Investigation of Activity Concentrations of NORMs for Industrial Use in Japan

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Abstract. Natural radioactive nuclides are contained in natural materials, namely, ores, rocks and oils. These materials are frequently used as industrial raw materials. If these materials contain natural radioactive nuclides in high concentration, workers can be exposed to radiation at a serious level. Therefore, it is important to investigate the activities in these materials.

In this study, natural materials which are actually used as industrial raw materials were collected and the activities in them were determined using ICP-MS and gamma ray spectrometry. The activities of $^{238}$U series, $^{232}$Th series and $^{40}$K in these materials were lower than values suggested in RS-G-1.7.

KEYWORDS: NORM, decomposition method, industrial raw material.

1. Introduction

Natural radioactive nuclides, such as Uranium-238 ($^{238}$U), Thorium-232 ($^{232}$Th), and Radium-226 ($^{226}$Ra), are widely distributed in the environment. Zirconium(Zr) [1-5] ore, titanium(Ti) [4-6] ore, and phosphate(P) [7-12] ores which are generally used as industrial raw materials, contain radioactive nuclides in a relatively high concentration. The International Commission on Radiological Protection (ICRP) 1990 Recommendations recommend that the occupational exposure of NORMs should be controlled. However, the current extent of the industrial use of NORMs is not clearly perceived, because the radioactive concentrations in NORMs have a wide distribution from very low level, and NORMs are used for a variety of purposes.

Because Japan has few natural resources, most ores used as industrial raw materials are imported. If these resources, containing radioactive nuclides in high concentration, are imported and used, the workers handling them can be exposed to high levels of radiation without being aware of it. The activity in many natural resources should be investigated to evaluate the radiation exposure of workers. In this study, several imported natural resources were collected for a primary survey, and the activity in these resources was measured using ICP-MS (inductively-coupled plasma mass spectrometry) and gamma ray spectrometry.

2. Materials and methods

2.1. Samples

The sample of natural resources actually used as industrial raw materials should be investigated. The Al, Ti, Fe, Mn and Mo ores were provided by, or purchased from several companies in Japan. The local origins of Al ore were Indonesia (1 samples) and Australia (1 sample), those of Ti ore were Australia (2 samples), Vietnam (2 samples) and India (2 samples), those of Fe ore were Australia (2 samples), those of Mn ore were South Africa (1 sample) and those of Mo ore were Chile (1 sample) and Canada (1 sample), respectively (herein referred to as Al-ININDSIA, Al-AUSTRAL, Ti-AUSTRAL1, Ti-AUSTRAL2, Ti-VIETNAM1, Ti-VIETNAM2, Ti-INDIA1, Ti-INDIA2, Fe-AUSTRAL1, Fe-AUSTRAL2, Mn-S AFRICA, Mo-CHILE, and Mo-CANADA).

2.2. ICP-MS

The samples were milled into fine powder and dried at 105°C for 24 hours. Dissolution and decomposition of the powder samples was performed using two methods: acid decomposition (called DA), and decomposition using an alkali fusion (called DF).
A) DA method

The powder samples (0.1 g) were placed in Teflon vessels containing HNO₃ (7 ml) and HF (7 ml). A microwave digester heated the samples. Then, HClO₄ (1 ml) was added, and the samples were dried on a hot plate. Dried samples were dissolved again with HNO₃ (1 ml) and H₂O₂ (0.5 ml), and then dried again. Re-dried samples were dissolved in a 50 ml vial container with 5 % HNO₃ (w/w). The solutions were diluted to a one-tenth with 5 % HNO₃ before performing ICP-MS.

B) DF method

The powder samples (0.5 g) were placed in a platinum crucible with 0.5 g Na₂CO₃, and then heated with a burner for alkali fusion. After standing to cool, the samples were transferred to Teflon vessels containing HCl (2.5ml) and distilled water (5 ml). After the samples in Teflon vessels were dissolved on the hotplate, samples were transferred in a 50 mL polypropylene vial container with 5 % HNO₃. The solutions were diluted to a one-tenth with 5% HNO₃ before measurements.

The determination of the concentration of U and Th in the prepared sample solutions was performed using ICP-MS (Agents 7500a, Yokokawa). Standard solutions for acid wave and alkali fusion samples were prepared. ²³⁵U and ²³⁵Th concentrations were measured twice and the average values were used for analysis. The error for these results was derived from the counting error.

2.3. Gamma-ray spectrometry

Samples were cut smaller than two millimetres with an iron mortar. The samples were dried at 105°C for 24 hours to remove water vapour that adhered to them during clashing. Dried samples were packed in a polystyrene container (height, 50 mm; diameter, 44 mm). Packed samples were left for four weeks. The gamma-ray spectrums of samples were collected using a high-purity germanium (HPGe) detector. The activity of ²²⁶Ra was estimated from the energy peak of 609.31 KeV, that of ²³⁵Ra from the energy peak of 911.20 KeV, and that of ⁴⁰K from the energy peak of 1460.75 KeV. The count time for samples was 80000 s. The error for these activities was derived from the counting error.

3. Results and Discussion

Results of the dissolution and decomposition for each sample are shown Table1. The DA method was used to decompose Al and Fe samples for ICP-MS. The other samples, however, could not be decomposed; therefore, AF method was used to decompose these samples. These samples decomposed with alkali-fusion might contain insoluble mineral species.

The results obtained using ICP-MS and HPGe, and the value in RS-G-1.7 [13] are shown Table2. The activity of ²³⁸U, ²²⁶Ra, ²³³Th, and ²²⁸Ra in Ti ores was largest in that of Al, Ti, Fe, Mn and Mo ores. The activity of ²³⁸U series (²³⁸U and ²²⁶Ra) in Ti-VIETNAM1 was 0.22 Bq g⁻¹ and the largest in that of Ti ores. The activity of ²³³Th series (²³³Th and ²²⁸Ra) in Ti-VIETNAM1 was 0.31 Bq g⁻¹ and the largest in that of Ti ores. The activity in materials is often compared to the values suggested in RS-G-1.7. In RS-G-1.7, the values of activity concentration for radionuclides of

<table>
<thead>
<tr>
<th>Table 1: Results of dissolution and decomposition.</th>
<th>DA</th>
<th>AF</th>
</tr>
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<tbody>
<tr>
<td>Al-INDINSIA</td>
<td>○</td>
<td>-</td>
</tr>
<tr>
<td>Al-AUSTRAL</td>
<td>○</td>
<td>-</td>
</tr>
<tr>
<td>Ti-AUSTRAL1</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Ti-AUSTRAL2</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Ti-VIETNAM1</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Ti-VIETNAM2</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Ti-INDIA1</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Ti-INDIA2</td>
<td>×</td>
<td>○</td>
</tr>
<tr>
<td>Fe-AUSTRAL1</td>
<td>○</td>
<td>-</td>
</tr>
<tr>
<td>Fe-AUSTRAL2</td>
<td>○</td>
<td>-</td>
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<tr>
<td>Mn-S AFRICA</td>
<td>×</td>
<td>○</td>
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<tr>
<td>Mo-CHILE</td>
<td>×</td>
<td>○</td>
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<tr>
<td>Mo-CANADA</td>
<td>×</td>
<td>○</td>
</tr>
</tbody>
</table>

○: resolvability, ×: irresolvability
The activity in each ores was measured using ICP-MS and gamma ray spectrometry. The activity in these ores was lower than the suggested values in RS-G-1.7. Thus, it is assumed that workers using each ores should have no problems with radiation risk.

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**REFERENCES**


