Decontamination of radioactive clothing using microemulsion in carbon dioxide

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1. Introduction

Nuclear power is intrinsically a clean energy source due to its high energy density and low generation of waste. However, as the nuclear industry grows, a variety of radioactive wastes are increased gradually. Major subjects include contaminated components, tools, equipment, containers and facilities as well as nuclear waste such as uranium scrap and radioactive clothing [1]. The radioactive waste can be classified by its creation. There are Trans-Uranium Nuclides (TRU), Fission Products (FP) and corrosion products. Nuclear decontamination has become an important issue in the nuclear industry.

The conventional methods have some problems such as the production of secondary wastes and the use of toxic solvents. We need to develop a new method of decontamination and suggest a use of microemulsion in carbon dioxide to overcome these disadvantages.

The microemulsion is the clear solution that contains the water, surfactant and carbon dioxide. The surfactant surrounded the droplet into carbon dioxide and this state is thermodynamically stable. That is, the microemulsion has a structure similar to that of a conventional water-based surfactant system. Generally, the size of droplet is about 5~10nm [2]. The microemulsion is able to decontaminate radioactive waste so that the polar substance is removed by water and the non-polar substance is removed by carbon dioxide. After the decontamination process, the microemulsion is separated easily to surfactant and water by decreasing the pressure under the cloud point. This way, only radioactive wastes are left in the system. Cleaned carbon dioxide is then collected and reused. Thus, there are no secondary wastes.

Carbon dioxide is considered an alternative process medium. This is because it is non-toxic, non-flammable, inexpensive and easy to handle [3]. Additionally, the tunable properties of carbon dioxide through pressure and temperature control are versatile for use in extracting organic materials [4]. In this paper, we examine the decontamination of radioactive clothing using the microemulsion in carbon dioxide.

2. Methods and Results

2.1 Apparatus

The experimental apparatus composed a liquid syringe pump, an extraction cell with a thermo-controller. The ranges of pressure and temperature are up to 200bar and 200℃ (Fig. 1). The volume of the extraction cell (HANWOUL ENGINEERING CO.) is 125ml. The operating temperature was controlled by thermo-controller. The radioactive clothing generated during the overhaul periods was obtained from Ulchin nuclear power plant.

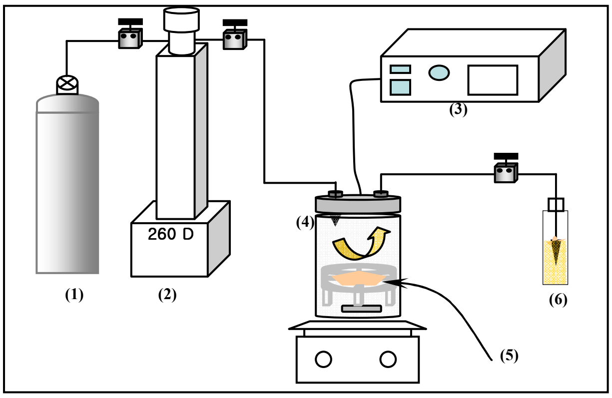

Figure 1.(1) CO_2 Tank (2) Syringe pump
(3) Thermo-controller (4) Extraction cell
(5) Specimen (6) Collector

2.2 Experiments

Before the decontamination test, we measured the formation of microemulsion in liquid carbon dioxide. Figure 2 shows the results. As the concentration of nitric acid increases, the formation pressure increases as well to form the microemulsion stably. In the 3M HNO_3, the water value (w-value) was restricted under 14 values.

According to this data, we considered experimental condition. The amount of surfactant was fixed (146mg) and temperature was 20℃. The water value (w-value) was fixed (25 values). The extraction time was 30min since that is the time required for the formation of microemulsion. Flushing time was 90min. The concentration of nitric acid was changed up to 6M. Then, we used the experimental condition for a mock-up test. The mock-up specimen was made so that standard solution was inserted into the oil and dehydrated. The result of mock-up test approved the experimental condition. Next, we applied this cleaning method (microemulsion in carbon dioxide) for the decontamination of radioactive clothing.

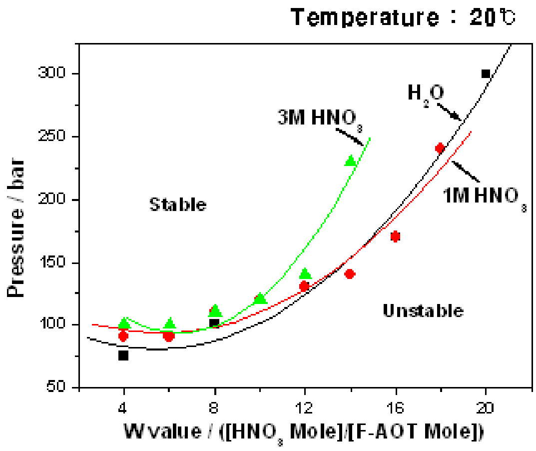

Figure 2. Formation of microemulsion (according to concentration of nitric acid)

2.3 Results and discussion

The formation of microemulsion in carbon dioxide is able to remove radioactive clothing as the radionuclide is dissolved by water of nitric acid in microemulsion.

Gamma-ray activity of radioactive clothing was measured by HPGe gamma detector before and after the experiment. After the decontamination, the activity of radioactive clothing is lower than before experiment. As the concentration of nitric acid was 1M which removal efficiency (Co-60(71%), Cs-137(88%)) is higher than 6M (Co-60(59%), Cs-137(61%)). Because of the microemulsion into carbon dioxide was not formed in 6M nitric acid. So the microemulsion was not enough for dissolved the radioactive waste. As the repetition of cleaning process, the efficiency is improved. It shows that 3-times of cleaning process that removal efficiency is above 98%. And the removal efficiency is depending on the flushing time. The removal efficiency is 90min (Co-60(67%), Cs-137(88%)) and 30min (Co-60(41%), Cs-137(32%)).

Table 1. Removal efficiency of changed the experimental condition

	HNO_3 [M]	Flushing time [min]	Frequency of cleaning	Removal efficiency[%]
Co-60	1	30	1	41
Cs-137				32
Co-60	6	90	1	59
Co-60				66
Co-60	1	90	1	71
Cs-137				88
Co-60	1	90	2	92
Cs-137				100
Co-60	1	90	3	98
Cs-137				100

3. Conclusion

This research intended to find the feasibility of the decontamination of radioactive clothing using microemulsion in carbon dioxide. The concentration of nitric acid in microemulsion was 1M. Flushing time was about 90min and extraction time was 30min. We cleaned the clothing 3-times. The removal efficiency turned out to be above 98%. We expect that the decontamination of radioactive clothing is possible by microemulsion in carbon dioxide.

Acknowledgment

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