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Measurement of Uranium Concentrations, Radium Content and Radon Exhalation Rate in Iraqian Building Materials Samples

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Abstract Uranium, radium concentration and radon exhalation rate in twenty one building material samples collected from markets of Iraq were measured using the sealed-can technique based on the CR-39 $SSNTD_S$. The values of effective radium content were found to vary from (0.037 to 4.986) Bq/kg with a mean value of 0.745Bq/kg. The values of mass exhalation rates of radon vary from (0.688 $\times 10^{-8}$to 46.910$\times 10^{-8}$)Bq/kg.$day$with a mean value 7.012$\times 10^{-8}$$Bq$/kg.$day$, while the surface exhalation rates of radon vary from (0.344$\times 10^{-6}$$to23.472\times 10^{-6}$) $Bq/m^2.day$with a mean value of 3.508$\times 10^{-6}$$Bq/m^2.day$. Uranium content in these samples has been found, it is varying from 0.074 to 5.055 ppm with a mean value of 0.755ppm. The mean values of radon exhalation rate, radium content and uranium concentration in building material samples of study area were found well below the values of 57.600 mBq/m^2.h , 370 Bq/kg and 3ppm, respectively.

Keywords: *uranium concentration, radium content, radon exhalation rates*

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1. Introduction

Radiation plays an important role in our everyday life as the world is naturally radioactive and each of us is exposed to naturally occurring quantities of radiation. In fact, radioactivity can be in the air webreathe, the soil on which we walk the dwellings in which we live and even within our bodies [16].

The majority of exposure to radiation comes from natural sources that may be terrestrial and extra-terrestrial. Extraterrestrial radiation originates in outer space as primary cosmic rays and reaches the atmosphere. Terrestrial radiation is emitted from radioactive nuclides present in trace amounts throughout the earth's crust including soils and rocks. Such types of radiations are also emitted from those nuclides which get transferred to human beings through food chains or by inhalation and get deposited in their tissues. Human population is always exposed to ionizing radiation from natural sources [19].

The exposure of population to high concentration of alpha radioactivity mainly of radon for a long period leads to pathological effects like there respiratory functional changes and the occurrence of lung cancer [6]. Knowledge of radioactivity present in building materials enables one to assess any possible radiological hazard to mankind by the use of such materials. In the light of the above-mentioned facts, it is therefore, important to assess the radioactivity in common building construction materials. The measured values of radon concentration and radon exhalation rates for building materials are important from the radiation protection point of continue.

The alpha-emitting radioactive substance are harmful to normal tissues of the human body because of their high attenuation power. These alpha particles may cause damage to normal tissues of various organs by their chemical and radioactive toxicity effects [8].

The short lived decay products of radon are responsible for most of the hazards by inhalation. The hazard of radon comes from its radioactive progeny, which trapped in the lung and depositing their alpha-particle energies in the tissue, producing higher ionization density than beta particles or gamma-rays. Lung cancer, skin cancer, and kidney diseases are the health effects attributed to inhalation of radon-decay products [14].

The activity concentrations of radionuclides in the building materials and its components are important in the assessment of population exposures as most individuals spending 80% of their time indoors [5].

Inhalation of radon gas and its daughters will expose the lung tissue to short-lived alpha emitting radionuclides, which will increase the risk of lung cancer. One of the major factors of increasing skin cancer is radon gas, where it is due to the deposition of radon on the skin. Kidney related diseases have also been observed in some people exposed to radon. The reason is that kidney receives the highest dose compared to other body organs, after radon is transferred from the lung to the kidney by blood [10].

The dominant isotope, uranium-238, forms a long series of decay products that include the key radionuclides radium-226, and radon-222. Radon is the decay product of radium in the naturally occurring uranium series. As an inert gas, radon can move freely through the soil from its source to a distance which is determined by many factors such as rate of diffusion, effective permeability of the soil and its own half-life. Being a natural alpha emitter, radon can be detected by an alpha sensitive detector [3].

So, the measurement of alpha emitter's concentration in building material is necessary to investigate the role of alpha emitting in causing various diseases, especially cancer.

The purpose of this work is to study the uranium concentration, radium content and exhalation rates of radon from different building materials commonly used in the structure of Iraqian houses.

