Characterization for Soil Fixation by Polyelectrolyte Complex

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1. Introduction

Since the nuclear accident at the Fukushima nuclear power station in 2011, radioactive contaminants have been released into the environment. The radioactive contaminants were spread to a residential area, forest, agricultural field by wind and water. Among the various radioactive contaminants, radioactive cesium (Cs-137) is the most apprehensive element due to its long half-lives, high solubility in water, and strong radiation emission in the form of gamma rays.

According to report, the radioactivity bulk (approx. 95%) is localized within topsoil. Therefore soil surface on topsoil should be fixed to prevent the spreading of the contaminated soils with Cs-137 by wind and water erosion. Many methods have been developing for soil fixation to remove radioactive contaminants in soil and prevent to diffuse radioactive materials. Various materials have been also used as fixatives such as clays, molecular sieves, polymer, and petroleum based products.

One of the methods is a soil fixation or solidification using polyelectrolyte [1-3]. Polyelectrolytes have many ionic groups and make into the polyelectrolyte complex (PEC) due to electrostatic interaction of polyanion and polycation in an aqueous solution. It can be avoids using the chemical cross-linking agents, and reducing the possible toxicity and other undesirable effects of the reagents. PEC can fix soil particles by flocculation and formation of crust between soil. The method can also prevent a spread of radioactive material by floating on a soil surface. Recently, PEC used for the solidification of soil near the Fukushima nuclear power plant in Japan [4]. The decontamination efficiency of the surface soils reached 90%, and dust release was effectively suppressed during the removal of surface soils.

In this study, it was investigated the fixation of the soil by PEC to avoid the spread of the contamination in addition to the separation of soil and PEC.

2. Methods and Results

Cationic polymer, Polydiallyldimethyl ammonium chloride (PDADMAC, 200,000 ~350,000, 20 wt% in water, Aldrich), and anionic polymer, Polyacrylic acid (PAA, 250,000, 30wt%, Aldrich) carboxymethyl cellulose sodium (CMC, molecular weight = 90,000) were used for formation of polyelectrolyte complex. Potassium chloride (KCl) and sodium hydroxide (NaOH) were used for the adjustment of salt concentration and pH, respectively.

In order to prepare the PEC solution, KCl and NaOH dissolved in water and 10wt% PDADMAC and then 10wt% PAA solution is adding to 10wt% PDADMAC solution slowly with stirring. When 10wt% PAA solution is adding to 10wt% PDADMAC solution, PAA agglomerate was formed due to low pH of PAA as shown in Fig. 1. It takes several days to prepare the PEC solution because the PAA agglomerate was not easily dissolved in the aqueous solution. But PAA agglomerate was not formed when NaOH was added to PAA solution instead of adding to 10wt% PDADMAC solution. The mode of the addition is important to prepare the PEC solution without PAA agglomerate.

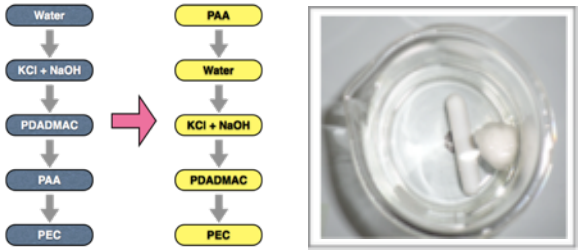

Fig. 1. Improved procedure for the PEC solution without a PAA agglomerate.

To investigate the optimum conditions for soil fixation, various PEC solutions were prepared with concentrations of KCl. The addition of KCl affected the complex formation condition and size distribution of PEC particle. PEC is formed below the so-called critical aggregate point. The turbidity of PEC solution increases with decreasing salt concentration, the reason is that amount of PEC is increased by the interaction of polycation and polyanion. Amount of precipitate increases with decreasing salt as shown in Fig. 2.

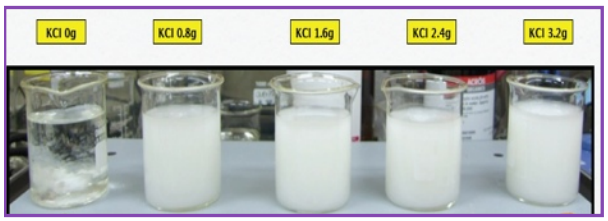

Fig. 2. PEC solution with various KCl concentrations

In order to the fixation of soil by PEC solution, 20 ml of PEC solution was applied to 150g of sea sand (Junsei) and dried at room temperatures (Fig.3). In case of a low KCl concentration soil was partly fixated from the results of soil fixation, The low capacity of soil

fixation was caused by low contents of polymer due to the precipitation of PEC. Therefore, a content of salt is a very important to the application of PEC for the soil fixation.

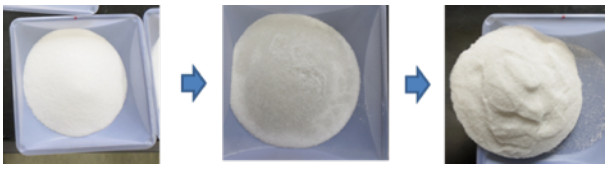

Fig. 3. Process of soil fixation by PEC solution.

The measurement for physical strength of fixed soil was performed in order to the investigation of stability of fixed soil. To prepare fixed soil samples with polymer molecular weight, each 6ml of PEC solution with different molecular weight was added to 16g of soil and then was dried at room temperature during two week. Physical strength of fixed soil was determined by universal testing machine. As the increasing the contents of PEC, numbers of adding, and the molecular weight of polyelectrolyte the physical strength of fixed soil sample increased. From the results, physical strength of fixed soil is affected to numbers of adding PEC solution more than a molecular weight of polymer.

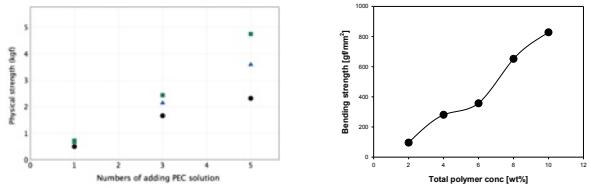

Fig. 4. The change of physical strength of fixed soil

Wind erosion tests were carried out with a crust prepared by a high salt concentration PEC solution. From the results of the wind erosion test, wind erosion was not detected up to a flow rate of 15m/s (Table I).

Table I: The change of soil weight by wind erosion

	초기 무게	12 m/s	13 m/s	14 m/s	15 m/s
Without PEC	949.3g	949.2g (0.1 g)	949.0g (0.2 g)	948.4g (0.6 g)	937.6g (10.8 g)
2.1g PDADMAC-PAA	998.3g	998.3g (0 g)	998.3g (0 g)	998.3g (0 g)	998.3g (0 g)
4.2g PDADMAC-PAA	1076.2g	1076.2g (0 g)	1076.2g (0 g)	1076.2g (0 g)	1076.2g (0 g)

3. Conclusions

The physicochemical properties of polyelectrolyte complex solution and the stability of fixed soil by PEC were investigated. The mode of the addition is important to prepare the polyelectrolytes complex without PAA agglomerate. The concentration of salt in the polyelectrolyte complex solution is a very important parameter for the soil fixation. The physical strength of fixed soil was increased with increasing amount of PEC solution and molecular weight of polymer. To preparation of optimized PEC solution and to fine optimized condition for fixation of contaminated soil, it also have to considered various factors such as the effect of salt, ion in the soil, pH of PEC, water content in soil and chemical components of soil in the interaction of soil and polymer.

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