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Determination of Radium and Radon Exhalation Rates in Soil Samples Collected from Kerbala Governorate

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Abstract In the present work, radium concentration and radon exhalation rates in soil samples collected from Kerbala Governorate area (Iraq) have been measured through "Sealed cup technique" containing CN-85 solid state nuclear detector. This area is honorable position in the entire world, millions of peoples and religious sciences students visit it, in addition the soil of this area was used in brick manufacturing for building construction. Radium concentration varies from (1.1001- 2.6003) $Bqkg^{-1}$ with an average of 1.7921Bq kg^{-1}. The radon exhalation rate in terms of area varies from (0.9463 – 2.2369) $Bqm^{-2}h^{-1}$ with an average of 1.4785$Bqm^{-2}h^{-1}$, while radon exhalation rate in terms of mass varies from (29.715– 70.237) $\times10^{-3}$ $Bqkg^{-1}h^{-1}$ with an average of 48.409$\times10^{-3}$ $Bqkg^{-1}h^{-1}$. Positive correlation has been observed between radium concentration and radon exhalation rate in soil. The values of radium concentration in all the soil samples were less than the recommended by Organization for Economic Cooperation and Development (OECD) 1979. Also the radium concentration and radon exhalation rate in these samples has been found to be well below of 40 Bq/kg and 57.6 Bq. m^{-2}.s, respectively. The results have revealed that the radium concentration in studied area and the associated exhalation radon does not pose risk to human health.

Keywords: *radium, radon exhalation rates, nuclear track detector, soil*

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1. Introduction

Radium and its ultimate precursor uranium are the source of radon (α-radioactive) inert gas. Noble radon gas (^{222}Rn) originates from radioactive transformation of radium (^{226}Ra) in the uranium (^{238}U) decay chain in the earth's crust. Radon varies in different quantities in different materials and place to place, because radon is chemically unreactive with several materials, it is freely moving between particles of materials (like soil, rock and sand) to the soil surface. According to the world health organization, radon is first most important cause of lung cancer among nonsmoker. The proportion of lung cancers attributable to radon is estimated to range from 3% to 14%. When radium decays in soil, the resulting atoms of radon isotopes first escape from the mineral to air-filled pores. The rate at which radon escapes from soil into the surrounding air is known as radon exhalation rate of the soil. This measured by either per unit area or per unit mass of the soil. The measurement of radon exhalation rates in soil is helpful to study radon health hazard [1,2,3,4]. The National Radiological Protection Board (NRPB) has shown that at least 50% of the total dose for an average person in UK is received from combined radon and thoron [5]. Therefore measurements of radon in the soil samples are important from public health point of view. In the present study, radium concentration and radon exhalation rates in various soil samples in Kerbala governorate has been made. The motivation of work is to measure radiological health risk level of radon exhalation rates and radium in this area which would be of great help for radiological database of Iraq.

2. Materials and Method

Soil samples have been obtained from different locations of the region. The area of the study included twenty stations, they are Kerbala center, Hayy-Alhur, Alhussainia, Alebrahimia, Alhindia, western Aljadwal, Ain Altamer, Hayy Almelad and AlRazaza lake as shown in Figure 1. The soil samples were taken from the surface of each location. The soil samples were dried in the oven at 120°C and milled in the grinder. Finally, all samples are sieved in sieve with 3 mm pores. The sealed cup technique [6,7,8] as shown in the Figure 2 was used for the measurement of radium concentration and radon exhalation rates in the soil samples. The concentrations of alpha particles emitted from radon gas in soil samples were performed by using the nuclear track detector type (CN-85) of thickness (250 μm) with dimensions of (1×1 cm^2). 40 gm of each sample which has placed at the bottom of cylindrical aplastic cup of 7.5 cm hight and 4cm diameter, while the sample-detector distance is still 5.5 cm. The cups were sealed for 60 days, thus the lower sensitive part of the detector was exposed freely to the emergent radon from the sample in the cup.

