Assessment of Radon Concentrations in the Soil of South Baghdad Suburbs

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Abstract

Measurements of radon gas concentrations were carried out for 12 soil samples at 3 sampling depths (surface, 5 cm and 10 cm) collected from (4) locations in south Baghdad suburbs (Bu'aitha) using solid state nuclear track detector CR-39 and sealed can technique. Radon concentrations for surface samples were ranged from 402.2 to 1538.4 $Bq.m^{-3}$ with an average 994.4 $Bq.m^{-3}$. Whereas, radon concentration was ranged from 813.1to 2050.4 $Bq.m^{-3}$ and from 1309.8 to 4626. 1$Bq.m^{-3}$ with an average values of 1359.8 $Bq.m^{-3}$ and 2338.3 $Bq.m^{-3}$ for 5 cm and 10 cm depths respectively. Maximum radon level was found at the location near to the river (site S4) while the minimum radon level was found at residential area (site S2). Radium contents were ranged from 0.42 to 1.62 $Bq.kg^{-1}$, from 0.85 to 2.15 $Bq.kg^{-1}$ and from 1.38 to 4.86 $Bq.kg^{-1}$ with average values of 1.04, 1.43 and 2.46 $Bq.kg^{-1}$ for surface, 5 cm and 10 cm depths respectively. Radon exhalation rates as a function of area and mass were also obtained. Surface exhalation rate ranged from 0.05 to 0.18 $Bq.m^{-2}.h^{-1}$, from 0.09 to 0.24 $Bq.m^{-2}.h^{-1}$ and from 0.15 to 0.53 $Bq.m^{-2}.h^{-1}$ with average values 0.11, 0.16 and 0.27 $Bq.m^{-2}.h^{-1}$ for surface, 5 cm and 10 cm depths respectively. Mass exhalation rate ranged from 0.02 to 0.06 $Bq.kg^{-1}.h$, from 0.03 to 0.08 $Bq.kg^{-1}.h$ and from 0.05 to 0.18 $Bq.kg^{-1}.h$ with average values 0.04, 0.05 and 0.09 $Bq.kg^{-1}.h$ for surface, 5 cm and 10 cm depths respectively. The results obtained from this study indicate that the region background radiation levels are within the natural limits.

Keywords: Radon, Soil, CR-39, Radon Exhalation Rates.

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Introduction

Natural environment normally contains radionuclides of uranium and thorium series which are considered to be the main contributors of gamma radiation in addition to ^{40}K which is mainly present in soil and building materials [1]. Plants, water, food, and air [2]. The level of radiation differs according to the geological location as it differs from one place to another, demanding spatial proper measurement to determine gamma dose rate [3]. Measurement of natural radioactivity in the soil has been globally of interest to many scientists as it determines the natural change of radioactivity with time [4].

Three radioactive decay series produce Radon isotopes [5], namely radon (^{222}Rn) with 3.82 days' half-life, thoron (^{220}Rn) of 54.4 seconds half-life and actinium (^{219}Rn) whose half-life is 3.92 seconds. The three radon isotopes are gamma emitters. In studying radon levels, the radon alone is frequently considered important as the other two isotopes that decay before they can be flow out from the soil due to their short half-lives.

Depending on the composition of soil, the measurements of soil gas underneath soil surface will normally indicate thoron presence, while the top few meters of the ground emits 80% of the radon usually present in the atmosphere [6]. The radon emanation rate differs according to the concentration of radium and the soil parameters such as permeability, moisture content, porosity, and grain size [7]. There are two mechanisms resulting to the exhalation of radon from soil, emanation and transport (diffusion and convection) which are affected by several issues among which are the properties of the soil [8]. Several studies in many countries were focusing on radiation hazards indices, radon emanation and migration in the Earth and the atmosphere [9, 10, 11, 12, and 13]. Radon has a massive physical effect on humans as it is considered as the main cause of lung cancer among non-smokers [14], and ^{222}Rn is considered as the most prevailing harmful radionuclide compared with the other radon isotopes. Ambient air holds radon isotopes and their progenies emitted from the soil, attached to the aerosols enabling ^{222}Rn gas to get into the houses, penetrate and concentrated into closed rooms, sometimes reaching harmful levels for humans' health [15].

Radon's concentration rises with depth, reaching its maximum levels at a depth of 2 m [16], while its exhalation from soil depends on several factors other than the radium concentration, such as:

- The amount of radon flowing out from the soil to the surrounding vicinity, referred to as emission power of constituents.
- The pores size of the composition material.
- Conditions of the soil surface and its covering [17].

