DECONTAMINATION EXPERIMENT OF PLANT SOIL USING SOIL WASHING METHOD

J. Son, K. Kang, H. Kim, K. Kim, M. Song
Nuclear Environment Technology Institute
P.O. Box 149, Yuseong Taejeon, 305-600, Korea

ABSTRACT

In Korea, there are not detailed analysis data on soil contamination in nuclear power plant(NPP) and suitable treatment criteria of contaminated soils. When the soils of NPP were contaminated, they have been simply collected and kept in radioactive waste building. But contamination of soils in NPP is inevitable and enormous amounts of contaminated soils can be produced during decommissioning. Therefore, generation of soil wastes should be minimized using proper decontamination methods. For this purpose, we investigated several decontamination methods and selected soil washing method as the best decontamination method for the contaminated soil in NPP. To achieve design data of decontamination equipment using soil washing method, several lab-scale experiments were performed using contaminated soils. Based on the results of experiment, decontamination equipment which is composed of particle separator and soil washer has been manufactured and installed. Contaminated soils were used to perform verification experiment of this equipment, and we proved its decontamination capability. Decontamination efficiency above 80% can be acquired by verification experiments according to the combination of experiment conditions.

INTRODUCTION

Radioactive soil can be generated during normal operation in nuclear power plant (NPP). Small amounts of radioactive particles released from NPP are deposited onto soils inside NPP and concentrated in particular regions due to the migration of nuclide by ground water or rain. Therefore the rise of contamination level by long-lived radionuclide can be caused in particular region after long operation of NPP. It is possible that this situation can be considered as careless release of radioactive material.

When the soils of NPP were contaminated, they have been simply collected and kept in radioactive waste building. In Korea, there are not detailed analysis data on soil contamination in nuclear power plant and suitable treatment criteria of contaminated soils. But contamination of soils in NPP is inevitable and decommissioning of nuclear power plant can produce large amounts of contaminated soils. Therefore, generation of soil wastes should be minimized using proper decontamination methods.

For this purpose, we investigated the characteristics of several available decontamination methods.[1-6] Also the characteristics of radioactive contaminated soils such as radiation level, radionuclide, particle size and radiation level according to the particle size of soils were investigated.[7] Among several decontamination methods, particle separation method and soil washing method, which uses water as decontamination agent, were selected as the best decontamination process based on the investigation results. Based on the results of the lab scale experiments, we designed the soil decontamination equipment composed of soil separator, soil washer and water circulator and then installed. Water, citric acid, HNO_3, Na_2CO_3, strong acids and strong bases are also tested as decontamination agent in laboratory. Above chemical agent showed higher decontamination efficiency greater than 90%. But they did not show sufficient efficiency in case of highly radioactive fine sand and generated secondary liquid waste which is difficult to treat. This results show that decontamination using chemical agent is inappropriate. Therefore we selected water as decontamination agent.

The verification experiment was performed to prove the decontamination capability of this equipment using 5 drums of contaminated soils. Soils were separated into several groups according to the radiation level before verification experiments. And the soil groups were separated according to the particle size. Particle sizes of soils are classified into three categories; ≥ 2.0 mm, 2.0 ~ 0.5 mm and ≤ 0.5 mm. The experiments to obtain the decontamination efficiencies of the equipment were performed according to particle size, radiation level, ratio of soil and decontamination agent and decontamination time.

Materials and Methods

Decontamination Equipment

To develop decontamination equipment for contaminated soil, the characteristics of several available decontamination processes were investigated and soil washing process was selected as the best process for contaminated soil. To acquire design data for soil decontamination equipment, several lab-scale experiments were performed using contaminated soil.[8] Based on the acquired data, soil washing decontamination equipment using water, which can use chemical agent in particular situation, was manufactured and installed in NPP. And verification experiments for this equipment were performed.

The decontamination equipment was composed of particle separator using vibration screen, soil washer and liquid waste circulator. Fig. 1. is the process of this equipment.

