Radon in the Underground Workplaces; Assessment of the Annual Effective Dose due to Inhaled Radon for the Seoul Subway Station Staffs

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The effective dose of the Seoul subway staffs due to inhaled radon (^{222}Rn) in their workplace was investigated depended on radon concentration exposed at each workplace, and working hours and working types of the staffs. Annual average radon concentrations ranged from 16.5 to 93.0 Bq·m^{-3}. The staffs commonly spend 2,304 hours in the underground spaces a year. With the radon concentrations and the working hours of the staffs, estimated annual effective doses ranged from 0.23 to 0.73 mSv·y^{-1}.

Keywords : Radon, Effective dose, Subway staffs, Underground facility

INTRODUCTION

Radon is one of the most important natural radiation sources exposed to human body and it is known to secondarily cause of lung cancer following smoking [1-4]. On the average, the Korean exposure dose due to inhaled radon is 1.35 mSv·y^{-1} of whole annual natural radiation exposure, 2.99 mSv·y^{-1} [5].

Radon, naturally occurring radionuclide produced from ^{238}U decay chain, is ubiquitous in the environment. Typically radon is diffused to air through rocks crevice or gaps of soils and flowed into the air of underground resulting in its accumulation in the underground facilities (e.g. subway stations, caves, shopping malls, parking lots) and higher indoor radon level compared to outdoor [1-4]. Therefore, the workers and public using the underground facilities could be exposed to relatively high levels of radon. However, internal exposure to human caused by inhaled radon in underground facilities has been focused on the public in Korea, although the workers spend much more time in the underground spaces compared to the public.

The subway, the major public transportation in Seoul, is one of the typical underground facilities exposed to radon. There are several subway stations with high radon concentrations in Seoul which were paid attentions. Some subway stations were constructed in deep places where granite distributes in most regions of Seoul and have old building structure with a leak. This supported previous studies indicated that radon concentrations in the Seoul subway stations were higher than those of other cities [6-10]. This implies that Seoul subway station staffs spending significantly longer residence time in the underground spaces might be exposed to the high radon dose. The purpose of this study is the assessment of the annual effective doses due to inhaled radon of the staffs working in the subway station in Seoul.

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MATERIALS AND METHODS

Eight subway stations shown high radon level were selected among the seventy seven stations operated by Seoul Metro on the basis of the report of Korea Occupational Safety and Health Agency (KOSHA) [7].

The granite is distributed over a wide area and the alluviums distribute along the water system of the Han River. Some investigated subway stations are located on the granite area (Figure 1). The measurement points of radon concentration were selected by working types of the staffs in the stations. The measurement was conducted four times for a year during three months (Sept.

