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Research Article
Radon, Radium Concentrations and Radiological Parameters in Soil Samples of Amara at Maysan, Iraq

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Abstract

Objective: Radon concentration and the radiological parameters were measured from the randomly collected soil samples of Amara in Maysan, Iraq. **Materials and Methods:** Using SSNTD (LR-115 type II), radon concentration for eighteen soil samples that collected from different locations at Maysan area in Iraq were measured. The study also included calculating radium concentrations, the exhalation rates, the effective dose equivalent and the annual effective dose in all the soil samples. Data statistically analyzed by using SPSS 20. **Results:** The results show that, radon concentrations values ranged from 53.18-2047.51 Bq m^{-3} with an average 776.98$\pm$126.08 Bq m^{-3}, while the radium concentrations values ranged from 2.58-99.61 Bq kg^{-1} with an average 37.79$\pm$6.13 Bq kg^{-1}. The average values of exhalation rates in term of area, the effective dose equivalent and the annual effective dose were 40.08$\pm$6.50 µBq m^{-2} h, 3.635$\pm$0.59 WLM/y and 24.50$\pm$3.97 mSv/y, respectively. **Conclusion:** It was concluded that the average value of radon concentrations, radium concentrations and radiological effect in the present study were within the safe limits as recommended by ICRP and WHO. The results showed that these areas are safe in terms of health hazard as far as the radon is concerned.

Key words: Radon, radium content, LR-115 plastic track detectors and radiological parameters

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The existence of radionuclide in soil affects the lives of people extremely. Since, the natural radionuclide represent 10% of the common annual dose to the bod from all alternative forms of radiation and exposure to radiation, in typically thought about undesirable in the least levels[1]. Radionuclides exist naturally in air, water and soil. They exist even in our bodies, being that we are products of our environment. The ingest or inhale radionuclide by doing our normal activities such as , eating, drinking or breathing. It can be said that natural radioactivity exists almost everywhere in all materials that constitutes the planet earth in the rocks and soil, in water and oceans and in our building materials and homes. There is no single place on earth that we cannot find natural radioactivity[2]. Natural radiation of terrestrial and cosmogenic origins, internal radioisotopes, medical radiation, technologically reinforcement natural radiation and consumer products are the main sources of radiation exposure to general public according to the International Atomic Energy Agency[3]. ^{226}Ra and ^{228}Ra are considered to be among the most radiotoxic and most important isotopes among the several daughters in the decay chains of the two natural series of uranium and thorium. These two isotopes are an alpha emitter with half-life about1602 years and a beta emitter with half-life of 5.8 years, respectively[4]. The disintegration of certain natural radioactive isotopes (e.g.,^{238}U and ^{232}Th) continues to produce radon. The ^{222}Rn which is produced from the decay of ^{238}U, can be considered as the main internal radiation source of exposure (around 55%) to human life[5]. Radon emanates from the uranium that is existed in nearly all types of soils. It mainly appears by process of spread from the point of origin which followed by α-decaying of ^{226}Ra in underground soil and rocks. Cracks and other holes in the foundation of homes are the main passage where the radiation moves through. A decay chain starting with Uranium, a naturally occurring radioactive element produces radium as a main product of it. Radium can be traced in considerable amounts in nearly all rocks, soils and groundwater as well as building materials, plants, animals and the human body. Radon gas undergoes radioactive decay and has a radioactive half-life of about 3.8 days[6]. As the radiation sources in soil are ranked among the biggest contributors to the exposure to radiation, knowing distribution of radioactivity in the soil is very necessary though. It is known that the Al-Emera city, of Maysan, on the verge of expansion of population settlement terms it is necessary to know the distribution of radioactivity in that area and it determined the ^{222}Rn concentrations, ^{226}Ra and compared the levels of global radioactivity and draw the map of the radioactive areas that samples taken from her to be the nucleus of the radiation map of the province of Maysan integration with current and future studies. Many studies in different parts of the world were conducted on radon concentration in soil using different types of solid state nuclear track[7-10]. This study aimed at investigating the radon concentration, radium concentrations and some radiological parameters such as the exhalation rates in term of area, the effective dose equivalent and the annual effective dose by analyzing different samples taken from soil of Al-Emera sites at Maysan district using solid state nuclear track detector (LR-115 type II).

MATERIALS AND METHODS

The measurements were conducted in April 2017. Amara City Center of Maysan province and located in the Southern part of Iraq and lies about 375 km South East of the capital Baghdad and the South West Basra. Located at (31°50` 26.9°N) and (47°09` 02.1) indicated in Fig. 1. The region was divided surveyed in the current investigation according to a systematic selection for radial distribution with sampling sites.The soil samples were collected from the soil of the city of Amara Iraq have been identified geographical location of the study area (Fig. 1).

