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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 method[1)].

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 frictions 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).

$$F = \sum \mu_s F_f^s + \sum \mu_c F_f^c + \sum F_t \,. \qquad (1)$$

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Here F is the applied static force, $\Sigma\mu_c F^c{}_f$ the friction force between the container wall and soil particle, $\Sigma\mu_s F^s{}_f$ the friction force between the soil particles, and ΣF_t the force from strain stress. And μ_c and μ_s are the friction coefficients between the container wall and the particles and between the particles, respectively. Next, the ultrasound radiated from Langevin-type ultrasonic transducers is applied to the soil sample together with the static pressure, as shown in Fig. 1(b). The compaction by the ultrasonic as well as by the static pressure occurs. Specifically, the ultrasonic vibration reduces the friction coefficient(μ'_c) between the soil particle and the container wall and the friction coefficient(μ'_s) between the soil particles. As a result, the rearrangement between the particles occurs and an additional compaction occurs.

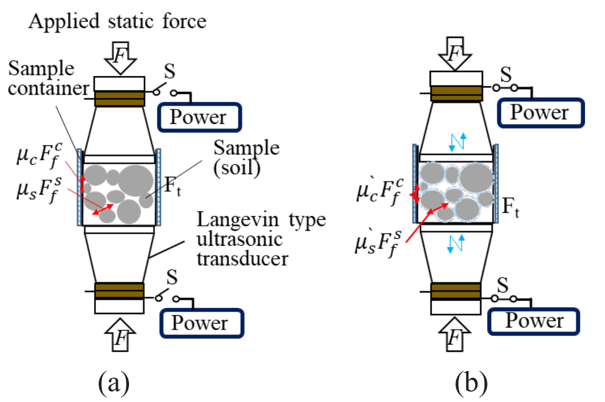

Fig. 1 Schematics of the compaction process of soil sample using high power ultrasound.

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 mass of the added sample, Δm, is measured as follows.

$$\Delta m = \sum_i m_i = m_1 + m_2 + m_3 + \cdots. \quad (2)$$

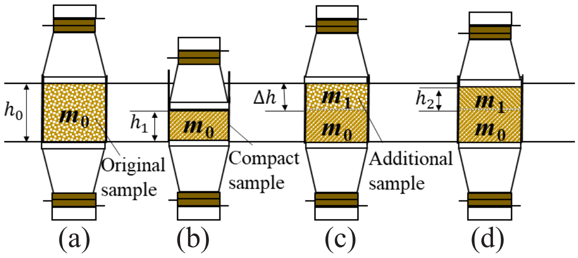

Fig. 2 Additional mass as a parameter of compaction sample.

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.

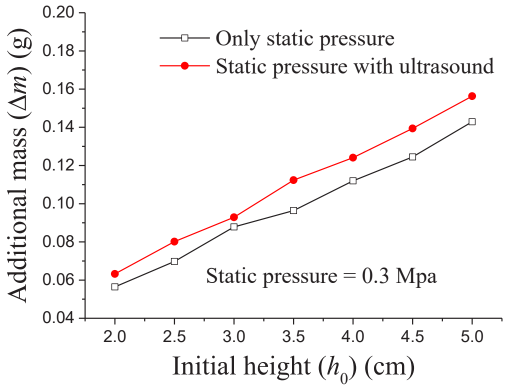

Fig. 3 Additional mass as a function of initial height of soil sample.

Environmental radionuclides of the soil sample compacted by high power ultrasound were analyzed. **Figure 4** shows the results of γ-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.

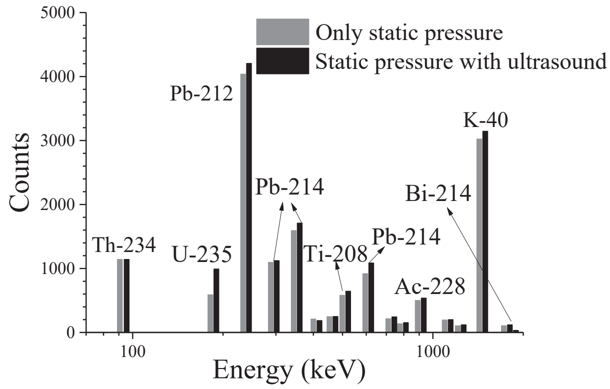

Fig. 4 γ-ray spectra of the compacted radioactive sample.

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 γ-ray spectroscopy. It was confirmed that the number of counts increased by about 200 compared with that by the conventional method.

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References
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