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Characteristics of Airborne Particulates Containing Naturally Occurring Radioactive Materials in Monazite Industry

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1. Introduction

Monazite is one of the minerals containing naturally occurring radioactive material (NORM). Therefore, external and internal exposure can be occurred to the workers in monazite industry. The major exposure pathway of the workers is internal exposure due to inhalation of airborne particulates [1].

According to International Commission on Radiological Protection (ICRP), radiation dose due to inhaled particulates containing NORM depends on particulate properties. Therefore, ICRP recommended the internal dose assessment using measured physicochemical properties of the airborne particulates. In the absence of specific information, ICRP provided default reference values [2]. According to previous studies, measured particulate properties were often different from the ICRP reference values. Dorrian and Bailey measured airborne particulate size distribution at different industries. The particulate sizes were widely distributed and ranged 0.12-25 μm in workplace [3]. Therefore, measurements of particulate properties are required for accurate radiation dose assessment.

The objective of this study was to characterize physicochemical properties of airborne particulates at a monazite pulverization industry. The properties included particulate size distribution, concentration, shape, density, and radioactivity concentration.

2. Material and Method

Sampling sites were selected by considering workplace condition. Selected processes for airborne particulate samplings included raw material classification process, pulverizer decontamination process, and dust collector decontamination process. Raw materials contained not only monazite but also other raw materials. Therefore, the raw materials were classified according to external dose rate. Raw materials were classified to group A (< 0.5 μSv/h), group B (0.5-5 μSv/h), and group C (5-50 μSv/h). Decontamination processes were performed on surface and inside pulverizer and dust collectors.

2.1 Particulate size distribution and concentration

Airborne particulates were collected using cascade impactor to characterize the particulate size distribution and concentration at the selected sampling sites. The cascade impactor is composed of 0^{st}-7^{st} impactor stages and filter stage. Table 1 shows the aerodynamic size and geometric mean diameter for each stage of cascade impactor.

Table I: Particulate size range and geometric mean diameter for each stage

Stage	Particulate size range (μm)	Geometric mean diameter (μm)
0	9.00-10.0	30.0
1	5.80-9.00	7.22
2	4.70-5.80	5.22
3	3.30-4.70	3.94
4	2.10-3.30	2.63
5	1.10-2.10	1.52
6	0.65-1.10	0.88
7	0.40-0.65	0.53
Filter	0.03-0.40	0.11

2.2 Particulate density and shape

Mass density was measured using a pycnometer for the raw materials from sampling sites. Airborne particulate samples collected by cascade impactor were analyzed for shape using Scanning Electron Microscopy (SEM).

2.3 Radioactivity concentration

The measurements of radioactivity concentrations of the particulates taken from the major process of monazite industry were performed using High Purity Germanium (HPGe) detector. Collected samples were sealed for 30 days in marinelli beaker for equilibrium in the uranium and thorium series prior to the radioactivity measurement. Analysis of radioactivity in samples was performed based on measurements of Pb-214 and Bi-214 for Ra-226 and Ac-228 for Ra-228.

3. Results and Discussion

3.1 Particulate size distribution and concentration

Fig. 1. shows the size distribution and concentration of the airborne particulates in monazite pulverization industry. Particulate size was widely distributed from 0.1 to 100 μm. The particulate concentration at each cascade stage ranged 0.001-0.251 μg/L. Generally particulate concentrations increased with particulate size, reached the maximum at particulate size of 4.70 μm or 9.00 μm, and decreased after the size. The concentration of airborne particulates was the lowest at dust collector decontamination area because this process was performed after that external pathway of dust collector sealed to prevent the spread of dust containing monazite to environmental.

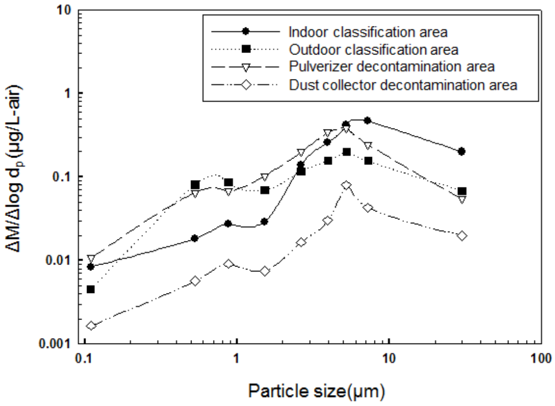

Fig. 1. Particulate size distribution and concentration in monazite pulverization industry

3.2 Particulate density and shape

The mass density of the monazites collected at classification process area was 5.1 g/cm^3, which was similar to general monazite densities [4]. The mass densities of other samples at classification process areas were 2.7, 2.8, and 4.2 g/cm^3 for raw materials of group A, B and C, respectively. The mass densities of dusts in pulverizer and dust collector decontamination process areas were 3.2 and 3.9 g/cm^3. These values were lower than monazite density because the samples were mixture of monazite and other raw materials.

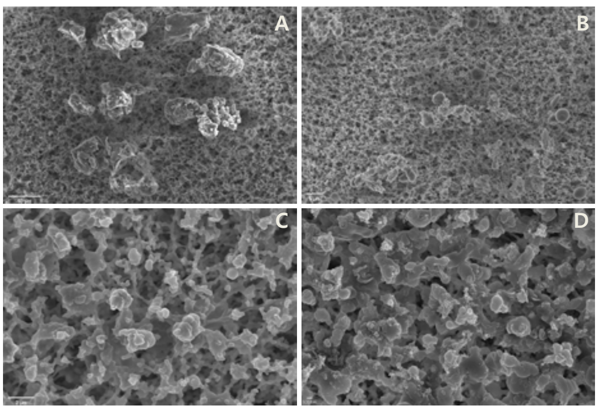

Fig. 2. Shape of airborne particulate in monazite pulverization industry

Fig. 2. shows scanning electron microscope images of airborne particulates collected at 0th (A), 3rd (B), 5th (C), 7th (D) stages of cascade impactor. All airborne particulates were appeared to be spherical shape. Therefore, the shape factor of unity was assigned for inhalation dose assessment.

3.3 Radioactivity concentration

Table 2 shows radioactivity concentrations of samples collected in monazite pulverization industry. The radioactivity concentrations of monazite sample were 21.4 Bq/g for Ra-226 and 213 Bq/g for Ra-228, respectively, similar with the values in literature [5]. Compared with monazite sample, the radioactivity concentrations of samples from group C, pulverizer decontamination process area, and collector decontamination process area were lower by about 8-25% for Ra-226 and 15-57% for Ra-228.

Table II: Radioactivity concentration of Ra-226 and Ra-228 for collected samples in monazite pulverization industry

Sample	Ra-226 (Bq/g)	Ra-228 (Bq/g)
Monazite	2.14 ± 1.4	213 ± 9.4
Raw material of group A	0.0595 ± 0.0015	0.272 ± 0.004
Raw material of group B	0.7895 ±0.0145	6.51 ±0.062
Raw material of group C	19.6 ±0.19	180 ±1.3
Pulverizer decontamination dust	10.2 ±0.66	91.8 ±4.1
Dust collector decontamination dust	0.041 ±0.001	0.326 ±0.004

4. Conclusions

In this study, we characterized physicochemical properties of airborne particulates at a monazite pulverization industry. The databases of particulate information can be used for accurate internal dose assessment of worker. In addition, it is useful to monazite industry and regulators in their consideration of radiation protection as basic data for establishing a system of natural radiation safety management.

Acknowledge

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