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Annual indoor concentration of radon decay products

M. Mostafa [1,2]

1 Ural Federal University, Ekaterinburg, Russia

2 Department of Physics, Minia University, El-Minia, Egypt

ABSTRACT

Radon (^{222}Rn) and its decay products are the dominating contributors to the total collective radiation exposure of world's population. Besides that, the exposure to radon and its decay products have been identified as the second significant cause of lung cancer after smoking (WHO 2009). The value of indoor and outdoor exposure can be varied and the study of indoor value is important due to its apparent health implications in particular dwellings. Radon and its decay products are present in the indoor air since their parent nuclei radium is present in the soil, natural construction and building materials. The Concentrations of radon decay products were measured using an alpha-spectroscopy with surface barrier detector during one year in radiation laboratory, physics department, faculty of science, minia University, at least one measure per week. The mean activity concentrations of ^{218}Po, ^{214}Pb and ^{214}Bi over one year are founded to be 6.6 ± 0.64, 5.3 ± 0.5 and 4±0.42 Bq/m^3 respectively. Radon EEC and The annual effective dose is calculated using UNSCEAR model and the result is within the national indoor recommended limit. The annual effective dose is 0.33 mSv y^{-1}.

Keywords:*radon; radon decay products; EEC; annual dose*

1. Introduction

Radiation dose is produced by naturally occurring radionuclides are mostly caused by tissue irradiation from inhaled short-lived radon decay products (^{218}Po, ^{214}Pb and $^{214}Bi/^{214}Po$). About a half of the annual effective dose received by a member of the general public from all natural radioactive sources, is due to inhalation of short-lived radon decay products while present in indoor or outdoor air[1,2]. Inhaled radon decay products are deposited in different regions of the human bronchial tree as functions of particle size, flow rate and flow dynamics.

To calculate the absorbed dose through the human lung we rely on different dosimetric models, which always need information about the parameters of radon and its decay products like activity concentration, activity size distributions, equilibrium factor and unattached fraction of radon decay products in the air.

The parameter of interest in evaluating radiation exposure from radon decay products is the Equilibrium Equivalent Concentration of Radon (EEC_{Rn}). The measurement of the EEC_{Rn} has been the traditional procedure used to control the levels of exposure due to the inhalation of these nuclides. The equilibrium-equivalent concentration (EEC_{Rn}) computed according to UNSCEAR[3] which is defined as

$$EEC_{Rn} = 0.105C_1 + 0.516C_2 + 0.379C_3 \quad (1)$$

where C_1, C_2 and C_3 are the total activity concentrations (Bq/m^3) of ^{218}Po, ^{214}Pb and ^{214}Bi, respectively. For ultrafine equilibrium equivalent concentration

Evaluation of internal exposure to radon decay products.

The dose conversion factors reported by UNSCEAR[4-6] have been used to estimate the annual effective doses due to indoors inhalation. In this estimation, the doses from radon gases themselves are not included, because their contribution is considered to be low. Annual effective doses (mSv y^{-1}) for radon D_{Rn} was calculated using the following formulas:

D (mSv y^{-1}) $= EEC_{Rn} \times DCF_{RnP} \times OF$

Where EEC_{Rn} is the equilibrium equivalent radon concentration (Bqm^{-3}; DCF_{Rn} (9×10^{-6}mSv (Bq h $m^{-3})^{-1}$) is the radon dose conversion factor and OF is the occupancy factor (7000 h and 3500 h i.e. the time spent indoors in a year at home and office respectively).

Therefore, the aim of the present study is to summarize the measured data on the annual activity concentrations of radon decay products in indoor air. And a simple annual effective dose is calculated using UNSCEAR model.

2. Materials and methods

The experimental site was a laboratory room, located in 3rd floor in multi-storied building; the lab room volume is about 72 m^3 with composite structure of concrete, with one entering door and one large wall to-wall glass windows. The measurements were carried out under normal conditions in the lab room i.e. sometimes door 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 aerosol particles, radon and its decay products. In all experiments, the measuring instruments were placed at the center of room and one meter above the ground. The human activities were kept as a minimum as possible during the measurement periods. The measurement was conducted during one year, the period from Oct, 2008 to Sep, 2009; the experimental period was divided in to four segments by defining as the seasons. Winter from December to February; spring was defined as the period from March to May; summer from late July to August and autumn from September to November. At least four measurements were carried out for each month. The measurements were performed during the typical working hours i.e. from 9:00 am to 5:00 pm.