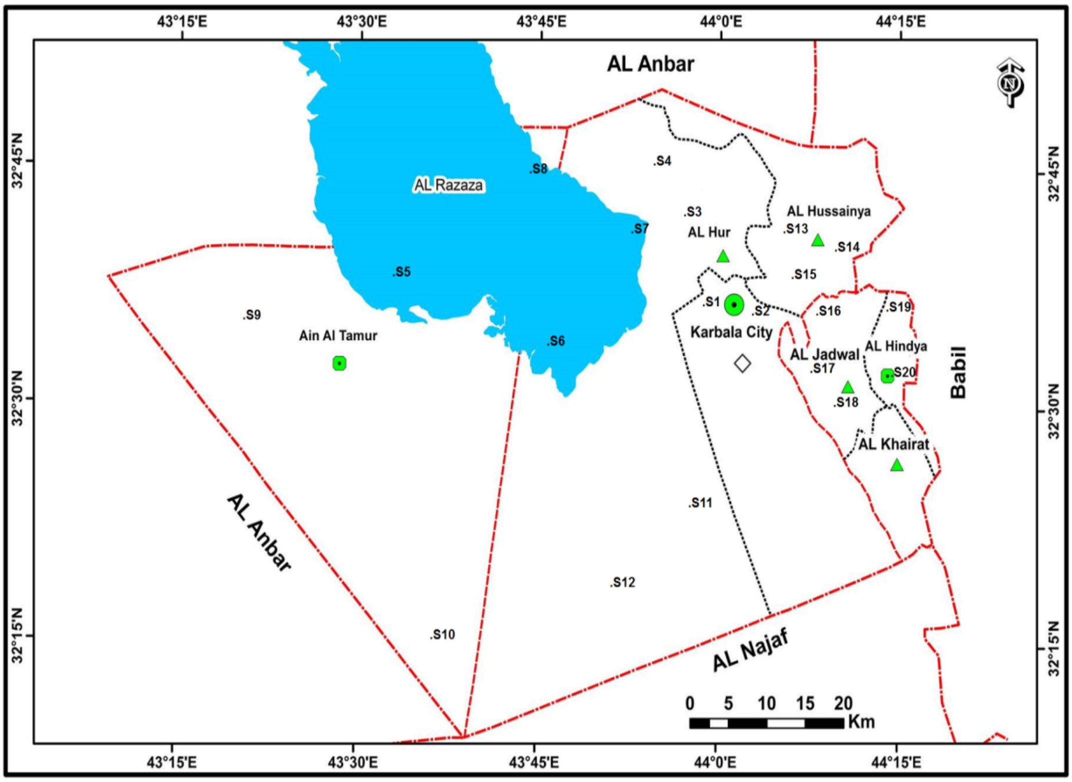

Figure 1. Kerbala Governorate, numbering in station number (s), represent the places where samples taken

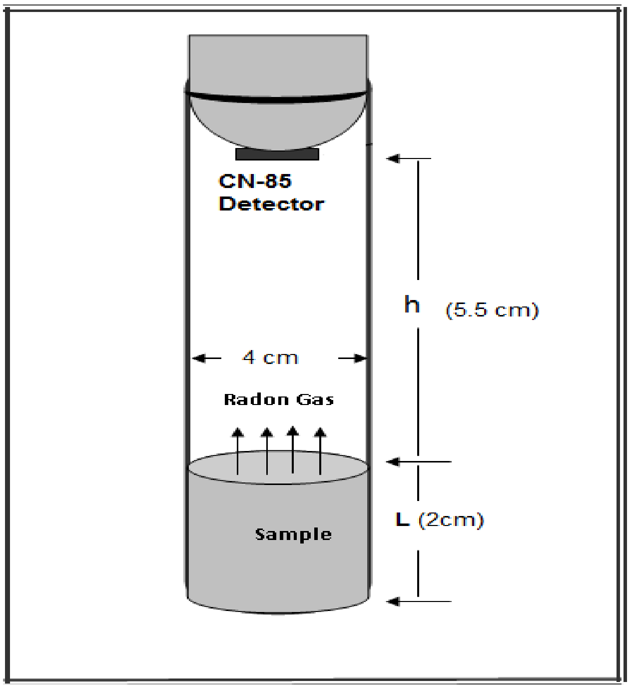

Figure 2. Experimental setup for measurements of radium concentration and radon exhalation rates in soil samples