2. Materials and Methods

The uranium concentration, effective radium content and exhalation rate of radon were detected by a passive technique of solid state nuclear track detectors using the "sealed can technique" [7,12,17,18,28].

2.1. Sampling and Samples Preparing

Twenty one building material samples were collected from different markets in Iraq. These samples (see Table 1) were dried in oven, milled, crushed, sieved by 2-mm mesh, 48.14 gm of each sample which was placed inside a plastic cylindrical container facing a CR-39 track detector into a diffusion chamber Figure 1. In this technique, the same weight of the building material sample was placed in an emanation chamber, which was then closed for a period of four weeks in order to get equilibrium between radium and radon.

Table 1. Track density, Sample concentration, Radium effective concentration, surface and mass exhalation rates and uranium concentration for building material samples of the same mass.

Sample No.	Building material samples	Building materialcode	$\rho\times10^3$ (Trak/cm^2)	$C_S\times10^3$ (Bq/m^3)	C_{Ra} (Bq/Kg)	$E_X(M)$ $\times10^{-8}$Bq/kg.d	$E_X(S)$ $\times10^{-6}$Bq/m^2.d	C_U (ppm)
1	Sand A	SA	23.103	106.322	4.986	46.910	23.472	5.055
2	Block	BK	1.909	8.788	0.412	3.878	1.940	0.418
3	Soft gypsum	SG	1.259	5.796	0.272	2.558	1.279	0.276
4	Republican Bricks	RB	0.636	2.929	0.137	1.293	0.646	0.139
5	Normal Bricks	NB	0.555	2.555	0.120	1.128	0.564	0.122
6	Limestone Bricks	LB	3.171	14.595	0.684	6.440	3.222	0.694
7	White Cement	WC	0.853	3.926	0.184	1.733	0.866	0.187
8	Stone	SE	0.826	3.802	0.178	1.678	0.839	0.181
9	Sand B	SB	15.045	69.236	3.247	30.548	15.284	3.292
10	Dye powder	DP	9.571	44.045	2.065	19.433	9.723	2.094
11	Gypsum	GP	0.338	1.558	0.073	0.688	0.344	0.074
12	Ceramics	CC	0.392	1.807	0.085	0.798	0.399	0.086
13	Gray Cement	GC	2.072	9.536	0.447	4.208	2.105	0.453
14	Limestone	LN	0.988	4.549	0.213	2.008	1.00447	0.216
15	Kashi	KI	1.015	4.674	0.219	2.063	1.031	0.222
16	Marble	MB	1.801	8.289	0.389	3.658	1.830	0.394
17	Granite	GT	2.370	10.907	0.511	4.813	2.407	0.519
18	Rock	RK	2.018	9.286	0.435	4.098	2.050	0.442
19	Gravel	GV	1.774	8.165	0.383	3.603	1.802	0.388
20	Porcelain	PC	1.665	7.666	0.359	3.383	1.692	0.365
21	Thermiston	TM	1.151	5.297	0.248	2.338	1.169	0.252
Maximum			23.103	106.322	4.986	46.910	23.472	5.055
Minimum			0.338	1.558	0.073	0.688	0.344	0.074
Mean			3.452	15.891	0.745	7.012	3.508	0.755

