Radon Concentration in Groundwater in the Central Region of Gyeongju, Korea - 13130

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ABSTRACT

Radon is a naturally occurring radioactive gas that is a well known cause of lung cancer through inhalation. Nevertheless, stomach cancer can also occur if radon-containing water is ingested. This study measured the radon concentration in groundwater for drinking or other domestic uses in the central region of Gyeongju, Korea. The groundwater samples were taken from 11 points chosen from the 11 administrative districts in the central region of Gyeongju by selecting a point per district considering the demographic distribution including the number of tourists who visit the ancient ruins and archaeological sites. The mean radon concentrations in the groundwater samples ranged from 14.38 to 9050.73 Bq·m^{-3}, which were below the recommendations by the U.S. EPA and WHO.

Key words: Radon, naturally occurring radioactive gas, groundwater, Gyeongju

INTRODUCTION

Radon gas is a naturally occurring radioactive gas that is formed in the decay series of uranium and thorium. Since both these series are ubiquitous, radon gas is produced continually in all soils depending on the concentration of uranium or thorium. [1, 2]

A portion of the radon released by radioactive decay moves through the air or water-filled pores in the soil to the soil surface and enters the air, whereas some remains below the surface and dissolves in the groundwater. Because it is a gas, radon tends to be released into the air when water containing it is exposed to the air. If groundwater is supplied to a house, radon in the water can be released into the air of the house via various water uses, such as showering, cooking, washing and flushing toilets. Therefore, exposure to radon in drinking water results from drinking the water (ingestion) and breathing air containing both radon and radon decay products released from water (inhalation). [3]

Although the primary health effects of radon is lung cancer resulting from the inhalation of radon in indoor air originating from soil underneath the house or to a much lesser extent, the escape of radon gas into indoor air during the household use of water, it can also cause stomach cancer if radon in water is ingested. Therefore, some studies have paid attention to the health effects of radon-containing drinking water. [4, 5, 6] This study measured the radon concentration in groundwater for drinking or other domestic uses in the central region of Gyeongju, Korea, and estimated the annual effective dose due to radon in groundwater to determine if and how much the residents are at risk resulting from radon.

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MATERIALS AND METHODS

Area under measurement

Gyeongju is in the far southeastern corner of the Korean peninsula, located over 35°39'N~36°04'N, 128°58'~129°31'. The territory is spread over 1,324.41 km^2 with a population of 265,488 as of 2011. Gyeongju is divided into 23 administrative districts: 4 eups, 8 myeons, and 11 dongs, which are the standard subdivisions of cities and counties in South Korea. Approximately 54% of its population resides in the central region of Gyeongju, which is spread over the 11 dongs. [7] This was the capital of the ancient kingdom of Silla (57 B.C. – 935 A.D.), which ruled approximately two-thirds of the Korean peninsula between the 7th and 9th centuries. Since a vast number of archaeological sites and cultural properties from this period remain in the city, Gyeongju is a major tourist destination for South Koreans and foreign visitors. Six million tourists including 750,000 foreigners per year are estimated to visit to Gyeongju. Most Gyeongju area lies in the Gyeongsang Basin but a few areas of the city belong to the Pohang Basin. The Gyeongsan Basin consists of the Bulguksa intrusive rock penetrating layers of sedimentary rocks, mainly granite and porphyry. In contrast, the Pohang Basin areas are made up of stratum that formed in the Tertiary period of the Cenozoic era, which consist of igneous rock, aqueous rock, porphyry, sandstone and tuff. Gyeongju was chosen as the area under measurement area due to its geological setting and demographic distribution. [8]

Experimental methods and setup

Groundwater samples were taken at 11 points from the 11 dongs spread over the central region in Gyeongju, as shown in fig. 1, by selecting one sampling point at each district considering the demographic distribution including the number of tourists who visit to ancient ruins and archaeological sites in them. Table I provides details of the measurement points. The reason why those points were chosen is that groundwater is obtained through the bedrock and is normally used as an auxiliary source for drinking or other domestic use, such as irrigation in those areas. Therefore, it is essential to determine if and how much the residents are at risk from radon

