

Comparative study on the heavy metals stabilization performance of different organic chelating agents in municipal solid waste incineration fly ash

Ze Zhang¹, Chuanfu Wu¹, Xiaona Wang¹, Zhongli Luo² and Qunhui Wang¹

¹ School of Energy and Environmental Engineer, University of Science and Technology Beijing, 30 Xueyuan Road, Haidian District, Beijing 100083, China

² Organic Materials Research Laboratory, Tosoh Corporation, Shunan, 746-8501, Japan

INTRODUCTION

Municipal solid waste (MSW) output is rising as urbanization is accelerating and people's quality of life is improving. Waste incineration technology has a high rate of weight and capacity reduction, and the heat generated from incinerator can be reused, it has gradually replaced other methods for handling domestic waste in Chinese cities¹.

Bottom ash (BA) and fly ash (FA) are the byproducts of incineration for solid waste². Among them, FA contains a significant amount of hazardous wastes, including chlorides, persistent organic pollutants, and toxic heavy metals (Pb, Cr, Cd, As, Hg, etc.)³. It is worth noting that heavy metals in fly ash are the primary source of heavy metal pollution in China, with a high potential for leaching and pollution⁴. Therefore, to avoid secondary pollution, the fly ash has to be well treated before disposal.

At the present, the primary FA treatment methods are cement solidification, chemical agent stabilization, and heat treatment⁵. The chlorine content of FA is typically high, which devastates the cement hydration reaction, resulting in a greatly reduced treatment effect of cement solidification. Thermal treatment is typically associated with high energy consumption. Chemical agent stabilization, on the other hand, has the advantages of low compatibilization rate, low cost, and good effect, making it a very promising method for treating heavy metals in FA. Numerous studies have demonstrated that organic chelating agents have a better effect than inorganic stabilizers^{6,7}.

In this study, FA was treated with three different organic chelating agents (CA), and the stabilization effects on the target heavy metal Pb were examined in order to determine the best organic chelating agent and the best addition ratio.

MATERIALS AND METHODS

(1) Materials

This study utilized MSWI FA from Chengdu Xingrong Group Co., Ltd. Grate type incinerators are the kind that are employed.

(2) Stabilization and heavy metal analysis

Different CA solution were applied to FA samples based on weight at 0.3 - 1.5% (water-FA ratio = 0.25). Mechanical stirring was carried out for 10 mins until a paste formed.

Microwave digestion method was used to determine the total heavy metal contents in raw FA. < The Solid Waste Leaching Toxicity Leaching Method Acetic Acid Buffer Solution Method > (HJ/T 300 - 2007) was used in this study to determine the leaching toxicity of heavy metals in FA. The modified BCR method is used to determine the heavy metal forms of FA (acid soluble, reducible, oxidizable, residue). Heavy metal concentrations were analyzed by inductively coupled plasma-atomic emission spectrometry (ICP-AES)

RESULT AND DISCUSSION

(1) Heavy metal analysis of raw FA

The amount of heavy metals leached from the raw FA and the total amount are shown in Table 1. The raw FA had the highest metal Zn content, but its leaching was limited, indicating that Zn is not easily leached and migrated in the environment. The HJ/T 300 leaching of raw FA showed that the leaching of Pb exceeded the limit value of the < pollution control standard for domestic waste landfills > (GB 16889-2008), so Pb was chosen as the target heavy metal for this study.

Table 1 Heavy metals leaching and total amount of raw FA

	HJ/T 300 (mg/L)	Total contents (mg/kg)
As	0.005	170
Zn	0.345	4770
Pb	0.461	740
Ni	0.004	350
Cd	0.013	220
Cr	0.021	10
Cu	0.030	405

(2) Comparison of leaching toxicity with different CA

The immobilization effects of Pb with different CA are shown in Fig. 1. The three chelating agents used at a 0.3%

concentration already have a lower leaching concentration of Pb than the standard limit value given in GB 16889-2008. The lowest leaching amount of TS300 was 0.009mg/L at 1.5% addition. Future thorough investigations on the variation of Pb leaching from chelator treatment between 0% and 0.3% of the dosage rate are planned in order to lower treatment costs and find the minimal dosing rate that satisfies the requirements.