This paper measures radon concentration, surface exhalation rate and mass exhalation rate as a function of depth in the south Baghdad suburbs (Bu'aitha, Ad-Dorah) soil samples.

Description of Study Area

The study area (northern part of Bu'aitha, Ad-Dorah, Baghdad, Iraq) is 2 Km to the South of Ad-Dorah refinery center, covering an area of almost 0.9 Km^2 (1.6Km x 0.57Km), bordered by Ad-Dorah highway to the North while Tigris River to the East, abandoned arable land to the south and inhabited rural area to the West called (Hawasha and Tulusiya).

The samples have been chosen from four locations, (S1) near the highway, (S2) next to a random residential area, (S3) surrounded by palm dates planting and (S4) where US missile place which had been shot down during war operation in 2003.

The study area land use is mainly of two parts. The Eastern (500 m x 500 m) is mainly Palm dates' planting, containing some stripped areas (S3 and S4). The other part extend to the West is abandoned arable land containing few random residential houses which is present near (S2). Map of the study area is shown in Fig.1.

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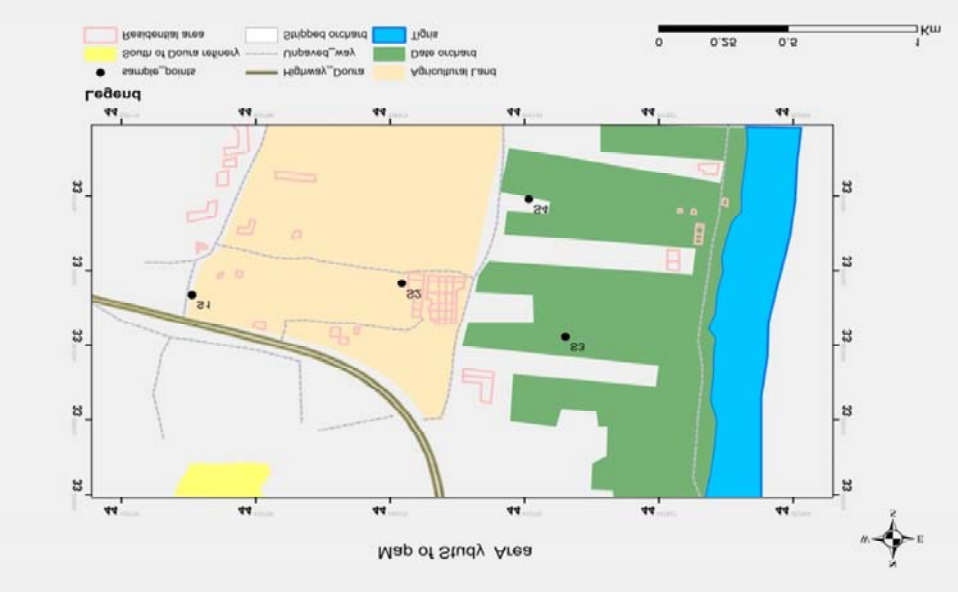

Figure (1): Map of the study area

Materials and Methods

Sample Preparation

Alpha particles which emitted from radon were detected using CR-39 SSNTD (thickness 500 µm) and sealed can technique [18]. Twelve soil samples from 4 sites were collected from a land situated in Bu'Aitha, Baghdad. Three samples at three different depths (surface, 5 cm and 10 cm) were collected from each site as shown in Table 1. The samples were dehydrated in order to get rid of their humidity, after drying the samples were crushed to a fine powder then sieved with 200µm cross section size. A weight of ten grams of each sample were put at the bottom of a plastic cup (height = 7.5 cm, diameter = 6 cm). CR-39 detector (1.5 × 1.5) cm^2 was sticked in the inner side of the cover of the cup (distance = 6 cm from the sample) Figure 1. Then the dosimeters were kept aside for two months which is long enough to record alpha particles emitted from radon in the samples. Then, CR-39 plastics were treated in 6.25N NaOH at 70°C for 4 h [19]. After chemical treatment, CR-39 plastics were analyzed for α-tracks utilizing an optical magnifying lens with (10×40) amplification.