After the irradiation, the CN-85 track detectors were etched in (6.25 N) of (NaOH) solution at temperature of (70°C) for (5 h.). The tracks were observed and counted by using microscope with a magnification of 400X. The surface density of the tracks (ρ) in the samples were calculated according to relation:

$$\text{Track density } (\rho) = \frac{\text{Average number of total pits (tracks)}}{\text{Area of field view}}$$

The radium concentration were found by using this formula: [9,10]

$$C_{Ra} = \frac{\rho h A}{M K T_e} (Bq.kg^{-1}) \qquad (1)$$

Where, C_{Ra} is the radium content of the given sample ($Bq.\ kg^{-1}$), ρ is the track density (track cm^{-2}), M is the mass of the sample (0.040 kg), A is the area of cross-section of the cup ($12.65\times10^{-4} m^2$), h is the distance between the detector and the top of the sample (0.055m), K is the sensitivity factor, which is equal to 0.0092 track. $cm^{-2}h^{-1}$ /(Bq m^{-3}) [11] and T_e is the effective exposure time (in h) which is related to the actual exposure time T and decay constant λ for ^{222}Rn according to the following [9,10]:

$$T_e = T - \frac{1}{\lambda(e^{-\lambda T} - 1)]} \qquad (2)$$

The radon exhalation rate in terms of area was obtained from the expression [9,10]:

$$E_A = \frac{C_{Rn} \ V\lambda}{A[T + \lambda^{-1}(e^{-\lambda T} - 1)]} (Bq\, m^{-2}\, h^{-1}) \qquad (3)$$

Where, E_A is the radon exhalation rate in terms of area expressed in $Bqm^{-2}h^{-1}$, C_{Rn} is the integrated radon exposure expressed in $Bqm^{-3}h$, V is the effective volume of the cup in m^3, T is the exposure time in hour, λ is the decay constant for ^{222}Rn radon (h^{-1}), and A is the area of the cup (m^2).

The radon exhalation rate in terms of mass is given by [9,10]:

$$E_M = \frac{C_{Rn} V \lambda}{M[T + \lambda^{-1}(e^{-\lambda T} - 1)]} (Bq\,kg^{-1}\,h^{-1}) \quad (4)$$

Where, E_M is the radon exhalation rate in terms of mass expressed in $Bqkg^{-1}h^{-1}$ and M is the mass of the sample (kg).

3. Results and Discussion

The results of radium concentration in addition of radon exhalation rates from the soil surface samples are presented in Table 1. Figure 3 and Figure 4 show the general trend that radium concentration increases which enhances the radon exhalation rates i.e. positive correlation has been observed between radium concentration and area exhalation rate in soil of the studied area. Figure 5 shows variation of radium concentration in these soil samples. The values of radium concentration in studied area varies from 1.1001 to 2.6003Bq/kg with an average of 1.7921Bq/kg and a standard deviation of 0.3652. The values of radium concentration found to be maximum (2.6003$Bqkg^{-1}$) at Alebrahimia and minimum (1.1001 $Bqkg^{-1}$) at Almelad. The radon exhalation rate in terms of area varies from (0.9463 – 2.2369) $Bqm^{-2}h^{-1}$ with an average of 1.4785$Bqm^{-2}h^{-1}$and standard deviation of 0.4380. Radon exhalation rate in terms of mass varies from (29.715– 70.237) $\times10^{-3}$ $Bqkg^{-1}h^{-1}$ with an average of 48.409$\times10^{-3}$$Bqkg^{-1}h^{-1}$ and standard deviation of 9.866. The observed values of radium concentration in soil samples in the present study were less than the recommended action level 370 $Bqkg^{-1}$ [12] and also lower than the average global value of 35 $Bqkg^{-1}$ [13]. The observed values of radon exhalation rate in the present study are were below the world average of 0.016 $Bqm^{-2}s^{-1}$ (57.6 $Bqm^{-2}h^{-1}$) [13]. The results have revealed that the radium concentration in studied area and the associated exhalation radon does not pose risk to human health.

