The Measurement of Size Distribution of Indoor Natural Radioactive Aerosols by Imaging Plate Technique

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Abstract. The indoor radioactive aerosols of radon decay products are considered as a main radioactive contaminant in human environment. In this study, the particle size distribution was measured with low pressure cascade impactor and imaging plate. The temporal and spatial variations of indoor radioactive aerosols were measured at eight indoor sites of Nagoya, Japan. Effective doses were assessed using ICRP 66 and UNSCEAR 2000 approaches.

Keywords: radioactive aerosol, radon decay products, particle size distribution, low pressure cascade impactor, imaging plate, effective dose
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INTRODUCTION

The natural radioactive aerosols of radon decay products are considered as a main radioactive contaminant in human environment. 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 (1). The detrimental affects of alpha emitters by inhalation to the respiratory tract are governed by a number of physical and biological factors. In dose assessment due to the exposure from radon decay products, particle size distribution plays an important rule.

MEASUREMENT METHOD

Aerosol particle size distribution can be obtained by various techniques using impactors, impingers or multi-channel graded wire screens. In this study, particle size distribution was measured with low pressure cascade impactor (LP-20RPS47, Tokyo Dylec Co. Ltd.) consisting of twelve stage with backup filter holder. The unattached particles were separated at the entrance of impactor using wire screen mesh # 635.

After sampling and separating radioactive particles according to size, the alpha activity is either measured usually with solid state detector or ZnS(Ag) scintillation counter. Most of these instruments are expensive, too large, less portable and cumbersome to conduct experiment in the environment. Under this context, the imaging plate technique was recommended to triumph over these limitations. Imaging plate is a reusable sensor for detection and storage of ionizing radiation energy in photostimulable phosphor crystals. The imaging plate could detect and store the image of alpha particles. The alpha spot images on the imaging plate were analyzed by a computer program "Alpha Counting Program" coded in Visual Basic (2).

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The performance and reliability of imaging plate technique were studied by comparing with the traditional ZnS (Ag) scintillation counting technique. The overlapping area was 77 % for the two techniques. The reliability of imaging plate technique was then verified with the scanning mobility particle sizers (SMPS) technique and the overlapping area was 46 % conformity between two techniques.

At this context, modifications were adopted to improve the sizing characteristics of cascade impactor. A 1 mm thick flat ring spacer was inserted in every stage of the impactor to reduce between nozzle surface and impaction plate from 3 mm to 2 mm. To prevent the bounce of solid particles on the collection media, the collection media was changed from Teflon binder glass fiber filter to stainless steel plate with a coating of grease. To avoid overlapping of alpha particle incidences on the imaging plate, the separation spacer was introduced between the imaging plate and the collection media during exposure. The improved activity size distribution of radioactive aerosol with all these modifications was represented in **FIGURE 1**. Comparison of the output of imaging plate technique with the data from SMPS leads to an 80 % overlapped area of the size distribution curve.

Moreover the detection efficiency of imaging plate for alpha particles was also determined and found to be 39.0 %.

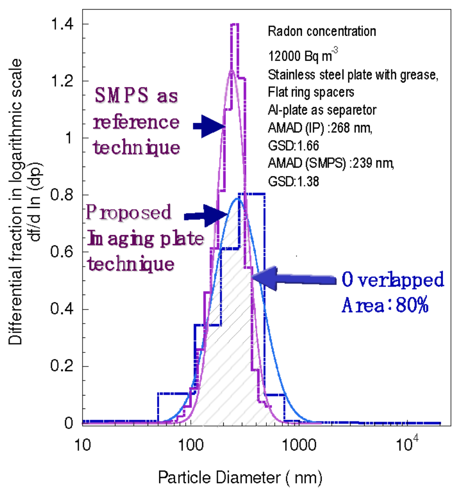

FIGURE 1. Activity size distribution measurement: Comparison of the output of imaging plate technique with the data from SMPS.

EXPERIMENT

Three homes and five workplaces of Nagoya, Japan were selected for perceiving the spatial variation of the size distribution of indoor natural radioactive aerosols. The experiment was conducted during the typical business hours of Japanese office from 9:00 am to 5:00 pm through out the time span of April to December 2006. The experimental period was divided into five segments by defining as the seasons: Spring was defined from March to May, rainy season was from late June to July, summer from late July to August, Autumn from September to November, and winter from December to February.

