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Effect of Block Copolymer-based Formulation on Foam Stability

Chong-Hun Jung*, Wang-Kyu Choi, and Seon-Byeong Kim

Decommissioning Tchnology Korea Atomic Energy Research Institute, Yuseong, Daejeon,Korea

Abstract : This study conducted experiments to evaluate the stability of foaming agents by adding various types of surfactants with different molecular weights, as well as viscosifiers, with the aim of enhancing the stability of foaming agents. The effect of the surfactant's concentration and pH of foaming agent on the foam stability was also investigated. Nonionic block copolymer surfactants prepared at concentrations below 1 wt.%, increased the foam stability as the molecular weight and concentration of the surfactant increased. The most stable foam was formed at a neutral pH condition. Among the various viscosifiers added to increase the stability of the foam, Xanthan gum showed the best performance.

Keywords: Decontamination, Foam, Block copolymer, Surfactant, Viscosifier, Stability

Introduction

Facilities that handle radioactive materials have aged after a long period of operation. Hence, the maintenance, repair, and decommissioning of the facilities are periodically required. Consequently, decontamination technology has been developed to prevent the proliferation of radioactive materials and to reduce the radiation exposure of operators during work [1-2]. Currently, chemical solution decontamination technology is being widely used as it exhibits a high decontamination effect achieved through chemical dissolution as well as oxidation and reduction reactions. However, this technology has a drawback in that a large amount of radioactive liquid waste is produced, which means that the amount of liquid waste produced by applying of decontamination technology needs to be reduced. Foam decontamination technology can significantly reduce the radioactive waste produced after decontamination, since more than 90% of the decontaminating materials used in this technology consist of gases. It can also be used for decontaminating large-sized equipment or large facilities where applying decontamination technology is difficult. The technology also allows for remote decontamination [3-5]. Decontamination efficiency generally increases with an increase in the contact time between the contaminated surface and the chemical decontaminant. Therefore, maintaining the foam without breaking for a certain time period is required to increase the decontamination efficiency of the decontaminant. To improve the stability

* Corresponding author*: nchjung@kaeri.re.kr*

of the foam, surfactants and polymers or inorganic materials such as nanoparticles can be added [6-8]. Factors that may affect the stabilization of the foam decontaminating agent may include the type and concentration of the surfactant, the type of viscosifier, the hydrophobicity of the surface of nanoparticles, and the pH of the foaming agent. The pH change affects the zeta potential of the bubbles and may affect the stability of the surfactant monolayer at the bubble interface due to the ionization of the surfactant. Therefore, it is possible to control the adsorption of the surfactant at the bubble interface, the rate of breaking the liquid film, and the like [9].

The present study evaluated the stability of a foaming agent by using various types of surfactants with different molecular weights, as well as viscosifiers. The effect of the concentration of the surfactant and pH of foaming agent on the foam stability was also investigated. This evaluation will contribute to an increase in the stability of the foam decontaminant as part of the development of an efficient foam decontaminant that can replace chemical solution decontaminant.

Experimental

Among the various surfactants that can form bubbles, nonionic block copolymer surfactant is chemically stable and has a relatively wide range of applications because it is relatively insensitive to changes in temperature and pH. Foam stabilization experiments were performed by changing the types of block copolymers (4400 Mn, 8400 Mn, 14600 Mn) with different solubilities and molecular weights. The concentration of the nonionic block copolymer surfactant and pH range of the foaming agent were 0.1-1wt% and 0.5-12, respectively. Xanthan gum, Glycerol, and Carboxymethylcellulose sodium salt were used in the viscosifier experiment.

The stability of the foaming agent was measured through image analysis using a Dynamic Foam Analyzer (DFA-100, KRUSS, Germany). A certain amount of surfactant was dissolved in 200 ml of distilled water, 0.5 g of viscosifier was mixed, and nitrogen gas was injected to generate foams to measure in real time. The amount of foam measured with time using the column test equipment is shown in Fig. 1.

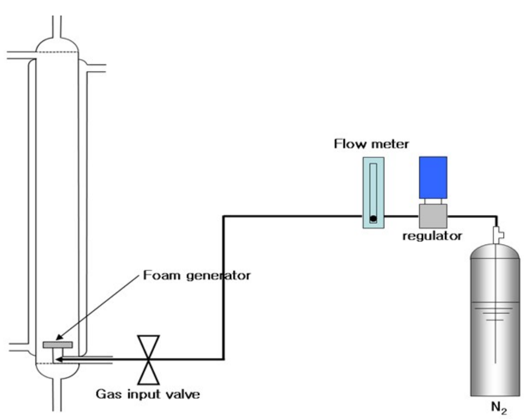

Fig. 1. Columnar equipment for the measurement of foam stability.

Results and Discussion

Fig. 2 shows the measurement results of the stability of foam from adding three block copolymers with different molecular weights and hydrophobicity. As shown in this figure, the foam disappeared within 20 minutes when 4400 Mn, a strongly hydrophobic block copolymer, was used. On the other hand, the hydrophilic block copolymers, 8400 Mn and 14600 Mn showed higher foam stability than 4400 Mn. In particular, the foams produced using 14600 Mn with a high molecular weight and long chain length showed higher foam stability than the foams prepared with 8400 Mn. At least 50% of the foam was maintained for more than 2 hours.

