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Activity concentration of natural radioactive nuclides in nonmetallic industrial raw materials in Japan

Kazuki Iwaoka [a, b, *], Hiroyuki Tabe [a], Hidenori Yonehara [a]

[a] Research Center for Radiation Protection, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan
[b] Institute of Radiation Emergency Medicine, Hirosaki University, 66-1 Honcho, Hirosaki, Aomori 036-8564, Japan

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ABSTRACT

Natural materials such as rock, ore, and clay, containing natural radioactive nuclides are widely used as industrial raw materials in Japan. If these are high concentrations, the workers who handle the material can be unknowingly exposed to radiation at a high level. In this study, about 80 nonmetallic natural materials frequently used as industrial raw materials in Japan were comprehensively collected from several industrial companies, and the activity concentrations of ^{238}U series, ^{232}Th series and ^{40}K in the materials was determined by ICP-MS (inductively-coupled plasma mass spectrometer) and gamma ray spectrum analyses. Effective doses to workers handling them were estimated by using methods for dose estimation given in the RP 122. We found the activity concentrations to be lower than the critical values defined by regulatory requirements as described in the IAEA Safety Guide. The maximum estimated effective dose to workers handling these materials was 0.16 mSv y^{-1}, which was lower than the reference level (1–20 mSv y^{-1}) for existing situation given in the ICRP Publ.103.

1. Introduction

Natural materials contain natural radioactive nuclides such as ^{238}U, ^{232}Th, ^{226}Ra, ^{228}Ra and ^{40}K. A material containing a significant amount of natural radioactive nuclides is referred to as a naturally occurring radioactive material (NORM). The necessity of some regulations to control the exposure to NORM was pointed out in the International Commission of Radiological Protection Publication 60 (ICRP Publ.60) (ICRP, 1991). The critical values (named as IAEA critical values) were provided in the International Atomic Energy Agency (IAEA) Safety Guide (IAEA, 2004). The policy of the IAEA safety guide requires that in situations where the activity concentration of the radioactive nuclide exceeds the IAEA critical values, the regulatory body should decide on the extent to which further regulatory requirements should be applied. In Japan, the guideline for safety control of natural materials containing uranium and thorium was published in June, 2009 by the Ministry of Education Culture, Sports, Science and Technology (MEXT). The guideline requires a self-regulation of users handling specified materials including monazite, bastnaesite, zircon, tantalite, phosphate rock, uranium ore, thorium ore, titanium ore, coal ash, and metal, glass and others added with refined uranium and thorium.

Recently, it has been reported that metallic natural materials such as thorium ore (monazite) (El Afifi et al., 2006; Mohanty et al., 2004a; Panda and Rajagopalan, 2003), zirconium ore (Ballesteros et al., 2008; Johnston, 1991) and titanium ore (Haridasan et al., 2008; Johnston, 1991; Mohanty et al., 2004b) contain radioactive nuclides in relatively high concentration. In Japan, since these metallic materials are often used as industrial raw material, the activity concentration in these metallic materials used in Japan was investigated (Iwaoka et al., 2009).

On the other hand, although nonmetallic natural materials as well as metallic natural materials are frequently used as industrial raw material in Japan, the literature has little data for nonmetallic natural materials used in Japan. If these are high concentrations, the workers who handle the material can be unknowingly exposed to radiation at a high level. In this study, nonmetallic natural materials used as industrial raw materials for building material, refractory, electric heater, ceramic ware, fertilizer, soil conditioner, decolorant, glass, and resinoid in Japan were comprehensively collected from industrial companies, and the activity concentration of ^{238}U series, ^{232}Th series and ^{40}K in them was determined by ICP-MS (inductively-coupled plasma mass spectrometer) and gamma ray spectrum analyses. Effective doses to workers handling the materials were estimated.

* Corresponding author. Research Center for Radiation Protection, National Institute of Radiological Sciences, 4-9-1 Anagawa, Inage, Chiba 263-8555, Japan. Fax: +81 43 251 6089.
E-mail address: iwaoka@nirs.go.jp (K. Iwaoka).

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Table 1
Local origins and principal uses of samples.

