Determination of alpha radioactivity in soil samples collected from University of Kerbala, Iraq

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Abstract: In this study, alpha particles in 60 soil samples of the University of Kerbala (Freiha-Sites) were determined using a CN-85 detector. The results show that the average values of radon concentrations in air space, radon concentrations ^{222}Rn in samples, annual effective dose, radium content, mass exhalation rates, surface exhalation rates and uranium concentrations were 120.82 ± 1.19 Bq/m^3, 3769.71 ± 6.67 Bq/m^3, 3.02 ± 0.18 mSv/y, $0.093 \pm .033$ Bq/kg, 0.70 ± 0.09 mBq/kg.h, 30.93 ± 0.62 mBq/m^2.h and 2.75 ± 0.18 Bq/kg, respectively. It was concluded that as recommended by (ICRP) and (WHO), the average values of alpha particle concentrations in this study were within safe limits and the results showed that these areas are healthy with regard to radon gas in terms of a health threat.

Keywords: alpha particles; soil samples; CN-85; University of Kerbala; Iraq.

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1 Introduction

Radon (^{222}Rn) is a torpid gas, that starts from the radioactive converting of radium (^{226}Ra) in the alpha-decay of uranium (^{238}U) chain in the crust of the Earth. The amount and presence of radon varies with different materials and locations, provided that radon is chemically unreactive to multi-materials (UNSCEAR, 2000). It plainly moves to the surface of the soil between particles of material (such as soil, sand and rock). Radon is the first significant cause for lung cancer in non-smokers, as shown by the World Health Organisation (WHO) (Kónya and Nagy, 2018). The lung cancer rate due to radon is estimated to range from 3 to 14% at the stage where radium decays in the soil, the resulting atoms of radon isotopes first decay. The measurement of soil radon exhalation concentrations is useful for researching radon health hazards (Abdalla and Jastaniah, 2013). The average exhalation of radon from the soil into the air is known as the exhalation rate of radon from the soil. This is determined by either the unit area or the mass of the soil per unit (Abojassim et al., 2020). The National Radiological Protection Board (NRPB) has shown up that the combined radon and thoron are used for at least 50% of the total dose for an average person in the UK. Radionuclides present normally in the water, soil and air there is no single place on Earth that we can’t discover natural radioactivity just as it exists even in our bodies because of products of our environment inhaling radionuclide through doing our typical activities (Hashim et al., 2015) such as eating and drinking. Natural radioactivity is found in the building materials, homes, rocks, and the oceans. The presence of radionuclides impacts on lives because exposure to radiation and it is undesirable in the least levels the main sources of radiation exposure to the general public (Abojassim, 2021). For example but not limited to, the natural radiation of terrestrial and cosmogonic origins internal radioisotopes medical radiation technologically and consumer products as indicated by the International Atomic Energy Agency. Also, ^{226}Ra are and ^{228}Ra considered the most radiotoxic and most important isotopes among the several daughters in the decay chains of the two natural series of uranium and thorium (Hashim et al., 2015). Radon is found in three radioactive isotopes, specifically radon (^{222}Rn, 3.82 days), thoron (^{220}Rn, 55 seconds), and activity (^{219}Rn, 4 seconds). When studying the problem of radon, it is accepted that the thoron and actinone isotopes, just as their daughters, have been ignored by researchers (Abojassim et al., 2020). Radon is created immediately from radium (^{226}Ra), which has a half-life of 1600 years, which spreads widely, in materials that are made of metal products (Kónya and Nagy, 2018). Radium is created by the decomposition of uranium (^{238}U), whose half-life is (4.7×10^9) years. Generally, as the water is pumped into the well, radon reaches the water. In this case, through the rocks and the soil containing radioactive contaminants, radon flows through the groundwater (Abdalla and Jastaniah, 2013). There are many researchers study of radon gas concentrations in soil at different locations of Iraq (Abojassim, 2021; Salman, 2021; Ibrahim et al., 2021). The purpose of the present work was to measure the alpha activity of (Radon, Radium and Uranium), in soil Samples of the university of Kerbala (Freiha-sites), using a CN-85 detector. Also, finally, it is drawn to establish of natural radioactivity and radiological map to be a reference to the next studies using GIS technical.

