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Ceramic Rn^{222} exhalation rates from different countries

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Abstract—In the present study, the alpha radioactivity from radon emanated from some ceramic samples collected from different countries was measured using the can technique, containing CR-39. The average ^{222}Rn and ^{226}Ra concentrations are found to be 371.79 Bq m^{-3} and 1.68 Bq kg^{-1}, respectively. The highest radon exhalation rate was found in Chinese ceramic. The values of effective radium content are less than the permissible value of 370 Bq kg^{-1}.

Index Terms— ceramic, radon, CR-39, exhalation rate

1 Introduction

The CR-39 detectors are used for long-term measurements of radon exhalation rate. The majority of exposure to radiation comes from natural sources, which may be terrestrial (soils and rocks) or extra terrestrial (cosmic rays). ^{222}Rn and their short-lived decay products are primary contributors to the effective dose received by the population due to natural radiation [1]. Radon levels show important variations on a regional or local scale. The present work deals with radon exhalation rate in ceramic in which radon gas is emanated in the air as a product of ^{238}U that occur as a trace element in the naturally occurring materials. The most sources of indoor radon are the soil and geology under the building. Radon sources may include domestic, drinking water from drilled wells (ground water supplies), and emanation of radon from building materials, including concrete, bricks, ceramic, natural building stones, natural gypsum, and materials using industrial by products such as phosphor gypsum, blast furnace slag, and coal fly ash [2, 3]. The exposure of population to high concentrations of alpha radioactivity from radon for a long period leads to pathological effects like the respiratory functional changes and the occurrence of lung cancer [4]. CR-39 detectors are used in radon detection and alpha-particle spectroscopy to measure the natural alpha radioactivity in human and animal tissues [5-10]. The aims of this study are to ascertain the radon exhalation rate in ceramic samples.

2 Materials and Methods

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In this study, CR-39 detectors were placed at the closed top end of a plastic cup (6 cm X 7.5 cm). The radon level was measured using TASTRAK™ track-etch detectors with chemical composition of $C_{12}H_{18}O_7$, a density of 1.32 g cm^{-3}, and size 1 cm^2 purchased from Track Analysis Systems Ltd., Bristol, UK. The radon level was measured in ceramic samples from different countries. Ceramic samples were dried at 100 °C for 3 h in an oven to ensure complete moisture removal. The ceramic was stored at room temperature for about 90 d before counting to achieve equilibrium for ^{238}U and ^{232}Th with their respective progeny [11]. In the present calibration experiment was used to determine ^{222}Rn gas concentration emanating from a ^{226}Ra source with 3.3 kBq from the International Atomic Energy Agency in a close system. After exposure, the CR-39 detectors are removed and chemically etched in a 6.25 N aqueous NaOH solution using a water bath at 70 °C for 7 h. Alpha-particle track measurement per cm^2 produced by the decay of ^{222}Rn and its daughters was conducted using an optical microscope (NOVEL, China) of 40x magnification power with USB 2.0 Camera Application V 2.3 software.

Radon concentration (C_{Rn}) was calculated [12]

$$C_{Rn}(Bq\ m^{-3}) = \frac{N_o t_o \rho}{\rho_o t} \quad , \tag{1}$$

where N_o = activity concentration for a standard source (radium), t_o = exposure time for standard source, ρ_o = track density for a standard source (track cm^{-2}), ρ = track density for sample (track cm^{-2}), and t = exposure time of the sample.

The effective radium content can be calculated [13, 14]:

$$C_{Ra}(Bq\ kg^{-1}) = (\frac{\rho}{kT_e})(\frac{hA}{M}) \tag{2}$$

where M is the mass of the sample in kg, A is the area of a cross section of the cylindrical (m^2) and h is the distance between the detector and the top of the sample in m. ρ is the counted track density, k is the calibration factor of the CR-39 track detector, and T_e denotes the effective exposure time.

The exhalation rate was calculated [15]:

$$E_x = \frac{CV\lambda}{A(T + \frac{(e^{-\lambda T} - 1)}{\lambda})} \quad , \tag{3}$$

where E_x is the radon exhalation rate (Bq kg^{-1} d^{-1}), C is the measured radon concentration by the CR-39 detector (Bq m^{-3} d^{-1}), λ is the decay constant of radon (d^{-1}), T is the exposure time (d), V is the volume of the radon chamber (m^3), and A is the mass of the sample.

$$H_E = C \times F \times T \times D \tag{4}$$

where C is the radon concentration in Bq m^{-3}, F is the ^{222}Rn indoor equilibrium factor (0.4), T is time (8760 h y^{-1}), and D for dose conversion factor (9×10^{-6} mSv y^{-1} (Bq m^{-3})$^{-1}$).