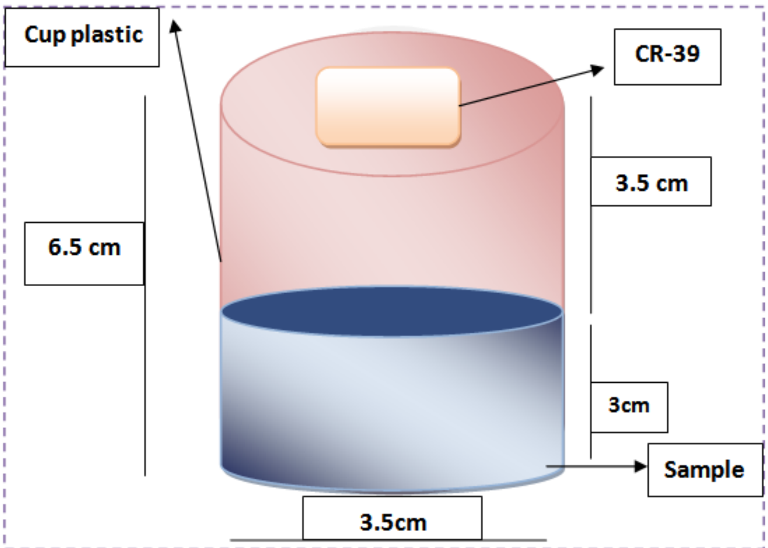

Figure 1. A test tube technique used in the study

CR-39 detectors of thickness (250µm) and area of (1×1cm^2) were placed at the closed top end of a plastic cup (diameter 3.5 cm and length 6.5 cm). While the sample- detector distance 3 cm were kept in plastic cans as shown in Figure 1.

2.2. Etching and Scanning Process

The detector records the tracks of α-particles emitted by radon gas produced through the α-decay of radium contents of the samples. The detectors were exposed for a period of about 76 days. After exposure, the detectors were retrieved and etched for six hours in 6.25N NaOH solution maintained at a temperature of (70 ± 1)°C in a constant temperature water bath to reveal the tracks. The detectors were washed and dried. Subsequently, α-tracks were counted using an optical microscope (kruss-mbl 2000) at a magnification of 400x.

3. Theoretical Considerations

3.1. Radon Concentration

The track densities were measured using the following equation [20]:

$$\rho = \frac{\sum_i N_i}{nA} \tag{1}$$

Where: A=The area of the field of view, N_i is the total number of tracks and n is the total number offields of views.

The track density ρ (in track/cm^2) is related to the radon activity concentration C_{Rn} (Bq/m^3) and the exposure time T by the formula [9]:

$$\rho = KC_{Rn}T \tag{2}$$

Where K is the sensitivity factor of CR-39 plastic track detector, the value of K equal to $(4.5987 \times 10^{-2} Traks.cm^{-2}.day^{-1}/Bq.m^{-3}$.

Since the half-life of ^{226}Ra is 1600 years and that of ^{222}Rn is 3.82 days, it is reasonable to assume that an effective equilibrium (about 98%) for radium-radon members of the decay series is reached in about four weeks. Once the radioactive equilibrium is established, one may use the radon alpha analysis for the determination of steady state activity concentration of radium. The activity concentration of radon increase with time T, after the closing of the can, according to the relation [26]:

$$C_{Rn} = C_{Ra}(1 - e^{-\lambda_{Rn} T}) \tag{3}$$

Where C_{Ra} is the effective radium content of the sample and λ_{Rn} is the decay constant of ^{222}Rn. Since a plastic track detector measures the time-integrated value of the above expression, i.e. the total number of alpha disintegrations in unit volume of the can with a sensitivity K during the exposure time T, hence the track density observed is given bythe relation [27]:

$$\rho = KC_{Ra}T_e \tag{4}$$

where T_e denotes, by definition, the effective exposure time given by [4];

$$T_e = [T - \lambda_{Rn}^{-1}\left(1 - e^{-\lambda_{Rn} T}\right)] \tag{5}$$

The dissolved radon concentration in building material samples (C_s) was calculated using equation (2) used by various researchers such as [29]:

$$C_s = \frac{C_{Rn}\lambda hT}{L} \tag{6}$$

Where C_{Rn} is radon concentration in ambient air (Bq/L), λ is Decay constant for radon (0.1814d^{-1}), h is the distance from the surface of building materials to detector (3.5 cm), T is time of exposure (81day) and L is the depth of the sample (3 cm).

3.2. Effective Radium Content

The effective radium content of the building materials sample can be calculated by the formula [2,17,18,27]:

$$C_{Ra}\left(Bq.\text{kg}^{-1}\right) = \left(\frac{\rho}{KT_e}\right)\left(\frac{hA}{M}\right) \tag{7}$$

Where M is the mass of the building materials sample in kg, A is the area of cross-section of the can in m^2; h is the distance between the detector and top surface of the building material samples in meter (0.03m).

