

Stability of Decontamination Foam Containing Silica Nanoparticles and Viscosifier

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1. Introduction

A large amount of liquid waste is generated from the decontamination that occurs when dismantling nuclear facilities. A process is needed to decrease the amounts of chemical reagents and secondary waste produced during the decontamination process. Decontamination foam is a non-stable, two-phase fluid with aqueous and gas phases representing not more than 10% and 90% of the total volume, respectively. This formulation can significantly decrease the amounts of chemical reagents and secondary waste [1].

The advantage of decontamination foam is its potentially wide application for metallic walls, overhead surfaces, and the elements of complex components and facilities. In addition, foam is a good material for in situ decontamination because it generates low final waste volumes owing to its volume expansion. The application of foam allows for remote decontamination processing using only an injection nozzle and the equipment to generate the decontamination foam, which reduces operator exposure to high radioactivity [2,3].

The decontamination efficiency can be enhanced by improving the contact time between chemical reagents and a contaminated surface through the addition of surfactants and viscosifiers into the decontamination foam. The objective of this study is to investigate the effect of silica nanoparticles and a viscosifier on the foam stability and the dissolution behaviors of corroded specimens using a non-ionic surfactant.

2. Materials and Methods

2.1 Stability test for the decontamination foam

Elotant™ Milcoside 440N (EM 440N) is a decyl glucoside supplied by LG Household & Health Care. Xanthan gum (Sigma) and silica nanoparticles (M-5, Cabosil) were selected for testing as viscosifiers. The foaming properties (i.e., foam formation and foam stability) were determined using a Foamscan instrument (Teclis/IT Concept, Logessaigne, France). The foam is generated by blowing nitrogen gas at a flow rate of 200 ml/min through a porous glass filter at the bottom of a glass tube where 60 ml of the foaming aqueous solution (25 ± 1 °C) is placed.

In all experiments, the foam was allowed to reach a volume of 200 ml. The bubbling was then stopped, and

the evolution of the foam was analyzed using conductivity and optical measurements. The generated foam rose along a circular glass column, and the volume measurement was captured by an image analysis using a CCD camera. The amount of liquid incorporated in the foam, the foam homogeneity, and the liquid drainage from the foam were measured based on the conductivity in the glass column at the liquid sample and at different heights in the glass column using electrodes.

2.2 Dissolution test using decontamination foam

Inconel specimens 20 mm × 20 mm × 2 mm in size were used for the dissolution test. They were polished with abrasive paper and washed with water and ethyl alcohol. The corroded layer of the specimens was grown in a semi-loop filled with a solution, simulating the primary water in light water reactors. Four types of decontamination foam were prepared. Nanoparticles of 1 and 3 wt.% M-5 were added to 30 mL of a 1% EM 440N surfactant solution without or with 0.1 wt.% xanthan gum containing 1M HNO₃ to prepare the decontamination foam. The specimen was immersed in decontamination foam contained in 100 ml test bottles after shaking the decontamination foam. The concentration of dissolved iron from the specimens was measured using Flame Atomic Absorption Spectroscopy.

3. Results and Discussion

3.1 Stability test for the decontamination foam

The graph for the foam volume and liquid volume in foam as a function of time for four different formulations of EM 440N, xanthan gum, and M-5 nanoparticles shows an identical initial liquid volume in foam, v_0 , but different foam stabilities. In Fig. 1, the addition of 0.1 % xanthan gum increases the liquid volume in the foam by delaying the drainage. Compared to the foam stabilized only with 1% EM 440N, the addition of 0.1% xanthan gum improves the half-life [$\tau_{(v1/2)}$] by a factor of 5.5. The addition of 1% M-5 nanoparticles to 1% EM 440N and 0.1% xanthan gum did not increase the liquid volume in the foam. Compared to the foam stabilized by 1% EM 440N and 0.1% xanthan gum, the addition of 3% M-5 improve the half-life [$\tau_{(v1/2)}$] by a factor of 1.27. These results

indicate that the addition of a high concentration of nanoparticles improves the foam stability.

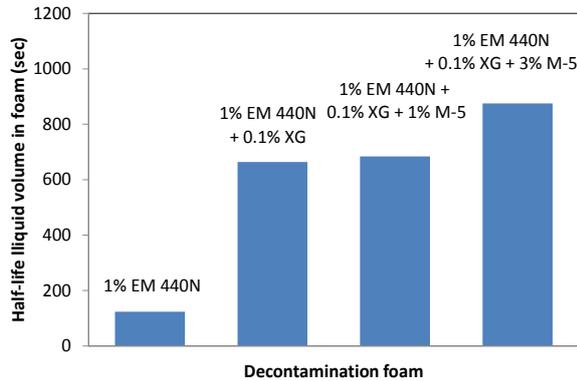


Fig. 1. Variation in the half-life liquid volume in foams that contain 1% EM 440N and 0.1% xanthan gum (XG) with 1% and 3% M-5 silica nanoparticles.

3.2 Dissolution test using decontamination foam

The concentration of the dissolved iron was analyzed by Flame-AAS after the dissolution tests for the decontamination liquid and foams. The results showed that the EM 440N foam had approximately 56% of the level of dissolved iron compared with the decontamination liquid (Fig. 2). Approximately 59% and 66% of the control level of dissolved iron were found using 1% EM 440N and 0.1% xanthan gum without and with 1% M-5, respectively. However, the 1% EM 440N and 0.1% xanthan gum solution containing 3% M-5 improves to 94% of the value of dissolved iron compared with the decontamination liquid control (Fig. 2). These results indicate that an increase in the foam stability increases the concentration of dissolved iron, which suggests that enhancing the contact time between the chemical reagents and the specimen increases the iron dissolution.

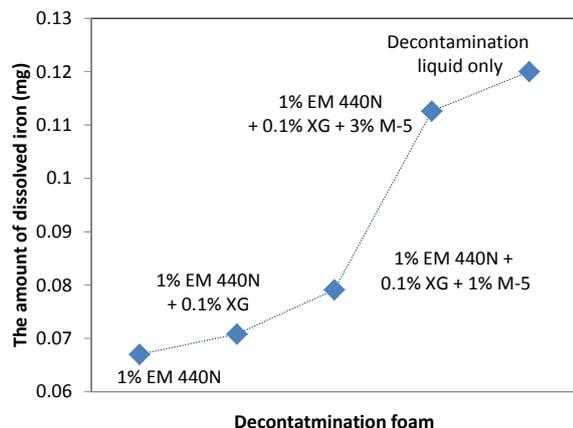


Fig. 2. The concentration of dissolved iron using bottle tests of decontamination foam and liquid.

4. Conclusions

This study showed the effect of viscosifiers and nanoparticles on the foam stability when developing new formulations of decontamination foam. The addition of xanthan gum and the mixture of xanthan gum and silica nanoparticles (M-5) significantly increased the foam stability, compared to the surfactant solution alone. This result indicates that both the viscosifier and nanoparticles have a synergistic effect on the foam stability. As the contact time increased, the dissolution rate increased to become similar to the dissolution that contained decontamination liquid.

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