After collecting 18 soil sample at depth 15 cm from all area of Amara city in Maysan governorate. The samples dried, then crashed and milled into a powder (10 g). After that it placed at the bottom of a closed cylindrical plastic can of 3.5 cm diameter and 6.5 cm length as shown in Fig. 2. LR-115 type II was fixed in the mouth from inside. The tracks of alpha particles recorded on the detector from ^{222}Rn decay. The detectors, fixed for 3 months, then it's removed and developed in a Sodium hydroxide (NaOH) solution (NaOH is a white crystalline odorless solid ionic compound consisting of sodium cations Na^+, hydroxide anions OH^- and its molar mass is 40.01 g mol^{-1})of (2.5) N at (60 ±1°C) during 120 sec[11]. An ordinary microscope (System Microscope N-120A with HDCE-50B Digital Camera, made in Korea of 400X magnification power) uses to number alpha (α) tracks in LR-115 type II detectors.

Calculations: Track density in unit (Track cm^{-2})(ρ) in the soil samples can be calculated according to the following relation[11]:

$$\rho = \frac{\text{Number of track}}{\text{Area of view}} \quad (1)$$

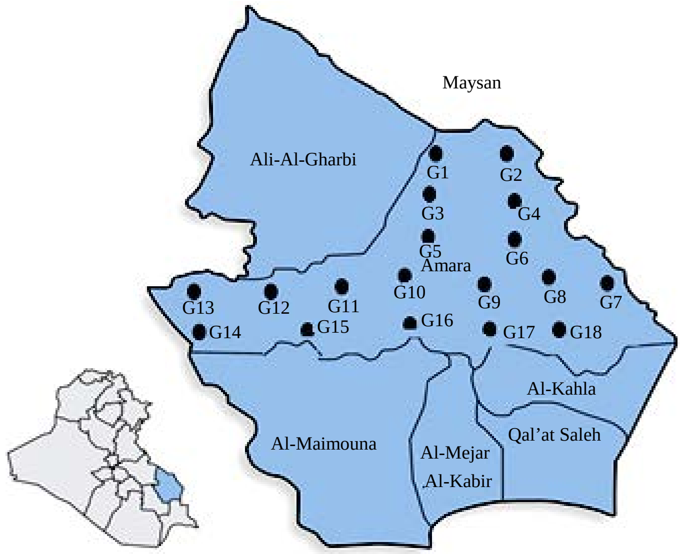

Fig. 1: Map of location area

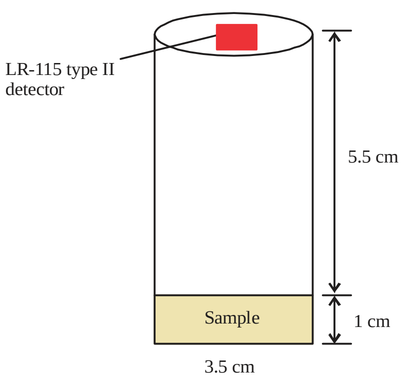

Fig. 2: Closed cylindrical plastic can

The value of radon concentration at secular equilibrium given by the following Eq. 2:

$$C_{Rn} = \frac{\rho}{kt} \tag{2}$$

where, ρ is refers to track density, C_{Rn} is refers to radon concentrations, t is refers to the exposure time (day), k is refers to the calibration coefficient of LR-115 detectors in (tracks cm^{-2} day/Bq m^{-3}) which it is may be calculated according to the following relation[12,13]:

$$K = \frac{1}{4}\alpha\cos\theta_c\left(2 - \frac{a_1}{a} - \frac{a}{a_o}\right) \text{If } \left(a_1 \prec a \prec a_o\right) \tag{3}$$

where, θ_c equal (40) is the critical angle, a is the radius of the can, $a_o = R_o \cos\theta_c$, $R_o = R\text{-}R_{min}$, $a_1 = R_1 \cos\theta_c$ and $R_1 = R\text{-}R_{max}$. R equal (3.90 cm) is the alpha range of ^{222}Rn in air, R_{max} equal (3.44 cm) and R_{min} equal (0.80 cm). Consequently, K = 0.0324 tracks cm^{-2} day^{-1}/Bq m^{-3}.