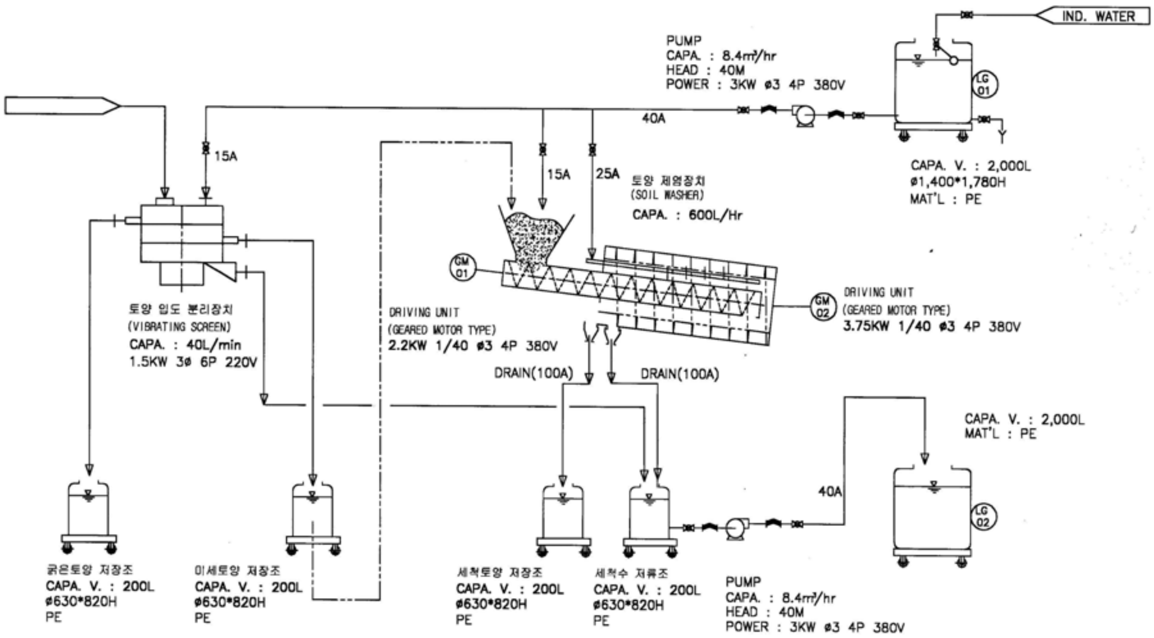


Fig. 1. Process of soil decontamination

Excavated soil should be separated according to the radiation level or the possibility of decontamination. The volume of soil waste can be reduced by separation. Contaminated soil was separated according to particle size and analyzed using HPGe detector. Major nuclides were Co-60, Cs-134 and Cs-137. Radioactivity was not detected in particles above 4.76 mm, coarse sand, and the radioactivity was increased with the decrease of particle size. Main contaminant was Cs-137. In this study, Cs-137 was selected as target nuclide for decontamination.

Separated soil was decontaminated using soil washer. Washed soil was dried and analyzed using HPGe detector. And decontamination efficiency was acquired. Generated liquid waste was sent to the liquid waste circulator composed of MF filter and ion exchange resin. Water passed through circulator was sent to soil washer and re-used as decontamination agent.

Materials and Methods

For the verification experiment, 5 contaminated soil drums were opened and classified according to the conditions of soil. Large stone and various wastes with large size such as tree were excluded. Soil was sufficiently dried for smooth particle separation. Dried soil was separated by particle separator. Particle sizes of soil were classified into three categories; ≥ 2.0 mm, 2.0 ~ 0.5 mm and ≤ 0.5 mm. The volume of soil below 0.5 mm occupied about 30% of total volume and did not use in the experiments. Two kinds of soil(≥ 2.0 mm, 2.0 ~ 0.5 mm) were analyzed using HPGe detector and re-classified according to radiation level. For convenience, we classified each soil groups as high and low radiation groups according to radiation level.

To acquire decontamination efficiency of equipment, the decontamination experiments were performed according to radiation level, particle size, ratio of water to soil, and decontamination time as shown in table 1. The contaminated soils, decontaminated soils and the liquid waste were analyzed. And the decontamination efficiencies were acquired.

