Bricks Rn^{222} Exhalation Rates in Some Samples from Different Countries

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***Abstract*—Radon concentrations in brick samples collected from different countries were measured using the sealed-can technique based on the CR-39 SSNTDs. CR-39 detectors are widely used for radon exhalation rate measurements in bricks under different conditions. The detectors were exposed to standard radon concentration from a standard ^{226}Ra source. The average ^{222}Rn and ^{226}Ra concentrations are found to be 280 Bq m^{-3} and 1.72 Bq kg^{-1}, respectively. The highest radon exhalation rate was found in Samawah bricks, Iraq. The values of effective radium content are less than the permissible value of 370 Bq kg^{-1}.**

***Keywords*— Bricks, radon, CR-39, exhalation rate.**

I. Introduction

The CR-39 detectors are used for long-term measurement of radon exhalation rate. Plastic track detector is used for radon measurements, in homes and in the field. Track-etch plastic detector is passive device. 222Rn and their short-lived decay products are primary contributors to the effective dose received by the population due to natural radiation [1]. Radon concentration is determined by measuring the emitted alpha particles that causes damage to the detector surface. Radon levels show important spatial variations on a regional or local scale. The track density (track cm-2 in detector surface), exposure time, and calibration factor are necessary for calculating the radon concentration. The present work deals with radon exhalation rate in brick in which radon gas (3.8 d) is emanated in the air as a product of 238U that occur as a trace element in the naturally occurring materials including the cementious materials used in the construction of cement grouts, mortars, bricks, and concrete. The most sources of indoor radon are the soil and geology under the building. However, radon sources may include domestic, drinking water from drilled wells (groundwater supplies), and emanation of radon from building materials, including concrete, bricks, natural building stones, natural gypsum, and materials using industrial by products such as phosphor gypsum, blast furnace slag, and coal fly ash [2, 3]. Radon sources and radon transport mechanisms may have a considerable influence on the cost-effectiveness of various prevention and mitigation strategies. CR-39 detectors are used in radon detection and alpha-particle spectroscopy to measure the natural alpha radioactivity in human and animal tissues [4-8]. The aims of this study are to ascertain the radon exhalation rate in brick samples.

II. Materials and Methods

In this study, CR-39 detectors were placed at the closed top end of a plastic cup (diameter 6 cm and length 7.5 cm). The radon level was measured using TASTRAKTM 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 using CR-39 detectors in brick samples from different countries. Brick samples were dried at 100 °C for 3 h in an oven to ensure complete moisture removal. Dried samples were pulverized and sifted through a 2 mm sieve. The brick was stored at room temperature for about 90 d before counting to achieve equilibrium for ^{238}U and ^{232}Th with their respective progeny [9]. In the present calibration experiment was used to determine ^{222}Rn gas concentration emanating from a 226Ra source with 3.3 kBq from the International Atomic Energy Agency in a close system. After exposure, the CR-39 detector is 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 cm2 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. The formula used to measure track density was as follows

Track Density (ρ) (Track cm^{-2})= $\frac{Average\ of\ Total\ Track}{Area\ of\ Field\ of\ View}$ (1)

Radon concentration (C_{Rn}) was calculated by [10]

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

(2)

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 of the brick samples can be calculated by [11, 12, 13]:

$$C_{Ra}(Bq\ kg^{-1}) = \left(\frac{\rho}{kT_e}\right)\left(\frac{hA}{M}\right) \quad (3)$$

where M is the mass of the brick 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 brick sample in m. ρ is the counted track density, k is the calibration factor of the CR-39 track detector, and Te denotes the effective exposure time.

The exhalation rate was calculated using [13, 14]:

$$E_x = \frac{CV\lambda}{A\left(T + \frac{(e^{-\lambda T} - 1)}{\lambda}\right)} \quad (4)$$

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.

The annual effective dose (H_E) was calculated [1]:
H_E (mSv y^{-1}) = C × F × T × D (5)

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 x 10^{-6} mSv y^{-1} (Bq m^{-3})$^{-1}$).

