Transactions of the Korean Nuclear Society Virtual Autumn Meeting
October 21-22, 2021

Development of decontamination technology for contaminated soil using non-radioactive isotopes

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1. Introduction

The forests and surrounding soil around nuclear power plants could be contaminated by trace amounts of radioactive materials released during normal operation of Nuclear Power Plant and unexpected accidents, such as the accident at Fukushima Daiichi Nuclear Power Plant in Japan. There are a variety of nuclides in contaminated soil, among which radioactive cesium is generally strongly adsorbed into clay, with a depth of 1 to 5 cm due to its good adsorption with the soil[1]. Therefore, from the perspective of the total volume of waste, it is very important to accurately identify the level of contamination according to soil characteristics, and the classification of soil by particle size can significantly reduce the volume of contaminated soil waste

1.1 Objectives

In this study, a pilot-scale soil washing-based soil decontamination process was developed and applied by mixing surface fine-soil around nuclear power plants artificially contaminated with non-radioactive cesium with native soil. In addition, operational factors of critical processes for optimal physical distribution and cleaning were optimized and operating performance was carried out

2. Method and Results

2.1 Configuration of Soil Decontamination System

Based on basic lab-scale experiments and basic operating conditions, the process is manufactured to be movable, control operating conditions, and operate through remote control at contaminated sites. Soil washing allows relatively large particle-sized like gravel and sand to be separated and treated for general waste disposal site or reuse. And contaminated fine soil can send to permanent disposal site in drum form.

Figure 1 shows the schematic diagram of the soil decontamination system developed in this study, consisting of hoppers, belt conveyors, high-pressure washing devices, vibration dehydration screens for multi-stage particle size separation, hydrocyclone, fine soil cohesion tank, screw decanter centrifugation, waste water storage tank, bag-filter, submerged UF membrane, CDI(Capacitive deionization) and FEDI(Fractional Electrodeionization).

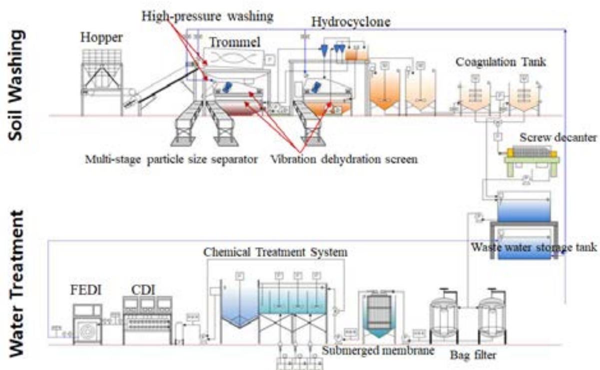


Fig. 1. Schematic diagram of contaminated soil decontamination process

2.2 Evaluation of pilot-scale decontamination system performance

Field surface soil (35°21'10.9"N 129°19'37.1"E) near nuclear power plant was collected around a 20m radius around the sampling point. Artificially contaminated soil was manufactured by spiking non-radioactive Cs into soil of less than 0.19 mm and mixed with surface soil for at least three to four weeks to obtain homogeneity of the specimen. Due to the environment in which radioactive soil cannot be obtained, the decontamination performance of the pilot system was evaluated using 100kg of experimental soil, which produced a ratio of 1:25 of non-radioactive cesium contaminated soil and raw soil. To determine the best decontamination parameters soil was decontaminated by varying the ratio of water and soil, and was tested by giving parameters such as hydrocyclone cones caliber control and the selection of agglomerates.

High pressure washing for decontamination of soil is performed in three parts of the soil decontamination system. When contaminated soil is poured in hopper, a certain amount of soil discharged from the feeder are transferred to the trommel through the belt conveyor, and less than 25 mm of soil is transferred to the wet vibration screen, sufficiently decontaminated by inlet and secondary high-pressure water sprayed from nozzle in the trommel. The soil of 5 mm and 2 mm is additionally decontaminated with high pressure water in the multi-stage vibration screen, respectively, and decontaminated soil of 5mm and 2mm is discharged through belt-conveyor, respectively. Contaminated water mixed with less than 2mm of soil is stored in the reservoir and transferred to the 1st and 2nd hydrocyclone.

In hydrocyclone, the 0.2 mm to 2mm particle size soil is selected and discharged to clean soil through washing, 0.2 mm to 0.075 mm particle size soil is over-flowed to the primary discharge tank, and 0.05mm or less fine soil is transferred to secondary discharge tank.