3.3. Radon Exhalation Rates

The mass exhalation rate $E_x(M)$ of the sample for the release of the radon can be calculated by using the expression [13]:

$$E_x(M)\left(Bq.\text{kg}^{-1}.\text{d}^{-1}\right) = C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{T_e} \tag{8}$$

λ_{Ra} and λ_{Rn} are the decay constants of radiuam and radon .

The surface exhalation rate of $E_x(S)$ the sample for release of radon can be calculated by using the expression [13]:

$$E_x(S)\left(Bq.\text{m}^{-2}.\text{d}^{-1}\right) = \left[C_{Ra}\left(\frac{\lambda_{Ra}}{\lambda_{Rn}}\right)\frac{1}{T_e}\right]\frac{M}{A} \tag{9}$$

$$E_x(S)\left(Bq.\text{m}^{-2}.\text{d}^{-1}\right) = E_x(M)\left(\frac{M}{A}\right) \tag{10}$$

3.4. Uranium Concentration

The concentration of uranium C_U of building material samples can be calculated by using the formula [1,22]:

$$C_U(ppm) = \frac{W_U}{W_S} \tag{11}$$

where W_U is the weight of uranium in sample and W_S *is* the weight of sample.

4. Results and Discussion

In this work, twenty one different samples of building materials were analyzed using closed can technique. Table 1 shows the values of the effective radium content, uranium concentrations, surface and mass exhalation rates.

From these data, we found that the value of effective radium content in collected samples varies from 0.073 to 4.986 Bq /kg with a mean value of 0.745Bq /kg.

Also, the mass exhalation rates has been found to vary from (0.688 $\times10^{-8}$to 46.910$\times10^{-8}$)Bq/kg $d.y$with a mean value of 7.012$\times10^{-8}$Bq /kg .d, whilethe surface exhalation rates has been found to vary from (0.344$\times10^{-6}$ to 23.472$\times10^{-6}$) Bq /$m^2.d$, with a mean value of 3.508$\times10^{-6}$Bq /m^2. d.

The uranium concentration is tabulated in Table 1 for different building material samples in Iraq. It has been shown that thehighest uranium concentration was 5.055 ppm in SA (Sand A), while the lowesturanium concentration was 0.074ppm in GP (Gypsum) with mean value 0.755 ppm. In most of the places, the uranium concentration is lower than the average concentration of uranium in soil of 3 ppm [23,30,31]

Figure 2 and Figure 3 have shown the distribution of radium content and uranium concentration in the different building material samples of Iraq, While Figure 4 and Figure 5 have shown the distribution values of mass and surface exhalation rates of radon for all building material samples, respectively.

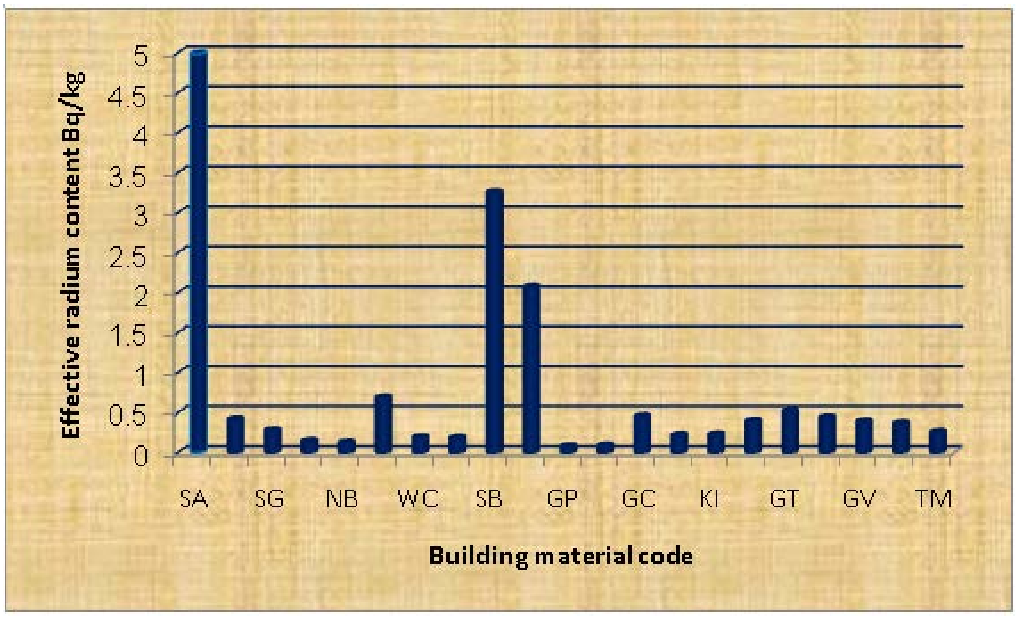

Figure 2. Effective radium content for different building material samples(Bq/kg)

