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Deposition pattern of inhaled radon progeny size distribution in human lung

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ABSTRACT

One of the important factors controlling the distribution of radiation dose to the different portions of the human respiratory tract is the deposition pattern of radon progeny containing aerosol. Based on the activity size distribution parameters of radon progeny, which were measured in Minia University, the deposition behavior of radon progeny (attached and unattached) has been studied by using a stochastic deposition model. The attached fraction was collected using a low pressure Berner cascade impactor technique. A screen diffusion battery was used for collecting the unattached fraction. Most of the attached activities for ^{222}Rn progeny were associated with aerosol particles of the accumulation mode. The bronchial deposition fraction of particles in the size range of attached radon progeny was found to be lower than those of unattached progeny. The effect of radon progeny deposition by adult male has been also studied for various levels of physical exertion. An increase in the breathing rate was found to decrease the fraction with which inhaled progeny were deposited in the bronchi. As the ventilation rate increases from 0.54 to 1.5 $m^3\,h^{-1}$, the average deposition fraction of airway generation 1 through 8 are expected to decrease by 22% for 1.4 nm particles and by 38% for 150 nm particles.

1. Introduction

Deposition theoretical modeling of radon containing aerosol in human lung represents a useful tool to interpret health effects from inhaled particular and to study the effectiveness of different inhalation procedure. Deposition is the process that determines what fraction of the inspired particles is caught in the respiratory tract and, thus, fails to exit with expired air. It is likely that all particles that touch a wet surface are deposited, thus, the site of contact is the site of initial deposition. Distinct physical mechanisms operate on inspired particles move them toward respiratory tract surfaces. Major

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mechanisms are inertial forces, gravitational sedimentation, Brownian diffusion, interception, and electrostatic forces.

A major factor governing the effectiveness of the deposition mechanisms is the parameters of the activity size distribution (active median thermodynamic diameter, AMTD, active median aerodynamic diameter, AMAD, standard deviation, σ_g) of unattached and attached radon progeny in the atmospheric air. Radon decay products have a particular size as molecular species but then attach to particles with a wide range of sizes. Since size helps to determine particles within the size range that can penetrate the oropharynx. The physics of air flow in human airways and the resulting deposition pattern of inhaled aerosol particles throughout the respiratory tract are determined by the size of the inhaled particles and by the breathing pattern for a given airway generation (Hofamann & Daschil, 1986). These airways form the trachea to the alveolar sacs form a structure similar to the crown of tree. Physical and mathematical of these models are usually based on airway geometry which approximated by a sequence of straight cylindrical tubes (Horsfield, Dart, Olson, Filley, & Cumming, 1971; ICRP, 1994; Koblinker & Hofmann, 1990; Weible 1963; Yeh and Schum, 1980; Zock, Porstendorfer, & Reineking, 1996). These models always require some information about the parameters of activity size distribution. Therefore, it is necessary to measure the activity size distribution of radon progeny to compute the deposition fraction of radon progeny through the human lung.

The activity size distribution of radon progeny has been determined by tagging the natural aerosol particles with radon or thoron progeny. However, some measurements of radon progeny, for attached and unattached fraction, have been performed in the atmospheric air (Bochicchio et al. 1996; Doi & Kobayashi, 1994; Guo, Shimo, Ikebe, & Minato, 1992; Hadad, Doulatdar, & Mehdizadeh, 2007; Jacobi & Andre, 1963; Kim et al. 2005; Malczewski & Zaba, 2007; Porstendorfer, Reineking, Butterweck, & El-Hussein, 1990; Shimo, Guo, Ikebe, & Minato, 1990). Most of the observed data of these literatures shown that the size distribution consisted of ultrafine clusters with median diameters below 4 nm (unattached activity) and progenies associated with ambient aerosol particles in sizes ranging between 100 and 400 nm (attached activity). The unattached fraction is deposited nearly completely in the respiratory tract during inhalation, whereas 80 percent of the attached are exhaled without deposition. The amount of unattached activities up to about 10 percent of the total activity, but is considered to yield about 50 percent of the total radiation dose (Butterweck-Dempewolf, Shuler, & Vezzu, 1997).

Based on obtained measurements, deposition fraction of radon progeny has been evaluated by using a stochastic deposition model (Koblinker & Hofmann, 1990). It has been also discussed the effect of radon progeny deposition fraction by adult male for various levels of physical exertion.

2. Methods and experimental techniques

2.1. *Experimental approach*

The separation of the unattached and attached ^{218}Po was performed with a wire screen diffusion battery similar to that employed and calibrated by Cheng et al, (Cheng, Su, Newten, & Yeh, 1992). The diffusion sampler contained up to five screens with a back-up filter and operated at flow rate of 0.36 $m^3 h^{-1}$. With monodisperse silver aerosols the 50% cut-off diameters of the screens were determined to be 0.9, 1.3, 1.9, 4.0 and 7.9 nm (Cheng et al. 1992). The sampler could detect 0.5 mBq m^{-3} within 2 h counting time with 25% statistical

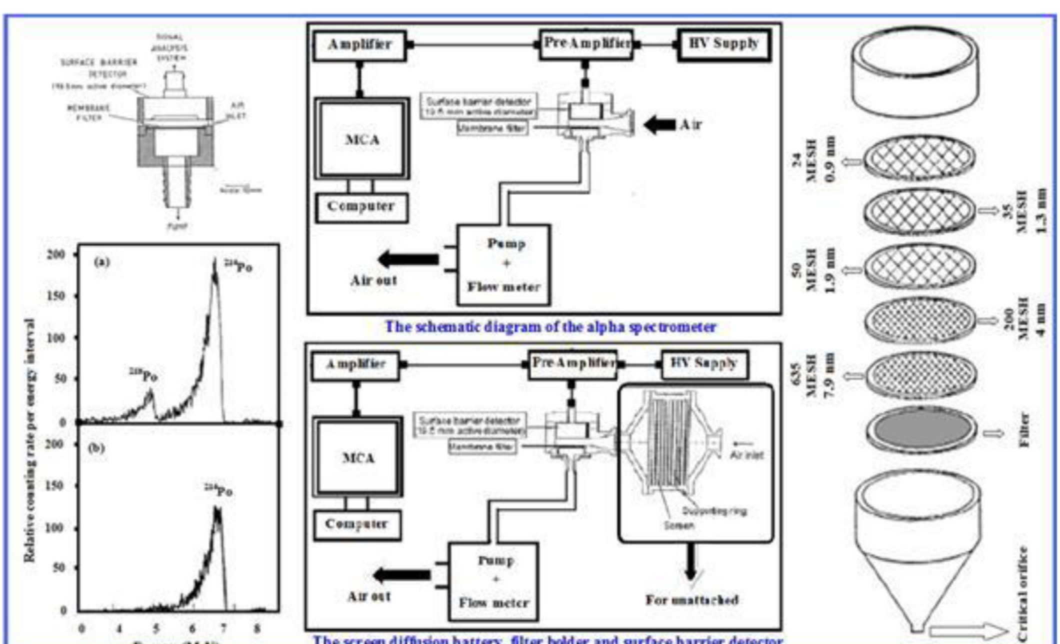

Fig. 1 – The screen diffusion battery, filter holder and surface barrier detector arrangement for the measurements of the unattached fractions of radon progeny.