Radiation Exposure of NORM Workers in Korea: Current Status and Suggestions

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1. Introduction

All rocks and minerals contain radioactive nuclides of terrestrial origin. The ^{238}U and ^{232}Th decay series and ^{40}K are radioactive nuclides of main interest in the safety control of naturally occurring radioactive materials (NORM). The activity concentrations of these radioactive nuclides in raw materials are low, but it can go high after technical treatment, making technically enhanced naturally occurring radioactive materials (TENORM). Workers handling NORM-containing materials would most probably experience radiation exposure. IAEA recommends member states to provide safety measures to workers of NORM industries [*1*].

In Korea, huge amount of raw materials containing NORM are imported to be utilized for commercial goods production. Workers in NORM industries and consumers of the commercial products are most probably exposed to radiation of NORM origin. In Korea, 'The Act on Safety Control of Radioactive Rays around Living Environment' was enforced as of July in 2012. Now, NORM workers and the consumers of NORM goods are protected by law from exposure to radiation of NORM origin. In this paper, we analyze the radiological environment of selected domestic NORM industries and suggest a safety guide for NORM workers.

2. Radiological aspects of NORM industries in Korea

The Korea Institute of Nuclear Safety has performed an extensive survey on the environmental radioactivity in the working areas of domestic NORM industries [*2-4*]. The radioactivity concentrations of raw materials were measured and the external and internal radiation doses to workers were estimated by adopting likely scenarios of radiation exposure. A part of the survey data are summarized in the following.

2.1 Activity concentrations of raw materials

The activity concentration of raw materials measured in the range of up to 3869 Bq/g (see Table I). Zircon in foundries shows the highest activity concentrations in both ^{238}U and ^{232}Th decay series. Dose rates at the surface of the bulk materials were estimated at 0.26 to 0.28 μSv/h. The highest value of ^{40}K activity concentration comes from potassium chloride in fertilizer industries. Dose rate at the surface of bulk material ranged from 0.87 to 1.36 μSv/h. The range of surface dose rate was above that of natural radiation dose in Korea as estimated at 0.05 to 0.3 μSv/h [*5*].

Table I. Radioactivity concentrations of raw materials in domestic NORM industries [*2-4*]

raw materials	activity concentration (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
bauxite	344 ± 34	391 ± 32	95 ± 7
phosphate ore	92 – 850	0.72 – 9.1	62 – 180
potassium chloride	< 0.7	< 2.6	16,373 – 16,910
zircon	1,192 – 3,869	138 – 792	< MDA*

*MDA: Minimum Detectable Activity

2.2 External exposure

Raw materials in bulk are usually placed in temporary storages until they are put into processing. Relatively higher radiation exposure was expected while workers carry raw materials from the temporary storage to the next stage of processing or handle by-products of processing. Radioactivity of by-products tends to be higher than that of raw materials. Original activity equilibrium of radionuclides in raw materials may be broken due to selective mobilization of radionuclides during physical and/or chemical processing.

External dose to workers was estimated by measuring the gamma-ray exposure rate at multiple hot spots in working areas and then assuming possible scenarios of a worker staying at different locations during working hours. The maximum external dose was estimated at 0.76 mSv per year for workers handling potassium chloride.

2.3 Internal exposure

Internal dose to the workers is attributed mainly to the aerosols containing radioactive nuclides, which are inhaled and deposited in the respiratory tract of the workers. Once the aerosol characteristics, including aerosol size, density, particle shape and type of particle absorption, are determined, the internal dose can be estimated by using the IMBA code [*6*]. The dose estimation scheme of IMBA is based on the Human Respiratory Tract Model published by the International Commission on Radiological Protection (ICRP) [*7*].

For the workers in NORM industries, the internal dose was calculated by assuming them light workers who wear dustproof masks that block 80% of aerosols during inhalation. The internal dose was estimated below 17.4 μSv/y.

2.4 The status of safety management for NORM

'The Act on Safety Control of Radioactive Rays around Living Environment' defines the *raw materials* and *by-products* and sets the registration criteria as *NORM industries*. According to the survey data published by KINS for radiological aspects of NORM industries in Korea [*2-4*], the annual dose of NORM workers is expected below 1 mSv. The current dose limits for NORM workers are the same as for the radiation workers in nuclear industry, i.e., 50 mSv/y and 100 mSv for consecutive 5 years.

3. Discussion

European Commission operates a system of four control bands categorized by effective annual doses under normal and abnormal situations of radiation exposure (see Table II) [*8*], which is in accord with the graded approach of IAEA in safety assessment. Data from the KINS Reports deliver that the annual dose of workers in domestic industries handling NORM is least probably over 1 mSv. We suggest that a more practical classification of *NORM industries* be developed for cost-effective management in Korea. Note that the "NORM industries" quoted in this paper to mention the industries surveyed by KINS have not all been judged whether they meet the criteria as *NORM industries* set by the Act.

Table II. Classification of regulatory levels for NORM processing in European Basic Safety Standards Directive concerning natural radiation sources [*8*]

	Effective dose (mSv/y)	
	Normal	Unlikely
Band 1 No regulatory necessary	1	6
Band 2 Low level of regulation	6	20
Band 3 Higher level of regulation	20	50
Band 4 Process not permitted	-	-

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REFERENCES

[1] International Atomic Energy Agency, Assessing the need for radiation protection Measures in Work involving Minerals and Raw materials, IAEA Safety Reports Series No. 49, 2006.
[2] Korea Institute of Nuclear Safety, Development of radiological safety inspection requirements for naturally occurring radioactive materials used for mineral and oil industry, KINS/HR-1386, 2015.
[3] Korea Institute of Nuclear Safety, Development of radiological safety inspection requirements for naturally occurring radioactive materials used for industry and building, KINS/HR-1317, 2013.
[4] Korea Institute of Nuclear Safety, Development of dosimetry method using cascade impactor and particle property data, KINS/HR-1271, 2013.
[5] http://iernet.kins.re.kr/, Integrated Environmental Radiation Monitor Network Homepage.
[6] A. Birchall. N.S. Jarvis, M.S. Peace, A.E. Riddell and W.P. Battersby, The IMBA suite: Integrated Modules for Bioassay Analysis, *J Radiat Dosim* Vol. 79(1-4), pp. 107-110, 1998.
[7] International Commission on Radiological Protection, Human respiratory tract model for radiological protection, ICRP Publication 66. Ann. ICRP 24(1-3), 1994.
[8] European Commission, Reference levels for workplaces processing materials with enhanced levels of naturally occurring radionuclides, A guide to assist implementation of Title VII of the European Basic Safety Standards Directive (BSS) concerning natural radiation sources, Radiation Protection 95, 1999.