



Measurements of the size distribution of unattached radon progeny by using the imaging plate



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HIGHLIGHTS

- A new graded screen array system based on imaging plate technique is developed.
- The front to total activity ratio of wire screens measured by the imaging plate technique is considered in the system.
- The system is capable to evaluate the size distribution of unattached radon progeny in air.
- The size distribution of ^{218}Pb , ^{214}Po , ^{214}Bi is measured by the system under different particle concentrations.

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ABSTRACT

The size distribution of unattached radon progeny is an important parameter for an accurate estimation of the internal dose of radon exposure. In this study, a new measuring system was developed to evaluate the size distribution of unattached radon progeny in air. In the system, airborne radon progeny were collected with a newly designed graded screen array (GSA), the activity concentrations were measured by using the imaging plate technique, and the size distribution of unattached fraction was retrieved by using an iterative nonlinear algorithm. The simulation results indicated that the collection characteristics of the new GSA system were well agreed with other systems. Test experiments showed that the activity-weighted median diameters (AMD) for unattached ^{218}Po , ^{214}Pb and ^{214}Bi were 0.89 ± 0.11 nm, 0.96 ± 0.13 nm and 1.01 ± 0.25 nm in a particle-free radon chamber, and the distribution changed with different concentrations of particles. As multiple measurements can be simultaneously carried out with a single IP, the new technique is considered as an optional and useful way to measure the size distribution measurement of unattached radon progeny.

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1. Introduction

Radon (^{222}Rn) and its progeny are the major contributors to human exposure from natural radiation sources, and compared to ^{222}Rn itself, its progeny attribute the dominant portion of the exposure (UNSCEAR, 2008). Based on the dosimetric models recommended by the United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR), both the concentration of ^{222}Rn progeny and their deposition fractions on different regions of the human respiratory tract are needed for an accurate estimation of the lung dose. However, it is generally difficult to directly measure the ^{222}Rn progeny deposited in the human respiratory tract, and the deposition fractions are usually estimated with the measured size distributions of ^{222}Rn progeny in air. Furthermore, as reported by

UNSCEAR (UNSCEAR, 2006), the deposition fractions in the radio-sensitive regions (ET: extra thoracic region) are strongly dependent on the particle size of ^{222}Rn progeny, particularly for those particles of below 10 nm diameter (generally called the unattached fraction of radon progeny). Therefore, for an accurate assessment of the exposure, it is necessary and important to measure the activity size distribution of unattached ^{222}Rn progeny in the environment.

The graded screen array (GSA) system was usually used to evaluate the size distribution of unattached radon progeny, and several sampling and measuring systems (Hopke et al., 1992; El-Hussein and Ahmed, 1995; Fukutsu et al., 2004) have been developed by now. Generally, the alpha particles collected by the systems were measured either with the alpha spectrometer or the alpha counter. However, the measuring process was relatively cumbersome. In addition, due to the limited number of detectors, it was hard to measure large numbers of samples simultaneously. Recently, as the imaging plate (IP) has large detection area, high sensitivity and portability, etc., coupled with the cascade impactor,

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the IP has been used for evaluation of the size distribution of attached ^{222}Rn progeny (Rahman et al., 2007). However, the method was not suit for measuring the size distribution of unattached ^{222}Rn progeny. Currently, by taking the overlapping tracks and fading effect into considerations a new alpha spot counting method for automatically counting alpha tracks (Chen et al., 2011a) and a more accurate method for measuring the concentrations of airborne ^{222}Rn progeny (Zhang et al., 2012) were developed in our previous studies.

In this study, on the basis of our previous studies, a new technique combining with the GSA and IP detector was developed to measure the size distribution of unattached ^{222}Rn progeny. It is expected to provide a more convenient method of simultaneously measuring multiple samples of the GSA systems.

2. Material and methods

2.1. The graded screen array

Fig. 1 illustrates the schematic diagram of the graded screen array (GSA) designed for this study. The effective diameter of the sampling face is 37 mm. The GSA consists of four layers of wire screens and a backup filter. Details of physical parameters of the wire screens are listed in Table 1.

2.2. The imaging plate system

The type of IP used in this study was BAS-MS (Fuji Film Co., Japan). It is constructed of a 9 μm thick of protective mylar film over 115 μm thick of photo-stimulable phosphor, with a size of 20.0 cm $\times$ 40.0 cm. The bio-imaging analyzer BAS-2500 (Fuji Film Co., Japan) was used as the image reader. The alpha signals

Table 1

Physical parameters of the wire screens used in this study.

Mesh no.	Diameter (μm)	Thickness (μm)	Solid volume fraction	50% Cut-off diameter ^a (nm)
30	160	322	0.15	1.2
60	180	374	0.332	2.2
200	40	89	0.2305	3.6
400	25	50	0.295	5.2

^a The values were estimated at a flow rate of 3 L min⁻¹.

originated from ^{222}Rn progeny and stored in the IP were automatically identified and counted by the software which was developed by our research group (Chen et al., 2011a).