Table I. Experimental Conditions

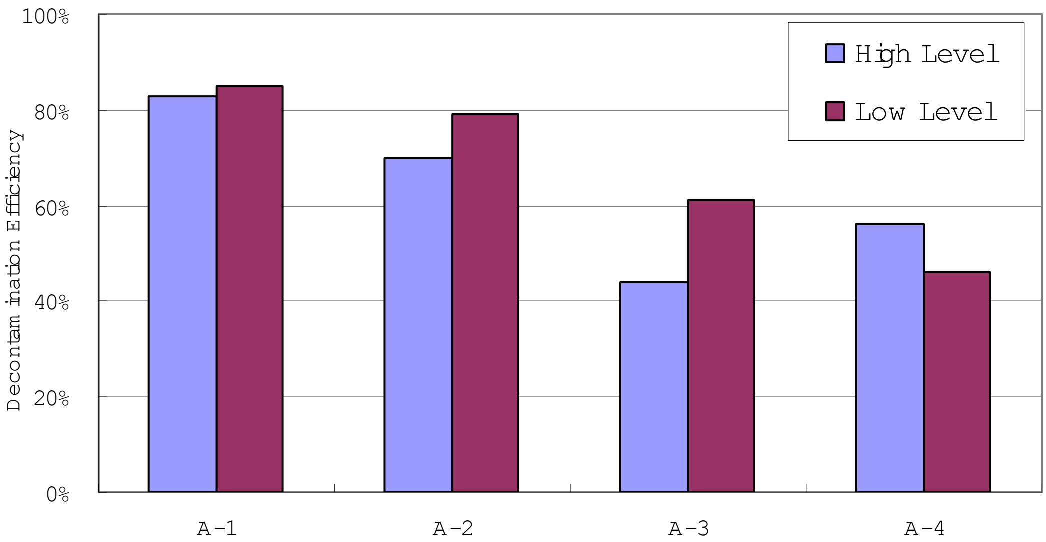
Radiation Level	Particle Size	Ratio (Water:Soil)	Time
Low Level	≥2.0 □	20:1	40 min
		20:1	60 min
	0.5 □ 2.0 □	20:1	40 min
		40:1	60 min
		20:1	60 min
High Level	≥2.0 □	20:1	40 min
		20:1	60 min
	0.5□2.0 □	20:1	40 min
		40:1	60 min
		20:1	60 min

After particle separation and grouping according to radiation level, soils were labeled. Then, the soils were injected into soil washer. Injection rate was 1.5 kg/min. In soil washer, high pressure water was sprayed and contaminants were removed. At last stage of washing, washed soil was rinsed with clean water. These soils were dried and analyzed. Liquid waste after soil washing and liquid waste passed liquid waste circulator were also analyzed using HPGe detector. In liquid waste passed liquid waste circulator, there was no radioactivity.

Discussions

In this study, soil decontamination equipment was developed and several verification experiments were performed. In these experiments, water was used as decontamination agent rather than chemical agents because of the difficulty of secondary liquid waste treatment.

Fig. 2 shows the decontamination efficiency for radiation level. In case of A-1, A-2 and A-3, decontamination efficiency of low radiation level soils was slightly higher than high radiation level soils. In case of A-4, the decontamination efficiency of high radiation level soils was slightly higher than low radiation level soils and it is estimated that the volume of water is the reason. As shown in Fig. 2, it is estimated that the efficiency was increased with the decrease of radiation level.