To determine the concentration of radon decay products in indoor air, air samples were collected on membrane filters (Sartorius membrane filter type SM, 1.2 µm pore size, 25mm diameter and collection efficiency of 100%) using a sampler pump with an air-flow rate of 15 l/min. The activities were detected during and after air sampling by a surface barrier detector (figure. 1). According to the Ruffle method[7], the counting efficiency of the detector was found to be 17±0.5% utilizing ^{241}Am as a radioactive source of α particles. The active area of the detector was 300 mm^2. The separation between the filter and detector was 6 mm. With an energy resolution of about 300±20 keV, it was possible to distinguish between the α-particle energies emitted during the decay of ^{218}Po (6.0 MeV) and ^{214}Po (7.8 MeV). In order to determine the activity concentrations of radon decay products, the measurements were performed in two steps. Firstly, the α-spectrum was accumulated during a sampling period of 30 min. Secondly, after waiting for a period of 30 min without sampling (to remove the ^{218}Po activity on the filter by radioactive decay), the α-spectrum was registered again for a period of 30 min.

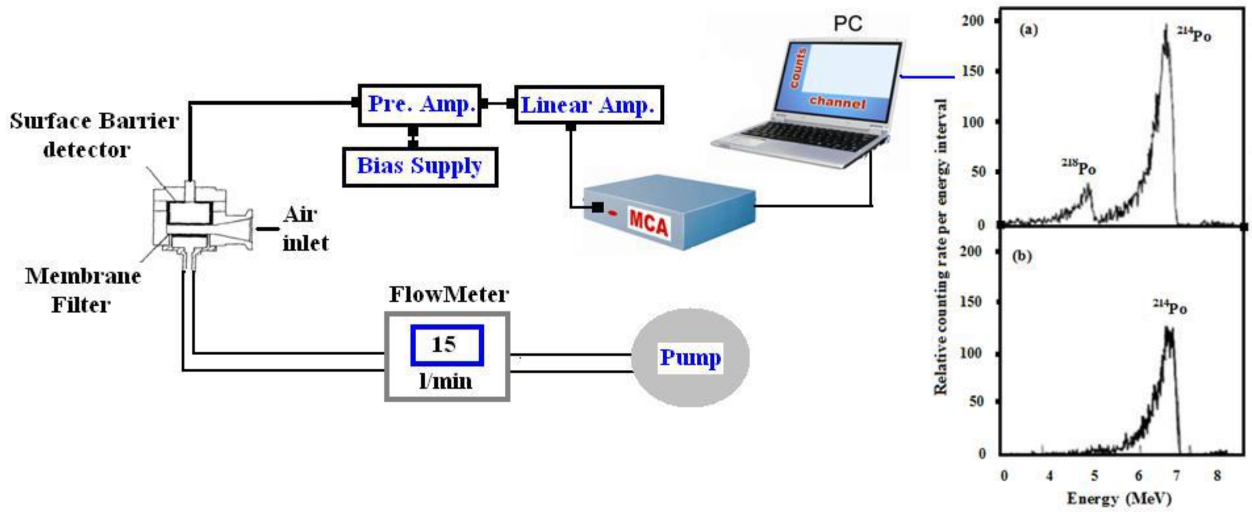

Figure 1. The experimental set-up of alpha spectrometer to measure indoor radon decay products.

From the measured α counts of ^{218}Po and ^{214}Po during the sampling period and the ^{214}Po counts during the decay period, the individual activity concentrations of ^{218}Po, ^{214}Pb and ^{214}Po can be calculated according to a method described by Wicke[8]. A typical α-particle spectrum obtained by collecting the short-lived radon progeny on membrane filter during the sampling and the decay period is shown in Figure. 3. The samples were collected at a single sampling room located about 10m above ground level. This room was far from any direct pollution sources (a typical natural location) with normal ventilation.

