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Seasonal behavior of radon decay products in indoor air and resulting radiation dose to human respiratory tract

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ABSTRACT

Most of radiation hazard of indoor radon is largely due to the radon progenies, which are inhaled and deposited in the human respiratory tract. It is essential to evaluate aerodynamic characteristics of the radon progenies, which are either attached or unattached to aerosol particles, because the dose is strongly dependent on the location of deposition in respiratory tract and hence on the aerodynamic characteristics of the aerosol particles. This paper presents the seasonal behavior of radon decay products in indoor air under domestic conditions at Nagoya University, Japan. A low pressure cascade impactor as an instrument for classifying aerosol sizes and imaging plate as a radiation detector have been employed to characterize the activity size distribution of short-lived radon decay products. In parallel, radon and its progenies concentrations were measured. Taking into account the progeny characteristics, the inhalation dose in the different seasons was also estimated based on a lung dose model with the structure that is related to the ICRP66 respiratory tract model. The result evident that, the highest dose 0.22 $mSvy^{-1}$ was observed during the winter where the highest value of equilibrium equivalent concentration of radon (EEC) and lowest value of the activity median aerodynamic diameter (AMAD) were found in this season; whereas, the dose in spring appeared to be lowest 0.02 $mSvy^{-1}$.

1. Introduction

The natural radioactive gas ^{222}Rn generated in the Earth's crust by the ^{238}U series, It's concentration levels depend strongly on geological and geophysical conditions, as well as on atmospheric influences such as barometric pressure. Radon escapes from the ground and accumulates in rooms according to the strength of its emanation and its dilution by ventilation (Hopke, 1992). High radon concentration in indoor air, in addition to long exposure periods related to indoor habitation, makes indoor radon a potential hazard (Marcinowski, 1992). Once in the atmosphere, the ^{222}Rn atoms decay producing short-lived (^{218}Po, ^{214}Pb, ^{214}Bi, ^{214}Po) and longlived (^{210}Pb, ^{210}Bi, ^{210}Po) radioactive decay products. Most of these radionuclides can be adsorbed on the surface of the

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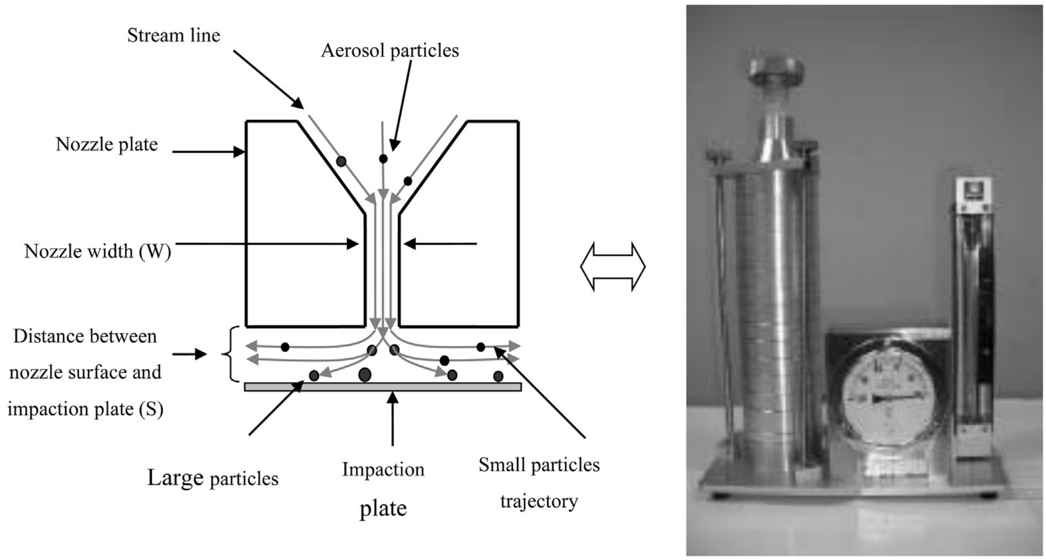

Fig. 1 – The low pressure cascade impactor with the schematic representation of a stage within impactor.

existing aerosol particles always present in various concentrations in the ambient air forming the radioactive aerosol of the radon progeny and their fate will follow that of the carrier aerosols (Mostafa, Tamaki, Moriizumi, Yamazawa, & Iida, 2011). The airborne radon decay products deposit in human respiratory tract by inhalation and damage the sensitive tissues of respiratory tract. Thus the inhaled radon decay products are determined to be the second leading cause of lung cancer after tobacco smoking (Frumkin & Samet, 2001). Knowing the size distribution of radon progeny aerosols is an important parameter needed for estimating the human lung dose with regard to radiation protection. The deposition of radon progeny in the human respiratory tract can be estimated more exactly if its size distribution is known (Shimo, Torii, & Ikebe, 1981). Atmospheric aerosol size distribution basically consists of three separate modes. Nucleation mode (particles smaller than 0.1 mm), accumulation mode (particles between 0.1 and 1 mm) and coarse mode (particles larger than 1 mm) (Camacho, Valles, Vargas, Gonzalez-Perosanz, & Ortega, 2009). For a few years following development of a suitable device, more detailed size distributions of radon progeny have been measured by several researchers (Becker, Reineking, Scheibel, & Porstendorfer, 1984; Hopke et al., 1992; Mohamed, Abd El-hady, Moustafa, Yuness, 2014; Reineking, Becker, & Porstendorfer, 1988; Tu, Knutson, & George, 1991; Wasiolek & Cheng, 1995). The aerosols behavior differs depending on many factors. The physical properties of aerosols are affected by particle size, shape, and density. Ambient humidity can be particularly important, as hygroscopic particles will increase in size as they flow through a moist airstream. The seasonal change can be recognized as one of the variation factors which influence the aerosols behavior. Therefore, in the present study, the seasonal variations of activity size distribution, radon and its progeny concentration, and the effective dose due to inhalation of radon and its decay products in indoor environment were estimated at Nagoya university, Japan. The climate of Nagoya, where the experiments were conducted, is typified with warm spring, a lasting rainy season followed by humid but less rainy summer, relatively mild autumn with rather periodic rains and slightly cool winter with occasional snowfalls. The measurements were carried out during the five seasons at one specific location. Despite that the rain falls more heavily during the rainy season, but there may be some intermittent rainy days during the other seasons.

2. Materials and methods

2.1. *Measurement conditions*

The experimental site was a laboratory room, located in 5th floor in new multi-storied building, the room volume is about 200 m^3 with composite structure of concrete and steel, with two entering doors and one large wall to-wall glass windows. The measurements were carried out under normal conditions in the laboratory room i.e. sometimes doors and/or windows were open. The air conditioner was stopped during sampling time to exclude the air conditioning affects on the concentrations and behaviors of radon, radon progeny, and aerosol particles. The human activities were kept as a minimum as possible during the measurement periods. All the instruments employed in this study were placed at the centre of room and one meter above the ground during performing. The measurement was conducted during the period from June, 2009 to July, 2010, the experimental period was divided in to five segments by defining as the seasons. Spring was defined as the period from March to May; rainy season from late June to July, summer from late July to August, autumn from September to November, and winter from December to February. At least five measurements were carried out for each season. The measurements were performed during the typical Japanese working hours i.e. from 9:00 am to 5:00 pm.