2 Study area

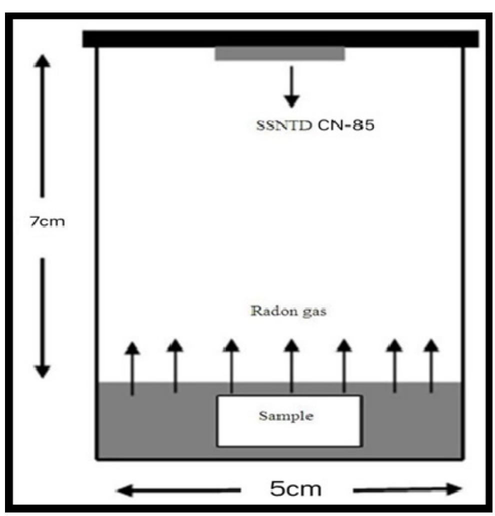
University of Kerbala (Freiha Site) lies between longitude of (44°05′E) and latitude of (32°36′N) (Hassan et al., 2019). It is consisted of nine colleges Engineering, Sciences, Tourism, Management, and Economics, Law, Education and Human Sciences, Islamic Sciences Education and Pure Sciences, The geotechnical structure of the soil in (Fariha Sites) is generally as follows: Gypsum soil: it is the soils that contain gypsum $2H_2O$ and $CaSO_4$ which contain two particles of water more than 3% within the root layer and spread in dry and semi-arid areas and it is in the form of rocks. Gypsum precipitates and its availability is important for the plant because it prevents the development of soda in the soil and it is important for the preparation of the calcium element. Soil problems: When you increase the percentage of gypsum by 10%, it affects the properties of the soil. It also has the ability to retain water and its low percentage of organic matter and a deficiency of elements due to the presence of calcium that is deposited from some element.

3 Materials and methods

In this work, 60 soil samples were obtained from various locations at Kerbala University (Freiha site) during the past year from October-November 2019 in a depth equal to15 cm from the earth’s Surface samples. Locations were determined using Global Positioning System (GPS) which is shown in Figure 1 These were placed in a plastic bag and marked with the sample code and symbol. The samples obtained were moved to the Physics Department’s Nuclear Physics laboratory, College of Sciences, the University of Kerbala, in the oven at 120°C the soil samples were dried. Then, milled in the grinder (electric mill). After that, all the samples were sieved through a 50 µm pore size diameter sieve to get homogeneity powder. The sealed cup technique was utilised to measure the alpha activity in study samples as shown in Figure 2. Alpha emitters in soil samples were estimated using CN-85 detector of thickness 12 µm and area of 1×1 cm^2 supplied by (Kodak path, France). After that, soil samples of (92 g) were placed in plastic containers of (7 cm) in height, and (5 cm) in width. , while the sample detector distance is still (3.5 cm) by closing the tube with cover and adhesive tape to prevent contact with the outside air for thirty days to reach equilibrium (^{226}Ra and ^{222}Rn) After this time, to prevent the release of radioactive particles into the outside air, the lid was quickly raised to add detectors (Al-Saadi et al., 2015; Shakir et al., 2011). The cups were sealed for 172 days. The detectors CN-85 were removed from cans and chemically etched for 3 hours in a (NaOH) solution of normality 2.5 M in a constant temperature bath at 70°C, after removing the detectors from the solution and washing them with well distilled water and dried on soft paper (Al-Kharouf et al., 2008). The number of alpha particle pathways is measured on the detector surface using a light microscope with a 400 X magnification.

Figure 1 Map of samples' locations of the (Freiha Site) in Kerbala University

Figure 2 Schematic diagram of the plastic container



4 Theoretical equations

^{222}Rn concentration in the airspace of the tube (C) was calculated from the formula (Abojassima et al., 2017):

$$C\left(\frac{Bq}{m^3}\right) = \frac{\rho}{K\,t} \tag{1}$$

ρ is the number of track per (cm^2) in the (CN-85) detector, and (t) is the exposure time (172) and, K is the calibration factor of the CN-85 plastic path detector, which was (0.256) Teack.cm^{-2} /Bq.m^{-3}$\cdot$day (Hashim and Nayif, 2019). Concentration of radon in soil sample, was calculated following (Mohammad and Al-Zubaidy, 2012):

$$C_{R_n}\left(\frac{Bq}{m^3}\right) = C\left(\frac{\lambda ht}{L}\right) \tag{2}$$

where C_{R_n} : Radon concentration in sample (Bq/m^3), λ : The radon gas constant decays and is equal to 0.1814 day^{-1}, h: thickness of the sample (3.5cm) and L: distance between CN-85 detector and soil samples (3.5 cm).

