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Radon exhalation rate from building materials using Passive Technique Nuclear Track Detectors

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Abstract

Radon activities and radon exhalation rate have been measured from building materials (gravel, cement, sand, gypsum, gypsum board, ceramic tile and block) on the public hospitals in Iraqi Kurdistan Region using passive (CR-39NTDs). The highest radon concentration was found in sand samples (480.71 ± 4.52 Bq /m^3) and lowest was found in ceramic tile (154.30 ± 5.24 Bq /m^3). Surface exhalation rate has been found to vary from (115.85 ± 6.38) to (345.86 ± 6.82) mBq/ m^2.h, whereas mass exhalation rate has been found to vary from (14.46 ± 1.84) to (22.32 ± 2.12) mBq/Kg.h.

Key words: CR-39NTDs, Radon, Building materials, Radon exhalation rate, Iraqi Kurdistan

1. Introduction

Materials obtained from the earth's crust, such as building materials, may contain traces of ^{238}U and ^{232}Th. These radionuclide's decay to radon (^{222}Rn), which is a radioactive gas with a half-life of 3.82 days. Prolonged exposure to radon may increase the risk of lung cancer [1-2]. People are exposed to ionizing radiation from natural sources of radionuclide's of which radioactivity in building materials is one of the most important sources. The air of homes and working places is a dominant exposure medium for humans to ionizing radiation in the form of alpha and beta particles and gamma photons emitted by radon and their corresponding progenies coming from building materials [3-4]. Building materials contain naturally occurring radioactive elements, the most important of which are potassium (^{40}K) and isotopes of thorium (^{232}Th) and radium (^{226}Ra). These radionuclide's can cause both internal and external exposure to people who live in the building. In a dwelling, the exposure rate depends on the concentration of radionuclide's in the building materials, the amount of building materials used and the type of dwelling. The surface finish of the building material is also important, probably because finish is related to the effective emitting surface, which is larger for an unpolished material [5-6]. The study of alpha activity in building materials is very important because alpha radiation is 1000 times more carcinogenic than gamma radiation [7]. Knowledge of the natural radioactivity in building materials as a main continuous source of indoor radiation exposure is essential in the assessment of population exposures because 80%of their lifetime is spent in indoor air[8-9]. Due to the long half-life of radon gas, it can reach from the earth's crust or from the walls and floors of buildings into both outdoor and indoor air. In the case of indoor air, the risk of exposure to radon is higher, especially for buildings with poor ventilation systems, which may lead to a higher indoor concentration of radon. The International Commission on Radiological Protection (ICRP) recommended radon concentration value ranges of 500-1500 and 200-600 Bq m−3 for work places and dwellings, respectively; those concentrations do not pose a significant risk for workers [10].

The purpose of this study was to assess the radon concentration, radon exhalation rate and the radium content in different building materials samples in selected public hospitals in Iraqi Kurdistan using passive techniques type CR-39 NTDs.

2- Materials and method

In the present work, 'can' technique was used to measure radon exhalation from the samples of the most commonly used building materials which were collected from the Iraqi Kurdistan Region for public hospitals. The building materials to public hospitals in general consists sand, gravel, cement, block, gypsum, gypsum board and ceramic tile. All samples were crushed to a fine powder form, the crushed samples were then kept in a closed plastic container, and then transferred to the School of Physics, Universiti Sains Malaysia, Penang, Malaysia. These samples are sieved in a mesh sieve, then it has dried in a hot air oven at a temperature of 110±°C for 24 hours and their bulk densities were determined. After that, the samples (each weighing 300 g) are put into PVC containers of volume (282.6 cm^3), and saved for 60 days as an exposure time. CR-39 based box type detectors were installed in cans at heights of 7 cm from the surface of the samples. Each sample is made of 10 cm thick layer having surface area of 28.26 cm^2 in the container .This chamber has been calibrated by Ismail and Jaafar [11]. More details about PVC dosimeter are shown in Fig.1. CR-39 track detectors of sizes (15×15×0.5) mm^3 were acquired from Moulding, UK, manufactures the detectors. After the exposure, CR-39 detectors were etched in 6N NaOH at $70C^o$ for 10h, and then the detectors were washed in distilled water and then, to determine the track density per cm^2, an optical microscope at 400X magnification.

3-THE MEASUREMENTS

3-1- Radon Concentration ($Bq.m^{-3}$)

Average radon concentration in the building material samples is calculated using the following formula [12];

$$C_{Rn}(Bq.m^{-3}) = \frac{\rho_{Rn}}{K_{(Rn)}.t} \qquad (1)$$

where ρ_{Rn} is the radon track density (track/cm^2) , $K_{(Rn)}$ is the calibration factor for radon (=0.2315 track. cm^{-2}. d^{-1}/ $Bq.m^{-3}$) which is calibrated in previous work [13], and this factor depended on the detector efficiency for detect alpha particles, which are emitted from radon and its progeny [14], and t is the exposure time (=60 days).