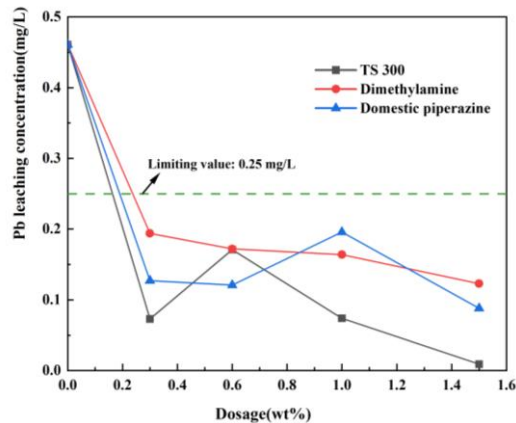


Fig.1 Pb leaching toxicity with different CA and dosages

(3) Variations in Pb speciation with different CA

As shown in Figure 2, the acid-soluble (F1) and reducible fraction(F2) of Pb in the original FA accounted for 10% and 41% of the total amount of Pb, respectively, which are unstable and easy to leach components. The percentage of F1 and F2 fraction reduced by a combined 33% for TS300 when the addition amount was raised from 0.3% to 0.6%, indicating that the addition of TS300 enhanced the conversion of Pb to the stable state in FA. Although the acid soluble state of Pb in the FA treated with the other two chelating agents was reduced compared to the original ash, however, its F2 fraction was significantly increased, leading to an increase in the unstable fraction. Therefore, the chelating agent TS300 was relatively more effective in the treatment.

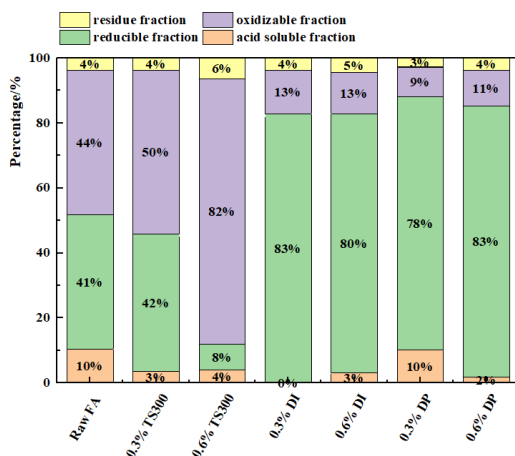


Fig 2 Speciation distribution of Pb with different CA

CONCLUSION

All three chelating agents in this study could meet the landfill limits at a 0.3% addition, and the leaching amount of TS300 is the lowest. By analyzing the proportion of four heavy metal forms of Pb, the F1 and F2 components of Pb treated with TS300 accounted for the least when the addition amounts were the same, indicating that the treatment effect of TS300 was better than the other two chelating agents.

ACKNOWLEDGEMENT

The study was supported by the National Key Research and Development Program of China (2021YFE0112100).

REFERENCE

- 1.NBS, C. China Statistical Yearbook of 2021.
- 2.Mao, Y.; Wu, H.; Wang, W.; Jia, M.; Che, X., Pretreatment of municipal solid waste incineration fly ash and preparation of solid waste source sulphoaluminate cementitious material. *Journal of Hazardous Materials* 2020, 385, (Mar.5), 121580.1-121580.9.
- 3.Hongwei; Luo; Ying; Cheng; Dongqin; He; En-Hua; Yang, Review of leaching behavior of municipal solid waste incineration (MSWI) ash. *The Science of the total environment* 2019.
- 4.Dou, X.; Ren, F.; Nguyen, M. Q.; Ahamed, A.; Yin, K.; Chan, W. P.; Chang, W. C., Review of MSWI bottom ash utilization from perspectives of collective characterization, treatment and existing application. *Renewable and Sustainable Energy Reviews* 2017, 79, (nov.), 24-38.
- 5.Lu, Y.; Tian, A.; Zhang, J.; Ang, Y.; Huang, Y., Physical and Chemical Properties, Pretreatment, and Recycling of Municipal Solid Waste Incineration Fly Ash and Bottom Ash for Highway Engineering: A Literature Review. *Advances in Civil Engineering* 2020, (12), 1-17.
6. Ma, W.; Chen, D.; Pan, M.; Gu, T.; Zhong, L.; Chen, G.; Yan, B.; Cheng, Z., Performance of chemical chelating agent stabilization and cement solidification on heavy metals in MSWI fly ash: A comparative study. *Journal of Environmental Management* 2019, 247, (Oct.1), 169-177.
7. Luo, Z.; Tang, C.; Hao, Y.; Wang, Z.; Mu, Y., Solidification/stabilization of heavy metals and its efficiency in lead-zinc tailings using different chemical agents. *Environmental Technology* 2020, 1-11.