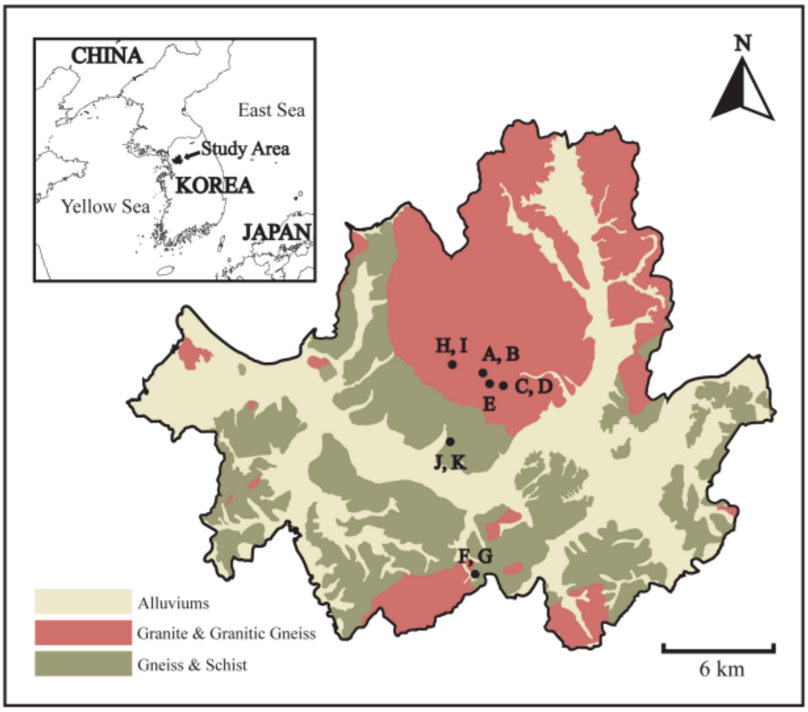

Fig. 1. The Geological characteristics of Seoul and the locations of investigated station.

2008 - Dec. 2008, Dec. 2008 - Feb. 2009, Feb. 2009 - Jun. 2009, and Jun. 2009 - Sept. 2009).

Radon is very sensitive to the changes of the environmental factors like humidity, temperature, pressure, and electronic/magnetic field. In addition, its concentration can be significantly influenced by thoron as well as the progeny of radon and thoron [11]. Therefore, the selection of the radon detector is very important. Raduet detector (Radosys Co., Ltd., Hungary) was used in this study. This detector is passive type Solid-State Nuclear-Track Detector (SSNTD) using CR-39 plastic. It can measure both radon and thoron concentrations and obtain cumulative radon concentration during the measurement period. For measurement of radon concentration, the CR-39 plastic chips in the detector chamber were chemically etched in 6.25 M NaOH solution at 90℃ during 4.5 hour [12] and the tracks produced on the CR-39 plastic chips by the alpha particles were counted with the automatic track reading system (RSV-6, Radosys Co., Ltd., Hungary). To assess the effective dose, the residence time in each workplace and working types of the staffs was assessed through interviews.

The annual effective doses of the staffs depended on working types and residence time were assessed using the dose calculation convention proposed by the International Commission on Radiological Protection (ICRP) Publication 65 [1]. The dose calculation convention is as follows.

$$E_D = R_C \times R_T \times E_F \times D_C \quad \cdots\cdots (1)$$

Where, E_D; effective dose
R_C; radon concentration
R_T; residence time
E_F; equilibrium factor between radon and its decay products
D_C; dose conversion coefficient

R_C and R_T were obtained according to the working types of the staffs. E_F was used typical indoor value of 0.4 given United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report [3]. The value of 12 $nSv{\cdot}(Bq{\cdot}m^{-3}{\cdot}h)^{-1}$ recommended from ICRP was applied to D_C [13].

RESULTS AND DISCUSSION

The annual average values of radon concentrations were in the range of 16.5 - 93.0 $Bq{\cdot}m^{-3}$ (Table 1). The values were below new action level of 1,000 $Bq{\cdot}m^{-3}$ recommended from ICRP [4,13] and also relatively low compared with previous surveys [6,7,9,10]. This may be related with the improvement of the air quality and the installation of screen doors, although most investigated stations are located on the granite area (Figure 1). Indoor radon could be insensitive to the changes of the environmental factors, because the measurement places are located on underground spaces.

The subway station staffs work in three shifts a day and about 40 hours a week. Therefore, they spend in the underground spaces about 2,304 hours a year (Table 2).

Table 1. The Annual Average Radon Concentrations with Places.

ID	Place	Station	Annual mean (Bq·m^{-3})	ID	Place	Station	Annual mean (Bq·m^{-3})
A-1	Office	Jongno 3-ga (line 1)	20.6±0.3	E-1	Office	Euljiro 4-ga (line 2)	35.8±0.4
A-2	Ticket office		17.7±0.2	E-3	Bedroom		27.5±0.6
A-3	Bedroom		28.3±0.8	F-1	Office	Namtaeryeong (line 4)	64.0±1.3
B-1	Office	Jongno 3-ga (line 3)	34.4±0.5	F-2	Ticket office		56.5±0.6
B-2	Ticket office		27.7±1.0	F-3	Bedroom		84.9±0.6
B-3	Bedroom		43.4±0.2	G-4	Driving control room		57.7±0.4
C-1	Office	Dongdaemun Stadium (line 2)	26.1±0.5	H-1	Office	Gyeongbokgung (line 3)	16.5±0.5
C-2	Ticket office		25.7±0.5	H-3	Bedroom		93.0±0.3
C-3	Bedroom		22.1±0.2	I-5	Service center		66.4±0.1
D-1	Office	Dongdaemun Stadium (line 4)	33.7±0.2	J-1	Office	Samgakgi (line 4)	19.9±0.6
D-3	Bedroom		32.2±0.3	J-2	Ticket office		27.6±0.6
				K-5	Service center		28.3±0.5

