TITLE: SYNTHESIS OF SULFUR-BASED WATER TREATMENT AGENT FROM SULFUR DIOXIDE WASTE STREAMS

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ABSTRACT

OBJECTIVE

The overall objective of this research is to develop sulfur byproducts from sulfur dioxide that is generated during gas-stream cleanup in advanced power systems. Specifically, we will explore synthesis of polymeric ferric sulfate (PFS), an aluminum-free flocculating agent, from sulfur dioxide. Integration of PFS synthesis with an electric power plant would be an important step toward realizing coal refineries, a concept in which every waste stream becomes a feedstock for another process.

ACCOMPLISHMENTS TO DATE

1. Literature search. A review of international literatures on synthesis, characterization, and application of polymeric ferric sulfate and other flocculating agents has been performed in last few months. The information was used to help design the sulfur removal system.

2. Design and construction of reactor system for polymeric ferric sulfate synthesis. A reactor system has been designed and constructed. The reaction system consists of a 4 dm^3 cylindrical reactor and ancillary equipment, including motors, acid-proof gas flow meters, pumps, a SO_2 on-line analyzer with detection range of 0-2%, and a model RTE-111 recalculating temperature controller. Chemicals for

PFS synthesis (including $NaClO_3$ and $FeSO_4 \cdot 7H_2O$) and gases for preparing synthetic flue gas (including SO_2 and N_2) have been ordered.

3. Assembly of polymeric ferric sulfate analysis system. All lab ware and chemicals needed to test the quality indices of polymeric ferric sulfate including total iron concentration and yanjidu (basicity) have been ordered. Standard solutions have been prepared and experiments for testing polymeric ferric sulfate quality indices have been practiced.

4. Jar test of PFS. A comparison of the coagulation performance of PFS and ferric sulfate (FS) was conducted. The results showed that PFS is, in general, more effective than FS in reducing the turbidity of kaolinite suspensions for various conditions used in the study.

5. Training students. We have hired four graduate students and four undergraduate students for the DOE UCR project. They have performed literature searches and been responsible for equipment and supplies, including the the synthesis reactor, SO_2 analyzer, and chemicals used for removing SO_2 and measuring quality of PFS. They have been trained on testing PFS quality and performing PFS coagulation.

6. Collaboration with industry. In addition to our industrial collaborators in the U.S., we have recently held discussions with Vitro, a large Mexican corporation with glass manufacturing facilities throughout North America. Their interest is to explore the use of high-sulfur fossil fuels in firing glass furnaces without producing high emissions of sulfur dioxide.

SIGNIFICANCE TO POWER GENERATION INDUSTRY

The conversion of coal to electricity generates vast quantities of sulfur-laden waste streams, either as gaseous sulfur dioxide emitted to the atmosphere or as sludge containing calcium sulfate, which is typically landfilled. Advanced coal conversion technologies will effectively remove sulfur but in the process generate a concentrated stream of sulfur dioxide. Industrial ecology principles mandate the conversion of this sulfur dioxide into a high-value product for market. Sulfur acid is an obvious product from sulfur dioxide, but the market price for this commodity chemical does not encourage new capital investment for its production.

Synthesis of polymeric ferric sulfate from sulfur dioxide is proposed in this project. Polymeric ferric sulfate is a flocculating agent that has been widely adopted for water treatment in some parts of the world because of public health concerns about aluminum-based flocculating agents. Several medical studies implicate aluminum as an agent in the development of Alzheimer’s disease. This project offers the prospect of addressing both air pollution and water pollution problems through the synthesis and application of PFS.

PLANS FOR THE COMING YEAR

We will perform a series of experiments to determine the optimal parameters for high conversion of SO_2 in the feedstock gas stream into PFS. Conditions to be evaluated include stoichiometry of each reaction, temperature of the reactor, partial pressure of SO_2 in the feedstock gas, iron concentration in the reactor, and polymerization time. Factorial experiments will be designed to evaluate the effects of the above parameters on sulfur conversion efficiency and PFS quality. The statistical applications package SAS will be used to develop factorial experiments among the experimental variables and to test the significance of each factor.

The kinetic model of SO_2 oxidation will be developed in the coming year. Also, modification of PFS with the addition of organic polymer will be explored in an effort to enhance the effectiveness of PFS on water and waste water treatment. Pilot scale tests of water treatment will be conducted at Des Moines Water Works (DMWW). The tests will determine the effectiveness of PFS on the treatment of surface water from Des Moines River at DMWW.

ARTICLES, PRESENTATION, AND STUDENT SUPPORT

Journal Articles (peer reviewed):

1. Maohong Fan, Robert C. Brown, Shih Wu Sung and Yahui Zhuang, "A Process for Synthesizing Polymeric Ferric Sulfate Using Sulfur Dioxide from Coal Combustion", submitted to the *International Journal of Environmental Protection.*

2 Maohong Fan, Shih-Wu Sung, Robert C. Brown, Thomas D. Wheelock and Fran C. Laabs, Synthesis, Characterization, and Coagulation Performance of Polymeric Ferric Sulfate, submitted to *Journal of Environmental Engineering*.

Conference Presentations:

1. Maohong Fan, Robert C. Brown, Shih Wu Sung and Yahui Zhuang, "A Process for Synthesizing Polymeric Ferric Sulfate Using Sulfur Dioxide from Coal Combustion", *Proceedings of the Seventh Annual International Pittsburgh Coal Conference*, Pittsburgh, Sep 11-15, 2000.

Students Supported under this Grant

- Aron D. Butler, graduate student in environmental engineering, Iowa State University
- Eric Carter, undergraduate student in mechanical engineering, Iowa State University
- Matt Byer, undergraduate student in chemistry, Iowa State University
- Lee Sunki, graduate student in environmental engineering, Iowa State University
- Yun Lu, graduate student in chemistry, Iowa State University
- Zhi Zhang, graduate student in agricultural and biosystems engineering, Iowa State University
- Fanghong Zhou, a special student at Iowa State University
- Karen Lodden, undergraduate student in chemistry, Iowa State University
- Duangmanee Thanapong, graduate student in environmental engineering, Iowa State University