PROJECT facts

Advanced Research

08/2007

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

NETL

Coal Biomodification to Reduce Mercury Emissions

Description

In partnership with a number of key stakeholders, the U.S. Department of Energy's Office of Fossil Energy (DOE/FE), through its National Energy Technology Laboratory (NETL), has been carrying out a comprehensive research program since the mid-1990s to develop advanced, cost-effective mercury control technologies for coal-fired power plants. Anticipating new Federal rules and possible state legislation, NETL's Advanced Research organization has supported the laboratory's Innovations for Existing Plants (IEP) Program, leading a consortium-based research effort to resolve mercury control issues. In one consortium project, bioengineering researchers at the Oak Ridge National Laboratory (ORNL) have investigated bioleaching of mercury (Hg) from coal by using iron and sulfur-oxidizing bacteria during sulfur removal prior to processing the coal for combustion. This is a novel approach in that most mercury control projects have focused on removing mercury from the gases produced by combustion.

Control of power plant mercury emissions is mandated by a U.S. Environmental Protection Agency (EPA) rule issued in 2005 (the Clean Air Mercury Rule, or CAMR), which establishes a "cap-and-trade" program that applies to both existing and new plants in the populous Eastern and Midwestern United States, where mercury deposition is the highest. Phase I will begin in 2010 with a 38 ton-per-year emissions cap, and Phase II requires a 15 ton cap beginning in 2018. It has been estimated that U.S. coal-fired power plants currently emit about 48 tons of mercury per year, so the Phase II cap will require an overall average reduction in mercury emissions of about 69 percent. The CAMR is tied to EPA's Clean Air Interstate Rule (CAIR), also issued in 2005, which permits "co-benefit" mercury reductions achieved through emission controls on sulfur dioxide (SO_2) and nitrogen oxides (NO_X). Together, the CAMR and the CAIR create a multi-pollutant strategy to reduce emissions throughout the United States.

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Objective and Technical Approach

The main objective of this project was to investigate a biological process to remove a large fraction of the mercury trapped in high-sulfur coal prior to thermal processing (combustion). Mercury-sulfur compounds were considered the most likely form of mercury found in coal. Oxidizing bacteria are known to release sulfur and iron from metal-binding sulfides in coal — in a process called microbial bioleaching. It was believed that the same process could be used to release the mercury into the leachate. The project focused on: selecting well-defined species of bacteria and coal for proof-of-concept tests; quantifying the amount of mercury removed by bioleaching, along with sulfur and iron (Fe); identifying bacteria capable of performing the bioleaching/biomodification of coal; assessing the effectiveness of the bioleaching process; and demonstrating a method for mercury removal from the leachate using sorbent resins.

Laboratory simulations of a coal biomodification process were conducted using columnar and heap configurations. In the former, 1-liter columns were used as bioreactors while in the latter, the coal sample was heaped using a sintered glass funnel to simulate a coal pile. A liquid medium was continuously circulated through the coal to provide nutrients to the microorganisms and to remove mercury dissolved from the coal by the microorganisms. It was anticipated that these microbes would operate synergistically and were likely to come from two or three bacterial families. One pure culture, *Acidithiobacillus ferrooxidans*, and several microbial consortia, were studied. Additional parameters also were studied, such as water composition and level of bacteria.

Results of semi-continuous experiments showed that up to 20 percent more mercury could be removed from the coal in the pure cultures than from environmental control samples obtained from acid mine drainage in several locations, which contained only indigenous bacteria. These experiments showed that up to 50 percent of the mercury could be removed from both pure and environmental types of samples under non-optimized conditions, leading to the hope that closer control of conditions could lead to even larger future gains.

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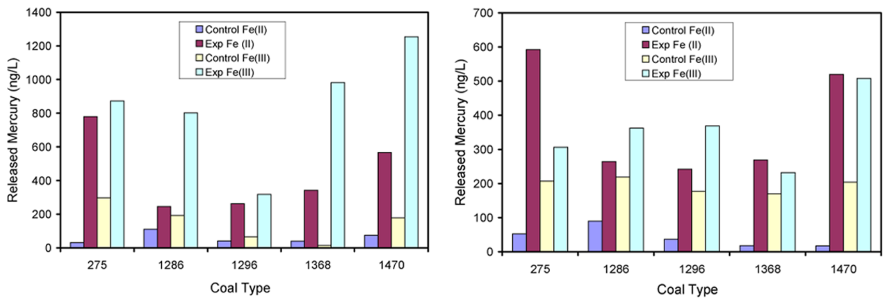

Removal of mercury from various coals by environmental culture enrichment VA#2 (left) and VA#3 (right) with different species of iron augmentation.

Growth of *At. ferrooxidans* in stirred tank reactor at time zero (middle) and after 48 h (right). Iron(II) oxidation is evident.

PROJECT DURATION

Start Date
10/01/02

End Date
09/30/07

COST

Total Project Value
$760,000

DOE/Non-DOE Share
$760,000 / $0

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Accomplishments

Results to date from this project demonstrated that mercury removal, along with sulfur and iron removal, increases the attractiveness of bioleaching technology as a commercial option sufficiently to warrant thorough larger-scale testing and modeling. It also demonstrated a method of mercury removal from the leachate so the leachate can be recycled. Further, the results demonstrate the potential for removal in a continuous process, in which the mercury is dissolved from the coal and volatilized in a single reactor/vessel into the gas phase for removal. Further research on this process is in progress.

Based on results from this project, an invention disclosure was submitted to the ORNL Technical Transfer Office on the bioleaching and removal of mercury from coal. This technology is currently being evaluated for patent application. A proposal also was made for collaboration with the U.S. Department of Agriculture (USDA) to investigate sorbents for mercury removal developed at the USDA.