Polyvinyl alcohol-borate hydrogel film containing Prussian blue for surface decontamination

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A polyvinyl alcohol (PVA)-borate hydrogel based strippable surface decontaminant containing ammonium salt and Prussian blue (PB) was developed for the removal of ^{137}Cs from the various surfaces. This surface decontaminant can be easily prepared by simple mixing each commercialized materials, such as PVA, borax, NH_4Cl and PB in water, and peeled off from the surface due to their high elastic property after surface decontamination. The hydrogel displayed an effective removal performance for Cs from the painted cement, aluminium, stainless steel surfaces and possible reusability. Therefore, PB/PVA-borate hydrogel has good potential as a new surface decontaminant.

I. INTRODUCTIPN

The radioactive cesium isotope ^{137}Cs is the most dangerous contaminant among the nuclear fallout and radioactive waste generated by nuclear facility including nuclear power plants due to its long half-life (30.2 years), high-energy gamma ray (γ-ray) emissions, and similar biological behavior similar to potassium [1]. The nuclear accident at the Fukushima Daiichi nuclear power station in 2011 released large amounts of radioactive cesium into the environment, which affected various urban structures such as roofs, building exterior surfaces, and roads [2]. Thus, decontaminating various surfaces of objects that now contain ^{137}Cs is a critical issue for people who lived in the urban area surrounding the site of the nuclear accident.

The water-based washing processes require an additional water treatment system to prevent a secondary environmental contamination; further, the conventional strippable coatings are often toxic because they include both carcinogenic solvents and chelators, and they can become radioactive waste after use, which will require costly waste disposal [3]. Our group recently reported a magnetic adsorbent embedded in Ca-alginate hydrogel beads combining with ionic washing for the removal of ^{137}Cs from the surface [4]. However, the surface decontamination procedure requires two steps because ionic washing using ammonium salt as irst step is necessary to desorb the Cs from the surface before the application of hydrogel bead for Cs capture as the last step. Moreover, a sophisticated synthetic procedure of magnetic adsorbent is needed although it has excellent maximum adsorption capacity for Cs (45.98mg/g) and distribution coefficient for Cs (3.34×10^4 mL/g) [4]. Consequently, new surface decontaminants are still desired for a facile and cost effective preparation and one-step surface decontamination.

II. EXPERIMENT

The PVA-borate based surface decontaminant were prepared by mixing the PVA solution containing Prussian Blue (PB) with borax solution. First, the PVA was dissolved in NH_4Cl solution by stirring and heating at 80 ℃ in sealed vials to prevent water from evaporating. Then, the desired amount of PB was also added into the PVA solution. Finally the aqueous borax solution was added drop-wise by stirring (vortex apparatus). The sample became rigid after few minutes.

III. RESULT AND DISCUSSION

Fig. 1 demonstrates the surface decontamination procedure using PVA-borate hydrogel film containing PB. The hydrogel containing NH_4Cl and PB was applied to the contaminated surface. Ammonium salts such as NH_4Cl have widely been used as chemical agents to solubilize the ^{137}Cs by ion-exchange with ^{137}Cs that is present on various surfaces [5]. During the contact time of hydrogel with contaminated surface, the ^{137}Cs begins to be solubilized and captured by the Cs adsorbent within the PVA-borate hydrogel. Due to the high elastic modulus, the hydrogel capturing ^{137}Cs can easily be peeled from the surface, resulting in some degree of surface decontamination. Finally, the adsorbent capturing the ^{137}Cs can be separated using ultrafiltration or centrifugation method after dissociation of PVA-borate complex in water for the volume reduction of radioactive waste and the reuse of PVA and borate. The ‘inversion of the glass vial’ method

was used to determine the formation of hydrogel having elasticity. The stable PVA-borate hydrogel formation was observed even in the presence of 0.2 wt% of PB and the color of PVA-borate hydrogel became dark blue due to the presence of PB.

To evaluate the decontamination ability of the PB/PVA-borate hydrogel film, ^{137}Cs-contaminated stainless steel, aluminium, and painted cement was used as a model surface. Fig 5(a) shows that the PB/PVA-borate hydrogel was completely removed from the surface in one piece and did not leave any residue. The ^{137}Cs removal performance of PB/PVA-borate hydrogel was evaluated in terms of removal efficiency ($R = A_0\text{-}A_e)/A_o \times 100\%$) and decontamination factor ($DF= A_0/A_f$). The ^{137}Cs activity in the initial surface (A_0) and the ^{137}Cs activity in the final surface (A_e) after treatment with PB/PVA-borate hydrogel were measured by using an automatic low-background Alpha/Beta counting system. The R values for surface decontamination were 67.21% for painted cement surface, 93.19% for aluminium surface, and 90.33 % for stainless steel surface, respectively, higher than those of surface decontamination using water. These results were attributed to the good surface exchange properties of NH_4^+ towards Cs^+

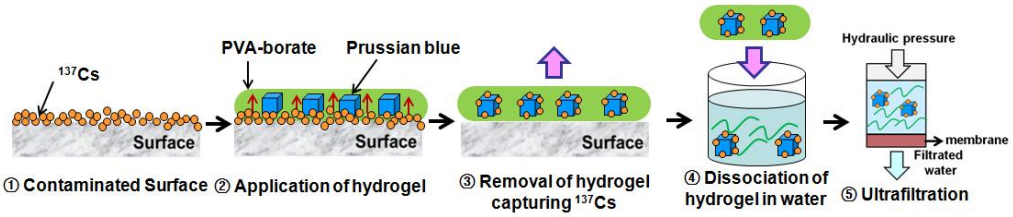

Fig.1. Schematic procedure of surface decontamination using PB/PVA-borate hydrogel.

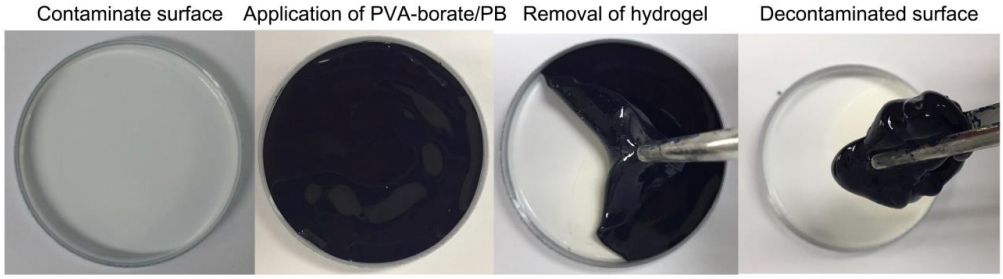

Fig.2. Surface decontamination procedure of paint surface using the strippable PVA-borate hydrogel film containing PB

IV. CONCLUSIONS

In this study, a PB/PVA-borate hydrogel film was successfully fabricated for the decontamination of ^{137}Cs-exposed surfaces such as painted cement, aluminium, and stainless steel. The hydrogel displayed a good removal performance with high DF exceeding 10 for ^{137}Cs-contaminated aluminium and stainlee steel surface, and enhanced removal efficiency for painted cement surface compared with water washing. Furthermore, the simple preparation, reusability, and eco-friendly volume reduction method of used PB/PVA-borate hydrogel make the material convenient, eco-friendly, and cost-effective. Therefore, PB/PVA-borate hydrogel has good potential as a new surface decontaminant.

ACKNOWLEDGMENTS

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