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ATTACHMENT 3

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CAPTURE OF TOXIC METALS BY VARIOUS SORBENTS DURING FLUIDIZED BED COAL COMBUSTION*

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ABSTRACT

This study investigated the potential of employing suitable sorbents to capture trace metallic substances during fluidized bed coal combustion. The objectives of the study were to demonstrate the capture process, identify effective sorbents, and characterize the capture efficiency.

Experiments were carried out in a 25.4 mm (1") quartz fluidized bed coal combustor enclosed in an electric furnace. In an experiment, a coal sample from the DOE Coal Sample Bank or the Illinois Basin Coal Sample Bank was burned in the bed with a sorbent under various combustion conditions and the amount of metal capture by the sorbent was determined. The metals involved in the study were arsenic, cadmium, lead, mercury and selenium, and the sorbents tested included bauxite, zeolite and lime. The combustion conditions examined included bed temperature, particle size, fluidization velocity (percent excess air), and sorbent bed height. In addition to the experimental investigations, potential metal-sorbent reactions were also identified through performing chemical equilibrium analyses based on the minimization of system free energy.

The work is still ongoing and the detailed experimental and theoretical results will be presented at the meeting.

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INTRODUCTION

Toxic trace metallic elements such as arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium are usually contained in coal in various forms. These metals will either stay in the ash or be vaporized during high temperature combustion. Portions of the vaporized metals may eventually be emitted from a combustion system. Most of the emitted metals will be in the form of metal fumes or particulates with diameters less than 1 micron and are potentially hazardous to the environment (1).

Current practice of controlling trace metal emissions during coal combustion employs conventional air pollution control devices (APCDs), e.g., venturi scrubbers, electrostatic precipitators, baghouses etc., to collect fly ash and metal fumes. The control may not always be effective on metal fumes due to their extremely fine sizes (2).

Concern over toxic trace metal emissions from coal-fired combustion sources is growing, especially as the result of the passage of the 1990 Clean Air Act Amendments (CAAA) where eleven metallic elements, i.e., antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium are listed as potential hazardous air pollutants. To address the concern, the US DOE has recently co-sponsored a workshop jointly with the Electric Power Research Institute (EPRI) and the Energy and Environmental Research Center (EERC) on Trace Elements Transformations in Coal-Fired Power Plants (held in Scottsdale, Arizona, April 19-22, 1993). The objective of the workshop was to evaluate the current level of understanding on metal behavior during coal combustion and to identify potential technologies for improved metal emission control.

This study is to explore the opportunities for improved control of toxic trace metal emissions from coal-fired combustion systems. Specifically, the technology proposed is to employ suitable sorbents to (1) reduce the amount of metal volatilization and (2) capture volatilized metal vapors during coal combustion. The proposed project is to demonstrate the technology in a fluidized bed coal combustor.

SCIENTIFIC DISCUSSION

During high temperature coal combustion, metals in coal will either stay in the ash or be vaporized in combustion chambers. Most of the vaporized metals will decompose and/or react and eventually recondense during the cooling of flue gas. Two competitive mechanisms are associated with the condensation process, namely, (1) homogeneous nucleation which generates metal fumes (particulates) and creates metal emission problems; and (2) heterogeneous condensation which deposits metals onto available surfaces such as pre-existing fly ash, boiler tubes and combustor walls (3). The proposed technology is to minimize the formation of metal fumes at the hot-end of the coal combustion process, i.e., in the combustion chamber.

Specifically, the technology is to employ suitable and effective sorbents to:

(1) reduce the amount of metal volatilization during coal combustion in the combustion chamber through promoting chemical reactions between metals and sorbents

to form less-volatile metal compounds at an elevated combustion temperature, and

(2) capture volatilized metal vapors by sorbents through the mechanism of chemisorption and/or heterogeneous deposition.

EXPERIMENTAL

Experiments were carried out semi-batchwise in a 25.4 mm (1") OD quartz fluidized bed coal combustor. For each experimental run, a bed of sorbent was preheated to the desired temperature under the designed operating conditions. A predetermined amount of coal was then charged in the bed at a constant feed rate for combustion. After the combustion was completed, the bed residue including sorbent and ash was discharged for analysis of metal concentration. The experimental parameters included: coal type and size, sorbent type and size, sorbent amount, combustion temperature, and air flow rate. The metals examined included arsenic, cadmium, chromium, lead, mercury, and selenium and the sorbents tested included limestone, bauxite, and zeolite.

Specifically, the objectives of the experimental work were to:

1. evaluate the effectiveness of the metal capture process,
2. characterize the effects of operating conditions,
3. investigate capture mechanisms, and
4. identify effective sorbents.

EQUILIBRIUM CALCULATION

A combustion equilibrium model was developed based on the minimization of system free energy to simulate the equilibrium speciation in a coal combustor under various combustion conditions. Potential metal-sorbent reactions were theoretically identified according to the simulation results.

CHEMICAL ANALYSIS

Metal concentration in the coal, original sorbent, and combustor residue was determined by an atomic absorption spectrophotometer. A modified EPA Method 3050 was used to digest metals from the sorbent surface, which involves the using of HNO_3, HCl and HF acids (4). Toxicity Characteristics Leaching Procedure (TCLP) tests were performed to determine the leachability of the process.

RESULTS AND DISCUSSION

Table 1 displays trace metal concentrations in several selected coal. The results indicate that most of the trace metal concentrations are very low below 10 ppm. It should be noted that the trace metal concentrations in coal are not uniform. The reported concentrations are the average of 30 measurements.

Preliminary metal capture results have indicated that metal capture efficiency varies with metal species and sorbent involved. However, additional experiments are required in order to provide a statistically accepted conclusion. The experiments are still ongoing and the results will be presented at the meeting.

CONCLUSIONS

Metal capture by sorbents has been observed to be highly promising during waste incineration. This study is to explore the possibility of employing this technology for metal emission control during coal combustion. Additional experiments are still ongoing to provide a statistically accepted conclusion, which will be reported at the meeting.

ACKNOWLEDGEMENTS

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LITERATURE CITED

1. Davidson, R. L., Natush, D. F. S., Wallace, J. R., and Evans, C. A., "Trace Elements in Fly Ash Dependence of Concentration on Particle Size," Environmental Science & Technology, **8**, 1107 (1974).

2. Oppelt, E. T., "Incineration of Hazardous Waste - A Critical Review," JAPCA, **37**, 558 (1987).

3. Friedlander, S. K., Smoke, Dust and Haze Fundamentals of Aerosol Behavior, John Wiley and Sons, New York, 1977.

4. Gao, D. and Silcox, G. D., "The Effect of Treatment temperature on Metal Recovery from a Porous Silica Sorbent by EPA Method 3050 and by An HF-Based Method," Air and Waste, **43**, 1004 (1993).

Table 1. Trace Metal Concentrations in Selected Coal (ppm)

Metal	Indiana V	Indiana VII	Illinois 6
As	4.7	6.1	3.3
Cd	0.4	0.4	0.3
Cr	11.0	14.0	14.0
Hg	1.8	2.1	0.1
Pb	10.0	18.0	27.0
Se	2.5	1.5	1.6