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The effect of grain size on radon exhalation rate in natural-dust and stone-dust samples

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Abstract

Radiation dose to human population due to inhalation of radon and its progeny contributes more than 50% of the total dose from the natural sources which is the second leading cause of lung cancer after smoking. In the present work the dependence of radon exhalation rate on the physical sample parameters of stone dust and natural dust were studied. The samples under study were first crushed, grinded, dried and then passed through sieves with different pore sizes to get samples of various grain sizes (μm). The average value of radon mass exhalation rate is 5.95±2.7 mBqkg^{-1}hr^{-1} and average value of radon surface exhalation rate is 286±36 mBqm^{-2} hr^{-1} for stone dust, and the average value of radon mass exhalation rate is 9.02±5.37 mBqkg^{-1}hr^{-1} and average value of radon surface exhalation rate is 360±67 mBqm^{-2} hr^{-1} for natural dust. The exhalation rate was found to increase with the increase in grain size of the sample. The obtained values of radon exhalation rate for all the samples are found to be under the radon exhalation rate limit reported worldwide.

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Keywords: Radon concentration; Radon exhalation Rate; grain size; Stone dust; Natural dust.

1. Introduction

In view of health physics, it is very important to have the knowledge of distribution of natural radionuclide materials in the environment. The main sources of continuous radiation exposure to human being are building materials, which indicate the radiological contamination in the indoor environment. Radon is a noble gas and is progeny product of ^{226}Ra, which is one of the nuclides results due to disintegration of ^{238}U series. The measurement of indoor radon exhalation rates are of utmost importance because inhalation of radon and its progeny contributes

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more than 50% of the total radiation dose from the natural sources. It is assumed to be a major contributor toward an increased lung cancer risk in the affected population (Khan et al., 1992; Kumar et al., 2005). The main interest behind this study is measurement of radiation exhalation rate in the construction material used in buildings. Knowledge of radioactivity present in building materials gives idea about possible radiological hazard to mankind by the use of such materials. The measurement of radon concentration and radon exhalation rates for building materials are important from radiation protection point of view (Abu-Jarad et al., 2005; Singh et al., 1997). The natural and stone dusts are used in various forms during the construction of buildings. In order to know the radiological effects due to natural radioactive materials, radon concentration and exhalation rates parameters calculations are important aspects. The value of radon concentration from natural dust and stone dust, according to the various researches carried out so far, depends on climatic factors, weather conditions and dust types (Barton and Ziemer, 1986). Additionally, the geological condition also strongly affects the ^{222}Rn concentration in dust. The radioactivity of the samples also depends on size of grain (Kalkwarf et al. 1985; Megumi and Mamuro 1977), so by knowing the radon concentration and exhalation rate for the particular grain size, a choice can be made to select the building material of a grain size which has minimum radiation hazards. The aim of this study was to determine the radon exhalation rate and its dependence on grain size of the sample, and for this purpose stone dust and natural dust samples were taken as these are used as building material in all over the world.

2. Experimental method

Can technique (Kant et al., 2001) was used for the radon exhalation measurements in this experiment. This is the simple and efficient method for the measurement of time integrated radon exhalation rate. Natural and Stone dust samples were collected from NCB, Faridabad (Haryana) INDIA and some stone mining area. Then samples were processed on the various steps leading to using can technique. The exhalation rate depends upon the material and its amount as well as on the dimension of the Can as reported in various studies (Kant et al., 2001; Kumar and Singh, 2004).

Radon and its progenies reach an equilibrium concentration after a week or more and thus the equilibrium activity of emergent radon could be obtained from the duration of exposure of the sample to the detectors inside the Can and the dimension of the Can. After the exposure of detectors for 100 days, the detectors from all the Cans were retrieved and etched in 2.5N NaOH at 60 ±1˚C for a period of 90 min in a constant temperature water bath for revelation of tracks. Resulting alpha tracks on the exposed face of the detector were counted with the help of spark counter which was pre sparked at 900V and operated at 450V.

3. Experimental results

The values of the surface exhalation rate and mass exhalation rate for radon have been calculated by using following expression 1 and 2 (Kumar and Singh, 2004; Kant and Chakarvarti, 2003):

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

$$E_m = CV\lambda/M\,[T + 1/\lambda\{e^{-\lambda T} - 1\}] \quad (2)$$

Where E_s is the radon surface exhalation rate in mBqm^{-2} hr^{-1}, E_m is the radon mass exhalation rate in mBq kg^{-1}hr^{-1}, C is the integrated radon exposure (Bqm^{-3}h), V is the effective volume of Can in m^3, λ is the decay constant for radon in h^{-1}, T is the exposure time in h, A is the area covered by the Can in m^2 and M is the mass of the sample in kg. On the basis, the calculated values of radon mass exhalation rate and radon surface exhalation rate for stone and natural dust samples are shown in table 1.

Table 1: Measurement of Radon Exhalation Rate for Stone Dust and Natural Dust

Sample Size (μm)	Mass (g)	Stone Dust		Natural Dust	
		Em ($mBqkg^{-1}hr^{-1}$)	Es ($mBqm^{-2}hr^{-1}$)	Em ($mBqkg^{-1}hr^{-1}$)	Es ($mBqm^{-2}hr^{-1}$)
≤150 and ≥75	100	1.05	119	3.66	152
	150	4.05	176	4.87	198
	200	8.60	289	7.89	367
≤300 and ≥150	100	3.26	167	3.89	159
	150	4.69	189	5.32	245
	200	9.91	343	9.12	378
≤600 and ≥300	100	7.45	256	4.10	162
	150	7.29	245	6.56	321
	200	15.08	489	9.35	378
≥600	100	11.58	289	4.23	177
	150	13.31	467	6.18	315
	200	19.64	522	10.39	381

4. Results and discussion

The measured values of radon mass exhalation rate varied from 3.66-10.39 $mBqkg^{-1}hr^{-1}$ with an average value 5.95±2.7 $mBqkg^{-1}hr^{-1}$ for stone dust, 1.05-19.64 $mBqkg^{-1}hr^{-1}$ with an average value 9.02±5.37 $mBqkg^{-1}hr^{-1}$ for natural dust and value of radon surface exhalation rate varied from 152-384 $mBqm^{-2}$ hr^{-1} with an average value 286±36 $mBqm^{-2}$ hr^{-1} for stone dust,119-522 $mBqm^{-2}$ hr^{-1} with an average value 360±67 $mBqm^{-2}$ hr^{-1} for natural dust for the used samples.

As can be observed from the table 1, exhalation rate increases with grain size of the sample because the porosity of the sample increases with grain size, which result in the increases in emanation rate, which finally results in increased exhalation rate of the sample.

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