This may be due to the ease of micelle formation with increasing molecular size, which contributed to the foam's stabilization.

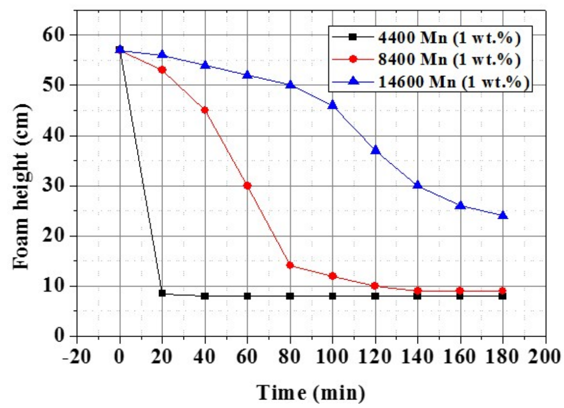

Fig. 2. Foam stability according to the various surfactant.

The stability test results of the foam according to the concentration changes in the block copolymer (Figure 3) shows that the foam was stable with an increasing concentration.

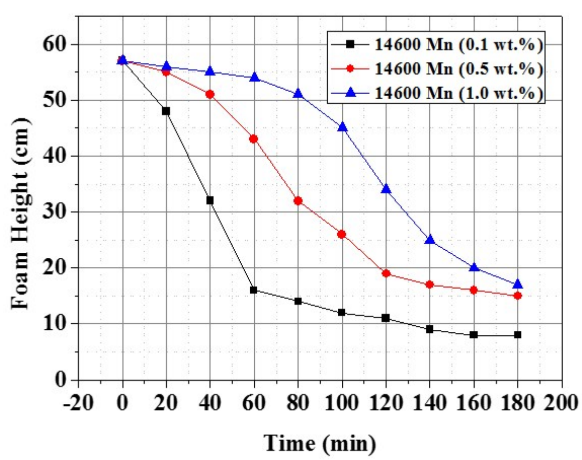

Fig. 3. Foam stability according to the concentration of surfactant.

Figure 4 shows the results of the foam stability measurements according to the changes in pH. As shown in this figure, the stability of the foam decreased in the order of neutral pH> acidic pH> basic pH. This may be due to the combination of electrical double layer distribution and surface tension.

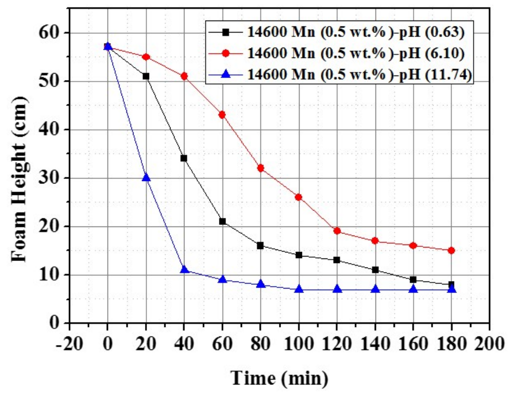

Fig. 4. Foam stability according to the pH.

The experimental results for the effect of the viscosifier on the foam stability are shown in Fig. 5. As can be seen in this figure, when Xanthan gum was added, more than 80% of the foam was maintained for 3 hr, and the most stable foam was obtained. The effect on the stability of the foam depends on the characteristics of the viscosifier.

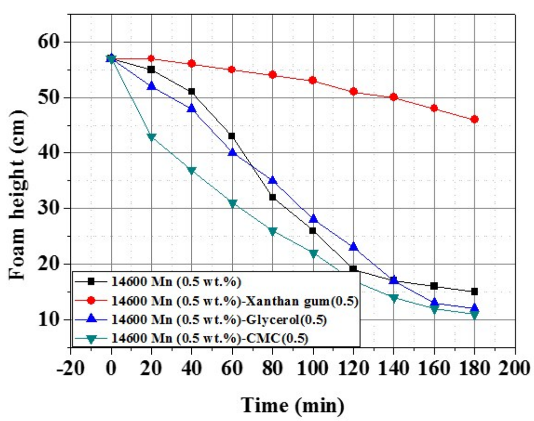

Fig. 5. Foam stability according to the various viscosifiers.

Conclusions

It has been investigated the stability of foaming agents by adding various types of surfactants with different molecular weights, viscosifiers, with the aim of enhancing the stability of foaming agents. The effect of the surfactant's concentration and pH of foaming agent on the foam stability was also investigated.

Nonionic block copolymer surfactants prepared at concentrations below 1 wt.%, increased the foam stability as the molecular weight and concentration of the surfactant increased. The most stable foam was formed at a neutral pH condition. Among the various viscosifiers added to increase the stability of foam, Xanthan gum showed the best performance.

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