Table (1): Soil sample site, code and depth

Site	Sample code	Depth cm
Near Highway	S11	surface
	S12	5
	S13	10
Residential Area	S21	surface
	S22	5
	S23	10

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Date palm Orchard	S31	surface
	S32	5
	S33	10
Stripped Orchard	S41	surface
	S42	5
	S43	10

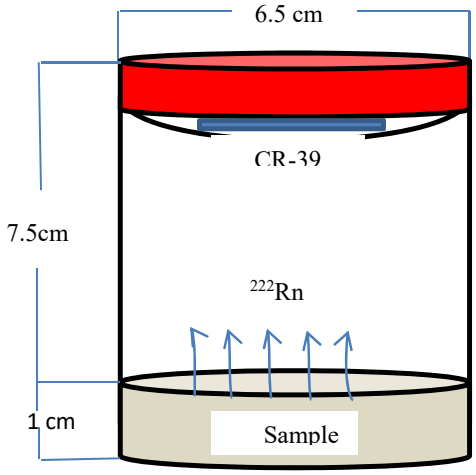

Figure (2): Sealed cans technique

Calculations

Radon concentrations A_{Rn} in (Bq.m^{-3}), effective radium content A_{Ra} in (Bq.kg^{-1}), Radon exhalation rates E_A in Bq.m^{-2}.h^{-1} and E_M in Bq.kg^{-1}.h^{-1} in the soil samples were given by Amin [20]:

$$A_{Rn} = \frac{\rho}{CF\ T} \quad (1)$$

$$A_{Ra} = \frac{\rho\ h\ A}{CF\ T\ M} \quad (2)$$

$$E_A = \frac{C\ V\ \lambda}{A[T + \lambda^{-1}\{e^{-\lambda T} - 1\}]} \quad (3)$$

$$E_M = \frac{C\ V\ \lambda}{M[T + \lambda^{-1}\{e^{-\lambda T} - 1\}]} \quad (4)$$

Where, ρ is the measured α-track density (units track cm^{-2}); h is the distance between the CR-39 detector and the sample (cm); A is the area of CR-39 (cm^2); T is exposure time (h); M is sample mass (kg); C is the integrated radon exposure (Bq.m^{-3} h^{-1}), V is volume of the container (cm^3), and λ is the decay constant of radon (h^{-1}). The mass exhalation rate E_M of the sample for radon emission in (Bq.kg^{-1} h^{-1}).

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The calibration factor is calculated using equation (5) given by Hussein [21] and its calculated value was found equal to 0.04891 $Tr.cm^{-2}.d^{-1}/Bq.m^{-3}$.

$$CF = \frac{1}{4}r\left[2cos\theta_c - \frac{r}{R_\alpha}\right] \qquad (5)$$

Where, r is the radius of the container (cm), θ_c (35°) is the critical angle of CR-39, and R_α (4.15 cm) is the range of α particles emitted from ^{222}Rn.

Results and Discussion

Radon concentration for surface samples ranged from (402.2 to 1538.4) $Bq.m^{-3}$ with an average (994.4) $Bq.m^{-3}$. Whereas, radon concentration was ranged from (813.1to 2050.4) $Bq.m^{-3}$ and from (1309.8 to 4626.1) $Bq.m^{-3}$ with an average values of 1359.8 $Bq.m^{-3}$ and 2338.3 $Bq.m^{-3}$ for 5 cm and 10 cm depths respectively. Maximum radon level was found at the stripped orchard where US missile place (site S4) while the minimum radon level was found at residential area (site S2). Figure 3 illustrates radon concentration at the four study sites. The results of radon concentration reveal that radon concentration increases with depth.

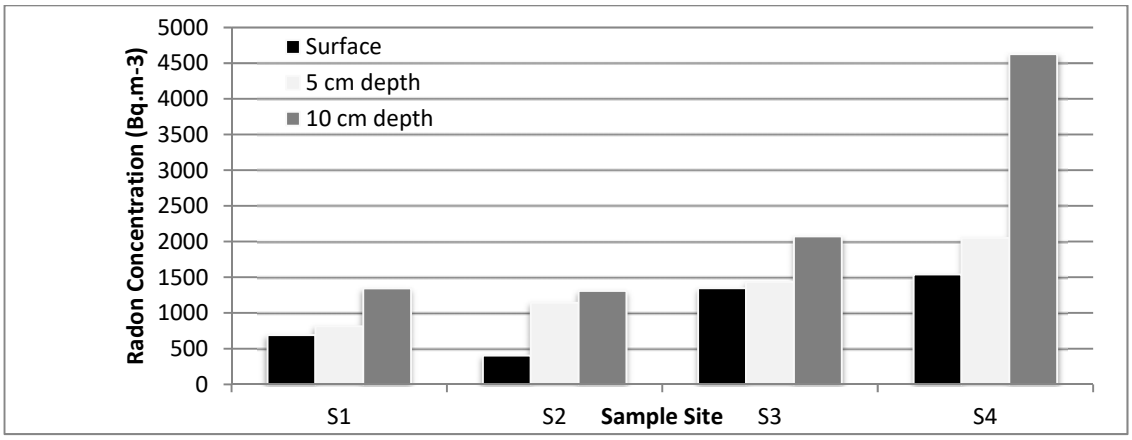

Figure (3): Radon concentration for the study sites

Radium content results are shown in figure 4. Radium content was ranged from (0.42 to 1.62) $Bq.kg^{-1}$, from (0.85 to 2.15) $Bq.kg^{-1}$ and from (1.38 to 4.86) $Bq.kg^{-1}$ with average values of (1.04, 1.43 and 2.46) $Bq.kg^{-1}$ for surface, 5 cm and 10 cm depths respectively.