To evaluate the radium concentration in unit (Bq kg^{-1}) for soil samples was calculated using equation below[14-16]:

$$C_{Ra} = \frac{\rho h A}{K T_e M} \tag{4}$$

where, h is the distance between the LR-115 type II detector and the top of the soil sample in unit (m), A is the surface area of the soil sample in unit (m^2), M is the mass of the soil sample in unit (kg) and T_e is the effective exposure time which it is calculated by Abojassim *et al.*[16]:

$$T_e = t - \frac{1}{\lambda(1 - e^{-\lambda t})} \tag{5}$$

The radon exhalation rate in term of area (E_A) and mass (E_M) from the soil samples determined[17] according to the following Eq. 6, 7:

$$E_A \frac{C_{Rn} V\lambda}{A\left[t + \lambda\left(e^{-\lambda t} - 1\right)\right]} \tag{6}$$

$$E_M \frac{C_{Rn} V\lambda}{M\left[t + \lambda\left(e^{-\lambda t} - 1\right)\right]} \tag{7}$$

where, V is the Volume of air in can for unit (m^3), λ is the decay constant of ^{222}Rn.

The potential exposure to alpha energy E_p annually (effective dose equivalent) in unit (WLM/y) and the annual effective dose (H_E) in unit (mSv/y) are then related to the average radon concentration[18] C_{Rn} by the following Eq. 8, 9:

$$E_P \frac{8760\times n\times F\times C_{Rn}}{170\times 3700} \quad (8)$$

$$H_E = C_{Rn}\times F\times 8760\times D \quad (9)$$

where, n is the fraction of time spent indoors equal (0.8), F is the radon indoor equilibrium factor equal (0.4), 8760 is the number of h/year, 170 represents the hours/working month, breathing in air in which concentration of the radon is 3700 Bq m^{-3} and D is dose conversion factor (9×10^{-6}) mSv/y per Bq m^{-3}.

Statistical analysis: Statistical analysis for analysis of the results was done by shrewd expectation and standard deviation for all results below study victimization SPSS 20[19]. In present study the value of $p<0.05$.

RESULTS AND DISCUSSION

The soil is the fundamental component for the agricultural purposes and construction in Iraq. Therefore, it is very essential to investigate the radon concentration to establish an estimate of radiation risk to the habitants. The radon and radium concentrations in the soil samples at the selected sites of the investigation were at depths of 15 cm are summarized in Table 1. The total average values of radon concentrations and radium concentrates were 776.98±126.08 and 37.79±6.13 Bq m^{-3}, respectively. The findings revealed that the highest percentage of radon are noticed at G2 (15%) and minimum at G3 (0%) sample (Fig. 3). This can be traced to the variation of radon concentrations in the soil to the variation content of uranium prospect beneath the soil samples. The rapid increase in the gas concentration of the soil at different sites can be explained by the possible differences in compaction of the soil (difference in soil profile). The results obtained this study apply to the average worldwide level of outdoor radon recommended by UNSCEAR[20]. The values of effective radium content are less than the allowable value of 370 Bq kg^{-1} as recommended by Organization for Economic Cooperation and Development (OECD)[21]. Hence, the result shows that this soil samples is safe as far as the health hazards of radium are concerned. The values of radon exhalation rates of the soil samples are summarized in Table 2. The results revealed that, the average value of radon exhalation rates in term area (E_A) and radon exhalation rates in term mass (E_M) in soil samples were 40.08±6.50 μBq m^{-2}. h and 36.34±5.89 μ Bq kg^{-1} h, respectively. It is also found that the values of radon exhalation rate were well below the world average value of 57600 mBq m^{-2} h[20]. Hence it was suggested that this soil is safe to be used for construction purpose, as low radon exhalation rate does not pose any health hazards. The values of the annual exposure to potential alpha energy E_p (effective dose equivalent) in terms of WLM and the annual effective dose (H_E) are summarized in Table 3. The overall annual exposures (average) in terms of WLM and the overall

Table 1: Radon and radium concentrations in the samples of soil collected from area under study

Sample code	C_{Rn} (Bq m^{-3})	C_{Ra} (Bq kg^{-1})
G1	637.18	31.03
G2	2047.51	99.61
G3	53.18	2.58
G4	1037.04	50.45
G5	638.18	31.04
G6	585.00	28.46
G7	132.95	6.46
G8	983.86	47.86
G9	372.27	18.11
G10	850.91	41.39
G11	1409.32	68.56
G12	212.72	10.34
G13	425.45	20.69
G14	957.27	46.57
G15	1037.04	50.45
G16	824.32	40.11
G17	292.50	14.23
G18	1489.09	72.44

