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CEMENT ^{222}RN AND ^{226}RA CONCENTRATION MEASUREMENTS IN SELECTED SAMPLES FROM DIFFERENT COMPANIES

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ABSTRACT

Solid-state nuclear track detectors (CR-39) are widely used for radon exhalation rate measurements in cement under different conditions. The detectors were exposed to standard radon concentration from a standard ^{226}Ra source. A calibration factor of 0.0107 track cm^{-2} per Bq d m^{-3} was determined. The ^{222}Rn and ^{226}Ra concentrations varied from 18Bq m^{-3} to 178 Bq m^{-3} and 0.09 Bq kg^{-1} to 1.30 Bq kg^{-1}, respectively. The highest radon exhalation rate was found in Sulaymanyah, Iraq.

Keywords: Cement, Radon, CR-39, Exhalation rate

INTRODUCTION

The solid-state nuclear track detectors (CR-39) are used for long-term measurement of radon concentrations. The passive detector is used for radon emission measurements. Plastic track detectors are typically used for radon measurements, in homes and in the field. Track-etch plastic detectors are passive devices.^{222}Rn and their short-lived decay products are primary contributors to the effective dose received by the population due to natural radiation [1]. Passive methods are more suitable for assessing radon exposure over long-term scales and can be used in large-scale surveys at a moderate cost. The sampling devices can be subdivided into active and passive. Radon concentrations are determined by measuring the emitted alpha particles that, causes damage to the detector surface. Radon levels can also 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 in cement in which radon gas ($T_{1/2}$=3.8 d) is emanated in the air as a product of ^{238}U that occur as a trace element in the naturally occurring materials including the cementious materials used in the construction of cement grouts, mortars, and concrete. The aims of this study are to ascertain the exhalation rate in cement samples.

MATERIALS AND METHODS

In this study, pieces of CR-39 detectors were placed at the closed top end of a plastic cup as shown in Fig. 1. The radon level was measured using TASTRAK^{TM}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 x 1 cm purchased from Track Analysis Systems Ltd., Bristol, UK. The radon level was measured using CR-39 detectors in cement samples (19-25 g) from different countries. Cement samples were dried at 100 °C for 3 h in an ovento ensurecomplete moisture removal. Dried samples were pulverized and sifted through a 2 mm sieve. The passive radon detectors (diameter 6 cm and length 7.5 cm) were placed at the top center of a plastic cup using tape. The cement was stored at room temperature for about 90 d before counting to achieve equilibrium for ^{238}U and ^{232}Th with their respective progeny [2].In the present calibration experiments was used to

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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.

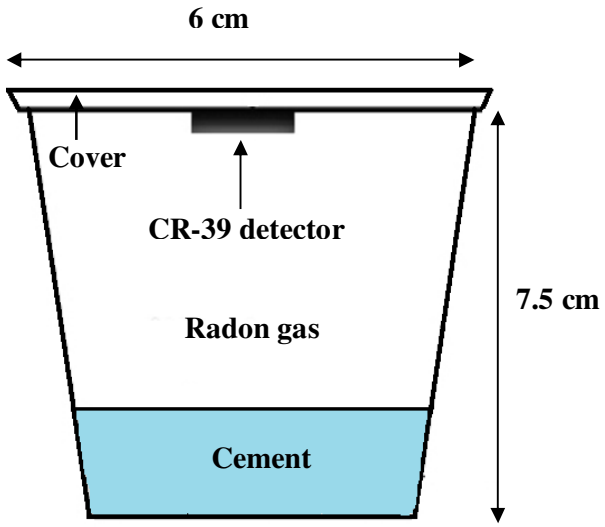

Figure 1. A schematic diagram of the sealed-cup technique

After exposure, the CR-39 detectors were removed and chemically etched in a 6.25 N aqueous NaOH solution using a water bath at 70 °C for 7 h, as reported in another study. 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. The shape of the etch pit and the diameter of the 'etch-pit opening' depended on two parameters: (a) the bulk etching velocity (V_B) for the etchant and (b) the track etching velocity (V_T) along the trajectory of the particle. The ratio $V = V_T/ V_B$ is an important parameter used to determine the properties of charged particles. The ratio (V) also provides the etching efficiency and the critical angle of etching (θ_c). For alpha particles, the value (V) is not very high in the CR-39 plastic, ranging from 2 to 3 [3]. $V_B$is equal to the thickness (h) of the removed layer from each face of the plastic upon etching time (t_e), whereas V_T is the full length of the etch pit to etching time (t_e).

