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Internal Exposure of a Seoul Subway Passenger due to Radon Inhalation: Before and After PSD Installation

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1. Introduction

Seoul subway system is a main public transportation of the city. Its underground environment, however, can be hazardous due to radon accumulation. Radon is the major source of public exposure to natural radiation and is also known to cause lung cancer. Platform screen doors (PSD) were installed primarily for passenger's safety purposes. Radon concentration [1,2] and aerosol distribution [3,4] have been changed since PSD installation.

In this study, we have assessed the annual effective dose of regular subway passengers, before and after PSD installation, by employing current available data on air concentration of radon in Seoul subways with aerosol size distributions taken into account.

2. Methods

2.1 Dose Estimation Program

Internal dose estimation was performed by using the IMBA (Integrated Modules for Bioassay Analysis, HPA, UK) program. IMBA is implemented with latest biokinetic and dosimetric models recommended by International Commission on Radiological Protection (ICRP). Input parameters for IMBA simulation include the radon concentration in the air along with aerosol characteristics, duration of human exposure to the radon-contaminated air and human respiration rate.

2.2 Exposure Scenario

Table I specifies each parametric values considered in this study. According to Seoul Institute City Information Center, an average subway passenger who commutes for work spends approximately 11 minutes at the platform and 35 minutes inside the train. Therefore, exposure time was set in separate, at the platform and inside the train, in Table I. Respiration rate was set the same as the ICRP 66 (Human Respiratory Tract Model) recommends for a light worker.

The average concentration of radon at the platform was reduced from 96.7 Bq/m^3 to 41.3 Bq/m^3 thanks to PSD installation [1]. Radon concentration inside the train, however, increased from 20.1 Bq/m^3 to 30.8 Bq/m^3 [2]. Radon shut in the tunnel out of the passenger platform because of PSD seems to have diffused into the train.

The aerosol size distribution was available only in two size groups, one of diameter below 2.5 μm ($PM_{2.5}$) and the other of diameter below 10 μm (PM_{10}). With PSD installed, the aerosol size has been shifted to larger in the train while being shifted to smaller at the platform.

Table I: Basic data for simulating the radiation exposure scenario of a passenger in radon-contaminated subways.

		Platform	Train
Exposure time (hour/day)		0.33	1.2
Respiration rate (m^3/hour)		1.2	1.2
Before PSDs	Radon concentration (Bq/m^3)	96.7	20.1
	Aerosol distribution ($PM_{2.5}/PM_{10}$)	0.56	0.62
After PSDs	Radon concentration (Bq/m^3)	41.3	30.8
	Aerosol distribution ($PM_{2.5}/PM_{10}$)	0.60	0.48

3. Results

3.1 Dose Estimate with Aerosol of Single Size

We calculated the annual effective dose for a passenger, who respires in the air contaminated with radon at the nominal respiration rate of 1.2 m^3/hour. In the first step, the annual effective dose was calculated assuming 1 Bq of daily radon intake. With the equilibrium factor of 0.4, the 1 Bq of daily radon intake was reflected in IMBA calculation by assigning 0.4 Bq of daily intakes of Po-218, Pb-214 and Bi-214, which are radon daughters in activity equilibrium with radon [5]. Preliminary calculations were made assuming single size of aerosol carrying the daughter radioisotopes.

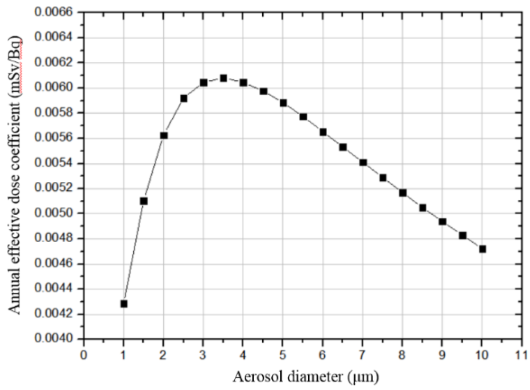

Fig. 1. Annual effective dose for 1 Bq of daily radon intake.

Dose dependency on aerosol size is sown in Figure 1. The annual effective dose from 1 Bq of daily radon intake increases with an increasing aerosol size up to 3.5 μm and then decreases. Particle densities for each size were calculated with the experimental density estimation equation [6].

3.2 Annual Effective Dose

The aerosol size distributions differ at the platform and in the train. Those also have changed after PSD installation (see Table I). The annual effective dose taking into account the aerosol size distribution is given in Table II when the daily radon intake is 1 Bq both at the platform and in the train. Dose was calculated for the highest conservatism from the radiation protection point of view. For the aerosol of size below 2.5 μm, dose was assumed at the value for 2.5 μm. Also, dose for 3.5 μm was taken for the aerosol of size ranging from 2.5 to 10 μm.

Table Ⅱ: Annual effective doses for a subway passenger either at the platform and in the train, assuming 1 Bq of daily radon intake.

	At the platform	In the train
Before PSDs	0.001977 mSv	0.007179 mSv
After PSDs	0.001975 mSv	0.007206 mSv

Summarized in Table Ⅲ are the annual effective dose estimates for a passenger commuting by radon-contaminated Seoul subways, before and after PSD installation. After PSD installation, the total (at the platform and in the train) annual effective dose has decreased from 0.34 mSv to 0.30 mSv.

Table Ⅲ: Total annual effective dose estimates for a Seoul subway passenger.

		Platform	Train
Before PSDs	Radon concentration (Bq/m^3)	96.7	20.1
	Total annual effective dose (mSv)	0.34	
After PSDs	Radon concentration (Bq/m^3)	41.3	30.8
	Total annual effective dose (mSv)	0.30	

Table II informs that the aerosol size distribution, specified by the $PM_{2.5}/PM_{10}$ value, makes difference in annual effective dose under the same air concentration of radon. After PSD installation, dose at the platform decreased due to not only the lower radon concentration but also the smaller portion of large aerosols. In the train, on the other hand, dose increased because of higher radon concentration and greater portion of large aerosols as well.

The maximum radon concentrations after PSD installation were recorded at 77.3 Bq/m^3 (platform) and 118.9 Bq/m^3 (train) [1,2]. The annual effective dose from internal radon exposure in Seoul subways may reach 1.01 mSv at maximum.

4. Conclusions

ICRP recommends that the reference value for internal dose from radon be between 1.0 and 20.0 mSv [7]. Korean Ministry of Environment enacted the indoor radon regulation, which requires the indoor radon level should not exceed 148 Bq/m^3. Radon concentrations in Seoul subways and annual dose estimates meet the requirements. Nevertheless, Seoul subway system should be monitored to maintain radon concentration the lowest possible.

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