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Technical Note

Analysis and radiation dose assessment of ^{222}Rn in indoor air at schools: Case study at Ulju County, Korea

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ABSTRACT

^{222}Rn exists in nature in the form of a rare radioactive gas. In terms of environmental radiation, issues regarding ^{222}Rn have persisted because of its radiological hazardousness. Ulju County is one of the regions of Ulsan metropolitan city, with a population of 227,699. Ulju County has the highest density of industrial complexes in Korea. In this study, ^{222}Rn radioactivity concentration was measured and analyzed in 57 schools in Ulju County using 114 passive LR-115 type detectors to secure radiological safety and confirm basic information for reduction of resident exposure to ^{222}Rn. The effective dose of ^{222}Rn was assessed to find the actual risk of the concentration surveyed in schools to human beings. The dose depended on four factors: subjects, ^{222}Rn concentration, dose coefficient, and time. The individuals subjected to dose estimation were classified into three types: students, teachers, and office workers. The subjects had different dwelling locations and times. The findings demonstrate that the radiological hazard to students and workers at schools in Ulju County owing to ^{222}Rn is negligible in terms of ^{222}Rn activity recommendation level.

1. Introduction

The radioactive nuclide ^{222}Rn exists in nature as a colorless, odorless, and tasteless noble gas resulting from the uranium series decay chain. ^{222}Rn forms monatomic gas with 9.73 kg/m^3 density, which is approximately eight times standard atmospheric density. ^{222}Rn has a half-life of 3.8 days and decays to the stable nuclide ^{206}Pb after four alpha and four beta decays through ^{218}Po, ^{214}Pb, ^{214}Bi, and others. It can cause lung cancer (through inhalation) [1–5] and stomach cancer (through ingestion) [6,7]. The environmental radiation caused by ^{222}Rn is considered one of the most important issues in this research field because of its known dangers. Another radioisotope, ^{220}Rn, is one of the nuclides in the thorium series decay chain. Owing to the shorter half-life of this nuclide (55s), it is of less interest.

^{222}Rn is affected by many factors, such as geogenic characteristics, ventilation, building materials, and geometrical structure (e.g., cracks at wall and window positions) [8–12], and exposure rate to humans varies according to human activity [13]. Therefore, it is important to set reference buildings to survey regional differences, and schools are a suitable place to survey such differences. The geometrical structure of rooms in schools is similar across different regions, and people of different ages are regularly present. Many studies have investigated schools to find regional differences in ^{222}Rn concentrations [14–16]. Moreover, children are generally thought to be more radiosensitive than adults and likely to be at greater risk of developing certain radiation-induced types of cancer [17]. No conclusive data exist to prove that children are at greater risk from ^{222}Rn than adults [18,19], but it is difficult to say that children would not be more affected. Hence, managing the risk of ^{222}Rn concentration in schools is important. Both children and adults spend a lot of time at schools; thus, the ^{222}Rn radioactivity concentration of indoor air should be analyzed to estimate the effect of ^{222}Rn exposure.

The mean indoor air ^{222}Rn concentration in houses in Korea is 53 Bq/m^3, which is 1.35 times higher than the global average (39 Bq/m^3) [20]. In response to increased public awareness of and concerns about the hazards of ^{222}Rn, the Ministry of Environment (ME) started the “indoor ^{222}Rn control comprehensive plan” to reduce the risk caused by ^{222}Rn. The Korea Institute of Nuclear Safety started a national ^{222}Rn survey after 2000 [21–23], and

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small-scale ^{222}Rn surveys and research in subway systems in Korea have been conducted at universities and institutes [24–29]. The national ^{222}Rn survey for public facilities has been conducted since 2008, based on established recommendations as a subplan of the ME indoor ^{222}Rn control comprehensive plan for ^{222}Rn reduction. Indoor air ^{222}Rn concentration has been measured in Ulju County every 2 years since 2008. The ^{222}Rn survey for government offices and elementary schools was conducted in 2008, while those for public buildings and residential houses were performed in 2009 and after 2010, respectively. However, only five of 58 schools in Ulju County were surveyed. Insufficient sampling of survey locations led to a significant analysis deviation in the estimation of ^{222}Rn effect in this area.

In the present study, an ^{222}Rn survey and analysis for 57 schools in Ulju County was performed to secure the radiological safety of students, teachers, and office workers and to provide basic information on reduction of ^{222}Rn exposure. The risk due to ^{222}Rn was calculated for different factors including subject, ^{222}Rn level, dwelling times, and dose coefficient.