Rn: Radon and Ra: Radium

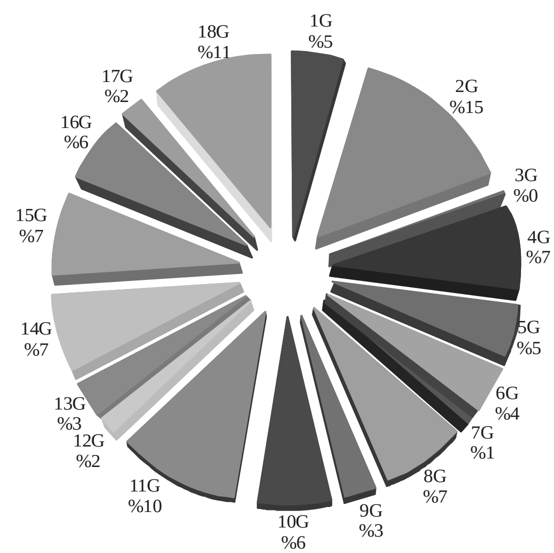

Fig. 3: Percentage of radon concentrations in soil samples under study

Table 2: Radon exhalation rates in term area (E_A) and in term mass (E_M) in soil samples collected from area under investigation

Sample code	E_A (μBq cm^{-2} h)	E_m (μ Bq kg^{-1} h)
G1	32.87	29.80
G2	105.63	95.77
G3	2.74	2.48
G4	53.50	48.51
G5	32.92	29.85
G6	30.18	27.36
G7	6.85	6.21
G8	50.76	46.02
G9	19.20	17.41
G10	43.90	39.80
G11	72.71	65.92
G12	10.97	9.95
G13	21.95	19.90
G14	49.38	44.77
G15	53.50	48.51
G16	42.52	38.55
G17	15.09	13.68
G18	76.82	69.65

Table 3: Effective dose equivalent (E_p) and the annual effective dose (H_E) in soil samples collected from area under investigation

Sample code	E_p (WLM/y)	H_E (mSv/y)
G1	2.981	20.092
G2	9.581	64.570
G3	0.248	1.677
G4	4.852	32.704
G5	2.986	20.125
G6	2.737	18.448
G7	0.622	4.192
G8	4.603	31.027
G9	1.742	11.740
G10	3.981	26.834
G11	6.594	44.444
G12	0.995	6.708
G13	1.990	13.417
G14	4.479	30.188
G15	4.852	32.704
G16	3.857	25.995
G17	1.368	9.224
G18	6.968	46.960

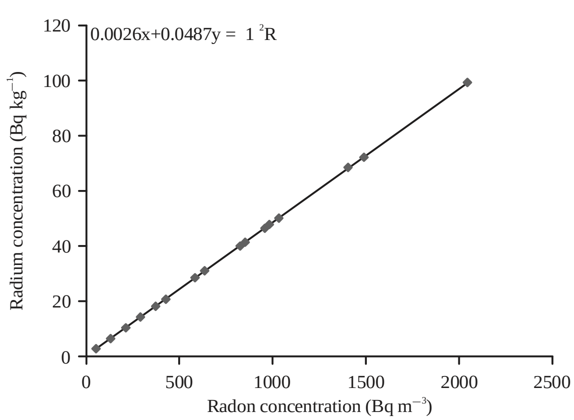

Fig. 4: Correlation between radon concentrations and radium concentrations

average values of annual effective dose were 3.635±0.59 WLM and 24.50±3.97 mSv/y, respectively. It was concluded that the values were slightly larger than the action levels (3 -10 mSv/y) recommended by ICRP[5]. Moreover, these values seem to be safe in terms of health hazards. The results showed that these territories are safe in terms of health hazards as far as the radon is concerned. A significant correlation (R^2= 1) has been observed between radon concentrations and radium concentrations as shown in Fig. 4.

CONCLUSION

The results of the current study indicated that the area under study has different radon levels according to geological properties of the locations of the sample sites. It has also been observed a systematic increase in radon concentration levels of the soil at depth for all the sites. The radon concentration levels and radium concentrations in soil samples from the studied area lie well within the reported range found by other investigators and on average, within the action level recommended by the UNSCEAR and OECD, respectively. Among the important results of the study, the radon exhalation rates were found to be less than the permissible value that it is recommended by UNSCEAR[20]. The effective dose equivalent and the annual effective dose due to alpha radiation were slightly larger than the action levels that is recommended by ICRP. Finally, these values seem to be safe in terms of health hazards. Hence, it could be conclude that human activities would not be with risk at these areas.

SIGNIFICANCE STATEMENT

The significant of this study is implied in establishing new data base which helps in drawing a radioactivity map in the soil of Al-Emera at Maysan Governorate, Iraq.

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