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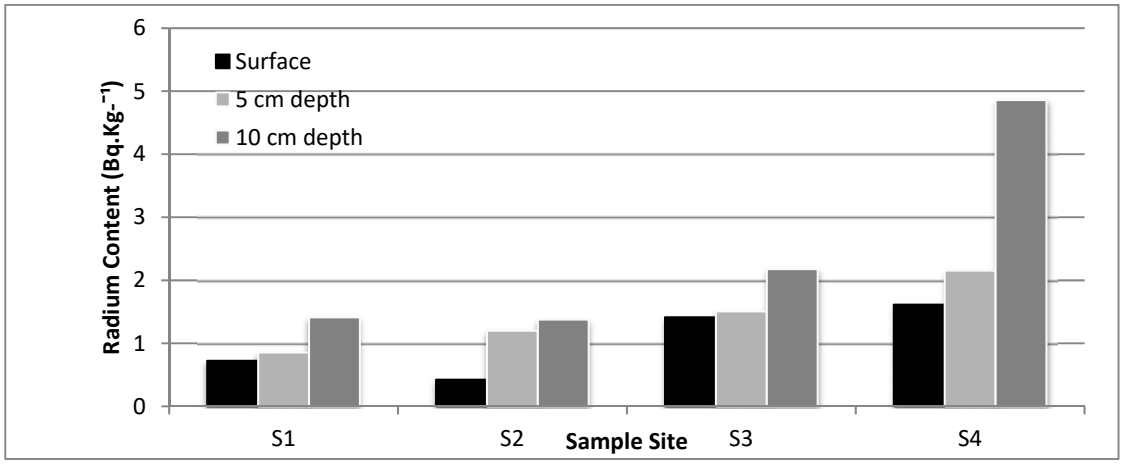

Figure (4): Radium content for the study sites

Radon exhalation rates (E_A and E_M) were also determined. Surface exhalation rate ranged from (0.05 to 0.18) $Bq.m^{-2}.h^{-1}$, from (0.09 to 0.24) $Bq.m^{-2}.h^{-1}$ and from (0.15 to 0.53) $Bq.m^{-2}.h^{-1}$ with average values (0.11, 0.16 and 0.27) $Bq.m^{-2}.h^{-1}$ for surface, 5 cm and 10 cm depths respectively. The results obtained from this study indicate that the region background radiation levels within the natural limits. Figures (5&6) show surface and mass exhalation rates for the study sites, respectively.

