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Foaming in Radioactive Waste Treatment and Immobilization Processes

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Research Objective

The objective of this research is to gain a basic understanding of the mechanisms that produce foaming during nuclear waste treatment, to identify the key parameters which aggravate foaming, and to identify effective ways to eliminate or mitigate foaming. The specific goal of this part of the study is to reveal the role of solid particles in colloidal range in foam formation and foam stability. The result of this study will aid in eliminating foaminess in three-phase gas/liquid/solid systems, thereby facilitating implementation of environmental technologies for radioactive waste treatment and waste immobilization processes.

Research Progress and Implications

This report summarizes work completed during the first year of a three-year project. To characterize the foam and identify key parameters for foaminess in a three-phase gas/liquid/solid system, a simulated (non-radioactive) acidified sludge was used. The sludge samples were prepared using PUREX sludge simulant and PHA (Precipitate Hydrolysis Aqueous) was prepared using irradiated precipitate. The pH of the sludge samples was 6.0-6.5 and pH of PHA was 4.0. Both of these samples were prepared at Savannah River Technical Center (SRTC) and were shipped to our laboratory at Illinois Institute of Technology, Chicago. The sludge contained Al (3.8 wt%), Hg (3.5 wt%), Fe (25.5 wt%) on dry basis and noble metals (Rh, Ru, Pd, Ag, Se) in small concentrations. The sludge particles were polydispersed in size varying from about 0.05 μ m to 10 μ m. Such a sludge sample is a good model representation of actual nuclear sludge. However, the preparation of sludge in terms of its constituents affects the foaminess.

Experiments were conducted by boiling the sludge in a small-scale evaporator after diluting it with PHA to 10-wt% from its original 20-wt%. The boiling point of the sludge was observed to be 101.5 - 102°C. The parameters which were found to play a key role during foaminess in this kind of three-phase system are the concentration of colloidal solid particles, heating temperature, electrolyte concentration, and composition of organic and inorganic components.

Solid Particles: The first set of experiments were conducted using a supernatant of sludge containing no particles. Foaminess was found to be 15-20%, where foaminess is defined as a percentage of air incorporation by volume. Other experiments with a sludge and PHA mixture showed 200-220% foaminess when solid particles were present. Thus, these experiments revealed that solid particles have a significant effect on foaminess. Besides foaminess, other noteworthy observations are that foaminess in such a system has negligible foam stability, i.e., as soon as the heating was stopped the foam collapsed, and the bubble size is only a few millimeters in diameter. Moreover, during boiling, the solid particle concentration increases and with increasing particle concentration, a maximum in foaminess is observed, which occurred around 18-19 wt% of the solid particle concentration for the sludge studied. The value of foaminess at this concentration was 200-220%. This maximum value of foaminess and solid concentration changes with the method of preparation of the sludge.

This maximum in foaminess can be attributed to the particles' surface properties such as hydrophilicity, hydrophobicity or biphilicity, and polydispersity in particle size. The solid colloidal particles stabilize the foam lamella, which leads to an increase in foaminess. But with an increase in particle concentration, due to an attractive depletion force, particles begin flocculating, and as a result we observe a maximum in foaminess. Therefore, the maximum in foaminess is a direct result

of the balance of two counter effects, namely the particle-particle interactions in the foam lamella leading to foam lamella stabilization before reaching a maximum value in particle concentration, and the attractive depletion force, which is predominant after the maximum concentration, thereby leading to foam destabilization.

Heating Temperature: The rate of generation of a gas is an important factor for foaminess, so the rate at which the gas is evolved has a direct bearing on foaminess. Foaminess increases exponentially with an increase in heating rate. But the noteworthy observation is that the maximum value of foaminess remains unaffected by heating rate.

Electrolyte Concentration: The effect of electrolyte concentration in sludge was studied by using the different diluting media: water, supernatant and PHA. Results showed comparatively lower foaminess in the case where supernatant and PHA are used to dilute the system. This observation can be explained by the fact that the lower foaming system has a higher electrolyte concentration. Besides foaminess, foam texture is also affected by electrolyte concentration, and with a higher concentration the foam lamella size becomes smaller. Further, as the electrolyte concentration increases during the boiling process, the particle-particle attraction improves, resulting in particle flocculation.

Organic and Inorganic Components: During the initial period of sludge boiling, higher foaminess is observed. As soon as the heating is started, the organic components and the decomposition of inorganic components lead to an evolution of a gas which causes an apparent increase in foaminess.

It is concluded that foaminess of the sludge is due to the presence of colloidal particles and has a maximum when particle concentration is increased. The foaminess increases with heating due to the higher gas bubble generation. With an increase in electrolyte concentration, the foam bubble size decreases. The presence of volatile organic components in the sludge leads to higher foaminess.

Planned Activities

The present study clearly revealed that the colloidal particles present in the sludge are the important cause for the foaminess observed. In the next year experiments are planned to study the effect of particle surface properties such as hydrophilicity, hydrophobicity and biphilicity of solid particles. One of the model systems proposed for our future experiments is a suspension of silica particles which are present in the sludge. We plan to use our newly developed capillary force balance technique to understand particle-particle interactions in causing foaminess and foam stability. Based on the results of these experiments, we will examine an antifoaming system which is able to mitigate foaminess at high temperatures.