In this analysis, radon and radium had to achieve an effective balance of about (98%) in almost (4 weeks). It was as the half-life of ^{226}Ra, ^{222}Rn, the auditory equilibrium has recently been achieved, radon alpha decomposition can be used to find radium activity, over time, increased radon concentration after closing of the can following (Khan et al., 2012):

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

where λ_{Rn} is the decay constant, and T is the real-exposure time.

Annual effective dose due to radon concentration in samples was calculated following (Mowlavi et al., 2012; Abumurad and Al-Omari, 2008):

$$\text{AED (mSv/y)} = C \times F \times H \times T \times D \tag{4}$$

where F was the equilibrium factor which equal to (0.4), T was the time in hours in a year, (8760 h/y), H was the occupancy factor which is equal to (0.8), and D was the dose conversion factor which equal to [9 × 10^{-6} (m Sv) / (Bq.h.m^{-3})]

The radium content of the samples soil, Using the 'Can technique' can be calculated by the relation (Hashim and Nayif, 2019).

$$C_{Ra}\left(Bq.Kg^{-1}\right) = \left(\frac{\rho}{k.Te}\right)\left(\frac{hA}{M}\right) \tag{5}$$

where C_{Ra} is the radium content of soil (Bq/kg), M is mass of soil sample, A is area of the can, h thickness of the sample and, T_{eff} is the time of actual exposure.

T_{eff} was computed following (Azam et al., 1995):

$$Te = \left[T - \lambda_{Rn}^{-1}\ \left(1 - e^{-\lambda_{Rn}\,T}\right)\right] \tag{6}$$

Further, the mass exhalation rate $\left(E_M\right)$ of the samples for release of the ^{222}Rn radon gas was calculated (Khan et al., 2011).

$$E_M = \frac{CV\lambda}{MT_{eff}} \tag{7}$$

The surface exhalation rate $\left(E_A\right)$ of the samples soil for release of radon gas was calculated following (Khan et al., 2011):

$$E_A = \frac{CV\lambda}{AT_{eff}} \tag{8}$$

The activity of uranium $\left(C_U\right)$ of soil samples was calculated following (Khan et al., 2011):

$$C_P\left(ppm\right) = \frac{W_U}{W_s} \tag{9}$$

where W_S was the weight of sample and, W_U is ^{238}U weight in sample. The uranium concentration unit to activity unit in Bq.kg^{-1} of ^{238}U uranium (Erdi-Krausz et al., 2003).

$$1 \text{ ppm of uranium} = 12.35 \text{ Bq.kg}^{-1} \tag{10}$$

5 Results and discussion

5.1 Radon concentration and annual effective dose

Solid state nuclear track CN-85 reagents are used for the measuring alpha radioactivity emitting from soil samples of (Freiha-sites) of Kerbala University, the results of radon and (AED) in soil samples are presented in Table 1. The concentrations of radon gas was found to range from (228.92±1.68) Bq·m^{3}in U27 Sample Code to (21.80±0.51) Bq·m^{3}in U41 sample Code with a mean value of (120.82±1.19). The results of radon concentration in soil was found to range from (7142.62±9.39) Bq·m^3 in U27 sample code to (680.25±2.89) Bq·m^3 in U41 Sample Code with a mean value of (3769.71±6.67) Figure 3 shows the geographical distribution of C_{Rn} for the present study that, it was drawn using the GIS technique. The concentrations of radon were classified into six range of colour according to radon concentrations, where different colours were used to differentiate between high, medium, and low concentrations (see Figure 3). Also annual effective dose varies from the highest value is (10.26±0.35) mSv/y in U14 Sample Code to the lowest values (2.10±0.16) mSv/y in ^{18}U Sample Code with mean value (4.11±0.22) mSv/y. From the measurement results in the studied are so the soil radon concentration are lower than the so the value of all samples are lower than the accordable limit, usually ranges from 0.4 to 40 kBq/m^3 (Buttafuoco et al., 2007). And also been indices values are found to be slightly less than the levels of (3–10) mSv/y which was recommended by ICRP (1993).