The formula used to measure track density was as follows:

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

Radon concentration (C_{Rn}) was calculated by the formula [4]

$$C_{Rn}(Bq\ m^{-3}) = \frac{N_o t_o \rho}{\rho_o t}, \qquad (2)$$

whereN_o = activity concentration for a standard source (^{226}Ra), 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 solid sample can be calculated by the formula [5, 6]:

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

where M is the mass of the solid sample in kg, A is the area of a cross section of the cylindrical can in m^2 and h is the distance between the detector and the top of the solid 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 using the following equation [3, 7]:

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

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) to the personal work of the hospitals was calculated from the following formula according [1]:

$$H_E\ (mSv\ y^{-1}) = C \times F \times T \times D \quad (5)$$

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})$^{-1}$).

RESULTS AND DISCUSSION

The calibration experiments were conducted to estimate the relationship between track density and radon concentration. The calibration factor obtained from the experiments has mean 0.0107 track cm^{-2} d^{-1} per (Bq m^{-3}).The ^{222}Rn and ^{226}Ra concentrations in cement samples from different companies are presented in Table 1. The minimum and maximum radon concentrations were found in S9 Alfares Company-Iran at 18 Bq m^{-3} and S25 Aljesr Cement Company-Bazyan-Sulaymanyah, Iraq at 177 Bq m^{-3}, respectively as shown in Fig. 2. The present results show that the radon gas concentration in cement samples is below the limit recommended (International Commission of Radiation Protection) (ICRP). The mass exhalation rates in the collected cement samples are given in Table 1.

Table 1. ^{222}Rn and ^{226}Ra concentrations in cement samples

SC	*Company /Location*	*E_x (Bq kg^{-1} d^{-1}) x10^{-5}*	*Effective radium content (Bq kg^{-1}) ±St. error*	*^{222}Rn (Bq m^{-3}) ±St. error*	*H_E (mSv y^{-1})*
S1	Hegmatan Cement-Iran	2.69	0.34±0.043	60.84±7.95	0.44±0.06
S2	Kangan Cement-Iran	5.15	0.65±0.066	97.23±10.05	0.7±0.07
S3	Sabahan-Iran	3.17	0.4±0.048	68.7±8.45	0.49±0.06
S4	Ardstaan Company-Iran	6.57	0.83±0.067	156.81±12.76	1.13±0.09
S5	Aldurood Company-Iran	1.74	0.22±0.034	40.86±6.51	0.29±0.05
S6	AbyekCemeny Company-Iran	3.01	0.38±0.050	56.37±7.65	0.41±0.05

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S7	CemenySafeedBnoyed Company-Iran	3.41	0.43±0.048	81.36±9.19	0.59±0.06
S8	Alkarawaan Company-Iran	3.25	0.41±0.046	76.49±8.91	0.55±0.06
S9	Alfares Company-Iran	0.71	0.09±0.022	17.65±4.28	0.13±0.03
S10	Aldalejaan Company-Iran	2.69	0.34±0.043	63.94±8.15	0.46±0.06
S11	Samaan Company-Iran	2.38	0.3±0.040	55.53±7.59	0.4±0.05
S12	Ilaam-Iran	3.64	0.46±0.049	85.75±9.44	0.62±0.07
S13	Thatt Cement-Pakistan	1.82	0.23±0.036	41.25±6.54	0.3±0.05
S14	-PakistanBest Way Cement	3.41	0.43±0.054	64.00±8.15	0.46±0.06
S15	Almabrokah Company-Pakistan	1.74	0.22±0.036	38.45±6.32	0.28±0.04
S16	Shaheen-Pakistan	2.22	0.28±0.040	51.04±7.28	0.37±0.05
S17	Power Cement-Pakistan	2.14	0.27±0.041	44.84±6.82	0.32±0.05
S18	AlkaleejAlmutahedah Company-UAE	1.74	0.22±0.035	39.46±6.40	0.28±0.05
S19	RaasAlkhymah- UAE	4.99	0.63±0.061	109.02±10.64	0.78±0.08
S20	UAE	1.90	0.24±0.040	35.05±6.03	0.25±0.04
S21	-TurkeyHasakeh Cement	3.96	0.5±0.060	70.74±8.57	0.51±0.06
S22	Turkey	1.90	0.24±0.039	37.49±6.24	0.27±0.04
S23	-TurkeyAdana Cement	3.80	0.48±0.054	78.78±9.04	0.57±0.06
S24	Aliraq Mass Company-Sulaymanyah, Iraq	4.83	0.61±0.057	115.42±10.95	0.83±0.08
S25	Aljesr Cement Company-Bazyan-Sulaymanyah, Iraq	8.16	1.03±0.077	176.98±13.56	1.27±0.1
S26	Unite Cement Company Bazyan-Sulaymanyah, Iraq	1.43	0.18±0.032	30.19±5.60	0.22±0.04
S27	Iraq	2.77	0.35±0.044	63.87±8.14	0.46±0.06
S28	General Cement and AlteemFaluja Company, Iraq	1.66	0.21±0.034	39.75±6.42	0.29±0.05
S29	Baghadad, Iraq	1.51	0.19±0.031	34.96±6.03	0.25±0.04
S30	Kufa, Iraq	3.10	0.39±0.046	74.23±8.78	0.53±0.06
S31	Asecoo Cement, Kuwait	1.35	0.17±0.03	31.92±5.76	0.23±0.04
S32	Hathi cement -India	4.83	0.61±0.057	114.04±10.88	0.82±0.08
Avg.		**3.05**	**0.38±0.05**	**67.28±8.09**	0.48±0.06