4. Conclusions

The radium activity concentration and radon exhalation rates in soil samples collected from Kerbala governorate were presented. The radium activity concentration in soil samples were less than the recommended action level 370 Bq kg^{-1} as recommended by Organization for Economic Cooperation and Development (OECD) [12] and also has been found to be well below the world average value of 35 Bq kg^{-1} [13]. In addition that, the radon exhalation in theses samples has been found to be well below the world a verage value [13].

Hence it can be conclude that the study area is safe from the health hazard of radium point of view, as they do not pose any health hazard due to low exhalation of radon. Positive correlation has been observed between radium content, area exhalation rate and mass exhalation rate in soil.

Table 1. Radium concentration (C_{Ra}), radon exhalation rates in terms of area (E_A) and in terms of mass (E_M) of the soil samples collected from Kerbala governorate

Sample Number	Location	C_{Ra} (Bq/kg)	Radon exhalation rates	
			E_A (Bq. $m^{-2}h^{-1}$)	$E_M\times10^{-3}$ (Bq. $kg^{-1}h^{-1}$)
S1	Kerbala center	1.5501	1.3335	41.872
S2		1.6301	1.4023	44.033
S3	HayyAlhur	1.9002	1.6346	51.327
S4		1.9302	1.6604	52.137
S5	AlRazaza lake	1.5801	1.3593	42.682
S6		1.7502	1.5056	47.275
S7		1.8002	1.5486	48.625
S8		2.2002	1.8927	59.431
S9	Ain Altamer	1.7502	1.5056	47.275
S10		1.9002	1.6346	51.327
S11	Hayy Almelad	1.1001	0.9463	29.715
S12		1.3001	1.1184	35.118
S13	Alhussainia town	1.6501	1.4195	44.573
S14		1.9002	1.6346	51327
S15	Alebrahimia town	2.4002	2.0648	64.834
S16		2.6003	2.2369	70.237
S17	Western Aljadwal	1.3001	1.1184	35.118
S18		1.9502	1.6776	52.677
S19	Alhindia town	1.4501	1.2475	39.170
S20		2.2002	1.8927	59.431
Minimum		1.1001	0.9463	29.715
Maximum		2.6003	2.2369	70.237
Mean		1.7921	1.4785	48.409
S. D.		0.3652	0.4380	9.866

