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ScienceDirect
Journal of Hazardous Materials 150 (2008) 27–36
Journal of Hazardous Materials
www.elsevier.com/locate/jhazmat

Emission of Pb and PAHs from thermally co-treated MSWI fly ash and bottom ash process

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Received 2 November 2006; received in revised form 12 April 2007; accepted 17 April 2007
Available online 20 April 2007

Abstract

Municipal solid waste incinerator (MSWI) fly ash was regarded as a hazardous material because concentrations of TCLP leaching solution exceeded regulations. Previous studies have investigated the characteristics of thermally treated slag. However, the emissions of pollutant during the thermal treatment of MSWI fly ash have seldom been addressed. The main objective of this study was to evaluate the emission of Pb and PAHs from thermally co-treated MSWI fly and bottom ash process. The experimental parameters included the form of pretreatment, the proportion of bottom ash (bottom ash/fly ash, B/F = 0, 0.1 and 1) and the retention time. The toxicity of thermally treated slag was also analyzed.

The results indicated that (1) Pb emission occurred only in the solid phase and that PAHs were emitted from both solid and gas phases during thermal treatment process. (2) Washing pretreatment reduced not only the TCLP leaching concentration of Pb (from 15.75 to 1.67 mg/L), but also the emission of PAHs from the solid phase during thermal treatment process. (3) Adding bottom ash reduced the TCLP leaching concentration of thermally treated slag. (4) The concentration of Pb emission increased with retention time. (5) The thermal treatment reduced the toxicity of raw fly ash effectively, the inhibition ratio of raw fly ash and thermal treated slag were 98.71 and 18.35%, respectively.

Keywords: MSWI fly ash; PAHs; Emission; Thermally co-treated; Toxicity

1. Introduction

Incineration is a major government-approved method for treating waste material in Taiwan. The Taiwanese government introduces nearly 20 municipal solid waste incinerators (MSWI) to eliminate the waste. During incineration some pollutants are released, and MSWI fly ash is a major one. Since much waste is treated every day, municipal solid waste incinerators produce a great quantity of MSWI fly ash every year. Table 1 lists the total MSWI fly ash and bottom ash produced from 2001 to 2005. The amount of MSWI fly ash produced is approximately 0.83 million tonnes and MSWI bottom ash is about 4.2 million tonnes. In the combustion process, some metal compounds are vaporized at high temperature and condensed on MSWI fly ash at low temperature in an air pollution control device [1–3]. The toxicity characteristic leaching procedure (TCLP) concentrations of MSWI fly ash are high, especially Pb concentration, that often exceed the levels allowed by Taiwan EPA. Therefore, MSWI fly ash is regarded as hazardous materials and must be treated to avoid damaging the environment.

The major methods of treating MSWI fly ash include melting, solidification/stabilization and sintering [4–8]. Solidification/stabilization often involves the addition of some additives to fix or encapsulate hazardous materials inside agglomerate. In sintering and melting, a high temperature is adopted to remove hazardous metals that are present in the MSWI fly ash. The ash obtained in this process can be used as additive in cement. The emission level of heavy metals depends on the composition of the MSWI fly ash and the thermal treatment conditions of the MSWI fly ash. If metal chlorides and sulfates are present in MSWI fly ash, then these also can be emitted during this process, because of their low boiling point [3,9–14]. The conditions of the thermal treatment also affect the levels of heavy metal emitted [15,16].

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0304-3894/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.jhazmat.2007.04.041

Table 1
MSWI fly ash and bottom ash product of incinerators of Taiwan from 2001 to 2005