SC= Sample Code

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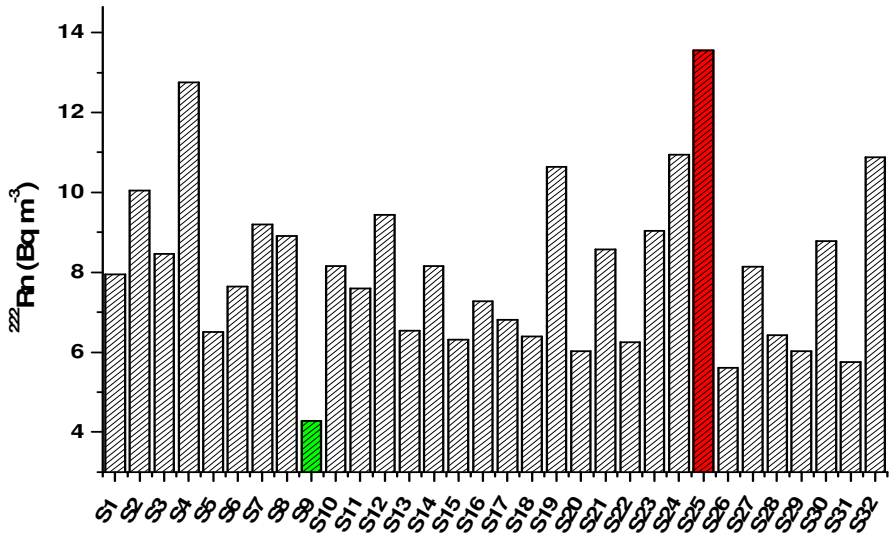

Figure 2. Average ^{222}Rn concentration. The green bar represents low concentration, and the red bar represents high concentration

The radon exhalation rate varied from 0.71x 10^{-5} to 8.16 x 10^{-5} Bq kg^{-1} d^{-1}.The minimum radon exhalation rate was 0.71x 10^{-5}Bq kg^{-1} h^{-1} in the S9 Alfares Company-Iran. The maximum radon exhalation rate was 8.16 x 10^{-5} Bq kg^{-1} h^{-1} in S25 Aljesr Cement Company-Bazyan-Sulaymanyah, Iraq. Radon exposure showed an extreme variation according to the location considered.

CONCLUSIONS

The ^{222}Rn concentration in the cement samples varies from 18Bq m^{-3} to 178 Bq m^{-3} with mean 67.28±8.09 Bq m^{-3}. The highest radon exhalation rates are found in Aljesr Cement Company-Bazyan-Sulaymanyah, Iraq. According to EPA and ICRP, the average indoor radon level should be 148 Bqm^{-3} and 300 Bqm^{-3}, respectively, whereas approximately 15 Bqm^{-3} (ranging from 1 Bqm^{-3} to 100 Bqm^{-3}) of radon concentration is normally found in outside air [8-11]. The annual effective dose equivalent range 0.13±0.03 mSv y^{-1} to 1.27±0.10 mSv y^{-1}, with an average of 0.48±0.06 mSv y^{-1}. The values of annual effective dose do not exceed limits recommended by the European Commission [12].

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