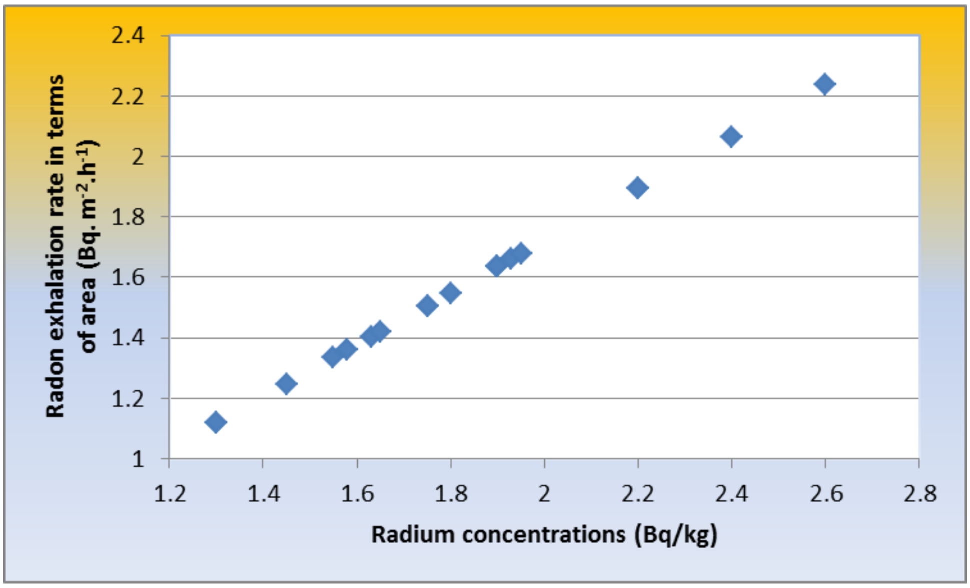

Figure 3. Correlation between radium concentration and area exhalation rate

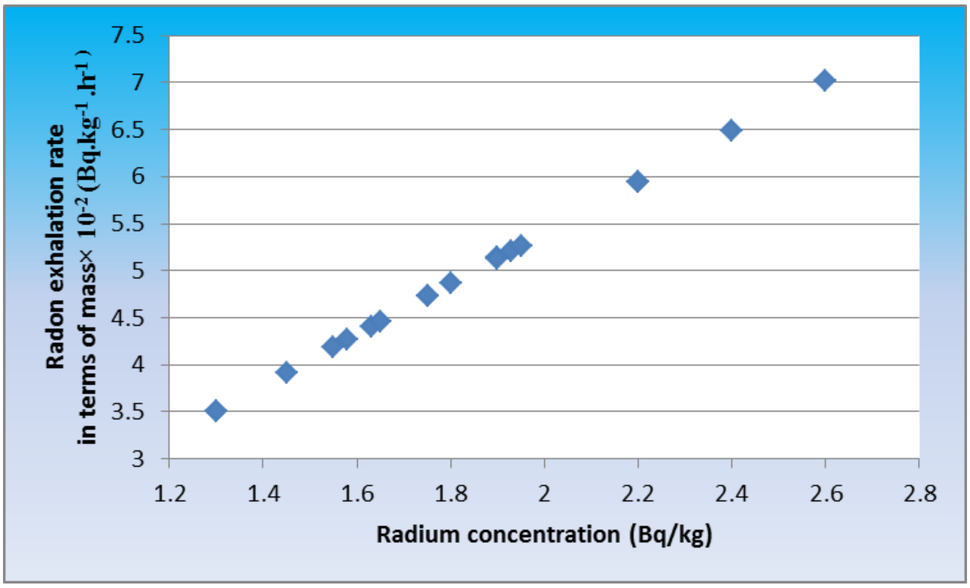

Figure 4. Correlation between radium concentration and mass exhalation rate

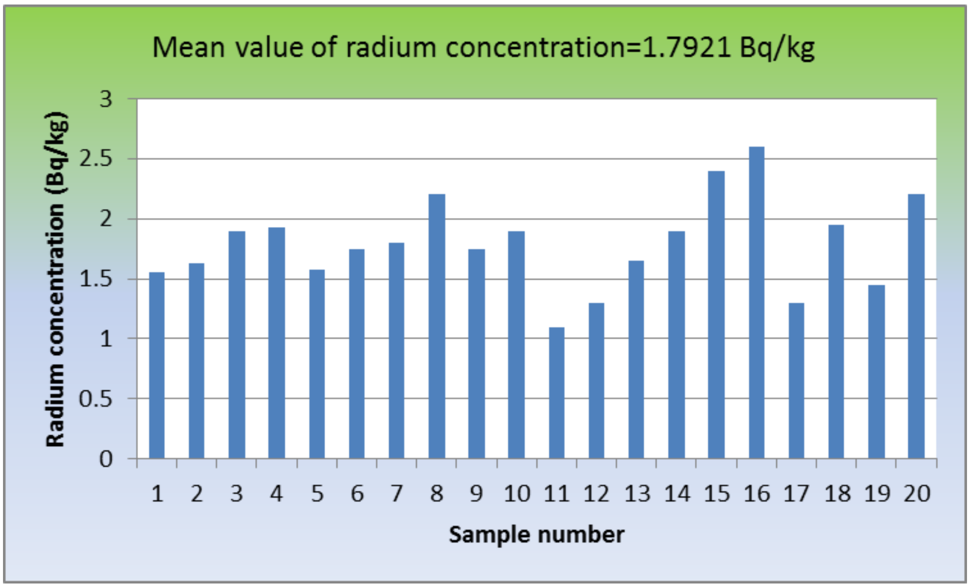

Figure 5. Radium concentration of the soil samples from the Kerbala governorate

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