Measurements for the activity size distribution have been performed using an Andersen low pressure cascade impactor. Alpha GUARD (Genitron Instrument GmbH) was employed to monitor indoor radon concentrations. The concentrations of radon decay products were measured with LCD-BWLM-PLUS (Tracerlab). The environmental parameters were observed with IAQ monitor (KANOMAX).

FIGURE 2 shows the temporal and spatial variations of the characteristics of indoor radon decay products at eight sites of Nagoya. The experimental results represent the variations of the activity median aerodynamic diameter (AMAD) and the geometric standard deviation (σ_g) obtained in fiver different seasons. During spring the AMAD ranged from 90 - 285 nm, in rainy season from 150 - 277 nm, in summer from 93 - 322 nm, in autumn from 126 - 226 nm, and in winter from 124 – 200 nm. It was observed that the AMAD varies with the seasons. In most of the experimental sites, the highest values of the AMAD were obtained during summer and the lowest during autumn. The activity concentrations of radon in all sites in five seasons followed almost similar types of variations. Mean radon concentration was obtained 19.0 Bq m^{-3} in spring, 13.7 Bq m^{-3} in rainy season, 14.8 Bq m^{-3} in summer, 17.2 Bq m^{-3} in autumn, and 21.8 Bq m^{-3} in winter.

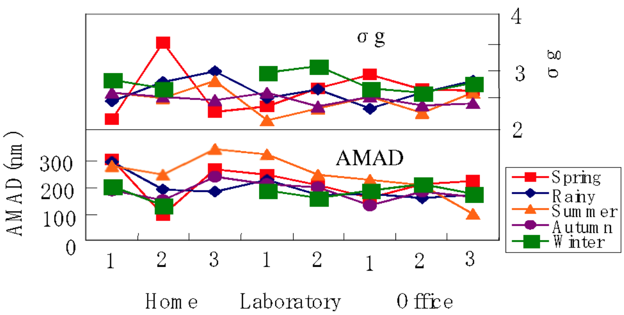

FIGURE 2 Illustration of the variation of AMAD and σ_g with the change of seasons.

Effective doses were assessed by ICRP 66[3] approach using LUDEP[4] at the beginning. The result depicts that in dose calculation, the particle size and the activity concentration of radon decay products play significant role. The variations of AMAD contribute significantly in the dose assessment. A higher value of dose was observed during autumn in most of the experimental sites, whereas the doses in summer appeared lower with the high values of AMAD's. The effective doses were 0.07 - 2.31 mSv y^{-1} in rainy season, 0.08 – 1.22 mSv y^{-1} in summer, 0.05 – 2.61 mSv y^{-1} in autumn and 0.37 – 2.91 mSv y^{-1} in winter. The effective doses were also estimated by UNSCEAR 2000 approach. The comparison of effective dose assessed by ICRP 66 and UNSCEAR 2000 approaches was shown in **FIGURE 3.** The average discrepancy of 2.1 – 3.9 times was found for all four seasons.

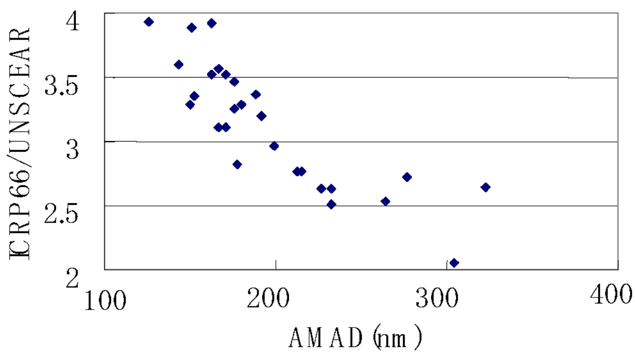

FIGURE 3 Comparison of effective dose assessed by ICRP 66 and UNSCEAR 2000 approaches.

CONCLUSION

In this study, the method using imaging plate and low pressure cascade impactor was applied to measure the particle size distribution of natural radioactive aerosols. The modifications were adopted to improve the sizing characteristics of cascade impactor. The comparison of the output of imaging plate technique with the data from SMPS leads to 80 % overlapped area of the size distribution curve. The detection efficiency of imaging plate for alpha particles was found to be 39.0 %. Three homes and five workplaces of Nagoya, Japan were selected for perceiving the spatial variation of the indoor natural radioactivity size distribution. The study revealed large variability of AMAD in various locations and with varying time. The effective doses assessed by ICRP 66 and UNSCEAR 2000 approaches were compared and the average discrepancy of 2.1 – 3.9 times was found.

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