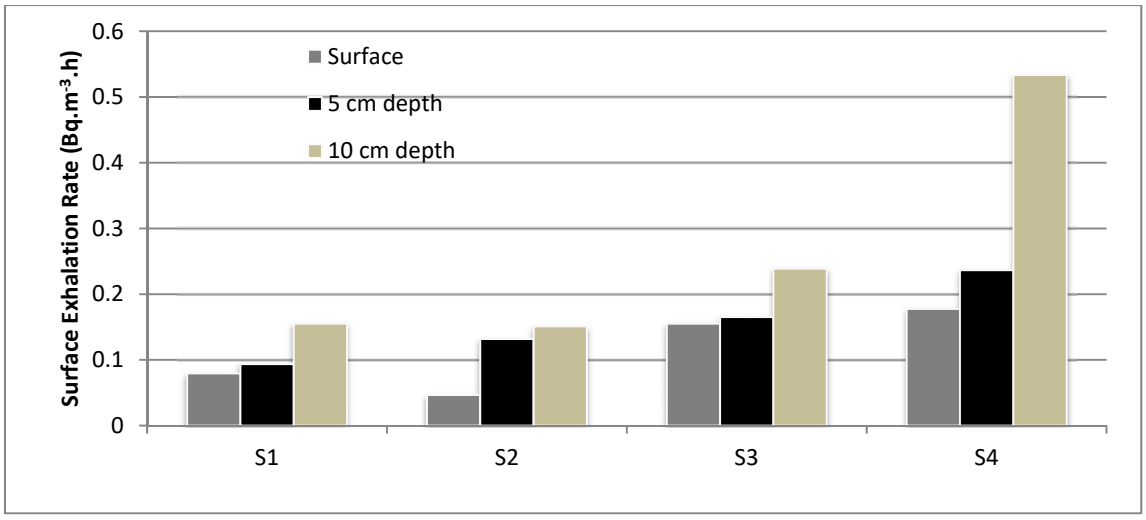

Figure (5): Surface exhalation rate for the study sites

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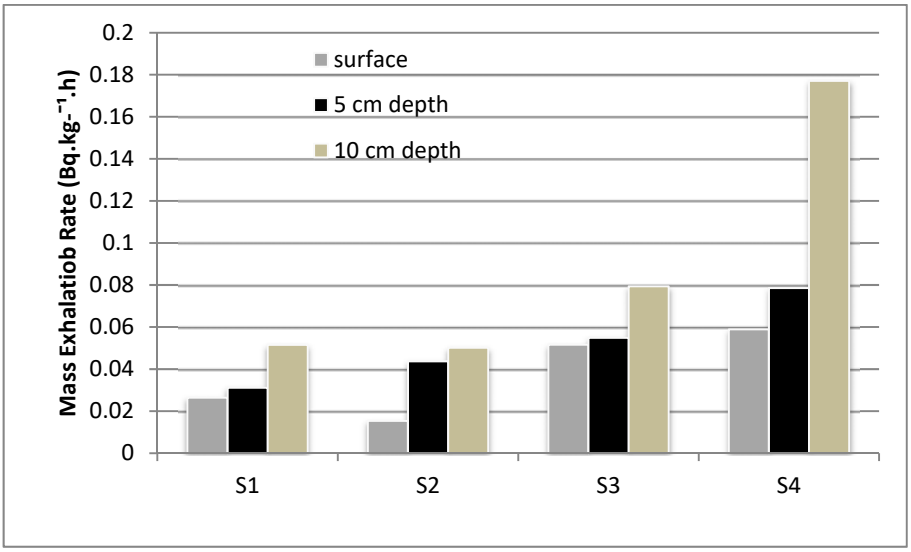

Figure (6): Mass exhalation rate for the study sites

The obtained results of radon concentrations, radium content and exhalation rates in terms of surface and mass are given in Table 2. The total average values of the 4 sites are (1564.2) $Bq.m^{-3}$, (1.6) $Bq.kg^{-1}$, (0.18) $Bq.m^{-2}.h^{-1}$ and (0.06) $Bq.kg^{-1}.h^{-1}$ for radon concentration, radium content, surface exhalation rate and mass exhalation rate, respectively.

The results of this paper show that Radium content in the study area, was below the recommended action level of (370) Bq.kg-1 [22] and also less than the average global value of (35) $Bq.kg^{-1}$ [1], while the values of radon exhalation rate are below the world average of (0.016) $Bq.kg^{-1}.s^{-1}$ (57.6) $Bq.m^{-2}.h^{-1}$ [1]. As a whole, the study has confirmed that the radium concentration in the studying area and the associated radon exhalation does not expose the human health to associated risk.

Conclusions

Radioactivity level in soil samples collected from an area located in Bu'aitha, Ad- Dorah, south of Baghdad were determined using SSNTD CR-39 and sealed can technique method. The obtained results show that:

1. Radium content and exhalation rates are less than the recommended world values.
2. Radon gas increases with increasing depths.
3. Maximum radon level was found in site S4 where US missile
4. The results show that the samples were safe as far as the health hazard effects are concerned.

Table (2): Radon concentration, radium content and exhalation rates

Site	Sample code	A_{Rn} $Bq.m^{-3}$	A_{Ra} $Bq.kg^{-1}$	E_A $Bq.m^{-2}.h^{-1}$	E_M $Bq.kg^{-1}.h^{-1}$
S1	S11	690. 1	0.7	0.08	0.03
	S12	813.1	0.9	0.09	0.03
	S13	1345.0	1.4	0.16	0.05
S2	S21	402.2	0.4	0.05	0.02
	S22	1142.8	1.2	0.13	0.04

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	S23	1310.0	1.4	0.15	0.05
	S31	1347.2	1.4	0.16	0.05
S3	S32	1432.9	1.5	0.17	0.05
	S33	2072.4	2.2	0.24	0.08
	S41	1538.4	1.6	0.18	0.06
S4	S42	2050.4	2.2	0.24	0.08
	S43	4626.1	4.9	0.53	0.18
Average		1564.2	1.6	0.18	0.06

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