Table 2. The Working Hours of the Staffs with Working Types.

Working type	Working place	Working hour (hr)			
		Daily	Weekly	Annual	Total
Station	Office	4	20	1248	2304
	Ticket office	3	15	672	
	Bedroom	1	5	384	
Driving control Dept.	Office	7	35	1920	2304
	Bedroom	1	5	384	
Service center	Office	8	40	2304	2304

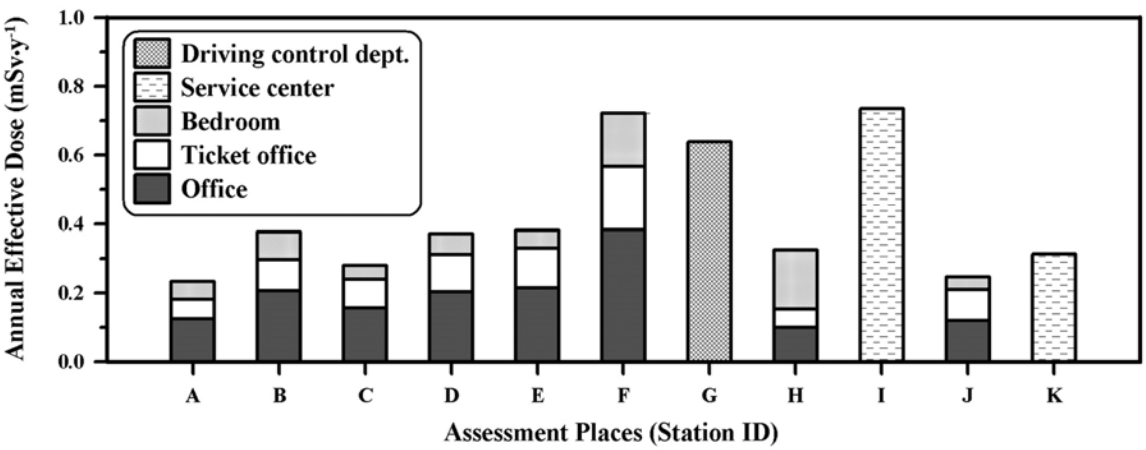

Fig. 2. The Annual effective dose due to inhaled Radon of the staffs with working types and workplaces.

The range of the annual effective doses of the staffs were from 0.23 to 0.73 mSv·y^{-1} and the values were very low compared to the reference level of 10 mSv·y^{-1} recommended from ICRP (Figure 2) [4,13]. The staffs working in the Namtaeryeong and the Gyeongbokgung station (F, G, and I in Figure 2) received relatively high radon exposure compared to the others. The reason is assumed that the stations are located on the granite, and particularly the Namtaeryeong station is deeper than the other stations. In the case of the Gyeongbokgung station, the annual effective dose of the staffs working in the service center (I in Figure 2) approximately two times higher than the staffs working in the office (H in Figure 2), although the staffs work in the same station. The main reason of this is considered due to poor ventilation.

CONCLUSION

The internal exposure due to inhaled radon of the staffs showed differences, even though the staffs work in the same station. Therefore, for assessing exposure dose caused by inhaled radon of certain work group in underground spaces, the residence time (working hours) of the workers depended on locations should be considered as real working hours. However, there is no need to consider radiological protection of general underground facilities if radon exposure for workers is managed to optimum level, because total occupancy time of public users using underground facilities is insignificant compared to the underground workers.

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