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Project Title: **Foaming in Radioactive Waste Treatment and Immobilization Processes**

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Summary/Project Report Required Data

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Research Objective

The overall objective of this research project is to develop a basic understanding of the mechanisms that produce foaming in a three-phase system (solid/liquid/gas) combined with a specific application to foaming during nuclear waste treatment. In our first annual report, we established the role of solid colloidal particles in generating foam. Therefore, the specific objective of this year=s research was to investigate the effects of the concentration of the particles, size and polydispersity in size on the nature and amount of foaminess. This study will aid in developing an understanding of tailoring the properties of solid particles to mitigate foaming.

Research Progress and Implications

This report summarizes the work completed during the second year of a three-year project. Nuclear waste treatment requires various engineered unit operations. These operations often require boiling and contacting of gas-liquid in the presence of solid particles, creating an environment which is often neglected in fundamental studies of foam formation: the three-phase gas/liquid/solid foaming system. The lack of basic understanding of foaming and antifoaming mechanisms has led to the implementation of empirical approaches to address foaming and its impact on the treatment process. Therefore, to fundamentally study the role of solid particles in generating foam in the absence of surface-active agents, we used a model of a suspension of silica particles, which are also present in the sludge simulant studied earlier by us.

The silica particles used for this study were supplied by Nalco Chemicals, Naperville, IL and Nissan Chemicals, NY. The silica particles were hydrophilic in nature and were supplied as a suspension in water. The pH of the suspension was measured to be between 9 and 10.5 for all particle sizes. The three- phase foam was generated by aeration of the suspension at the room temperature using a sintered glass filter. The three-phase foam studies were supplemented by a single foam lamella study to investigate the interaction between the solid particles confined between lamella surfaces. The single lamella studies were carried out using our novel Capillary Force Balance Apparatus, developed in our laboratory. The properties of solid particles found to play a role in foam formation are concentrations of solid particles, size of the particles and polydispersity in size. The other factor that was found to have an effect on foaminess is the rate of aeration.

<u>Effect of Solid Particle Concentrations</u>: The effect of the particle concentration on foaminess was studied by creating various dilutions of the supplied suspensions of silica particles. The size of the silica particle studied was 7-9nm and the three different concentrations studied were 2.5 vol%, 5 vol% and 10 vol%. A fixed volume of the suspension was aerated at the fixed rate of aeration to create three- phase foam. Foaminess is characterized by the amount of air incorporated into the system. When the silica particle concentration was increased from 2.5 vol% to 10 vol% the amount of foaminess in the system went up from 20% to 550%. Therefore, results of this study clearly revealed that the higher the particle concentration, the greater the foaminess. The gas bubbles were observed to be quite monodispersed in size averaging 4-6mm in diameter. Another noteworthy observation was that foam of this kind has negligible foam stability, i.e. when the aeration was stopped foam collapsed in few seconds. This observation confirms the fact that the system has no surface-active agents. In the absence of surface-active agents, during the bubble generation and rise, due to confinement in the foam lamella, solid particles organize themselves into a layered structure. This particle layer formation inside the foam lamella provides a barrier against coalescence of bubbles, and thereby causes foaminess. Using the Capillary Force Balance we verified that silica particles form a layered structure inside the single foam lamella. We also observed that the foam lamella thins more slowly with an increase in solid concentration. We have also theoretically predicted that the structural barrier provided by the layer formation of solid particles becomes stronger with the increase in concentration of solid particles. Therefore, the higher the concentration of solid particles, the stronger the structural barrier, resulting in greater foaminess.

<u>Effect of Particle Size</u>: The effect of particle size on foaminess was studied for different particle sizes at a constant particle concentration. The particle sizes studied were 7-9nm, 11-14nm, 19nm and 100nm. The foaminess experiments were carried out at 10 vol% of silica particle concentration. When particle size was increased from 7-9nm to 100nm, the amount of foaminess went down from 550% to 15%. The results show that foaminess decays exponentially with an increase in particle size. As we have stated above, in this kind of system foaminess is caused by particle layer formation inside the foam lamella, and this layering depends on the effective particle concentration. Therefore, as we increase the size of the particle, keeping the same geometrical volume fraction, the effective volume fraction of the particle goes down. Therefore, the greater the size of particle, the lower the effective volume fraction at a constant geometrical volume fraction. A lower effective volume fraction leads to weakening of the layer formation and, thus, a reduction in foaminess.

<u>Polydispersity in Particle Size</u>: To study the effect of polydispersity in size on foaminess, a small quantity, 2 vol%, of large-sized particles, 100nm, were added to an 8 vol% of 7-9nm sized silica particles. The results of a polydispersed system are compared with 10 % monodisperse system 7-9nm silica particles. The results showed that with the addition of just 2 vol% of 100nm particles, the foaminess was reduced drastically. Polydispersity in size leads to weakening of the particle layering and weaker layering in turn leads to a reduction in foaminess.

Effect of Aeration Rate: Foaminess is essentially a result of the dispersion of air bubbles in the suspension, so the rate at which bubbles are generated has a direct influence on the amount of foaminess. Thus, as expected, a higher flow rate leads to higher foaminess.

Planned Activities

The sludge is a multi-particle system. Therefore, to understand the role of individual components on foaminess, we plan to develop a single component simulant and study its effect on factors affecting the foaminess. We are also studying the antifoaming mechanisms that will help in developing a suitable antifoamer to operate at high temperature.