TABLE Ⅰ. Measurement Points

Administrative District	Map coordinates	Bed Rock type	Building type to which the measurement points belong
Seonggeon-dong	N 35°, 50', 35.7"	Fault	House
	E 129°, 12', 43"		
Hwango-dong	N 35°, 50', 24.5"	Fault	School
	E 129°, 13', 53.6"		
Dongcheon-dong	N 35°, 50', 42.2"	Fault	School
	E 129°, 13', 58.1"		
Hwangseong-dong	N 35°, 51', 25.3"	Fault	House
	E 129°, 12', 58.4"		

Hwangnam-dong	N 35°, 48', 23.6"	Granite	House
	E 129°, 10', 40.5"		
Seondo-dong	N 35°, 50', 20.1"	Sedimentary rock	Temple
	E 129°, 11', 15.9"		
Jungbu-dong	N 35°, 50', 12.1"	Fault	Temple
	E 129°, 12', 49.5"		
Wolseong-dong	N 35°, 49', 39.8"	Fault	House
	E 129°, 13', 16.6"		
Bulguk-dong	N 35°, 47', 47.4"	Fault	Temple
	E 129°, 16', 2.2"		
Bodeok-dong	N 35°, 49', 10.5"	Sedimentary rock	Temple
	E 129°, 20', 54.8"		
Younggang-dong	N 35°, 51', 45.5"	Fault	Temple
	E 129°, 13', 53.3"		