Table 1 Track density (ρ), radon concentration in air(c), radon concentrations in soil sample (C_{Rn}) and annual effective dose (AED) for the soil samples under study

Sample	*Location name*	*C Bq/m^3*	*C_{Rn} Bq/m^3*	*AED mSv/y*
U1	Student's internal departments	138.08±1.30	4308.25±7.29	3.48 ± 0.20
U2		105.37±1.14	3287.87±6.37	2.65±0.18
U3		83.57± 0.89	2607.62±5.01	2.10±0.14
U4	College of Science	65.40±1.01	2040.75±5.67	1.65±0.16
U5		152.61±1.37	4761.75±7.66	3.85±0.21
U6		221.65±1.65	6915.87±9.24	5.59±0.26
U7		94.47±1.08	2947.75±6.03	2.38 ±0.17
U8	deanship of the college of engineering	119.91±1.21	3741.37±6.79	3.02±0.19
U9		112.64±1.17	3514.62±6.58	2.84±0.18
U10	College of pure education	203.48±1.58	6349± 8.85	5.13±0.25
U11		127.18±1.25	3968.12±6.99	3.20±0.19
U12		109.01±1.16	3401.25±6.48	2.75±0.184
U13	College of human education	54.50±0.82	1700.62±4.58	1.37±0.13
U14		109.01±1.16	3401.25±6.48	2.75±0.18
U15		36.33 ±0.67	1133.75±3.74	0.91±0.10
U16	Central club	127.18±1.25	3968.12±6.99	3.20±0.19
U17		138.08±1.30	4308.25±7.29	3.48±0.20
U18	College of engineering	79.94 ± 0.99	2494.25±5.54	2.01±0.15
U19		83.57±1.01	2607.62±5.67	2.10±0.16
U20	College of biomedical engineering	72.67± 0 .94	2267.50±5.29	1.83±0.15
U21		119.91±1.21	3741.37±6.79	3.02±0.19
U22		130.81±1.27	4081.50±7.09	3.30±0.20
U23		174.41±1.46	5442 ± 8.19	4.40 ±0.23
U24	Electrical station	76.30±0.97	2380.87±5.42	1.92±0.15
U25		192.58±1.54	6008.87±8.61	4.85 ±0.24
U26		170.78±1.45	5328.62±8.11	4.30±0.23
U27		228.92±1.68	7142.62±9.39	5.77±0.26
U28	Presidency	145.34±1.34	4535 ± 7.48	3.66±0.21
U29		148.98±1.35	4648.37±7.57	3.75±0.21
U30		105.37±1.14	3287.87±6.37	2.65±0.18
U31	College of Islamic sciences	123.54±1.23	3854.75±6.89	3.11±0.19
U32		138.08±1.30	4308.24±7.29	3.48 ±0.20
U33		156.25±1.38	4875.12±7.75	3.94± 0.22
U34	College tourism of sciences	127.18±1.25	3968.12±6.99	3.20±0.19
U35		174.41±1.46	5442± 8.19	4.40±0.23
U36		156.25±1.38	4875.12±7.75	3.94 ±0.22
U37	Central library	192.58±1.54	6008.87±8.61	4.85±0.24
U38		69.041±0.92	2154.12±5.15	1.74± 0.14
U39		145.34±1.34	4535± 7.48	3.66±0.21
U40		156.25±1.38	4875.12±7.75	3.94± 0.22

Table 1 Track density (ρ), radon concentration in air(c), radon concentrations in soil sample (C_{Rn}) and annual effective dose (AED) for the soil samples under study (continued)

Sample	*Location name*	*C Bq/m^3*	*C_{Rn} Bq/m^3*	*AED mSv/y*
U41		21.80±0.51	680.25±2.89	0.55±0.08
U42	College of veterinary medicine	101.74±1.12	3174.50±6.26	2.56±0.17
U43		156.25±1.38	4875.12±7.75	3.94±0.22
U44		138.08±1.30	4308.25±7.29	3.48±0.20
U45		130.81±1.27	4081.50±7.09	3.30±0.20
U46	University gate	69.04±0.92	2154.12±5.15	1.74±0.14
U47		181.68±1.49	5668.75±8.36	4.58±0.23
U48		145.34±1.34	4535± 7.48	3.66±0.21
U49		109.01±1.16	3401.25±6.48	2.75± 0.18
U50	Internal sections	138.08±1.30	4308.25±7.29	3.48±0.20
U51		98.11±1.10	3061.12±6.14	2.47±0.175
U52		127.18±1.25	3968.12±6.99	3.20±0.19
U53		29.07±0.59	907±3.34	0.73±0.09
U54	College of Administration and Economy	167.15±1.43	5215.25±8.02	4.21±0.22
U55		54.50± 0.82	1700.62±4.58	1.37±0.13
U56		101.74±1.12	3174.5±6.26	2.56 ±0.17
U57		109.01±1.16	3401.25±6.48	2.75±0.18
U58	College of law	90.84±1.059	2834.37±5.91	2.29±0.16
U59		47.23±0.76	1473.87±4.26	1.19±0.12
U60		65.40±0.89	2040.75±5.01	1.65± 0.14
Max	228.92±1.68	7142.62±9.39	5.77±0.26	
Min	21.80±0.51	680.25±2.89	0.55 ±0.08	
Average±S.D	120.82±1.19	3769.71±6.67	3.02± 0.18	

