Validating the ICRP Reference Values on Airborne Contaminants as Representative of Domestic Workplace Environments Involving NORM

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1. Introduction

Workers handling Naturally Occurring Radioactive Material (NORM) can be exposed to ionizing radiation through inhaling airborne alpha-emitting radionuclides. Thus, the internal dose estimation is an essential process in safety management for the workers. Although individual monitoring combined with bioassay measurements is recommended for intake estimation [1], circumstances do not always allow individual monitoring but guide to workplace monitoring.

When workplace monitoring data are used for internal dose estimation, however, certain aspects of the airborne contaminants should be figured out. Internal doses to the workers in Korean NORM industries were reported to be lower than 1 mSv/y based on on-site measurements [2-4]. A sensitivity analysis study, on the other hand, warned that the lack of specific information on aerosol's physicochemical properties could result in the underestimation of internal dose by up to 1-2 orders of magnitude [5]. Despite the necessity for the site-specific data, the specification of aerosol properties can be a difficult task. Size selective air sampling can help but with an additional cost of monitoring program. Accurate information on the absorption rates of inhaled aerosol is another challenging task [6].

This study has been performed to evaluate the representativeness of the ICRP reference values in internal dose estimation for the workers of NORM industries in Korea. Among the key parameters of airborne contaminants we focused on the physical properties of aerosol: activity median aerodynamic diameter (AMAD) and density. When no specific information is available, ICRP publication 66 (Human Respiratory Tract Model) recommends using 5 μm and 3 g/cm^3 as default values for AMAD and density, respectively.

2. Methods and Results

2.1. Workplace monitoring data in Korean NORM industries

The on-site measurement data of aerosol in several Korean NORM industries, available in earlier reports by Korea Institute of Nuclear Safety (KINS) [2-4], have been collected for being used as test data. In each spot of measurement, aerosol properties were specified in terms of mass distribution obtained by operating a cascade impactor, and a density assumed to be the same as the raw materials. Neither the activity distributions nor AMAD data were available.

We calculated the mass median aerodynamic diameter (MMAD) from each given mass distribution. For AMAD, we assumed that aerosols of diameter less than 10 μm are uniform in activity so that AMAD has the same value as MMAD. The aerosol properties in different types of industries are listed in Table I. The mean values of AMAD and density were obtained from the aerosol collections in multiple workplaces in each industry. The mean values of AMAD and density are displayed in Fig. 1 in comparison with the ICRP reference values.

Table I: Aerosol properties in terms of mean AMAD and mean density calculated from the raw data reported by KINS for Korean NORM Industries [2-4]

Industry	AMAD (μm)		Density (g/cm^3)	
	Mean	Standard deviation	Mean	Standard deviation
Refractory	4.90	2.19	3.96	0.99
Welding rod	5.79	1.90	4.08	0.94
Precision metal	5.56	1.25	3.94	0.87
Facings	4.49	-	3.50	-
Enamel	3.44	1.33	4.14	0.80
Insulations	2.91	0.65	3.42	1.09
Coal	4.23	1.72	1.94	0.55
Potassium	4.83	1.98	2.00	0.20
Fertilizer	4.51	2.85	1.97	0.10
Cement	6.61	2.80	2.94	0.37
Overall mean	**4.91**	**2.14**	**3.44**	**1.28**

Overall mean of AMAD and density calculated with the raw data of aerosol properties from Korean NORM industries as reported by KINS [2-4], are well represented by the ICRP reference values of 5 μm in AMAD and 3.0 g/cm^3 in density.

2.2 Internal dose calculation

IMBA Professional Plus (HPA, UK) was employed to calculate the 50-year committed effective doses to the workers in 10 Korean NORM industries visited by KINS [2-4].

The parametric values for aerosol's AMAD and density were set in the ranges of 5 ± 2 μm in AMAD and 3 ± 1 g/cm^3 in density according to the data in Table I. The ICRP default value of 1.5 was assigned to the particle shape factor [1]. The absorption parameters

for individual radionuclides were specified as the ICRP publication 68 recommends. Other parametric choices were set as the ICRP defaults as well.

2.3 Estimation of dose coefficients

The data of dose coefficients calculated with IMBA are summarized in Table II for radionuclides of our interest. Those radionuclides correspond to relatively greater values of dose coefficient. According to the data in Table II, dose coefficients for the aerosols in Korean NORM industries vary in the range of -36% to 43% of that for the ICRP default aerosol.

If we assume the secular equilibrium among the radionuclides of ^{238}U and ^{232}Th decay series in ICRP default aerosol, the expected committed effective dose from unit intake is 0.0169 mSv for ^{238}U and 0.0607 mSv for ^{232}Th.

Table II: Dose coefficients for the ICRP default aerosol in AMAD and density and the variations for the aerosols in Korean NORM industries as reported by KINS [2-4].

Nuclide	Absorption type	Dose coefficient (mSv/Bq)		
		ICRP default aerosol	Korean on-site aerosols	
			Max	Min
^{238}U	M	1.65E-03	39%	-18%
^{234}U	M	2.11E-03	37%	-23%
^{230}Th	S	7.37E-03	42%	-31%
^{226}Ra	M	2.16E-03	36%	-23%
^{210}Pb	F	1.49E-03	3%	-7%
^{210}Po	M	2.16E-03	35%	-34%
Total		**1.69E-02**	**36%**	**-26%**
^{232}Th	S	2.44E-02	43%	-28%
^{228}Ra	M	1.18E-03	24%	-23%
^{228}Th	S	3.27E-02	14%	-29%
^{224}Ra	M	2.44E-03	33%	-36%
Total		**6.07E-02**	**27%**	**-29%**
^{40}K	F	2.96E-06	1%	-4%

3. Conclusion

'The Act on Safety Control of Radioactive Rays around Living Environment' requires the protection of NORM workers from radioactive contaminants. Workplace monitoring is a practical choice for managing the internal exposure of workers even though it involves interpretation of on-site aerosol properties, which would add uncertainty. The current aerosol properties, specifically AMAD and density, in Korean NORM industries are well represented by the ICRP references in internal exposure estimation with a limited uncertainty.

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REFERENCES

[1] ICRP, Occupational Intakes of Radionuclides: Part 1, ICRP Publication 130; Ann. ICRP, Vol. 44, No. 2, 2015.
[2] KINS, Development of Dosimetry Method Using Cascade Impactor and Particle Property Data, KINS/HR-1271, 2013.
[3] KINS, Development of Radiological Safety Inspection Requirements for Naturally Occurring Radioactive Materials Used for Industry and Building, KINS/HR-1317, 2013.
[4] KINS, Development of Radiological Safety Inspection Requirements for Naturally Occurring Radioactive Materials Used for Mineral and Oil Industry, KINS/HR-1386, 2015.
[5] S. Y. Kim, C. K. Choi, I. Park, Y. G. Kim, W. C. Choi, and K. P. Kim, Assessment of Inhalation Dose Sensitivity by Physicochemical Properties of Airborne Particulates Containing Naturally Occurring Radioactive Materials, Journal of Radiation Protection and Research, Vol. 40, No. 4, pp. 216-222, 2015.
[6] J. L. Lipsztein, D. R. Melo, W. Sousa, K. M. Dias da Cunha, A. M. G. Azeredo, L. Julião, and M. Santos, NORM Workers: A Challenge for Internal Dosimetry Programmes, Radiation Protection Dosimetry, Vol. 105, No. 1-4, pp. 317-320, 2003.