3. Results and discussions

About fifty measurements in one year from Oct 2008 to Sep 2009, in each week at least one measurement of short lived radon decay products by means of filter method using α- spectroscopy were carried out in indoor air of radiation lab.

Due to the different decay constants of radon decay products, the mean activity concentrations of ^{218}Po, ^{214}Pb and ^{214}Bi over the measured period are found to be 6.6 ± 0.64 (2.7 - 19.7), 5.3 ± 0.5 (1.22 - 17.9) and 4±0.42 (0.46 - 16.6) Bq/m^3 respectively. Figure1 present the average monthly radon decay products activity concentrations and the equilibrium equivalent concentration, EEC_{Rn}.

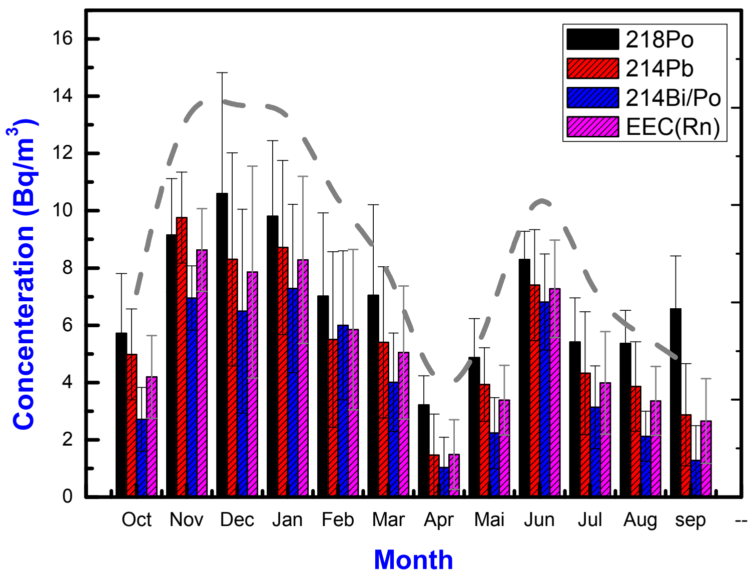

Figure 2. Annual radon decay products concentration in indoor air.

EEC_{Rn} values are calculated over one year using equation 1. The EEC value varied between 2 Bq m^{-3} to 13.5 Bq m^{-3} with an average value 5.2± 0.48. The frequency distribution of EEC_{Rn} is shown in **Figure 3.** This distribution of EECRn looks log-normal in nature and has also been observed by many other authors for measurements of radon and as well as its progeny concentrations[5,9-11]. This log normal distribution indicates the dynamic behavior of radon and its progeny concentrations, with either time or space. The parameters responsible for temporal variations are temperature, moisture content, ventilation of the different parts of the building, etc. and spatial variations are caused by parameters, such as 238U concentration and radon exhalation rate from the soil and building materials[10].

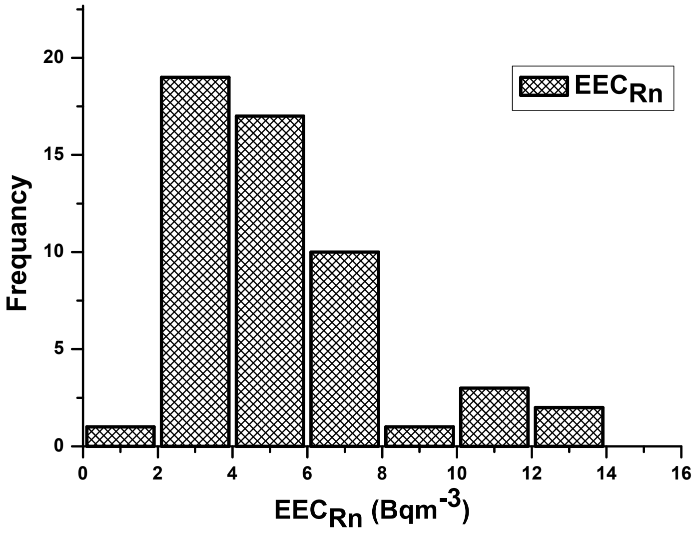

Figure 3. Radon EEC concentration frequency in indoor air.