5.2 *Radium content and radon exhalation rates*

The results of activity and exhalation rates of radium in terms of mass and surface, the uranium concentration in sample are presented in Table 2. The radium content ranged between (0.177±0.04) Bq/kg in U27 Sample Code to (0.017±0.01) Bq/kg in U41 Sample Code mean value of (0.093±0.033). At the geographical distribution of C_{Ra} at the Al-Fariha site (see Figure 4), different range of concentrations were used to differentiate between high, medium and low concentrations using the GIS technique , and the radon exhalation rate values for mass and area ranged from (1.33±0.12) m Bq/kg.h in ^{27}U Sample Code to (0.12±0.04) mBq/kg.h in U41 Sample Code with an average of (0.70±0.09) mBq/kg.h and ranged from (62.56±0.87) mBq/m^2.h in ^{27}U Sample Code to (5.95±0.27) mBq·m^2.h in U41 Sample Code with an average of (30.93±0.62) mBq·m^2.h. The values of radium content in samples were less than the level permissible limit of 370 Bq·kg^{-1} which was recommended by (OECD) (Shephard et al., 1988). The radon exhalation rate was much lower than the world average of (57.6 Bq·m^{-2}·h) in terms of mass and surface area of radon for the work (Nations, 2000).

Figure 3 The choropleth maps of the values of C_{Rn} for different soil samples

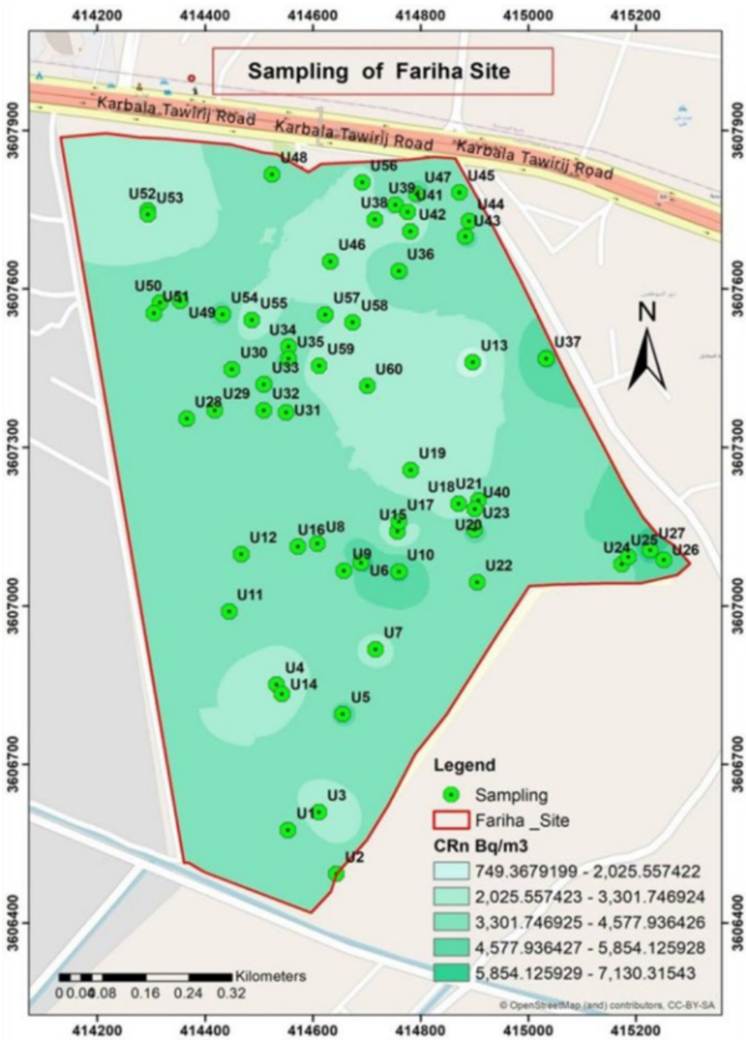


Table 2 Radium content (C_{Ra}), radon exhalation rates E_M and E_A, and uranium concentration for the soil samples under study

