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Decontamination of gravels contaminated with uranium

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ABSTRACT

Gravel washing equipment and electrokinetic–electrodialytic decontamination equipment were manufactured to decontaminate gravel contaminated with uranium. The removal efficiency according to the gravel size and weight and the removal efficiency according to the lapsed time using the manufactured equipment were investigated through several experiments. The volume of gravel in the high uranium concentration group was about 10%, the rock types of which were quartz, lamprophyre, and schist. The larger the gravel size, the higher the contaminated concentration of gravel. The average uranium (^{238}U) concentration of gravel after the first washing was about 1.45 Bq/g, and the average removal efficiency of gravel after the third washing was about 37%. In addition, the removal efficiency of the contaminated gravel was not related to its size. The contaminated concentration of the gravel decreased with an increasing gravel weight. In addition, the removal efficiency of contaminated gravel was not related to its weight. When the electrokinetic–electrodialytic decontamination period of 5 days, 10 days, 15 days, and 20 days elapsed, the ^{238}U in the gravel was removed by about 40%, 65%, 72%, and 81%. The more the electrokinetic–electrodialytic decontamination time elapsed, the more the removal efficiency ratio of ^{238}U decreased. Finally, the gravel with a size of less than 10 cm was treated by soil washing and electrokinetic decontamination methods with soil, and gravel with size of more than 10 cm but less than 20 cm was treated by gravel washing and electrokinetic–electrodialytic decontamination methods. Gravel with a size of more than 20 cm is treated by a gravel washing method, and gravel contaminated with a high concentration of uranium was treated by crushing and ball mill washing methods.

1. Introduction

The soil around nuclear facilities is contaminated with radionuclides during the operation and decommissioning of those facilities, especially during a nuclear accident such as the one at Chernobyl in Ukraine and the one at Fukushima in Japan. Korea has a lot of soil contaminated with uranium generated during its operation of nuclear facilities. Soil with a size of less than 10 cm is usually decontaminated using soil washing and electrokinetic technologies. However, it is difficult to use soil washing technology for decontamination of gravel with a size of more than 10 cm. It is impossible to scrub gravel in a washing tank, because the gravel sinks to the bottom (Fedje et al., 2013; Bisone et al., 2012; Gryschko et al., 2005; Tandy et al., 2004; Voglar and Lestan, 2013). In addition, when electrokinetic decontamination technology (Yang and Chang, 2011; Kaneta et al., 1992; Dong et al., 2005) is applied to gravel with a size of more than 10 cm, the removal efficiency of the radionuclides from the gravel is reduced, because the electro-osmotic flux at the surface of the gravel in an electrokinetic cell is reduced owing to a reduction of the particle surface area, which is attributable to the large size of the gravel (Yang and Chang, 2011; Kaneta et al., 1992; Dong et al., 2005; Kim et al., 2011; Kim et al., 2010, 2008). Meanwhile, there have been few studies on the decontamination of gravel with a size of more than 10 cm. The volume ratio of gravel whose size is more than 10 cm in the total volume of soil at KAERI was about 20%. Therefore, it is necessary to study the decontamination of gravel contaminated with radionuclides.

Vitoria et al. used three mechanical gravel cleaning methods: (1) tractor rotovating, using a Dowdeswell Powervator 35 rotovator, with a width of 90 cm, behind a Ford 1220 four-wheel drive tractor, (2) high pressure jet washing, using a KEW 5203 KD pressure washer, in which water was pumped at 150 bar through a hand-held lance with jets of 5 mm and 1 mm diameter, and (3)

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pump washing, using a Pacer pump with a 3 Hp Briggs and Stratton engine. The most effective method for cleaning river gravels appeared to be pump washing (Victoria et al., 1999). Pereira et al. used vegetable oil biodiesel for cleaning oiled shores. Pure oil biodiesels (rapeseed and soybean) were significantly more effective in the cleanup of oiled sands (up to 96%) than recycled waste cooking oil biodiesel (70%) (Pereira and Mudge, 2004). Clement et al. used a physic-chemical method for the treatment of dredged sediment. The positive effects of physic-chemical treatment are the reduction of sediment mass, materials easier to handle, reduction of visual and odor nuisances, better settability, the removal of ammonia emissions and associated ecotoxicological risks, removal of zinc and nickel emissions, and a reduction of sediment toxicity to amphipods and chrironomids (Clement et al., 2010). Min et al. used thermal and mechanical treatment to clean aggregates from concrete. Most pollutants are easily separated from the contaminated concrete waste, which concentrates mainly in the porous fine cement powder. Removal on pollutants in concrete was influenced by the heating temperature and crushed aggregate size. Heating temperature played an important role in moving the contaminants from the concrete waste (Min et al., 2010). Cho et al. used dry washing technology for the treatment of polluted railroad ballast gravel. A dry washing method removes the pollutants on the surface of ballast gravels by blasting media on the gravel. The technology efficiently removed heavy metals from contaminated gravel for a short time (Cho et al., 2012).