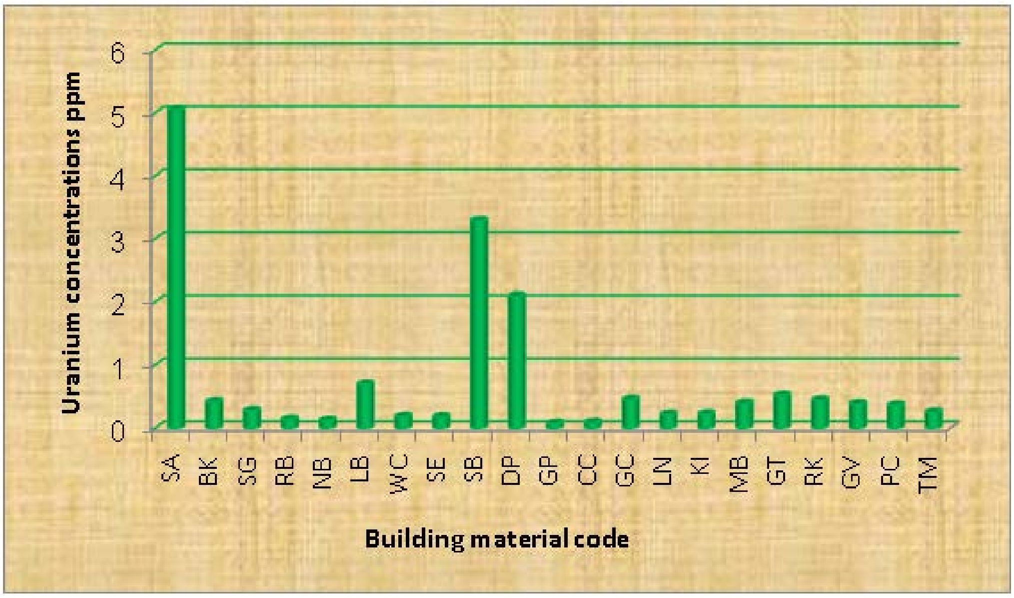

Figure 3. Uranium concentrations for different building material samples

The values of mass and surface exhalation rates of radon reported in Table 1 are less than the values reported by many researchers [11,12,15,32]. Radon exhalation rates observed in the present study are well below the world average of 57 600 mBqm^{-2} h^{-1}(0.016 Bqm^{-2} s^{-1}) and hence do not pose any health hazards to the residents [30,31].

The values of radium content reported in Table 1 less than the values reported by many researchers [24,25]. The values of effective radium content are less than the permissible value of 370 Bq/kg as recommended by Organization for Economic Cooperation and Development [21]. Hence, the result shows that this building materials is safe as for as the health hazards of radium are concerned.

It means that the building material samples from these locations cannot produce dangerous levels of indoor radon when used as building materials.

We found the uranium concentration in the building material samples was low and not significant from a health hazard point of view.