Sample	C_{Ra} *Bq/kg*	E_M *mBq/kg.h*	E_A *mBq/m*^{2}*.h*	*U Bq/kg*
U1	0.107 ±0.03	0.80 ±0.10	37.73±0.68	3.15 ±0.19
U2	0.081 ± 0.03	0.61±0.08	28.80±0.59	2.40±0.17
U3	0.064±0.02	0.48± 0.06	22.84±0.47	1.90± 0.13
U4	0.050±0.02	0.38 ±0.078	17.87± 0.53	1.49±0.15
U5	0.118±0.03	0.89± 0.10	41.71±0.71	3.48±0.20
U6	0.171±0.04	1.29± 0.12	60.57±0.86	5.05± 0.25
U7	0.073 ±0.03	0.55 ±0.08	25.82±0.56	2.15±0.16
U8	0.093±0.03	0.69 ±0.09	32.77 ±0.63	2.73±.184

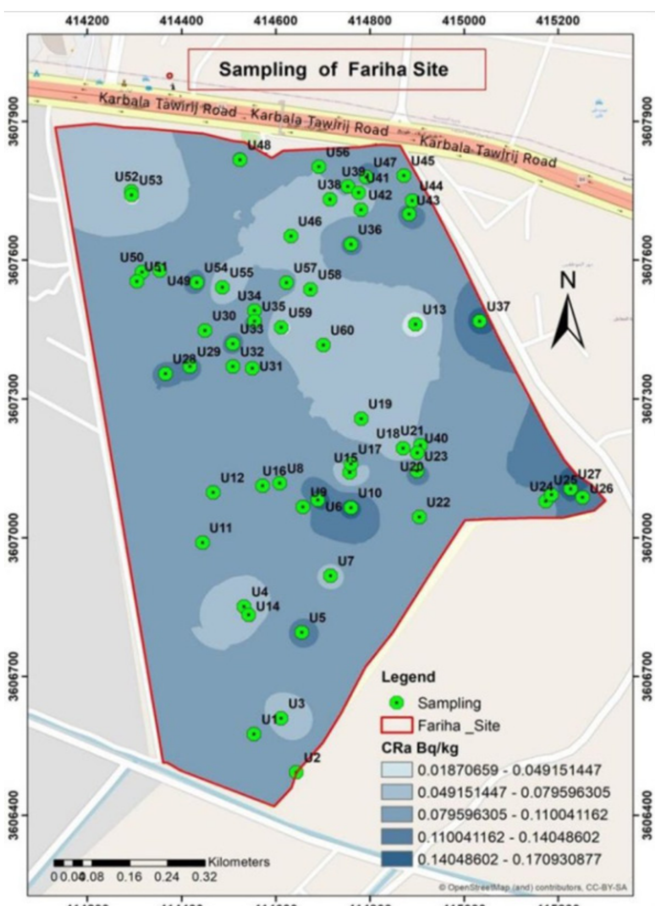
Table 2 Radium content (C_{Ra}), radon exhalation rates E_M and E_A, and uranium concentration for the soil samples under study (continued)