3-2- Radon Exhalation Rate

The ratio of the cup volume to the sample volume must exceed 10 in order to consider the back diffusion process negligible. So, in this study the radon exhalation rate affected by the back diffusion process, because the volume of the cup volume less than the sample volume. Therefore, the process of the back diffusion has to be taken into consideration. Back diffusion parameter (β) can be defined as [15];

$$\beta = \frac{\lambda_{Rn} \times p \times V_s}{V} \; ; p = 1 - \frac{V_d}{V_w} \qquad (2)$$

where λ_{Rn} is the decay constant of radon (7.5×10^{-3} h^{-1}), V is the effective volume (197.82×10^{-6} m^3) inside the container, Vs is the volume of sample, p is the porosity of porous material, V_w and V_d are the volumes of wet and dry sample, respectively.

The exhalation rate of radon in building material samples was determined in terms of surface area $E_{s\,(Rn)}$ and mass $E_{m\,(Rn)}$, using the following formula [16-17]:

$$E_{s(Rn)} = \frac{CV(\lambda_{Rn} + \beta)}{ATe}; E_{m(Rn)} = \frac{CV(\lambda_{Rn} + \beta)}{MTe} \qquad (3)$$

where, , M is the mass of the sample, A is the surface area of the sample, and C represents the integrated radon exposure ($Bq.m^{-3}.h$), and is defined as:

$$C = \frac{T_{rack}}{d.K_{(Rn)}} \times t \qquad (4)$$

T_{rack} and d represent the measured track density and the number of exposure days.

In the Eq. 3, Te is the effective exposure time (=1306.66h) which is related with the actual exposure time t(=1440 h) and is defined as.

$$\left[Te = t + \frac{1}{(\lambda_{Rn} + \beta)} \left\{ \exp^{-(\lambda_{Rn}+\beta)t} - 1 \right\} \right] \qquad (4)$$

3-3-Radium Content

The effective radium content of the building material samples C_{Radium} was calculated by using the following relation [18]:

$$C_{Radium} = C_{Rn}\,(Bq.m^{-3}) \times \frac{hA}{TeM} \qquad (6)$$

where h is the distance between the detector and the top of the soil sample (7×10^{-2}m).

4-RESULTS AND DISCUSSION

The values of radon concentration ($Bq.m^{-3}$), radon exhalation rates and the radium content in building material samples are listed in Table 1. The radon concentration had high value in sand sample480.71 ± 4.52 Bq/m^3 and lower in ceramic tile sample 154.30 ± 5.24 Bq/m^3 ,as showing in Fig. 2 . The radon exhalation rate from building materials varies appreciably from one building material to another. This may be due to the differences of radium content [19-20]. The radon exhalation rate we found 115.85 ± 6.38 to 345.86 ± 6.82 mBq/ m^2.h and 14.46 ±1.84 to 22.32 ± 2.12 mBq/ Kg.h . Fig. 3 distribution of radium content in building materials, the higher value we found in sand samples and lower in ceramic tile. Building materials like sand, bricks, and gravel aggregates contain a trace amount of ^{226}Ra which generates radon. However, only a fraction of radon from radioactive material becomes able to escape to the atmosphere that can be transported to an indoor environment through diffusion and convective flow. The amount of activity released per unit surface area per unit time from a material is termed as the exhalation rate. It depends on the radioactive content of the materials, emanation factor and diffusion coefficient of radon in that material, porosity and density of the material

5-Conclusions

To conclude, the radon exhalation rate from samples of building materials of public hospitals in Iraqi Kurdistan Region has been determined with an aim to assess the contribution of individual material (sand, cement, gravel, gypsum, gypsum board, block and ceramic tile). Results obtained from the current study shows that the radon exhalation rate from sand has relatively higher values as compared to those of gravel, block, gypsum, gypsum board, cement and ceramic tile. In general, the radon exhalation rate from the investigated building materials is low and thus the studied materials are safe as construction materials. The radon concentration levels, radium content and radon exhalation rate , on average, below the action level recommended by the ICRP [21-22].