Sample	Material	Country	Province	Principal use
	Raw materials for building material			
1	Bitumen	Trinidad and Tobago	–	Road paving, roofing, ink, rust retardant for ship bottom
2	Bitumen	Trinidad and Tobago	–	Road paving, roofing, ink, rust retardant for ship bottom
3	Bitumen	China	Jiangsu	Road paving, roofing, ink, rust retardant for ship bottom
4	Clayslate	Spain	–	Slate roof, ink stone, aggregate
5	Clayslate	Portugal	–	Slate roof, ink stone, aggregate
6	Clayslate	Japan	Miyagi	Slate roof, ink stone, aggregate
7	Fly ash	Japan	–	Cement admixture, freshly-mixed concrete
8	Fly ash cement	Japan	–	Cement admixture, freshly-mixed concrete
9	Obsidian	Japan	–	Concrete aggregate, soil conditioner, filter aid
10	Obsidian	Japan	–	Concrete aggregate, soil conditioner, filter aid
11	Obsidian	Russia	–	Concrete aggregate, soil conditioner, filter aid
12	Obsidian	Indonesia	–	Concrete aggregate, soil conditioner, filter aid
13	Obsidian	Japan	–	Concrete aggregate, soil conditioner, filter aid
14	Vermiculite	South Africa	Palabora	Concrete, antifire mortar, insulation
15	Vermiculite	South Africa	Palabora	Concrete, antifire mortar, insulation
16	Vermiculite	South Africa	Palabora	Concrete, antifire mortar, insulation
17	Limestone	Japan	Kouchi	Cement, concrete, steel
18	Limestone	Japan	Fukui	Cement, concrete, steel
19	Silica stone	Finland	–	Cement, concrete, steel
20	Silica stone	Japan	Fukui	Cement, concrete, steel
21	Silica stone	Japan	Fukui	Cement, concrete, steel
22	Silica stone	Japan	Fukui	Cement, concrete, steel
23	Silica stone	Japan	Shimane	Cement, concrete, steel
24	Silica stone	Japan	Tokushima	Cement, concrete, steel
25	Silica stone	Japan	Aichi	Cement, concrete, steel
	Raw materials for refractory			
26	Dolomite	Japan	Tochigi	Refractory, steel
27	Dolomite	Japan	Tochigi	Refractory, steel
28	Fire clay	Japan	Aichi	Refractory, steel
29	Fire clay	Japan	Nagasaki	Refractory, steel
30	Fire clay	USA	–	Refractory, steel
31	Fire clay	Japan	Aichi	Refractory, steel
32	Kyanite	Japan	Aichi	Firebrick, ceramic, clay pipe, foundry sand
33	Kyanite	USA	Virginia	Firebrick, ceramic, clay pipe, foundry sand
34	Magnesite	China	Liaoning	Firebrick, magnesia brick, electric furnace
35	Magnesite	China	–	Firebrick, magnesia brick, electric furnace
36	Peridotite	Japan	Iwate	Refractory, casting sand, foundry sand
37	Peridotite	Japan	Kochi	Refractory, casting sand, foundry sand
38	Pyrophyllite	Japan	Okayama	Refractory, ceramic, glass fiber
39	Pyrophyllite	Japan	Okayama	Refractory, ceramic, glass fiber
40	Pyrophyllite	South Korea	–	refractory, ceramic, glass fiber
	Raw materials for electric heater			
41	Mica	India	–	Electric insulation
42	Mica	Madagascar	–	Electric insulation
43	mica	India	–	Electric insulation
44	Mica	Madagascar	–	Electric insulation
45	Mica	Sri Lanka	–	Electric insulation
46	Mica	Madagascar	–	Electric insulation
	Raw materials for ceramic ware			
47	Feldspar	Japan	Shimane	Ceramic ware, grinding wheel, glass
48	Feldspar	Japan	Shimane	Ceramic ware, grinding wheel, glass
49	Feldspar	Japan	Shimane	Ceramic ware, grinding wheel, glass
50	Feldspar	India	Tamil Nadu	Ceramic ware, grinding wheel, glass
51	Feldspar	India	Tamil Nadu	Ceramic ware, grinding wheel, glass
52	Feldspar	India	Rajasthan	Ceramic ware, grinding wheel, glass
53	Feldspar	India	Andhra Pradesh	Ceramic ware, grinding wheel, glass
	Raw materials for fertilizer			
54	Phosphate ore	China	–	Fertilizer, phosphoric acid
55	Phosphate ore	China	–	Fertilizer, phosphoric acid
56	Phosphate ore	China	Hubei	Fertilizer, phosphoric acid
57	Phosphate ore	China	Hubei	Fertilizer, phosphoric acid
58	Phosphate ore	China	Hubei	Fertilizer, phosphoric acid
59	phosphate ore	China	Jiangxi	Fertilizer, phosphoric acid
60	phosphate ore	China	Hubei	Fertilizer, phosphoric acid
61	Serpentine	Japan	Saitama	Fertilizer, steel
62	Serpentine	Japan	Kouchi	Fertilizer, steel
	Raw materials for soil conditioner			
63	Bentonite	Japan	Shimane	Soil conditioner, bond for casting sand, foundry sand
64	Bentonite	Japan	Shimane	Soil conditioner, bond for casting sand, foundry sand
65	Bentonite	USA	Wyoming	Soil conditioner, bond for casting sand, foundry sand

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