Sample	C_{Ra} *Bq/kg*	E_M *mBq/kg.h*	E_A *mBq/m*^{2}*.h*	*U Bq/kg*
U9	0.087 ±0.03	0.65 ±0.09	30.78± 0.61	2.57 ±0.17
U10	0.157± 0.04	1.18±0.12	55.61±0.82	4.64±0.23
U11	0.098 ±0 .03	0.74±0.09	34.75± 0.65	2.90±0.18
U12	0.084±0.03	0.63±0.08	29.79±0.60	2.48±0.17
U13	0.042 ±0.02	0.31±0.06	14.89 ±0.42	1.24±0.12
U14	0.084± 0.03	0.63±0.08	29.79±0.60	2.48±0.17
U15	0.02±0.01	0.21± 0.05	9.93±0.35	0.82±0.10
U16	0.098±0.03	0.74± 0.09	34.75±0.65	2.90±0.19
U17	0.107± 0.03	0.80±0.10	37.73 ±0.68	3.15±0.19
U18	0.06± 0.02	0.46±0.07	21.84±0.51	1.82±0.15
U19	0.064± 0.02	0.48 ±0.07	22.84±0 .53	1.90± 0.15
U20	0.056± 0.02	0.42±0.07	19.86 ± 0.49	1.65±0.14
U21	0.093 ±0.03	0.69±0.09	32.77±0.636	2.73±0.18
U22	0.101 ±0.03	0.76± 0.09	35.75±0.66	2.98±0.19
U23	0.135 ±0.04	1.01± 0.11	47.66±0.76	3.98±0.22
U24	0.059±0.02	0.44±0.07	20.85±0.50	1.74±0.14
U25	0.149±0.04	1.12±0.11	52.63±0.80	4.39± 0.23
U26	0.132±0.04	0.99±0.11	46.67± 0.75	3.89±0.21
U27	0.17±0.04	1.33±0.12	62.56±0.87	5.22±0.25
U28	0.112±0.03	0.84±0.10	39.72±0.70	3.31±0.20
U29	0.115 ±0.03	0.86±0.10	40.71±0.709	3.40±0.20
U30	0.081±0.03	0.61±0.08	28.80± 0.59	2.40±0.17
U31	0.095 ±0.03	0.72±0.09	33.76±0.64	2.82±0.18
U32	0.107± 0.03	0.80±0.10	37.73± 0.68	3.15±0.19
U33	0.121±0.03	0.91± 0.10	42.70 ±0.72	3.56±0.21
U34	0.098±0.035	0.74±0.09	34.75±0.65	2.90±0.18
U35	0.135±0.041	1.01±0 .11	47.66±0.76	3.98±0.22
U36	0.121 ±0.03	0.91±0.10	42.70±0.72	3.56±0.21
U37	0.149±0 .04	1.12±0.11	52.63 ±0.80	4.39±0.23
U38	0.053 ±0.02	0.40±0.07	18.86±0.48	1.57±0.13
U39	0.112±0.03	0.84±0.10	39.72±0.70	3.31±0.20
U40	0.121±0.03	0.91±0.10	42.70 ±0.72	3.56±0.21
U41	0.017±0.01	0.127±0.04	5.95±0.27	0.49 ±0.07
U42	0.079±0.03	0.593±0.08	27.80±0.58	2.32±0.16
U43	0.121±0.03	0.91± 0.10	42.70±0.72	3.56±0 .21
U44	0.107±0.03	0.80±0.10	37.73±0.68	3.15±0.19
U45	0.101±0.03	0.76±0.09	35.75±0.66	2.98±0.19
U46	0.053±0.02	0.40±0.07	18.86±0.48	1.57±0.13
U47	0.140±0.04	1.06±0.11	49.65±0.78	4.14±0.22
U48	0.112±0.03	0.84±0.10	39.72±0.70	3.31±0.20
U49	0.084 ±0.03	0.63±0.08	29.79±0.60	2.48±0.17
U50	0.107±0 .03	0.80±0.10	37.73±0.683	3.15±0.19

Table 2 Radium content (C_{Ra}), radon exhalation rates E_M and E_A, and uranium concentration for the soil samples under study (continued)

Sample	C_{Ra} *Bq/kg*	E_M *mBq/kg.h*	E_A *mBq/m².h*	*U Bq/kg*
U51	0.076±0.03	0.57±0.08	26.81±0.57	2.23±0.16
U52	0.098±0.03	0.74±0.09	34.75±0.65	2.90±0.18
U53	0.022±0.01	0.17±0.04	7.94 ±0.31	0.66± 0.09
U54	0.129±0.04	0.97±0.11	45.68 ±0.75	3.81±0.21
U55	0.042±0.02	0.31 ±0.06	14.89±0.42	1.24±0.12
U56	0.079±0.03	0.59±0.08	27.80±0.58	2.32± 0.16
U57	0.084±0.03	0.63±0.08	29.79 ±0.60	2.48±0.17
U58	0.070 ±0.02	0.53±0.08	24.82±0.55	2.07±0.16
U59	0.036±0.02	0.27±0.05	12.91±0.39	1.07 ±0.11
U60	0.050 ±0.02	0.38±0.06	17.87± 0.47	1.49±0.13
Max	0.177± 0.04	1.33±0.12	62.56±0.87	5.22±0.25
Min	0.017±0.01	0.12±0.04	5.95±0.27	0.49±0.07
Average ±S.D	0.093±.033	0.70±0.09	30.93±0.62	2.75±0.18