2. Methods and materials

2.1. ^{222}Rn detector

A ^{222}Rn LR-115 type passive detector, one of the detectors used to measure the time integral concentration of ^{222}Rn in air, was used to survey ^{222}Rn concentration in schools in Ulju County. The detector has a hollow cylindrical form with 4 cm diameter and 3 cm height (Fig. 1) [30]. The detector consists of a filter, a detection part, and a connection part. The filter prevents inert gases other than ^{222}Rn, from reaching the detection unit, thereby minimizing the effects of radioactive substances other than ^{222}Rn. The detector has a solid-state track detector (SSTD) film, which forms chemical imperfections because of the damage of the atomic arrangement in the path of charged particles [31]. Thus, ^{222}Rn passes through the filter by diffusion and emits alpha particles that create tracks on the SSTD surface. The depth of the alpha particles on the SSTD is on the order of a few tens of micrometers. The number of tracks generated is converted to the ^{222}Rn concentration to derive it at the measurement point. The tracks created by the alpha particles are not directly readable using an optical microscope. Hence, etching was performed with 10% NaOH at 60°C for 150 min to enlarge the tracks and allow analysis by optical microscope. The average number of tracks in the unit area was converted to the ^{222}Rn concentration. The correlation between the ^{222}Rn concentration and the tracks is presented as follows [32]:

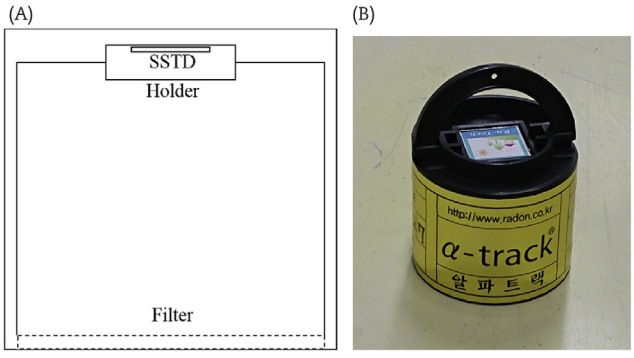

Fig. 1. (A) Schematics of LR-115 type II detector. (B) Actual shape of LR-115 type II detector.
SSTD, solid-state track detector.

Fig. 2. School location in Ulju County.

$$37y = 0.800x - 40.167 \quad (1)$$

where x is the number of tracks with unit area (Tr/cm^2), and y is the ^{222}Rn concentration (Bq m^3/day).

2.2. Survey design

A total of 57 of the 58 schools in Ulju County (one school was under reconstruction) were surveyed: 33 elementary, 13 middle, and 11 high schools. Figs. 2 and 3 show the locations of the schools and a geological map of Ulju County. The geology of Ulju County consists mostly of Mesozoic Cretaceous feature, except for alluvium, which is of Cenozoic age.

^{222}Rn concentration is lowest in summer and highest in winter [33–35]. Hence, it was planned to measure ^{222}Rn during the summer and the winter and during the middle season. ^{222}Rn was

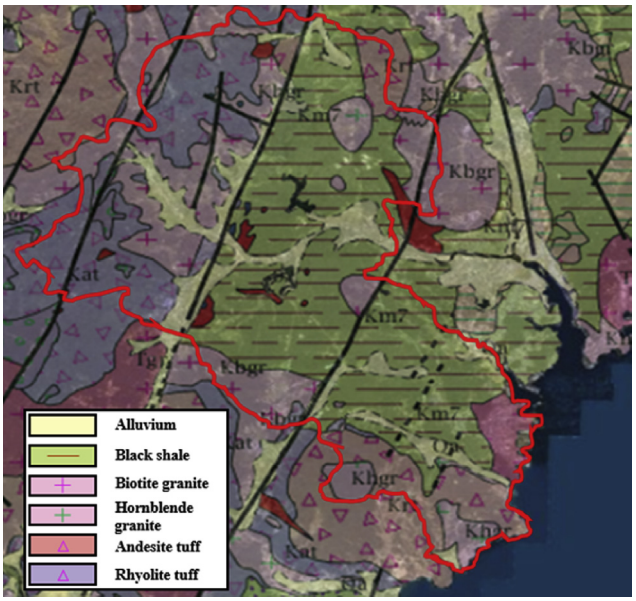

Fig. 3. Geological map in Ulju County.