution of bottom ash was measured by using a particle size separator consisting of seven sieves to separate bottom ash into seven particle size ranges.

Table 2 Composition of MSWI bottom ash used in this study

Composition Particle size, mm	Ca %	Al %	Fe %	Na %	Mn %
>7.9	9.58	8.60	6.78	2.57	0.16
7.9~5.6	15.2	8.99	5.49	3.12	0.12
5.6~4.8	14.9	9.82	7.84	3.82	0.14
4.8~3.4	16.8	26.9	5.24	3.04	0.12
3.4~2.4	19.0	12.9	5.32	4.25	0.15
2.4~1.7	18.3	11.2	6.22	4.24	0.18
1.7~1.2	37.1	23.1	15.5	8.22	0.34
1.2~0.6	19.3	11.6	7.75	3.87	0.20
0.6~0.3	13.7	12.2	6.30	3.95	0.20
<0.3	17.0	12.6	6.42	4.87	0.55
Composition Particle size, mm	Cu ppm	Zn ppm	Pb ppm	Mg %	Cd %
>7.9	142	387	174	0.93	6
7.9~5.6	314	499	74	1.09	6
5.6~4.8	2950	3370	74	1.31	7
4.8~3.4	653	5360	111	1.16	13
3.4~2.4	4240	2000	287	1.31	9
2.4~1.7	2490	2310	541	1.26	23
1.7~1.2	1350	2380	321	1.26	21
1.2~0.6	1200	2560	307	1.22	10
0.6~0.3	1260	3000	408	1.34	10
<0.3	1290	3740	609	1.24	24

The experimental apparatus is shown in Figure 1. The devices consisted of the shaker, which subjects to horizontally gyrating movement, and an acrylic vessel in which the particles are held. The vessel was a cylinder (0.10 m height and 0.10 m inner diameter) without top cover. Experiments were carried out using binary particle systems and incineration bottom ash. Each sample was poured into the vessel, and the particle bed was about 27 mm high. The vessel filled with the sample was mounted on the stage of the shaker and was driven with a constant rotational velocity for a given period of time. The vibration conditions varied between 2.5 ~ 4.3 s^{-1} of rotational velocities and 15 ~ 25 mm of rotational radii.

In this paper, rotational velocity means the gyration velocity of vessel. After stopping the rotation, the settled bed was divided into two vertical parts of the same volume using the acrylic separation panel. The front half bed was removed and three samples were taken from three sampling cells in the remaining half bed, shown in Figure 1. The metal composition of each component was determined by weighing after separating each component from mixture by sieve or using ICP/MS

Results and Discussion

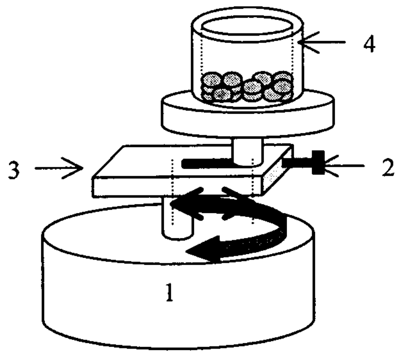

Fig.1 Experimental setup
1.Motor, 2.Control part or rotational radius 3. Stage of vessel, 4.Plastic vessel

Figure 2 shows the variation of concentration of particles with high density in function of particle size ratio R (=d_h/d_l). Here, the d_h is the diameter of particles with high density and d_l is that of particles with low density. The y-axis represents the concentration C_h^o of particles with high density at 30 s to the initial concentration C_h. In Figure 2, it can be seen that the size segregation occurred in the region I and density segregation was found in the region II. In the other hand the segregation in the region III arises from difference in shape.

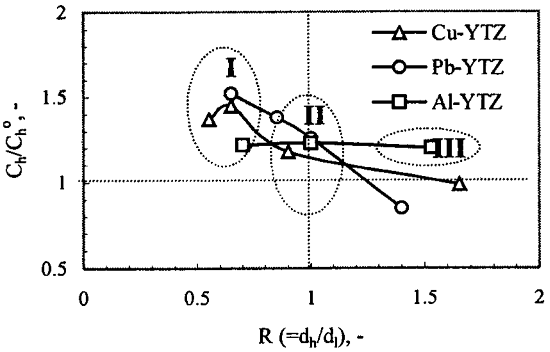

Fig. 2 Segregation in function of density, size and shape of particles. t=30s, r=2.0cm, Nr=180 rpm

Both of the rotational radius and the rotational velocity affected segregation of particles and can be combined in one parameter, namely the centrifugal effect Z defined as following equation.

$$Z = r\omega^2/g = r(2\pi N_r)^2/g$$

where ω is the angular velocity and g is the gravitational acceleration. That is, the centrifugal effect Z indicates the proportion of the centrifugal acceleration relative to the gravity acceleration.

Figure 3 shows the effect of centrifugal effect Z on segregation in the binary particle systems. At the centrifugal effect of about 0.65 the maximum concentration in copper or lead was observed for any rotational radius in both systems of the Pb-YTZ and Cu-YTZ mixtures, and it can be thought that the high segregation occurred in the condition of $Z = 0.65$. Meanwhile in the Al-YTZ system the YTZ concentration was the minimum at the centrifugal effect of 1 or less, and also it can be seen that the high segregation of aluminum in the upper side occurred. In case of $Z < 0.6$ the concentration in copper and lead decreased with decreasing the centrifugal effect, and this arises from low fluidization speed due to the weak centrifugal force. the centrifugal effect above 0.7 the concentration in copper or lead decreased as the centrifugal effect increased, and this is due to the strong centrifugal effect. That is, at $Z > 0.7$ the effect of the centrifugal force overcame the effect of gravity and the convection is quick in action according to the stronger centrifugal force.