In this study, the gravel contaminated with uranium was sampled at an area near a nuclear facility in Korea. The contamination characterization of gravels separated from soil was analyzed. The gravel washing equipment and electrokinetic–elctrodialytic decontamination equipment were manufactured to decontaminate the contaminated gravel. The removal efficiency according to the gravel size and weight, and the removal efficiency according to the lapsed time by electrokinetic–electrodialytic equipment, was investigated through several experiments. The optimum experiment conditions for uranium decontamination by the gravel washing and electrokinetic–elctrodialytic decontamination equipment were found. Finally, a process to decontaminate the contaminated gravel was developed for the self-disposal of radioactive gravel waste on the basis of the experimental decontamination results.

2. Materials and methods

2.1. Characteristics of contaminated gravels

About 30% of the volume of soil contaminated with uranium, which was excavated at an area near a nuclear facility, was gravel. The gravel contaminated with uranium is shown in Fig. 1. High and low concentration groups of contaminated gravels are shown in Table 1. The volume of gravel in the high uranium concentration group was about 10%, the rock types of which were quartz, lamprophyre, and schist. The reason is considered to be that uranium can infiltrate into the deep side of those rocks, because quartz that consists of a crystal cluster, lamprophyre that consists of biotite and amphibole, and schist that consists of biotite and muscovite are easy to be split. Washing after using a crushing method should be selected to decontaminate gravel in the high concentration group for an improvement of the decontamination efficiency.

2.2. Manufacturing of gravel washing equipment

The gravel washing equipment was manufactured to wash the contaminated gravel. The gravel washing equipment consisted of a trammel, nozzle, gravel injection box, gravel collection box,

Fig. 1. Gravel contaminated with uranium.

Table 1
High and low concentration groups of contaminated gravel.

Concentration (Bq/g)	High-concentration	Low-concentration
1	5.32	0.82
2	7.68	1.47
3	4.56	2.18
4	6.72	1.7
5	7.25	1.85
Average	6.31	1.60

waste solution collection box, nitric acid solution box, and drum hoist, as shown in Fig. 2.

The trammel circulates gravels in its inside at a fixed rpm, and the nozzles in the trammel spray a nitric acid solution to wash the contaminated gravel. The gravel injection box injects contaminated gravel into the trammel, and the gravel collection box collects the washed gravel. The waste solution collection box collects waste solution released during gravel washing, the nitric acid solution box supplies the nozzle in the trammel with nitric acid solution, and the drum hoist transports contaminated gravel to the gravel injection box. Images taken before and after gravel washing are shown in Fig. 3.

The optimum experimental conditions of the gravel washing equipment were obtained through several experiments: the optimum rpm of the gravel washing equipment, and the optimum concentration of nitric acid as a washing solution.

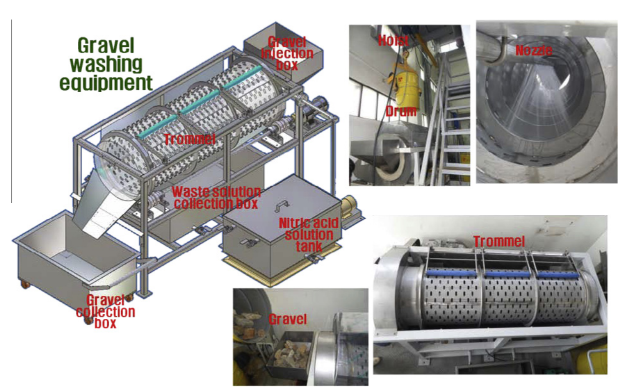

Fig. 2. Manufactured gravel washing equipment.