Development for mock-up gamma-ray source applied by 3D printer and natural radionuclide

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When the radioactivity in environmental samples was quantified by gamma-ray spectrometry, geometric conditions of the sample greatly affect the measurement.

Hence, it was attempted that the mock-up gamma-ray source is manufactured and non-destructive measurement by using a 3D scanner and StereoLithography Apparatus (SLA) type 3D printer.

The light curable resin for 3D printer was mixed with Lu_2O_3, which was involved natural radionuclide. And the digital data of the sample (hokutolite) that was modeled in 3D scanner has created a mock-up gamma-ray source in the SLA printer.

The radium concentration of hokutolite used by non-destructive samples were 30 – 80Bq/g, and, were relatively close values of previous reports. Therefore by utilizing this measurement method, it had enabled non-destructive measurement of radioactivity sample having an arbitrary shape..

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I. INTRODUCTION

When determinations of radioactivity by gamma-ray spectrometry or the like, it is very important to match the geometric conditions of the sample. Therefore, it may be necessary to destroy the sample and measure it by matching geometric conditions. However, the radioactivity of valuable samples (e.g. archaeological samples) should better be measured by non-destructive. Therefore, we developed to create mock-up gamma-ray source and determine the radioactivity, by applying a 3D scanner and a SLA type 3D printer.

II. EXPERIMENTAL

II.A. Description of sample

As the model source were chosen "hokutolite (5 samples of 2 production areas)", which were collected in October 1964 at Tamagawa hot spring in Senboku, Akita, Japan. The composition formula of hokutolite is lead-containing barite $Ba(Pb)SO_4$ and contains radium as an impurity. It is confirmed by gamma-ray spectrometry that these hokutolites does not contain radioactive material other than ^{226}Ra and its daughter nuclides. In addition, the ^{226}Ra and the progenies have reached secular equilibrium (Ref. 1).

II.B. Modeling and measurement method

First, the hokutolite was scanned with a 3D scanner (Matter & Form) to obtain 3D shaped digital data. The hokutolite digital data was imported into 3DCG software (Shade 3D), Boolean operation process, and created a cylindrical model with a concavity matching the hokutolite. The cylindrical model was printed out with a Fused Deposition Modeling (FDM) type 3D printer (UP! Plus 2) and used as a jig for aligning position.

Then the light curable resin for SLA 3D printer was mixed with Lu_2O_3, which was involved natural radionuclide. And a mock-up gamma-ray source, which was same shape of hokutolite, was created with the SLA printer (Nobel 1.0). The sample and the mock-up source, respectively, were placed on a jig and measured by gamma-ray spectrometry. The

efficiency curve of gamma-ray spectrometer was parallel translation by using the obtained radioactivity. Concentration of the sample was calculated by the detection efficiency of the translated efficiency curve.

III. RESULTS AND DISCUSSION

The concentrations of radium in hokutolite, which were measured by this study method, are given in Fig.1. Figure 1 shows that the radium concentration of hokutolite used by non-destructive samples were 30 - 80Bq/g. These concentrations were relatively close values of previous reports (Ref. 2, 3, 4).

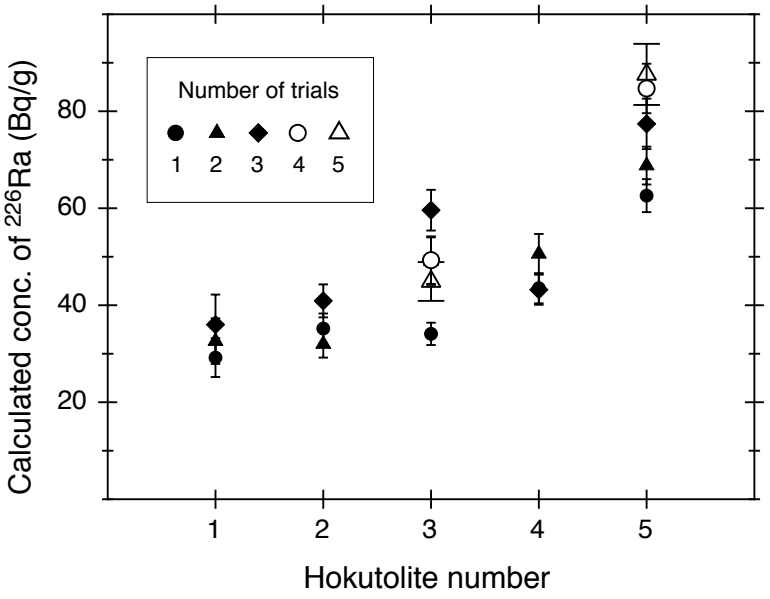

Fig.1. Number of trial creation of mock-up samples and calculated concentration of ^{226}Ra in hokutolite.

Therefore by utilizing SLA 3D printer and natural radionuclides, it became possible to non-destructive measurement of radioactivity sample having an arbitrary shape. However, there was a tendency that the concentration of ^{226}Ra was estimated to be high in each time the mock-up creation trial number was increased repetition (especially hokutolite No.5). In this study, it is assumed that the light curable resin and Lu_2O_3 are homogeneously mixed. Furthermore, since the specific gravity of Lu_2O_3 is larger than that of the resin, there is no problem in a short time, but Lu_2O_3 will precipitate bottom the resin bottle with the lapse of time. Therefore, unless the resin bottle is sufficiently shaken just before printing the mock-up, Lu_2O_3 is not uniformly mixed in the resin, and the radioactivity of the mock-up is lowered, so the radium concentration is estimated to become high.

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REFERENCES

1. T. SAITO, M. TAKAHASHI and Y. KOIKE, *Proc. 16th Workshop on Environmental Radioactivity*, 12-14 (2015).
2. T. SAITO and H. NAGAI, *J. Radioanal. Nucl. Chem.*, 272(2), 443-446 (2007).
3. T. OKUBO and M. SAKANOUE, *Geochem. J.*, 9(4), 221-226 (1975).
4. N. SAITO, Y. SASAKI and H. SASAKI, *Geochemistry of the Tamagawa Hot Sprigs*. Tokyo, 182–198 (1963).