TITLE: EFFECTS OF FLY ASH ON MERCURY OXIDATION DURING POST COMBUSTION CONDITIONS

PIs: R.C. Brown and G.A. Norton

STUDENTS: Hongqun Yang, Tim Eickman, Saw-choon Soo, Jason Lewis, Daniel Hummer, and Jonathan Rixen

INSTITUTION: Iowa State University
Center for Sustainable Environmental Technologies
Ames, Iowa 50011
rcbrown@iastate.edu
515-294-7934 (phone)
515-294-3091 (fax)

SUBCONTRACTORS: D.L. Laudal and J. Erjavec, University of North Dakota
J.M. Okoh, University of Maryland Eastern Shore

GRANT NO: DE-FG26-98FT40111

PERIOD OF PERFORMANCE: Sept. 1, 1998 – Aug. 31, 2001 DATE: March, 2001

ABSTRACT

OBJECTIVE

The goal of this research is to provide fundamental information on post-combustion flue gas chemistry by helping to elucidate the role of fly ash in Hg oxidation chemistry. Through an improved understanding of the role of fly ash on Hg chemistry, it is hoped that this will in turn help predict Hg speciation in gas streams from coal-fired boilers. Therefore, the focus of this work was to help identify major factors affecting Hg speciation, with a particular emphasis on the fly ash components present in the gas stream.

ACCOMPLISHMENTS TO DATE

Tests were performed in simulated flue gas streams using two fly ash samples from the electrostatic precipitators of two full-scale utility boilers. One fly ash was derived from a Powder River Basin (PRB) coal, while the other was derived from Blacksville coal (Pittsburgh No. 8 seam). The whole fly ashes as well as sized and magnetically separated subsamples were exposed to streams of elemental Hg in various gas matrices containing gases found in coal-derived flue gas. The amount of Hg oxidized in the presence of fly ash under a variety of test conditions was determined using the Ontario Hydro method. Although the two fly ashes tested were chemically and mineralogically diverse, there were generally no large differences in catalytic potential (for oxidizing Hg) between the two. The

Blacksville fly ash tended to show somewhat more catalytic activity than the PRB fly ash, but this could be largely due to the higher surface area of the Blacksville ash. The Blacksville fly ash was also much higher in unburned carbon than the PRB ash. However, the ash fraction that was enriched in unburned carbon did not show substantially elevated catalytic activity.

The gas stream composition and whether or not ash was present in the gas stream were the two most important variables. The presence of HCl, NO, NO_2, and SO_2 and all two-way gas interactions were found to be statistically significant. In addition, it appears that even four-factor interactions between those gases are significant. The HCl, NO_2, and SO_2 were critical gases resulting in Hg oxidation, while the presence of NO appeared to suppress oxidation. Temperature was not a statistically important factor. The magnetic (Fe-rich) phases did not appear to be more catalytically active than the nonmagnetic phases. However, differences in surface area between the magnetic and nonmagnetic phases cloud this issue somewhat.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAMS

Mercury emissions from coal-fired power plants, which are predominantly in the vapor phase, are of environmental interest and may be regulated in the future. Consequently, considerable research on the removal of Hg from flue gas streams is being performed. The effectiveness of Hg abatement technologies is highly dependent on the Hg species present, but the chemistry affecting Hg speciation is poorly understood. Therefore, it is currently impossible to predict Hg removal efficiencies for any Hg abatement technology. Fly ash is an important flue gas component that may lead to catalytic oxidation of elemental Hg or otherwise attenuate the Hg stream. However, the mechanisms by which fly ash affects the distribution of Hg species are unknown, and little work has been performed to study the role of fly ash as it relates to flue gas chemistry. Results of this study will yield important information relating to the chemistry associated with the oxidation of Hg by fly ash. This will enable more accurate predictions to be made on Hg removal efficiencies using a variety of Hg abatement technologies. In turn, this information will be useful in determining how best to optimize Hg removal by a given technology by adjusting plant operating and fuel composition variables.

PLANS FOR THE COMING YEAR

A 35 kW laboratory scale, down-flow combustor will be used to study Hg chemistry further. The combustor, which has been fitted with a double pulse-jet baghouse system (two baghouses in series), has the capability to entrain solids into the primary air flow and to inject chemicals into the secondary air flow. As one coal is being fired in the combustor, fly ash from a different coal will be injected into the clean gas stream after the first baghouse. The second baghouse will remove the injected fly ash prior to analyzing the flue gas stream for total Hg and elemental Hg vapors using a continuous emission monitor. This will be performed with both the PRB and Blacksville coals and fly ash samples. In other words, PRB fly ash will be injected into filtered Blacksville flue gas, and the change in the percentage of oxidized Hg (relative to total vapor phase Hg) will be observed as the fly ash is injected. Similarly, Blacksville fly ash will be injected into filtered PRB flue gas. Results of those tests will help determine whether the ash plays a critical role in determining Hg speciation, or whether it is actually the flue gas matrix generated by a particular coal that is the primary factor affecting Hg speciation.

ARTICLES, PRESENTATION, AND STUDENT SUPPORT

Journal Articles (peer reviewed): None

Conference Presentations:

- G. A. Norton, H. Yang, R. C. Brown, D. L. Laudal, G. E. Dunham, J. Erjavec, and J. M. Okoh, "Role of Fly Ash on Mercury Chemistry in Simulated Flue Gas Streams," to be presented at the 94th Annual Conf. of the Air & Waste Management Assoc., Orlando, FL, June 24-28, 2001.

- G. A. Norton, H. Yang, R. C. Brown, D. L. Laudal, G. E. Dunham, and J. M. Okoh, "Effects of Fly Ash on Mercury Oxidation in Simulated Flue Gas Environments," 93rd Annual Conf. of the Air & Waste Management Assoc., Salt Lake City, UT, June 18-22, 2000.

- G. A. Norton, H. Yang, R. C. Brown, D. L. Laudal, G. E. Dunham, and J. M. Okoh, "Effects of Fly Ash on Mercury Oxidation During Post Combustion Conditions," presented at the 2000 University Coal Research Contractors Review Meeting, Pittsburgh, PA, June 6-7, 2000.

- H. Yang and G. A. Norton, "Effects of Fly Ash on Mercury Oxidation in Simulated Flue Gas Environments," Annual Meeting of the Iowa Academy of Science, Des Moines, IA, April 21-22, 2000.

- G. A. Norton, H. Yang, R. C. Brown, D. L. Laudal, G. E. Dunham, and J. M. Okoh, "Effects of Fly Ash on Mercury Oxidation During Post Combustion Conditions," presented at the 1999 University Coal Research Contractors Review Meeting, Pittsburgh, PA, June, 1999.

Students Supported under this Grant

- Hongqun Yang, graduate (Ph.D) student in chemical engineering, Iowa State University
- Tim Eickman, undergraduate student in chemical engineering, Iowa State University
- Saw-choon Soo, undergraduate student in chemical engineering, Iowa State University
- Jason Lewis, undergraduate student in chemical engineering, Iowa State University
- Daniel Hummer, undergraduate student in chemistry, Iowa State University
- Jonathan Rixen, undergraduate student in chemical engineering, Iowa State University