High power ultrasonic effect on compaction and analysis of radioactive sample for γ-ray spectroscopy

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1. Introduction

Recently, there has been growing interest in environmental radiation monitoring. Accurate radionuclide analysis of environmental radioactive sample is therefore required. In the analysis, solid-state radioactive samples are generally compacted in standard containers and put in a high purity germanium detector (HPGe), and the radionuclides are measured by γ-ray spectroscopy. At this time, it is necessary to compact as much sample as possible in the container because the probability of finding radionuclides in γ-ray spectroscopy can be increased for dense sample. In the conventional sample compaction method, the sample is compacted according to the force applied by the measuring person using the acrylic pestle. The density of the compacted sample in the container is thus not equivalent. For this reason, there is a limitation in increasing the density of the compacted sample in the container. In this study, we suggest a new method to compact the environment solid radioactive samples of powder state using high power ultrasound. To verify the validity of the suggested method, the result of radionuclide analysis of the compacted samples that applied the suggested method is compared with that by the conventional method¹).

2. Soil sample compaction

Figure 1 is a schematic of the compaction process of soil sample using high power ultrasound. Two identical Langevin-type ultrasonic transducers, which have the radiation diameter of 42.70 mm, and the resonant frequency of 27 kHz, were installed on the top and bottom of the cylindrical container filled with soil sample. First, as shown in Fig. 1(a), the only static pressure as external pressure is applied to compact the soil sample. The sample is compacted until the total force, which are the frictional force and the force from strain stress, is up to the static force. At this time, the equilibrium relation of force within the container can be expressed by Eq. (1).

\[ F = \sum \mu_s F_f^s + \sum \mu_c F_f^c + \sum F_i. \]  

3. Experimental results

To examine the compaction effect of the soil sample by ultrasound, the sample container is filled with the soil sample until initial height \( h_0 \), as shown in Fig. 2(a). This sample is compacted at a height of \( h_1 \) by the external pressure, as shown in Fig. 2(b). After that, the soil is added to the initial height \( h_0 \), and then the sample is compacted again by the external pressure, as shown in Figs. 2(c) and (d). The compaction processes of Figs. 2(c) and (d) are repeated until the height of the compacted sample finally reaches the initial height of \( h_0 \). Thus, total

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mass of the added sample, $\Delta m$, is measured as follows.

$$\Delta m = \sum_{i} m_i = m_1 + m_2 + m_3 + \cdots . \quad (2)$$

![Fig. 2 Additional mass as a parameter of compaction sample.](image)

In this study, the external pressures are considered two cases. One is the static pressure applied by press machine and the other one is the static pressure with the ultrasound radiated from Langevin-type ultrasonic transducers.

**Figure 3** shows the additional mass of soil as a function of the initial height of $h_0$. In case of applying the static pressure with the ultrasound, the additional mass is more than that of the case of applying only the static pressure, within a given range of $h_0$, as shown in Fig. 3. From this result, it was confirmed that sample in the same volume can be additionally compacted by using high power ultrasound.

![Fig. 3 Additional mass as a function of initial height of soil sample.](image)

Environmental radionuclides of the soil sample compacted by high power ultrasound were analyzed. **Figure 4** shows the results of $\gamma$-ray spectra of the two samples which are compacted into $h_0=5$ cm by the static pressure with the ultrasound and by only the static pressure, respectively. In this figure, the x- and y- axes show the energy level and the number of counts for each radionuclide, respectively. The number of counts is proportional to the probability of finding a radionuclide of the corresponding energy level. As shown in Fig. 4, for example, in case of Pb-212 radionuclide, the number of counts that is obtained by the sample compacted by the static pressure with ultrasound is 4205, whereas that by the only static pressure is 4037. This means that the probability of finding Pb-212 radionuclide in the sample is higher when the sample is compacted by using the static pressure with the ultrasound than the only static pressure. It can be confirmed that the number of counts in most of the radionuclides is higher in the sample compacted by the static pressure with the ultrasound.

![Fig. 4 $\gamma$-ray spectra of the compacted radioactive sample.](image)

4. Summary

In this study, we proposed a new compaction method for an environmental radioactive soil sample. A high power ultrasound is additionally applied to the conventional static pressure for the analysis of environmental radionuclides. We confirmed experimentally that the compaction rate of the sample applying the suggested method was improved of 6 ~ 7%. The environmental radionuclides of the compacted samples were analyzed by $\gamma$-ray spectroscopy. It was confirmed that the number of counts increased by about 200 compared with that by the conventional method.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning (2015R1C1A2A01054839).

References