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Condensation behavior of lead and cadmium during municipal solid waste (MSW) combustion

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1. Introduction

Incineration is an efficient process for municipal solid waste treatment since it allows a great reduction of the volume of waste materials, stabilization, sanitation, and energy recovery for power generation. One of the major environmental concerns is the emission of toxic heavy metals and their distribution in the residues discharged from incinerators. To efficiently minimize and/or eliminate the adverse effects of heavy metals, a fully understanding of the condensation behavior of heavy metals becomes imperative. For this purpose, in this study a unique reactor with multi-cooling zones to simulate the flue gas quenching was developed to investigate the condensation behavior of Pb- and Cd-bearing inorganic vapors. The effects of impurities in flue gas such as HCl, SO_2 and H_2O were discussed in detail.

2. Experimental apparatus and procedure

Experiments were performed in a laboratory-scale electrically heated rotary furnace reactor with multi-cooling stages, the schematic of which was described in Fig.1. This experimental rig consists of two major parts, reaction zone and cooling zone. Reaction zone is a horizontal tubular quartz reactor with two layers termed inner tube and outer tube respectively. Once the temperature for the quartz reactor reaches 1273 K, the heavy metal-laden TiO_2 powders within inner tube were quickly pushed into the reaction zone where the temperature is constant. A mixture gas consisting of N_2, O_2, CO_2 and 2000 ppm HCl was constantly introduced into the inner tube to promote the vaporization of heavy metals. On the other hand, a few amounts of SO_2 and/or H_2O were introduced into outer tube to examine their influence on the condensation of inorganic vapors emitted from inner tube.

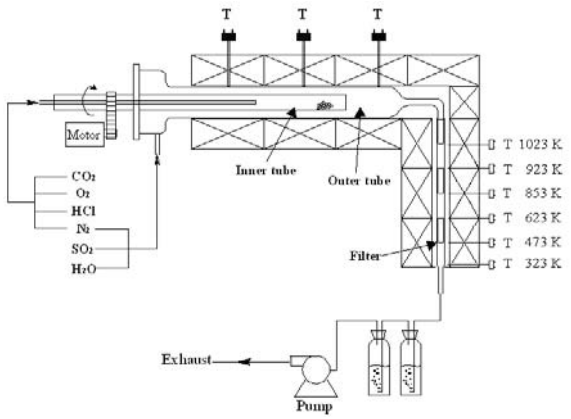

Fig. 1 schematic of the experimental apparatus

3. Results and discussion

3.1 $N_2/CO_2/O_2/HCl$ system (base condition)

Pb and Cd entirely deposited in a form of chloride at the temperatures below 853 K in the cooling zone in $N_2/CO_2/O_2/HCl$ system, as evidenced by the XRD spectra. Clearly, these two metals were entirely vaporized as gaseous chlorides under the given experimental conditions. This is consistent with the fact the boiling points of their chlorides are lower than the furnace temperature, *i.e.* 1223 K and 1233 K for $PbCl_2$ and $CdCl_2$, respectively.

3.2 Effect of SO_2 and H_2O on condensation of Pb and Cd

As demonstrated in Fig. 2, dosing 1000 ppm SO_2 into the outer tube caused the remarkable deposition of Pb at the temperature range of 1023-853 K, in comparison to no deposition occurring at the temperatures for the basic $N_2/O_2/CO_2/HCl$ system. With respect to Cd, its deposit at 923-853 K was also confirmed, whereas less was found at 1023-923 K. Elemental analysis indicated the dominance of sulfates for the high temperature deposits (>853 K), while both sulfates and chlorides were condensed at low temperature (853-473 K). Increasing SO_2 concentration to 2000 ppm caused the deposition of larger fractions of Pb and Cd at 1023-853 K.

Dosing 8% H_2O with 2000 ppm SO_2 together further shifted the deposition of Pb and Cd vapors to high temperatures. The deposition fraction of Pb and Cd at 1023-923 K was improved by 9% and 6%, respectively, implying the promotion effect of H_2O on the formation of high-melting species such as sulfate.

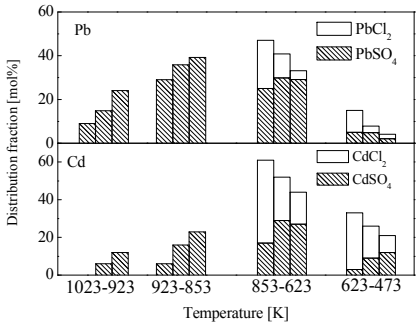

Fig.2 Deposition of Pb and Cd under the conditions with SO_2 and/or steam in outer tube. The three columns from left to right for each temperature respectively represent basic condition +1000 ppm SO_2, basic condition +2000 ppm SO_2, and basic condition +2000 ppm SO_2+8% H_2O)

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