Incineration plant	2001		2002		2003		2004		2005	
	F[a]	B[b]	F	B	F	B	F	B	F	B
Neihu	1532.47	8667.86	3706.28	16315.81	3948.15	18739.6	2893.6	13250.37	4453.42	15892.92
Mucha	1471.37	22567.56	4022.58	29523.89	4062.4	25621.17	3658.22	27762.59	2263.71	25999.54
Peitou	0	79671.74	509.24	70510.85	8250.41	39800.93	8936.39	45341.42	6680.14	40503.32
Shulin	8961.94	61338.91	8897.52	57557.31	7829.35	51056.04	7401.58	51887.99	6576.3	48087.44
Hisntien	4505.69	35647.26	5013.9	37770.88	5031.77	38865.8	4693.95	36170.38	4606.54	33139.07
Bali	4926.38	31807.8	14290.14	73642.29	13542.14	70152.76	12516.48	66447.5	12063.7	63595.8
Taoyuan	4106.31	17497.93	21801.6	96505.01	19115.17	78696.03	14408.6	70988.61	14301.1	63681.25
Hsinchu	4757.29	26046.96	6308.5	37987.67	7545.14	39334.48	8238.42	39771.14	6601.46	31663.25
Taichung	6646.32	33612.52	8906.94	34302.84	9504.05	28303.66	7545.98	27699.34	7366.51	27269.57
Houli	11482.16	60497.02	13143.14	52770.24	11425.97	47365.88	8548.48	44958.44	7640.09	48562.09
Wujih	0	0	0	0	0	0	3301.22	15652.62	8906.42	47905.64
Hsichou	15530.67	60635.83	16464.7	46348.13	12915.5	42890.79	7513.19	39530.8	7999.99	42731.12
Lutsao	1320.52	6465.61	13386.57	52584.1	10889.04	50183.77	8751.41	46268.62	8820.23	48889.74
Chiayi	0	11620.1	0	13567.6	1709.11	10954.35	2132.81	9684.59	1783.44	8743.09
Tainan	6056.03	30935.01	7598.5	31488.87	7329.18	32443.44	7269.63	33549.74	5105.66	32339.17
Renwu	9718.04	50321.28	13536.96	70055.29	12766.06	64898.75	12610.2	68457.82	12234.82	67363.2
Kangshan	3776	13135	13564.04	54530.13	16193.32	69137.68	8760.66	52264.41	9493.76	56311.35
Kaohsiung	5479.5	29472.66	6151.38	27984.15	6458	30040.25	6996.95	29938.01	8244.57	31269.65
Kaohsiung South	18692.59	71699.6	20040.79	80438.6	18567.94	73018.16	20362.42	88024.83	17487.85	73903.48
Kandi	7451.47	31491.46	9832.37	36164.12	12511.27	48835.83	12409.95	45649.04	12172.23	56250.25

Source: collected from Taiwan EPA.
[a] MSWI fly ash (tonnes/year).
[b] MSWI bottom ash (tonnes/year).

In addition to heavy metals, polycyclic aromatic hydrocarbons (PAHs) are also present in MSWI fly ash. The main species of PAHs in MSWI fly ash are low-ring compounds such as naphthalene, acenaphthylene and phenonthrene. Most of PAHs are in the gas phase and very few are present in the slag during the thermal treatment process [17,18]. Some studies have focused on the TCLP concentration in thermally treated slag and evaluated the feasibility of its reuse [19–21]. Some other studies of the conditions of the thermal treatment of MSWI fly ash and heavy metal transformation have been performed. Although considerable research has been done on the reuse of MSWI fly ash. However, very few reports have addressed the emission of PAHs and heavy metals during the thermal treatment process.

The aim of this study is to evaluate the emission of Pb and PAHs from thermally co-treated MSWI fly ash and bottom ash process. Studies focus on the effect of such parameters as retention time, pre-treatment and co-treatment on the emission of Pb and PAHs. The results of Pb and PAHs emission with pre-treatment and without pre-treatment are compared. This study also compares the toxicity of raw fly ash and thermally treated slag.

2. Experiment

2.1. Materials

MSWI fly ash and bottom ash used in this study were collected from a mass-burning incinerator in Taiwan. MSWI fly ash and bottom ash were sieved to make sure that they contained particles of the same size.

2.2. Apparatus

The thermal treatment of fly ash was conducted in the laboratory-constructed apparatus shown in Fig. 1. This apparatus was a pilot-scale rotary kiln reactor whose major components are a thermal chamber (210 cm long with an internal diameter of 9 cm), a control system and a collection system. The thermal chamber was made of steel (AISI 316). The control system had two parts: the temperature control system has two thermocouples and a proportional integral derivative (PID) controller; the other was a rotary kiln speed controller. The thermal chamber used an electrical heater to achieve the desired temperature and the temperature control system adjusted the temperature. The exhaust gas was cleaned using an air pollution control device and released to the atmosphere.

2.3. Experimental procedure

The fly ash collected from MSWI was mixed well and some of the fly ash was washed with distilled water for 3 h with a solid/water ratio of 1/10. Following washing, the solid/water mixture was separated through a glass fiber filter, and the solid part was dried overnight in an oven at 105 °C. This part of the fly ash was classified as the washed fly ash and the remaining portion of the MSWI fly ash was regarded as raw fly ash. MSWI bottom ash was added to both washed and raw fly ash in various ratios which called mixed ashes. The sampling time was identified that ash was fed into the thermal chamber and the thermally treated slag dropped into the collection system completely. The sampling time depended on the speed of reactor and there are three different sampling time in this study. Table 2 lists the experimen-