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Radon exhalation studies in building materials using solid-state nuclear track detectors

AJAY KUMAR and SURINDER SINGH
Department of Physics, Guru Nanak Dev University, Amritsar 143 005, India
Email: surinder51@yahoo.com

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Abstract. Indoor radon has been recognized as one of the health hazards for mankind. Building materials constitute the second most important source of radon in dwellings. The common building materials used in the construction of dwellings are studied for radon exhalation rate. The 'Can' technique using LR-115 type-II solid-state nuclear track detector has been used for these measurements. The radon exhalation rate in these samples varies from 4.75 m Bq m^{-2} h^{-1} (0.14 m Bq kg^{-1} h^{-1}) for limestone to 506.76 m Bq m^{-2} h^{-1} (15.24 m Bq kg^{-1} h^{-1}) for soil.

Keywords. Radon exhalation; building materials; track detector.

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1. Introduction

Radon is a radioactive inert gas, which is produced during the decay of radium, an element present in the naturally occurring uranium series. In the recent past, environmental scientists all over the world have been expressing great concern about the radiation hazards from ^{222}Rn and its short lived daughter products inside buildings. Inhalation of ^{222}Rn and its daughter products, especially ^{218}Po and ^{214}Po attached to aerosols present in ambient air, causes significant radiological hazard to human lungs. Radon appears mainly by diffusion processes from the point of origin, following α-decay of ^{226}Ra in underground soil and building materials used in the construction of floors, walls, ceilings, etc.

The magnitude of indoor radon concentration depends primarily on the construction materials of the building and the amount of radon in underlying soil. The concentration of radon and its decay products show large temporal and local fluctuations in the indoor atmosphere due to meteorological variables [1]. A study of radon exhalation rate from building materials is important for understanding the relative contributions of individual materials to the total radon content found inside a room. Such a study has been carried out in our laboratory using solid-state nuclear track detectors.

2. Experimental technique

2.1 *Radon exhalation measurements*

In the present work, 'Can' technique used by Abu-Jarad *et al* [2] for the measurement of radon exhalation rate has been used. It is established as a very simple and reliable technique for the exhalation rate measurements and has been used by many workers [3–7]. In the present experiments, about 250 g of the soil sample was placed in an emanation chamber (1 l glass bottle) which was then closed for a period of three weeks in order to get equilibrium between radium to radon. After this period, LR-115 type-II plastic track detector was fixed on the top inside of the glass bottle, which was closed for a period of 90 days. After exposure, the detectors were removed and then etched in 2.5 N NaOH solution at 60°C for 2 h using a constant temperature bath. The tracks were counted using an optical microscope at a magnification of 400×. The radon activity or integrated radon exposure inside the 'Can' was obtained from the track density of the detector by using the calibration constant of 4.8×10^2 tracks cm^{-2} d^{-1} per working level (WL) of radon at equilibrium determined by Subba Ramu *et al* [8] with an equilibrium factor of 0.4 between radon and its progeny. The 'radon exhalation rate' in terms of area and mass was obtained from the expression reported by Abu-Jarad [9] and Khan *et al* [4]:

$$E_A = \frac{CV\lambda}{A[T + 1/\lambda(\mathrm{e}^{-\lambda T} - 1)]},$$

where E_A is the radon exhalation rate in terms of area (Bq m^{-2} h^{-1}), C the integrated radon exposure as measured by LR-115 plastic track detector (Bq m^{-3} h), V the effective volume of the 'Can' (m^3), λ the decay constant for radon (h^{-1}), T the exposure time (h) and A the area of the 'Can' (m^2). This formula is also modified to calculate the radon exhalation rate in terms of mass (Bq kg^{-1} h^{-1}):

$$E_M = \frac{CV\lambda}{M[T + 1/\lambda(\mathrm{e}^{-\lambda T} - 1)]},$$

where E_M is the radon exhalation rate in terms of mass (Bq kg^{-1} h^{-1}) and M the mass of the sample.