Seasonal effective doses (mSv y^{-1}) for radon D_{Rn} was calculated using equation 2 and presented in figure 4 with seasonal radon equilibrium equivalent concentration, EEC_{Rn} and OF equal 0.8 as recommended for indoor homes UNSCEAR[3]. The highest concentration in winter is in agreement with literatures. In figure 5 the frequency of calculated effective doses during one year measurements in the radiation lab with OF equal 0.4. OF equal 0.4 is recommended for working places like offices or laboratories.

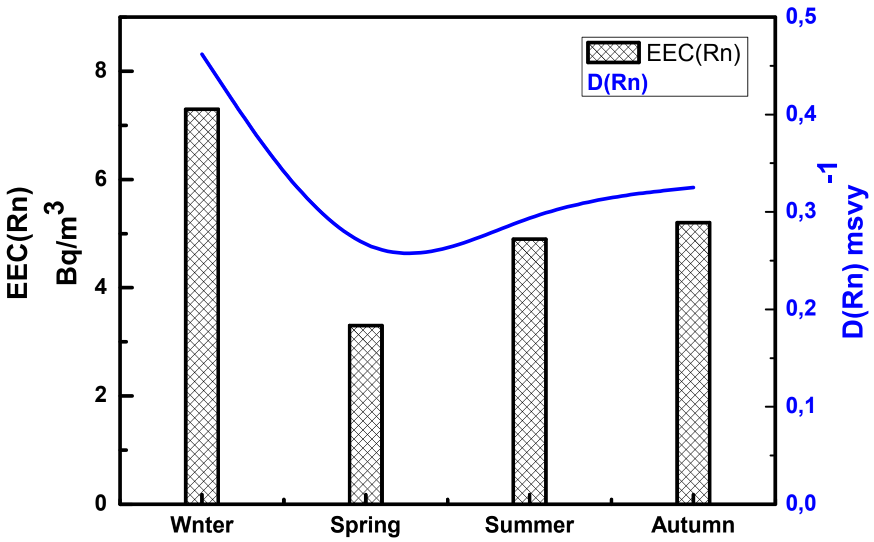

Figure 4. Seasonal effective doses (mSv y^{-1}) for radon D_{Rn} and seasonal radon equilibrium equivalent concentration, EEC_{Rn} in indoor air for OF = 0.8.

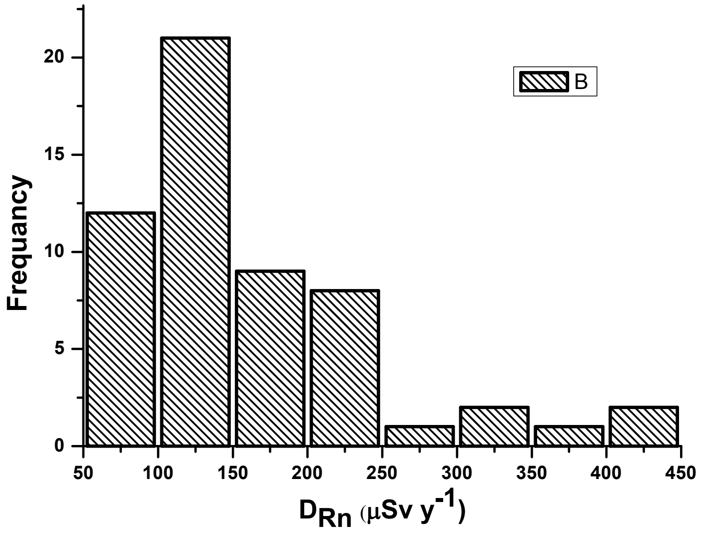

Figure 5. Radon effective dose frequency in indoor air for OF=0.4 (lab case).

4. Conclusions

In this study, radon, decay products concentrations were measured to estimate radiation dose due to inhalation in radiation lab of physics department, Minia University, Egypt. 50 measurements were carried out for one year. The results showed no major differences in radon decay products concentrations between deferent seasons excluding spring low concentration is observed. Effective doses due to inhalation were estimated to be 0.33 mSv y−1 for radon in general indoor. In the radiation lab, the internal exposure due to inhalation was small, but not negligible when compared with the external exposure.

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