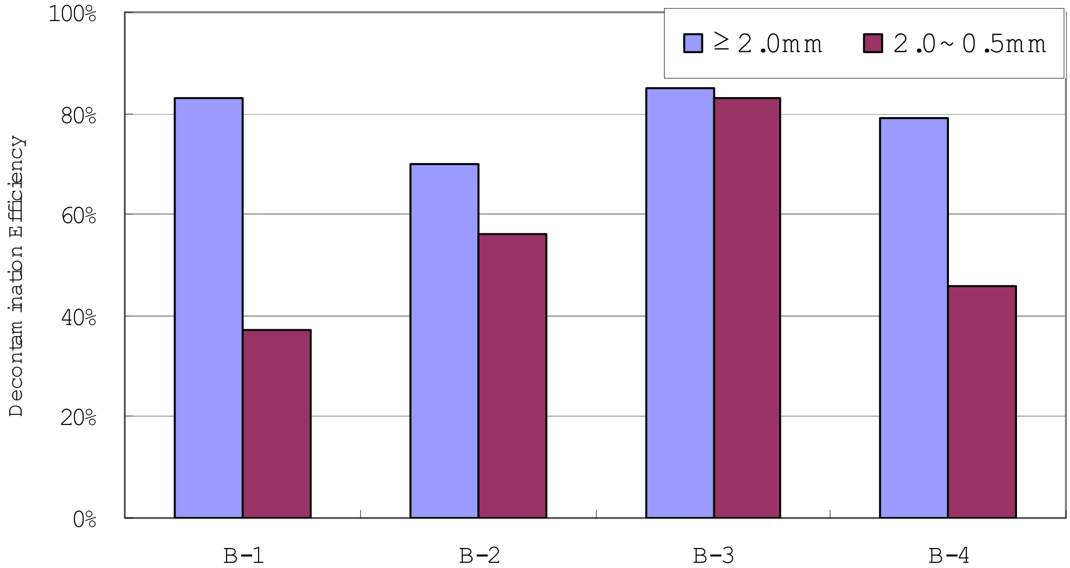
A-1 : ≥2.0 □, 20:1, 40 min.　　A-3 : 0.5□2.0 □, 40:1, 60 min
A-2 : ≥2.0 □, 20:1, 60 min.　　A-4 : 0.5□2.0 □, 20:1, 60 min

Fig. 2. Decontamination efficiency according to radiation level

Fig. 3 shows decontamination efficiency for particle size. In all cases, the decontamination efficiency of large particle soils was higher than small particle soils. In case of B-1, the difference of efficiency between large and small particles was high(46%). And in case of B-3, the difference of efficiency between large and small particles was small(2%) and it is estimated that the small volume of water and short decontamination time are the reasons. As shown in Fig. 3, the decontamination efficiency of large particle was higher than the decontamination efficiency of small particle. It is proved that contaminant combined with large particle was more easily washed. Therefore the distribution of soil particle affects to the decontamination efficiency primarily.

In case of decontamination for the volume ratio of water to soil, there was little difference between 20:1 and 40:1. It means that ratio of 20:1 is sufficient for decontamination of contaminated soil. To acquire higher efficiency, re-decontamination with the ratio of 20:1 is more effective than decontamination with the ratio of 40:1.

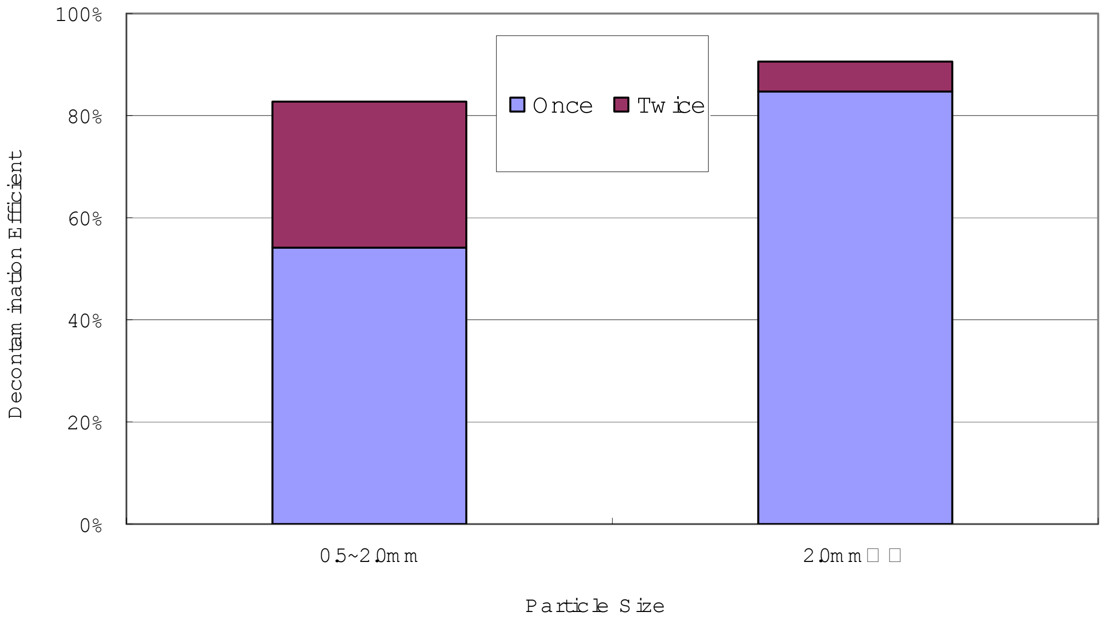
The efficiency for decontamination time shows little difference between 40 min and 60 min, especially in case of large particle and low radiation level.