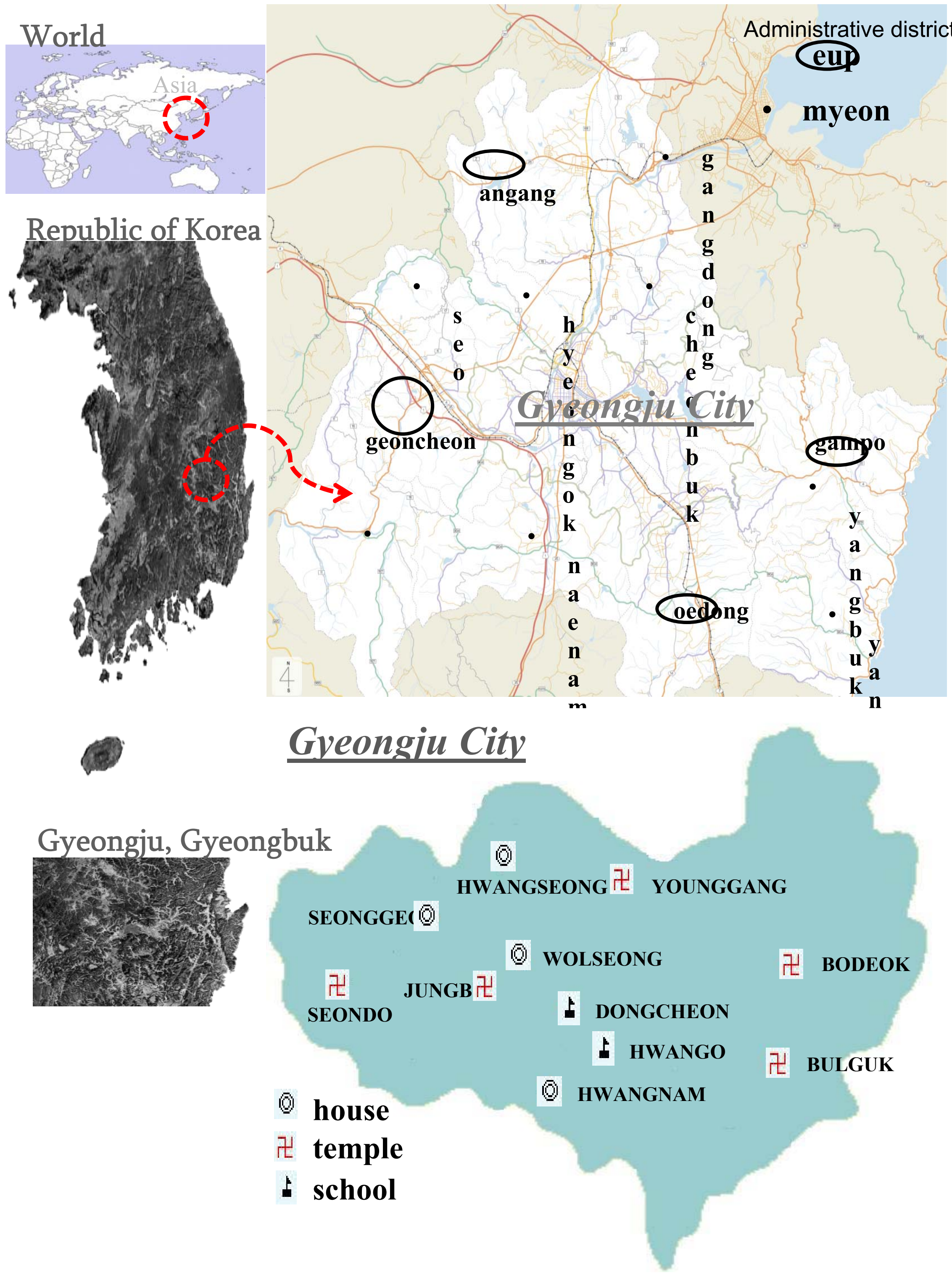

Fig. 1. Map of Gyeongju City

RAD7 of Durridge Company was used to measure the radon concentration in groundwater samples. RAD7 provides an accessory, called RAD H_2O, to measure the radon level in water with high accuracy over a wide range of concentrations that is capable of obtaining a reading for the radon concentration in water within one hour of taking the sample. [6] A 250 ml vial provided by RAD7 was used to take a groundwater sample. Care was taken when sampling the groundwater to ensure that it was never in contact with the open air. The groundwater samples were analyzed using the sniff mode of RAD7. An analysis of one sample was performed over a period of 3 hours by measuring the levels 6 times for 30 minutes each in sniff mode to obtain more stable measurement results.

RESULTS

Fig. 2 and table Ⅱ present the radon concentrations in the groundwater samples. The mean radon concentration varied from 14.38 to 9050.73 $Bq \cdot m^{-3}$. For comparison, the mean radon concentration in groundwater for 80 measurement points in Busan, Korea, which is adjacent to Gyeongju (approximately 100 km) was 6,258 $Bq \cdot m^{-3}$ (169 $pCi \cdot L^{-1}$), and the maximum concentration was 68,450 $Bq \cdot m^{-3}$ (1,850 $pCi \cdot L^{-1}$) [9]. The recommendations for drinking water by the U.S. EPA and WHO is 148,000 $Bq \cdot m^{-3}$ (4,000 $pCi \cdot L^{-1}$) and 99,900 $Bq \cdot m^{-3}$ (2,700 $pCi \cdot L^{-1}$), respectively. All mean radon concentrations in the 11 points in Gyeongju were below the recommendations by the U.S. EPA and WHO. On the other hand, the mean values at Hwangnam-dong and Seondo-dong were much higher than those at the other places.

TABLE Ⅱ. Summary of The Radon Concentrations and Annual Effective Doses

Administrative District	Radon concentration		Effective dose (mSv/y)
	Mean ($Bq \cdot m^{-3}$)	SD ($Bq \cdot m^{-3}$)	
Seonggeon-dong	406.27	118.72	1.48E-03
Hwango-dong	88.70	20.20	3.24E-04
Dongcheon-dong	14.38	4.79	5.25E-05
Hwangseong-dong	26.91	16.39	9.82E-05
Hwangnam-dong	9050.73	2348.47	3.30E-02
Seondo-dong	8758.23	260.29	3.20E-02
Jungbu-dong	2395.08	858.34	8.74E-03
Wolseong-dong	1011.48	42.74	3.69E-03
Bulguk-dong	336.03	85.69	1.23E-03
Bodeok-dong	134.45	14.90	4.91E-04
Younggang-dong	22.54	6.08	8.23E-05