2.3. The radon/aerosol chamber

For test experiments, an airtight radon chamber with a volume of about 2 m³ was used. Two solid ^{226}Ra sources were set inside the chamber to generate ^{222}Rn , and the concentration of ^{222}Rn was about 10,000 Bq m⁻³ in saturated conditions. Without injection of artificial particles, the particle concentration inside the chamber was monitored to be about 100 particles cm⁻³ by an ultrafine particle counter (Model P-TRAK 8525, TSI Inc., USA).

A modified Scinclair Lamer generator (Sinclair and LaMer, 1949) was employed to form the condensation of di(2-ethylhexyl) sebacate (DEHS) onto nuclei of sodium chloride. The median diameter of the particles was monitored to be 150–200 nm by the self-developed screen diffusion battery (SDB) (Chen et al., 2011b). During the experiments, both ^{222}Rn concentrations and the atmospheric parameters including air pressure, relative humidity and temperature inside the chamber were continuously monitored by the AlphaGUARD PQ2000 (Genitron Instrument GmbH). And the concentrations of ^{222}Rn progeny were measured with the BWLM-PLUS-2S (Tracerlab GmbH).

2.4. The front-to-total activity ratio

As the shielding of wire screens may affect accurate measurements of the concentrations of ^{222}Rn progeny (Solomon and Ren, 1992), the front-to-total activity ratio (noted as FT ratio herein-after) of the wire screens was also measured with the IP as the following steps in this study.

First, samples were simultaneously collected in the chamber by using two same size and type holders for 10 min at a flow rate of 3 L/min. One holder consisted of a screen and a backup filter, and another holder contained only a filter. Subsequently, both the screen and filters were placed on hollow plastic spacers with 0.5 mm thickness before the IP was exposed (Zhang et al., 2012). Having been exposed for 5 min, the alpha signals on the different

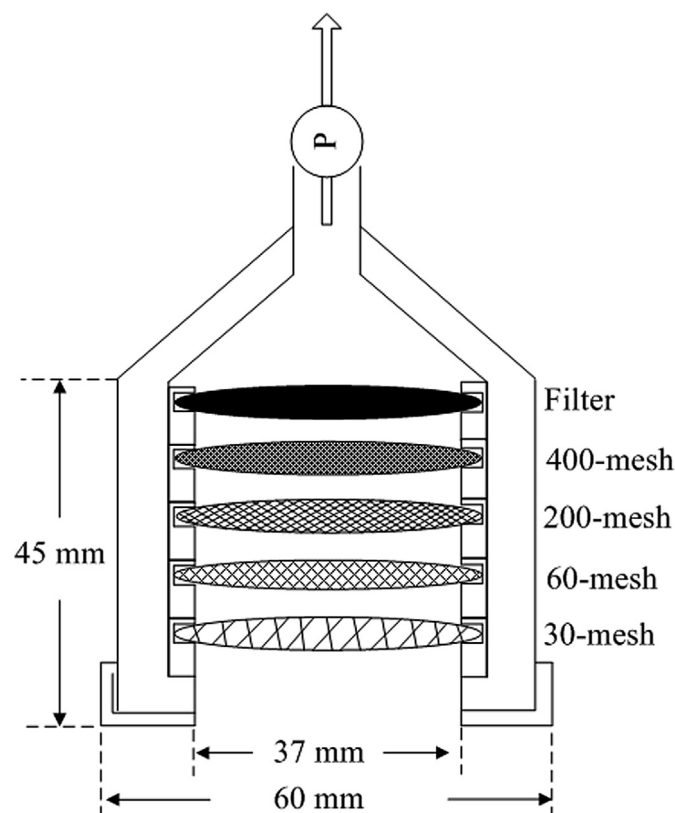


Fig. 1. Schematic diagram of the graded screen array.

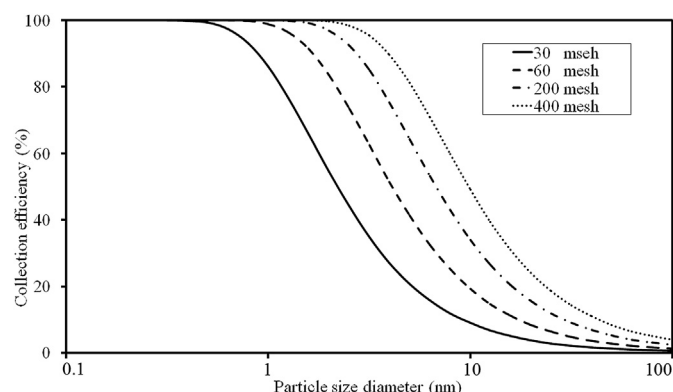


Fig. 2. Collection efficiencies of the wire screens at a flow rate of 3 L min⁻¹.

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