III. Results and Discussion

The calibration factor obtained from the

SC	Company /Location	E_x (Bq kg^{-1} d^{-1})	Effective radium content (Bq kg^{-1})	^{222}Rn (Bq m^{-3})	H_E (mSv y^{-1})
B1	Malika, Isfhan, Iran	0.00028	2.05	302	2.17
B2	Isfhan, Iran	0.00042	3.05	448	3.23
B3	Afzali, Isfhan, Iran	0.00026	1.92	283	2.04
B4	Maheer, Iran	0.00020	1.49	219	1.57
B5	Darekhoha, Iran	0.00017	1.27	188	1.35
B6	Shereen Asfaal, Iran	0.00024	1.75	257	1.85
B7	Yazdi Zaadah, Iran	0.00019	1.38	203	1.46
B8	Khoudadi Company (White), Iran	0.00026	1.92	339	2.44
B9	Khoudadi Company (Red), Iran	0.00007	0.53	106	0.76
B10	Seefal Toos Company, Iran	0.00028	2.01	370	2.66
B11	Tawakel Company	0.00027	1.97	319	2.30
B12	Najaf, Iraq	0.00032	2.36	348	2.50
B13	Kefil, Iraq	0.00023	1.66	245	1.76
B14	Nahrawan, Iraq	0.00021	1.54	239	1.72
B15	Meesan, Iraq	0.00012	0.91	167	1.20
B16	Jimhouri Samawah, Iraq	0.00026	1.90	308	2.22
B17	Samawah, Iraq	0.00044	3.18	492	3.54
B18	Alateeq Company (Red), Kuwait	0.00013	0.99	219	1.57
B19	Alateeq Company, Kuwait	0.00009	0.66	150	1.08
B20	AletehaadCompany, Kuwait	0.00024	1.78	393	2.83
Avg		**0.00024**	**1.72**	**280**	**2.1**

experiments has mean 0.0107 track cm-2 d-1 per (Bq m^{-3}). The ^{222}Rn and ^{226}Ra concentrations in brick samples are presented in Table 1. The minimum and maximum radon concentrations were found in B9 Khoudadi Company (red bricks), Iran at 106 Bq m-3 and B17 Samawah, Iraq at 492 Bq m-3 as shown in Fig. 1. The present results show that the radon concentration in brick samples is below the limit recommended (International Commission of Radiation Protection) (ICRP). The mass exhalation rates in the collected bricks samples are given in Table 1. The radon exhalation rate varied from 0.00007 Bq kg^{-1} d^{-1} to 0.00044 Bq kg^{-1} d^{-1}.

TABLE I
F222RN AND 226RA CONCENTRATIONS IN BRICK SAMPLES

SC= Sample Code

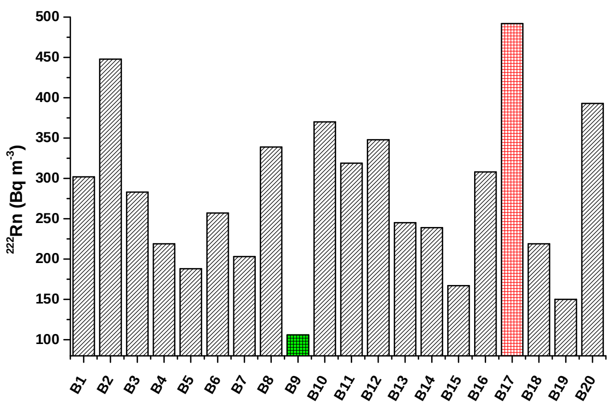

Fig. 1 Average 222Rn concentration. The green bar represents low concentration, and the red bar represents high concentration.

IV. CONCLUSIONS

T The 222Rn concentration in the brick samples varies from 106 Bq m-3 to 492 Bq m-3 with mean 280 Bq m-3. The highest radon exhalation rates are found in Samawah, Iraq. According to EPA and ICRP, the average indoor radon level should be 148 Bq m−3 and 300 Bq m−3, respectively, whereas approximately 15 Bqm−3 (ranging from 1 Bq m−3 to 100 Bq m−3) of radon concentration is normally found in outside air [15-17]. The annual effective dose equivalent ranges from 0.76 mSv y-1 to 3.54 mSv y-1, with an average of 2.01 mSv y-1. The values of radium content in brick samples were found to be lower than the permissible value of 370 Bq kg-1 recommended by Organization for Economic Cooperation and Development [18].

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