3. Results and discussion

The exhalation rates in building materials including soil have been determined from the samples collected from construction sites as well as from various agencies supplying raw materials for building construction. The materials studied are cement, cement plaster, brick, sand, limestone, chips, crasher and ceramics. The values of radon exhalation rate in terms of area and mass are summarized in table 1. Four samples of the cement, three samples of bricks and chips each and two samples of the soil and sand each and one each of the plaster of paris, limestone and crasher were studied and the average exhalation rates were determined. The value of radon exhalation rate varies from 4.75 m Bq m^{-2} h^{-1} (0.14 m Bq kg^{-1} h^{-1}) for limestone to 506.76 m Bq m^{-2} h^{-1} (15.24 m Bq kg^{-1} h^{-1}) for soil sample. The high value

Table 1. Radon exhalation rate in building materials.

Sl. No.	Material	Location	Radon exhalation rate E_M (m Bq kg^{-1} h^{-1})	Radon exhalation rate E_A (m Bq m^{-2} h^{-1})
1	Ceramics	Hardware store, Punjab	1.91	63.34
2	Brick	Amritsar, Punjab	1.63	53.84
3	Brick	Batala, Punjab	3.39	112.43
4	Brick	Batala, Punjab	0.67	22.17
5	ACC Cement (black)	Barmana, Himachal Pradesh	1.39	45.92
6	Ambuja Cement (black)	Ropar, Punjab	1.19	39.58
7	ACC Cement (black)	Gaggal, Himachal Pradesh	1.00	33.26
8	White Cement	Birla Company	0.57	19.00
9	Sand	Barsar, Himachal Pradesh	2.82	93.43
10	Sand	Amritsar, Punjab	0.76	25.34
11	Plaster of Paris	Hardware store, Punjab	0.38	12.67
12	Limestone	Hardware store	0.14	4.75
15	Yellow Chips	Kishangarh, Rajasthan	0.76	25.33
17	White Chips	Nathdiara, Rajasthan	0.43	14.25
18	Red Chips	Kishangarh, Rajasthan	2.39	79.18
19	Crasher	Amritsar, Punjab	0.33	11.09
20	Soil	Una, Himachal Pradesh	15.24	506.76
21	Soil	Amritsar, Punjab	4.89	161.53

of radon exhalation rate for the soil belonging to Himachal Pradesh may be due to the presence of uranium in some areas of the state reported earlier by some authors [10–12]. Exhalation rate for bricks has been found to vary from 22.17 m Bq m^{-2} h^{-1} (0.67m Bq kg^{-1} h^{-1}) to 112.43 m Bq m^{-2} h^{-1} (3.39 m Bq kg^{-1} h^{-1}) with an average value of 62.81 m Bq m^{-2} h^{-1} (1.89 m Bq kg^{-1} h^{-1}). Similarly the values for cement vary from 19.00 m Bq m^{-2} h^{-1} (0.57 m Bq kg^{-1} h^{-1}) to 45.92 m Bq m^{-2} h^{-1} (1.39 m Bq kg^{-1} h^{-1}) with an average value of 34.44 m Bq m^{-2} h^{-1} (1.04 m Bq kg^{-1} h^{-1}). The average values are found to be higher for the samples of soil and bricks when compared with the samples of other building materials. Our values for brick samples agree with those reported by Sharma and Virk [13] and for crasher are comparable with values reported by Azam *et al* [5]. Among different types of chips, white chips have shown the lowest value of exhalation rate (0.43 m Bq kg^{-1} h^{-1}), and so it is advisable to use white chips in building construction from the safety point of view. From table 1 it is evident that the radon exhalation rate for white cement of the Birla Company is very low when compared to the cement from other companies. Similarly a sample of brick (Sl. No. 4) from Batala (Punjab) has shown low value of radon exhalation rate. Hence the white cement of the Birla Company and the bricks with low values of radon exhalation rate should be used in building construction.

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