3 Results and Discussion

The calibration factor obtained from the experiments is 0.0107 track cm^{-2} d^{-1} per (Bq m^{-3}). The ^{222}Rn and ^{226}Ra concentrations in ceramic samples are presented in Table 1. The minimum and maximum radon concentrations were found to be 289.47±17.34 and 443.22±21.45 Bq m^{-3} in C9 and C5 (ceramic, china) as shown in Fig. 1. The present results show that the radon concentration in ceramic samples is below the limit recommended (International Commission of Radiation Protection) (ICRP). The mass exhalation rates in the collected ceramic samples are given in Table 1. The radon exhalation rate varied from 0.0005074 Bq kg^{-1} d^{-1} to 0.0007769 Bq kg^{-1} d^{-1}.

Table 1: ^{222}Rn and ^{226}Ra concentrations in ceramic samples

SC	Location	E_x (Bq kg^{-1} d^{-1})	C_{Ra} (Bq kg^{-1}) ±St. error	^{222}Rn (Bq m^{-3}) ±St. error	H_E (mSv y^{-1}) ±St.error
C1	China	0.0006458	1.67±0.08	368.44±19.56	2.65±0.14
C2	China	0.0006114	1.58±0.08	348.78±19.03	2.51±0.13
C3	China	0.0007339	1.90±0.09	418.70±20.85	3.01±0.15
C4	China	0.0006668	1.72±0.09	380.40±19.87	2.74±0.14
C5	China	0.0007769	2.01±0.09	443.22±21.45	3.19±0.15
C6	China	0.0007033	1.82±0.09	401.21±20.41	2.89±0.14
C7	China	0.0005091	1.32±0.08	290.43±17.37	2.09±0.12
C8	China	0.0005533	1.43±0.08	315.65±18.10	2.27±0.13
C9	China	0.0005074	1.31±0.08	289.47±17.34	2.08±0.12
C10	China	0.0007736	2.00±0.09	441.35±21.41	3.18±0.15
C11	India	0.0006631	1.71±0.09	378.30±19.82	2.72±0.14
C12	India	0.0007112	1.84±0.09	405.73±20.53	2.92±0.15
C13	Turkey	0.0006207	1.60±0.08	354.08±19.18	2.55±0.14
C14	Turkey	0.0006877	1.78±0.09	392.34±20.18	2.82±0.14
C15	Oman	0.0005409	1.40±0.08	308.61±17.90	2.22±0.13
C16	UEA	0.0007255	1.87±0.09	413.91±20.73	2.98±0.15
C17	Iran	0.0006877	1.78±0.09	392.33±20.18	2.82±0.14
C18	Iran	0.0007525	1.94±0.09	429.32±21.11	3.09±0.15
C19	Iran	0.0005953	1.54±0.08	339.63±18.78	2.45±0.13
C20	Tunisia	0.0005186	1.34±0.08	295.88±17.53	2.13±0.12
C21	Egypt	0.0007212	1.86±0.09	411.45±20.67	2.96±0.15
C22	Syria	0.0006312	1.63±0.08	360.12±19.34	2.59±0.14
Avg.		**0.0006517**	**1.68±0.08**	**371.79±19.61**	**2.68±0.14**

SC= Sample Code

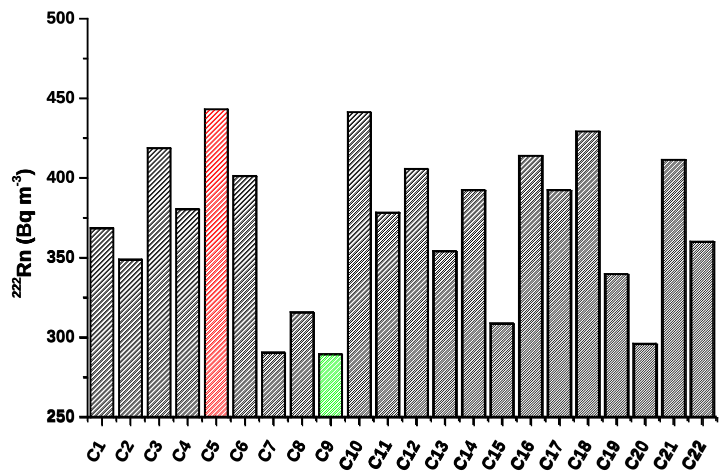

Fig. 1. Average ^{222}Rn concentration. The green bar represents low concentration, and the red bar represents high concentration.

4 Conclusions

The ^{222}Rn concentration in the ceramic samples varies from 289.47 to 443.22 Bq m^{-3} with mean 371.79 Bq m^{-3}. The highest radon exhalation rates are found in Chinese ceramic. According to EPA and ICRP, the average indoor radon level should be 148 Bq m^{-3} and 300 Bq m^{-3}, respectively, whereas 15 Bqm^{-3} (ranging from 1 Bq m^{-3} to 100 Bq m^{-3}) of radon concentration is found in outside air [16-18]. The annual effective dose equivalent ranges from 2.08 mSv y^{-1} to 3.19 mSv y^{-1}, with an average of 2.68 mSv y^{-1}. The values of radium content in ceramic samples were found to be lower than the permissible value of 370 Bq kg^{-1} recommended by Organization for Economic Cooperation and Development [19]. The used ceramic should be characterized by lower radon concentration to avoid the health hazards on human.

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