

**OHIO COAL DEVELOPMENT OFFICE  
ANNUAL PROJECT ABSTRACT  
AS OF DECEMBER 2004**

1. **PROJECT SPONSOR:**  
University of Cincinnati  
Department of Chemical Engineering  
P.O. Box 210012  
Cincinnati, OH 45221-0012
2. **PROJECT MANAGER/TITLE:**  
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3. **OCDO GRANT NO.** OCRC III B4.7
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5. **PROJECT TITLE:** Gas Phase Chelating Sorbents for Removal of Mercury from Flue Gases
6. **PROJECT TERM FROM:** September 1, 2003      **TO:** August 31, 2004
7. **PROJECT UPDATE**  **--OR--** **FINAL REPORT**
8. **BUDGET:**
- | <u>CO-SPONSOR'S NAME</u>    | <u>COST-SHARE</u> |
|-----------------------------|-------------------|
| OCDO                        | \$ 79,995         |
| University of Cincinnati    | \$ 28,189         |
| _____                       | \$ _____          |
| _____                       | \$ _____          |
| _____                       | \$ _____          |
| <b>TOTAL PROJECT VALUE:</b> | \$ 108,184        |

**ABSTRACT**

9. **OVERVIEW OF PROJECT & OBJECTIVES:**

The objective of this research is to develop a novel, cost-effective, chelate based adsorbent for the removal of mercury from flue gases emitted from a power plant burning Ohio coal. A robust adsorbent is being developed for the harsh flue gas environment in a coal-fired power plant. It is anticipated that the high specificity and capacity for mercury and rapid adsorption kinetics combined with a simple adsorbent architecture will

significantly reduce the cost of capture of mercury and minimize the generation of secondary wastes.

The use of chelation for the direct removal of mercury from flue gases is a unique aspect of this research, which ensures the high selectivity and binding strength.

The goals of the first year (2001-02) of the project were to synthesis and characterize a prototype of the adsorbent. The synthesis method was successfully developed and the detailed characterization was done for the adsorbent. In the second year (2002-03), the ability to capture vapor-phase mercuric chloride from nitrogen gas was evaluated. The adsorbent was found to have a very high operating capacity and good dynamic characteristics. The effects of the acid gases  $\text{SO}_2$  and  $\text{CO}_2$  on capture efficiency were individually investigated and no effect was observed. In the third year (2003-04), the dynamic capacity of the prototype for vapor-phase mercuric chloride was determined under simulated flue-gas conditions in the temperature range of 208-260°F. No breakthrough of pollutant was observed for all cases studied. It is estimated that the adsorbent has a minimum operating capacity of 18 mg Hg/g of adsorbent. The thermal stability of the adsorbent was tested in cyclic thermal stress experiments. It was shown that the adsorbent is stable up to 275°F. This implies that use of the prototype in an adsorption unit immediately downstream of the electrostatic precipitators will require some cooling prior to treatment. To eliminate this requirement, the syntheses of advanced versions of the adsorbent with a higher operating temperature were explored. Suitable chelating ligands were identified and the chemistry for bonding them to porous silica was researched. In the current year (2004-05) three objectives are being pursued: (1) Evaluation of  $\text{HgCl}_2$  capture from simulated flue gas with thermally robust adsorbents at temperatures in the range 280-350°F; (2) detailed investigations to relate performance to operating conditions in the fixed-bed contacting system; and (3) basic investigations to extend the capability of the adsorbent to the capture of elemental mercury.

## **10. WORK TO DATE & CONCLUSIONS:**

Five new types of chelating adsorbents were synthesized and characterized using TGA and elemental analysis. Thermal stability studies showed that adsorbents activated with 3-mercaptopropyltrimethoxysilane (MPTS), dithizone (CPTS-DZ), and 2-mercaptopbenzothiazole (APTS-MBT) have an upper temperature limit of 200°C, 180°C, and 190°C, respectively. These temperatures are higher than the expected upper temperature of flue gas exiting the particulate collector unit (160°C). The effect of HCl gas on mercuric chloride removal was also studied. HCl appears to enhance the solubility of  $\text{HgCl}_2$  in the solvent layer, which may further increase the operating capacity of the adsorbent. Mercury chloride removal by the cysteine prototype adsorbent was further studied under simulated flue- gas conditions with and without water vapor at 100°C. It was found that water vapor has no effect on capacity. The potential of the newly developed, thermally robust chelating adsorbents (MPTS, CPTS-DZ, and APTS-MBT) to capture mercuric chloride at 100°C under simulated flue gas conditions was also determined. Flue gas components were found not to interfere with mercuric chloride, and all three adsorbents showed high efficiency and capacity.

Homogeneous, as well as heterogeneous reduction mechanisms of  $\text{Hg}^{2+}$  to  $\text{Hg}^{\circ}$  in the gas phase were also studied at  $160^{\circ}\text{C}$ . Results showed that  $\text{SO}_2$  and water vapor were the main inhibitor for  $\text{Hg}^{\circ}$  oxidation, while the presence of  $\text{HCl}$  is critical for maintaining mercury in its oxidized form.

Research is now in progress to systematically study the potential of newly developed thermally robust adsorbents to capture mercuric chloride at temperatures above  $100^{\circ}\text{C}$ . The focus is to define operating conditions that will give complete effluent composition histories within a reasonable experimental timeframe (2-5 days). This will be followed by detailed studies to define basic characterization coefficients for fixed-bed adsorbent design.

#### **11. PLANS FOR COMING YEAR:**

Evaluation of mercuric chloride capture with thermally robust adsorbents in the temperature range of  $280\text{-}350^{\circ}\text{C}$  will be undertaken. The goal is to eliminate the existing need for gas cooling, lowering the process cost.

Fixed-bed adsorption as a contacting option will be evaluated in detail. The measurement of capacity and rate characteristics as a function of operating conditions is required to enable a systematic evaluation of the potential for scaling packed-bed systems.

Basic investigations will be initiated to extend the capability of the adsorbent to the capture of elemental mercury.

#### **12. HIGHLIGHTS/ACCOMPLISHMENTS:**

A) Advanced versions of the adsorbent with higher operating temperatures were successfully synthesized. These should enable use immediately downstream of the electrostatic precipitators without a cooling requirement.

B) The effects of flue gas components on mercuric chloride uptake were evaluated.

C) The reduction mechanisms of  $\text{Hg}^{2+}$  to  $\text{Hg}^{\circ}$  in the gas phase were studied at  $160^{\circ}\text{C}$ .

#### **13. ARTICLES/PRESENTATIONS:**

1. Abu Daabes, M. and N.G. Pinto, **Synthesis and Characterization of a Nano-structured Sorbent for the Direct Removal of Mercury from Flue Gases by Chelation**, in press Chem Eng. Sci., Jan. (2005).