B-1 : Low Level, 20:1, 40 min.
B-2 : Low Level, 20:1, 60 min.
B-3 : High Level, 20:1, 40 min
B-4 : High Level, 20:1, 60 min

Fig. 3. Decontamination efficiency according to particle size

To acquire the efficiency of re-decontamination, decontaminated(washed) soil was injected to soil washer again. Selected soil was high radiation soil group. Decontamination time was 60 minute and the ratio was 20:1. Fig. 4 shows the decontamination efficiency for re-decontamination. As shown in Fig. 4, the efficiency of small particle was increased highly than one-time decontamination. But the increase of large particle was low. In case of large particle group, the contaminant was removed sufficiently in first decontamination and there is little increase of efficiency by re-decontamination. In case of small particle group, it is difficult to acquire high efficiency by one-time decontamination but the efficiency more than 80% can be achieved by re-decontamination. It is estimated that the effect of re-decontamination is low in case of sufficiently decontaminated soil but the effect of re-decontamination is good to small particles with high radiation level which is difficult to get sufficient efficiency in first decontamination.



Fi

g. **Fig. 4. Decontamination efficiency by re-decontamination.**

CONCLUSION

The soil decontamination equipment was developed for contaminated soil generated during normal operation and decommissioning. Several processes were investigated and soil washing process which is composed of particle separation, soil washing and liquid waste circulation was selected. To acquire design data, quantity and quality analysis of soil were performed. And the preliminary experiment were performed to obtain the operating conditions of soil washing decontamination process such as decontamination agent, temperature, time and the ratio of soil and decontamination agent.

Contaminated soil was separated according to particle size using vibrating screen. The volume of soil below 0.5 mm occupied about 30% of total volume. Decontamination efficiency above 80% can be acquired by verification experiments with combination of experiment conditions. According to the result, the efficiency of large particle and low radiation level was somewhat higher. The influences of decontamination time and ratio were small. Re-decontamination is more effective for high radiation level and small particle which are somewhat difficult to decontaminate. The range of efficiency for first decontamination was 54~85% and the range of efficiency for second decontamination was 83~93%.

Volume and radioactivity generated from NPP can be reduced using this equipment. Therefore it is anticipated that this equipment can contribute to the efforts for solving the problem of radioactive waste storage space. Also, this equipment can be used effectively during decommissioning of NPP.

REFERENCES

1. EPA. Technology Screening Guide for Radioactively Contaminated Site, EPA402-R-96-017(1996)
2. EPA. Soil Screening Guidance for Radionuclide: Technical Background Document, EPA/540-R00-006(2000)

3. BNL. Radionuclide Contaminated Soil: Laboratory Study and Economic Analysis of Soil Washing, BNL-63679(1996)
4. DOE. Soil Washing Pilot Plant Treatability Test for 100-DR-1 Operable Unit, DOE/RL-95-46(1995)
5. ANL. Minimum Additive Waste Stabilization, Phase I: Soil Washing Final Report, ANL-95/46(1995)
6. Ahmet Suer Environmental Restoration Engineering. Soil Washing Technology Evaluation, WSRC-TR-95-0183(1995)
7. Jungkwon Son, Kidoo Kang et al, "Experiment for Decision of Operating Conditions for Soil Washing Decontamination Process," Proc. of International Symposium on Radiation Safety Management, pp. 458□466, Nov. 5□7, 2003, Daejeon
8. Nuclear Environment Technology Institute. Development of Management Technology for Environmental Radioactivity in Soil TR.A01NS19.M2004.7(2004)