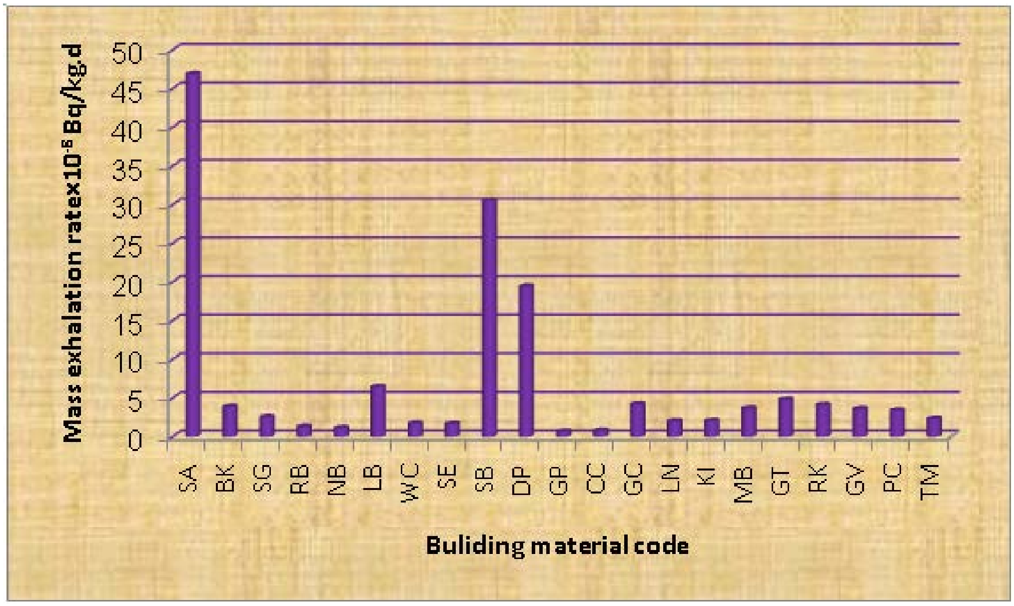

Figure 4. Mass exhalation rate of radon for different building material samples

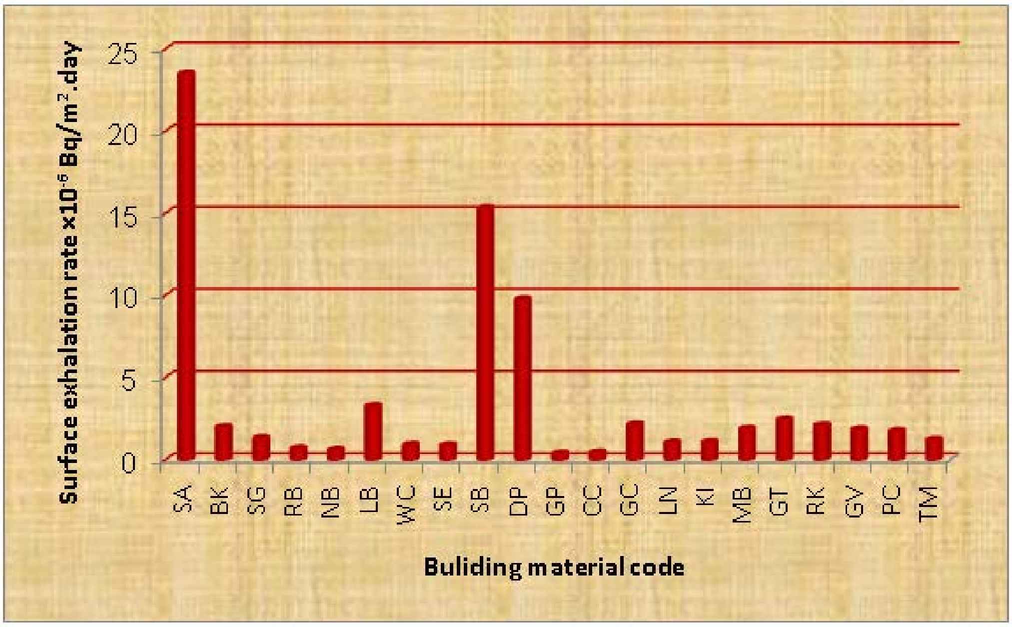

Figure 5. Surface exhalation rate of radon for different building material samples

5. Conclusions

CR-39 detectors are widely for radon exhalation rate, radium content and uranium concentration measurements in building material samples under different conditions.

The study of radon in bulding material samples showed that , all samples tested had radon exhalation rate well below the world average value of 57.600 mBq/m^2 h (0.016 Bq/m^2 s). it is concluded that the studied buliding materials can be used in construction safely from the radioprotection point of view.

The radon exhalation study is important for understanding the relative contribution of the building material to the total radon concentration found in the dwellings. The total values of radon exhalation rate and the radium contcentration are found below the safe limit recommended by Organization for Economic Cooperation and Development.

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