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Tale (1) Radon Concentration , Radium content and Radon exhalation rate for some building materials

Matriala Building	Radon dencity ($cm^{-2}.d^{-1}$)	Radon Concentration (Bq/m^3)	Radium Content (Bq / Kg)	Radon exhalation rate	
				EA ($mBq/m^2.h$)	EM (mBq/Kg.h)
sand	110.59 ± 2.14	480.71 ± 4.52	9.72 ± 1.68	345.86 ± 6.82	22.32 ± 2.12
Gravel	90.09 ± 2.12	391.69 ± 3.68	8.64 ± 1.52	272.54 ± 7.44	19.73 ± 1.88
Cement	79.17 ± 1.65	344.21 ± 3.76	7.33 ± 2.12	215.44 ± 5.82	18.56 ± 1.76
Block	72.34 ± 1.87	314.15 ± 5.12	6.24 ± 1.94	184.38 ± 7.82	17.84 ± 1.68
Gypsum	65.52 ± 2.45	284.86 ± 3.18	5.56 ± 1.64	156.34 ± 6.46	17.35 ± 2.16
Gypsum Board	54.60± 1.94	237.39 ± 4.48	4.78 ± 1.72	132.67 ± 5.18	16.56 ± 2.26
Ceramic Tile	35.49± 2.64	154.30± 5.24	3.35 ± 2.28	115.85± 6.38	14.46 ± 1.84

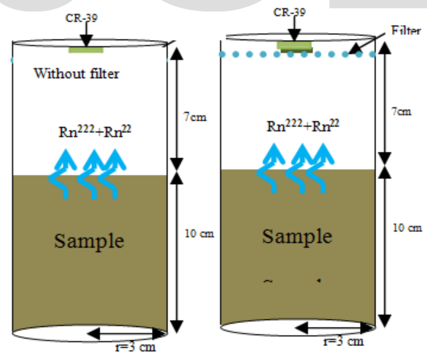

Fig. 1. Experimental set up for measuring radon exhalation rate; Two radon dosimeters; with and without filter.

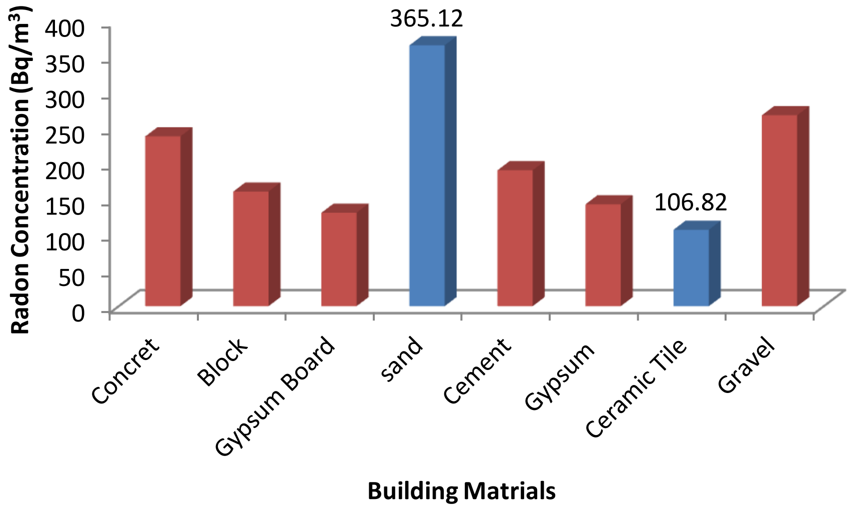

Fig. 2. Distribution of radon concentration in building materials

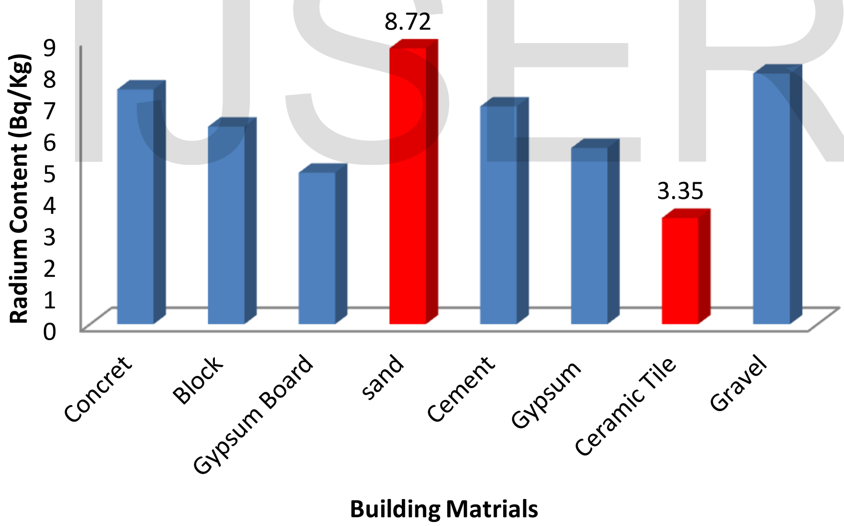

Fig. 3. Distribution of radium content in building materials