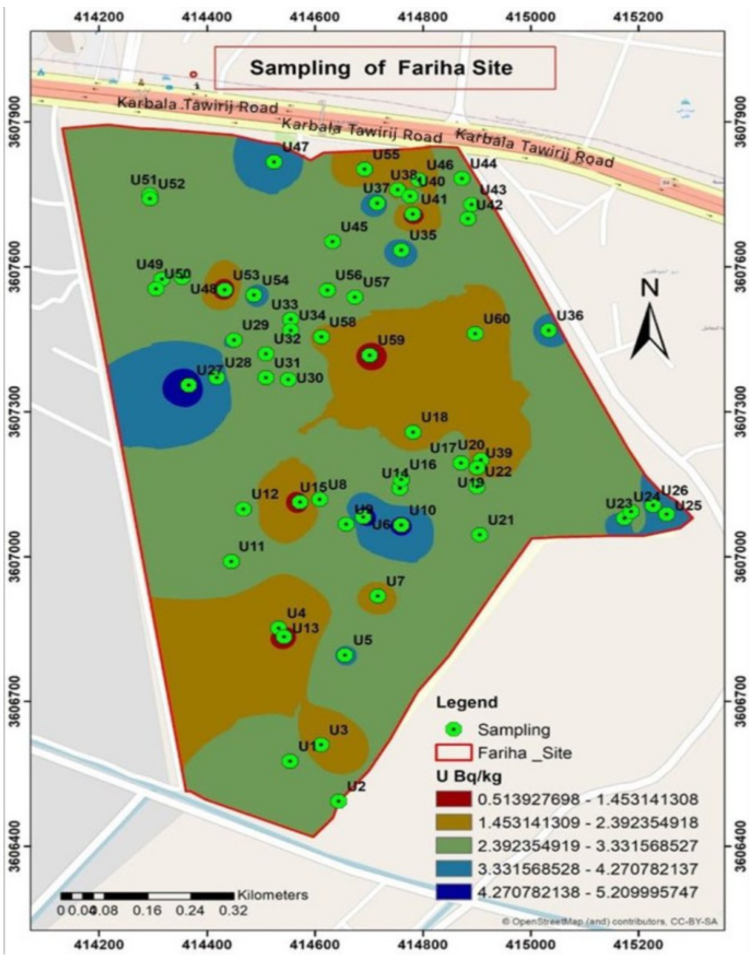
Figure 4 The choropleth maps of the values of C_{Ra} for different soil samples



5.3 Uranium concentration

Uranium concentration was found to range from (5.22±0.25) in U27 Sample Code to (0.49±0.07) in U41 Sample Code with a mean value of (2.75±0.18). The specific activities of ^{238}U uranium in samples soil are less than the allowed limit (33) Bq/kg from UNSCEAR (1993). Figure 5 showed the geographical distribution of U at the Al-Fariha-site, the concentrations of radon were classified in to six ranges according to radon concentrations. Different colours are used to differentiate between high, medium, and low concentrations.

Figure 5 The choropleth maps of the values of C_U for different soil samples



All the results of radon concentration levels, radium content and uranium concentration in were lower than the results of the other studies (see Table 3). So, the soil of Kerbala University in (Freiha-sites), Iraq, doest not pose any health risks to teachers and students.

Table 3 Comparison of the present study with others studied of many different countries

No	*Country*	*Radon (KBq/m^3)*	*Radium (Bq/kg)*	*Uranium (Bq/kg)*	*Ref.*
1	Pakistan	95.1	–	–	Iqbal et al. (2011)
2	Lebanon	–	1.079	18.11	Hashim et al. (2016)
3	Saudi Arabia	6.71	–	–	Farid (2016)
4	Sudan	8.20			Abd-Elmoniem et al. (2014)
5	Iraq (Karbala)	197.477	–	18.63	Al-Saadi et al. (2014)
6	Iraq (Al-Najaf)	894.21	136.18	18.52	Abojassim (2018)
7	Iraq Maysan	776.98	37.79	–	Abojassim et al. (2017)
8	Bulgaria	26	–	–	Kunovska et al. (2013)
9	Karbala University (Freiha Site)	3.76	0.09	2.75	Present study

6 Conclusion

Current study results show that the study area contains different levels of radon according to the geological characteristics of the locations of the sample sites. Radon concentration levels show a systematic increase in the depth of soil for all the regions. It was found that the samples have fewer alpha particles than the recommended limits was set by the UNSCEAR (2000) and ICRP (1993), respectively. Finally, these values show that human activities in these regions are stable and safe in terms of health hazards.

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