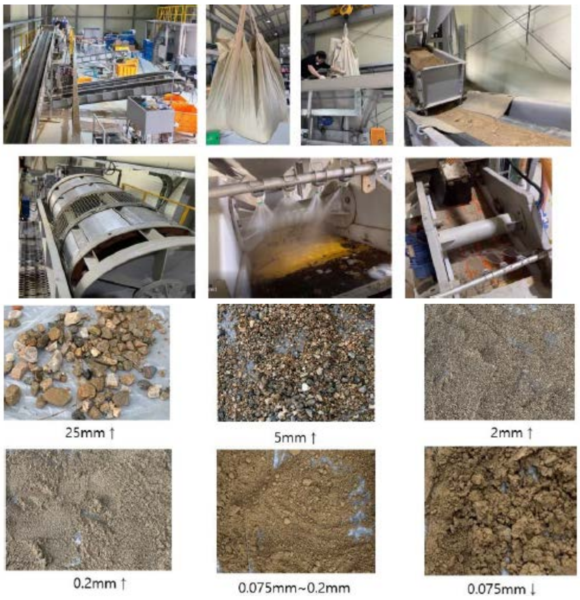
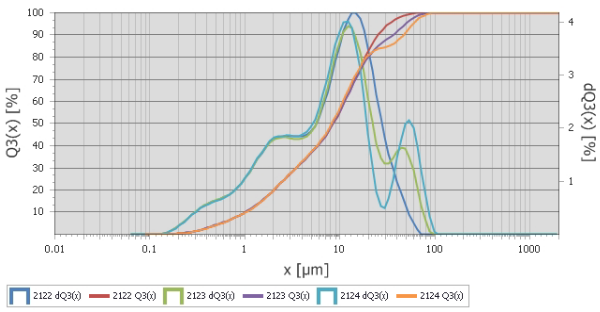


Fig. 2 Soil decontamination process and classified soil by particle size

The soil with particle diameters of 0.2~0.075mm and less than 0.075mm is subjected to a natural inorganic powder-type polymeric aggregate process, solid content is caked through a dehydration process in a screw decanter, and the separated supernatant and sludge dehydrate are transferred to a contaminated water storage tank.

Particle size of washing water and supernatant water was analyzed using a particle sizer(FRITSCH, Germany). Concentration of SS (Suspended Solid) in contaminated water was analyzed in accordance with the soil process testing method. The cesium concentration of soil, cleaning water, and supernatant water is completely decomposed using HNO_3 : HCl = 1: 3, filtered using 0.45 ㎛ membrane filter, and then analyzed using an ICP-OES.



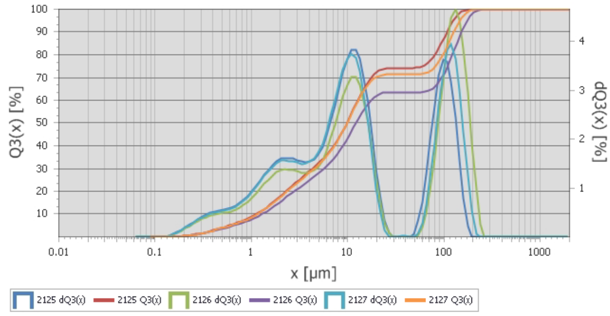


Fig. 3. Hydrocyclone overflow(left), underflow(right) : (Sand pump 1: Sand pump 2 = 90:70)

In order to achieve the target distribution, the ratio of sand pump 1 to sand pump 2 was 90:70 and it was confirmed that the under discharge water in the primary hydrocyclone had an average diameter of 10 and 100 ㎛, and that the upper discharge water had a particle diameter of 10 ㎛.

Table 1. Cs concentration by particle size after soil washing

Sample	Before washing Weight (%)	After washing Weight (%)	1th Washing Cs Conc (mg/kg)	2th Washing Cs Conc (mg/kg)
Initial soil Conc	4.18±0.06			
25mm↑	1.2	1.1	N.D	N.D
5mm~25mm	11	8.1	N.D	N.D
2mm~5mm	15	15.8	N.D	N.D
0.2mm~2mm	67.5	37.4	0.72±0.08	0.07±0.05
0.05mm~0.2mm	5.2	25.5	0.64±0.09	0.34±0.09
0.05mm		12.2	1.23±0.02	0.44±0.09
0.05mm~2mm			0.007	0.005
0.05mm ↓			0.005	0.005

For the parameters, the soil:water ratio of 1:15 showed the best particle size fraction efficiency and the sand pump ratio (sand pump 1: sand pump 2 = 90:70%) showed a size fraction of less than 50 micrometers. The elution of artificially contaminated soil using non-radioactive elements was assessed to be not easily eluted by high-pressure water cleaning and ultrasonic waves, and the proportion of soil that can be purified by decontamination systems is expected to be 63%.

3. Conclusions

Using the developed soil decontamination system, contaminated soil was classified into six levels according to particle size. Separation efficiency was best when the ratio of soil to water was 1:15 and about 63% of the contaminated soil could be decontaminated to the self-disposal level that could be classified as general waste. The concentration of trace-contaminated soil could be reduced to a self-disposal level by secondary cleaning. In the future, it will be planning to evaluate the decontamination performance of contaminated soil by spiking ~~using~~ the standard radioactive materials for more reliable cleaning efficiency evaluation.

REFERENCES

[1] Saito, K., Tanihata, I., Fujiwara, M., Saito, T., Shimoura, S., Otsuka, T., ... & Shibata, T. (2015). Detailed deposition density maps constructed by large-scale soil sampling for gamma-ray emitting radioactive nuclides from the Fukushima Dai-ichi Nuclear Power Plant accident. Journal of environmental radioactivity, 139, 308-319