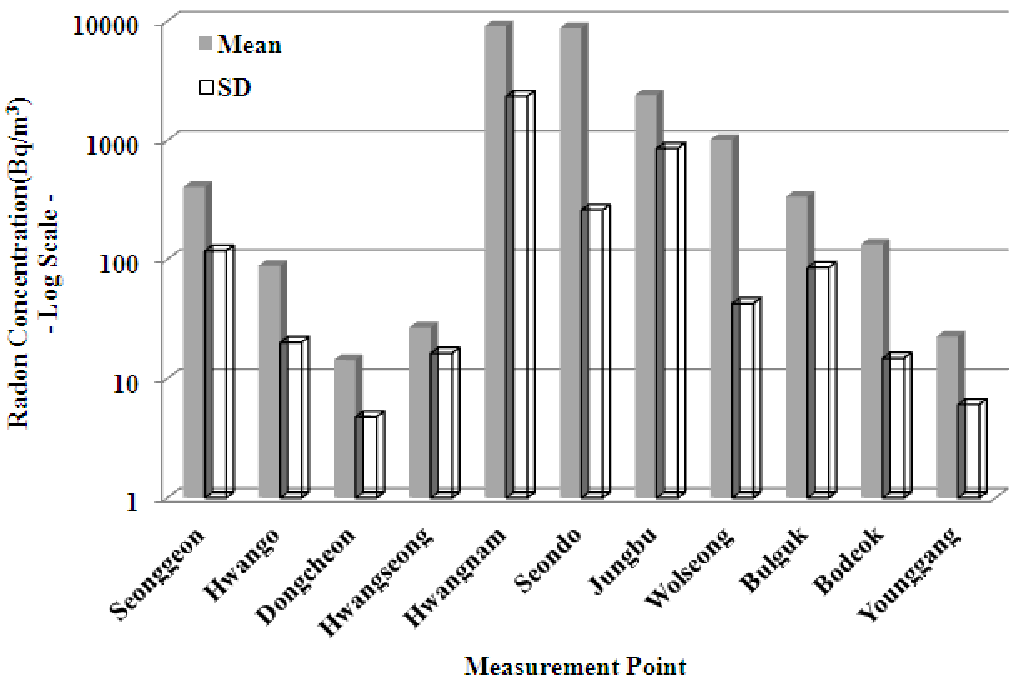

Figure 2. Summary of The Radon Concentration in Groundwater

The annual effective doses due to drinking radon-containing groundwater were calculated using the equation. [10]

$$H = C_{Rn} \times 1 \left(\frac{L}{day}\right) \times 365 \left(\frac{days}{year}\right) \times DCF\left(\frac{nSv}{Bq}\right) \qquad \text{(Eq. 1)}$$

where H is the annual effective dose and DCF is the dose conversion factor (= 10 nSv/Bq)

Assuming that an adult drinks 1 L of ground water per day at the 11 measurement points in Gyeongju, the annual effective doses are expected to range from 5.25×10^{-5} to 3.30×10^{-2} mSv/y, as shown in table 2. Regarding drinking water, measures for reducing the levels of radon are recommended if the radon concentration exceeds 150 $Bq\cdot L^{-1}$, which might cause an annual effective dose of 0.5 mSv to the public.

CONCLUSION

The radon concentrations in groundwater for drinking were measured in 11 points in the central region of Gyeongju, The mean radon concentrations ranged from 14.38 to 9050.73 $Bq\cdot m^{-3}$, which are below the recommendations for drinking water by the US. EPA and WHO. In addition, the annual effective doses due to the ingestion of groundwater were estimated to range from 5.25×10^{-5} to 3.30×10^{-2} mSv/y. This suggests that the central region of Gyeongju shows low radon concentrations in groundwater (i.e. below the US EPA recommendation).

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