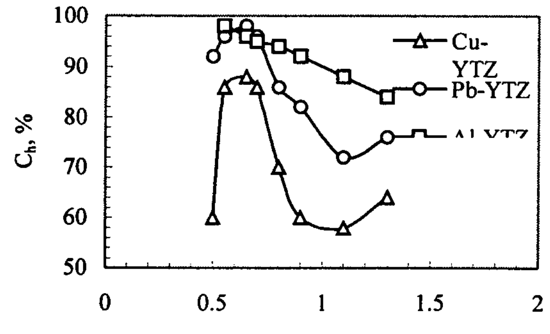

Fig. 3 The concentration in Cu, Pb and YTZ in function of centrifugal effect. t=30s, r=2.0cm d_{Cu}=0.65mm and d_{YTZ}=1mm in Cu-YTZ system, d_{Pb}=0.65mm and d_{YTZ}=1mm in Pb-YTZ system, d_{Al}=0.65mm and d_{YTZ}=1mm in Al-YTZ system

Figure 4 shows the variation of lead concentration in the upper side of bottom ash under the horizontal vibration. Here, the x-axis represents the particle size range of bottom ash tested. In the particle size range of 2.4-1.2 mm and 1.2-0.6 mm, the concentration of lead was the maximum value in the upper –center of bed. It is thought that the small lead particles were attached on the light large particle and light large particles were segregated in the upper side. However, below 0.6 mm there was no segregation.

Figures 5 and 6 show the variation of Zn and Cu concentration in the upper side of bottom ash under the horizontal vibration. In the particle size range of 2.4-1.2 mm and 1.2-0.6 mm, Zn and Cu were segregated in the upper side. However, below 0.6 mm there was no segregation.

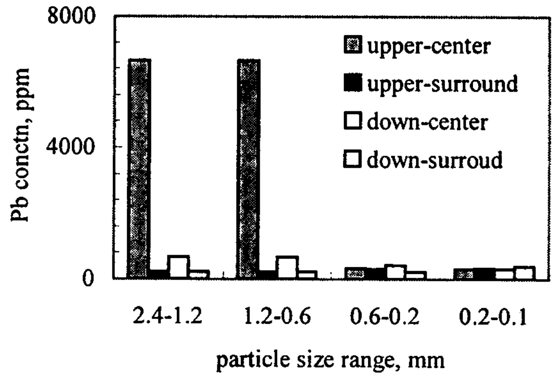

Fig. 4 The variation of Pb concentration according to particle size range at r = 2cm, 190 rpm. t= 5min.

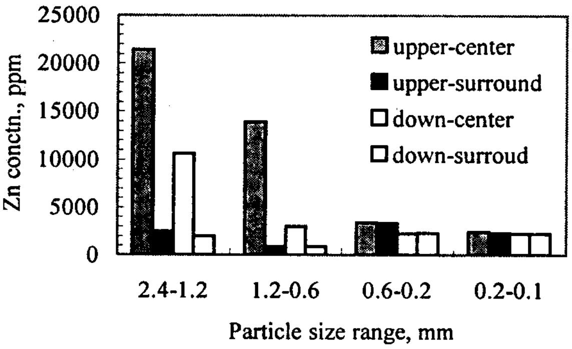

Fig. 5 The variation of Zn concentration according to particle size variation at r = 2cm, 190 rpm. t=5min.

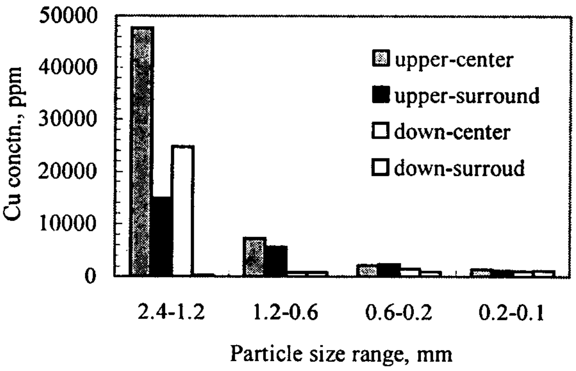

Fig. 6 The variation of Cu concentration according to particle size variation at r = 2cm, 190 rpm.

Conclusion

Segregation in a gyrated particle bed has been studied to apply for the concentration of heavy metals from MSWI bottom ash. Segregation was affected by differences in particle size, density, shape and vibration conditions. In spherical-spherical particle system the difference in particle size was the most predominant factor on segregation, and in spherical-nonspherical system the difference in particle shape was the most important factor. The heavy metals, i.e. Cu, Zn, Pb, was segregated in the upper side, and it can be thought that small heavy metals is ad- or absorbed on the light large particles. However, there was less change in concentration for other metals such as Mg, Al and Fe etc. The separation system with the horizontal gyrating separator proved to be an effective method for the concentration of Zn, Cu and Pb in MSWI bottom ash.

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