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Estimation of Human Radiation Exposure from Natural Radioactivity and Radon Concentrations in Soil Samples at Green Zone in Al-Najaf, Iraq

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Ar Specific activity of natural radionuclides namely (^{238}U, ^{232}Th, ^{40}K and ^{235}U) and radon concentrations were measured for soil samples collected from green zone in Al-Najaf city, Iraq. There are three nuclear techniques used in present study NaI(Tl), CR-39 and LR-115 type II) were used to determine these radionuclides. Also, the radiological hazard due to natural radioactivity and radon concentrations were calculated. The average of specific activity for ^{238}U,^{232}Th, ^{40}K and ^{235}U using NaI(Tl) detector were17.48±7.43, 8.59±3.18, 298.31±76.22 and 0.80±0.07Bq/kg, respectively. While the average value of radon concentrations using CR-39 detector and LR-115 type II detector was 579.65±33.30 Bq/m^3. The average value of radiological hazard due to natural radioactivity ($Ra_{eq.}$, D_r, E_γ, H_{ex}, H_{in}, I_γ, AEDE and ELCR) were within the permissible limits. Also the average values of radon exhalation rates for all samples were within the permissible limits. In addition, there is a good correlation (r= 0.93) for value of radon concentrations using CR-39 and LR-115 type II detectors. There is a good correlation between specific activity of uranium-238 and radon-222 concentrations were found which it is equal r=0.91. It can be concluded that, measurements have been taken as representing baseline of radionuclides present in the soil of the studied area. Therefore, the probability of occurrence of any radiation health effects is low.

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INTRODUCTION

The soil one of sources human food and the most important contributors to the radiation exposure, it is necessary to know the distribution of radioactivity in the soil. NORM stands for Naturally Occurring Radioactive Material and gives description to materials that contain radioactive elements of natural origin together with those nuclides generated by natural processes [1]. The International Atomic Energy Agency presents definition to NORM as "Radioactive materials containing no significant amounts of radionuclide other than naturally occurring radionuclides" [2]. Radionuclides essentially are existent in the process of creating of earth. Natural radioactivity emanates basically from primordial radionuclides, such as Potasium-40 and nuclides from the Thourium-232, Uranium-238 series and their decay products which happen at trace levels in all ground formations concerning earth [1]. The study of natural radioactivity is also important because naturally occurring radioactive materials (NORM) can served as good biochemical and geochemical tracers in environment in case of geological events such as earthquakes and eruptions volcanic. It is well known that even if a small amount of these radionuclides due to the gamma ray exposure of the body and irradiation of lung tissues from inhalation of radon and its daughters the biological effects harmful is produce [3]. Therefore, it is necessary to know the dose limits of exposure to measure the level of radiation provided by land, air, water, food, building and etc., to estimate exposure and protection of human and natural sources of radiation. Gamma radiation emitted from natural radioactive isotopes, such as ^{226}Ra and ^{232}Th series and decomposition products and ^{40}K, which are found in trace levels in all configurations land is the main external source of radiation to the human body. Gamma-ray emissions cause external the risk exposure and internally because inhalation of radon [3]. A considerable contribution to the radioactivity in the body comes from the gassy decay products of the uranium and thorium radioactive series, namely (Radon and Thoron). These gases diffuse from the (rocks and soil) and present in readily commensurable concentrations in the atmosphere, they are breathed by man during their decay products and are also taken up by plants and animals which resulting in most foodstuffs contain measurable amounts of natural radioactivity [4].

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Radon is a noble gas with the lifetime of a relatively longer than the breath time. When breathed into the lung it is mostly breathed out the again exception of a small amount that can be transferred into the blood or decay. Risk of radon arises from the fact that, when radon decays in the air its daughters are solids and when they are inhaled deposited on the inner surfaces of the lungs [5]. Radon forms in rocks and soil that contain uranium or thorium, rocks have generally been thought to be the main sources; radon produce and emigration in soil and bedrock define radon availability, while the location and construction properties control the radon transfer into houses [6]. Natural radioactivity in the soil measurement is great importance for many researchers all over the world, which led to worldwide national surveys in the past two decades. Measurement of natural radioactivity in the soil is very important to determine the amount of change of the natural background activity with time due or leak radioactive [7]. The Green Zone in the Province of Najaf is one of the most important recreational areas visited by a large number of citizens throughout the year for gardens, parks and amusement city. In addition, this area was scene of military operations in 2003 during the battles between the US and the former Iraqi army. Moreover, there are many workers living in this area, so it is very important to know the natural radiological activity as well as concentrations of radon in the soil of the green belt area and to estimate the radiation risk factors resulting from that radiation and to develop a database for the area under study. There are many researches that studied of natural radioactivity and radon concentrations using different technical and different counters [8-11]. The aim of the present study, to measure each of potassium ^{40}K, radium ^{226}Ra and thorium ^{232}Th in soil samples of green zone in Al-Najaf, Iraq using gamma ray spectroscopy and it calculates the radiological parameters due to exposure in soil of study area. Also it has been studied the radon concentrations using two types of detector such as CR-39 and LR-115 type II and at the same samples of soil of green zone. In addition to found correlation between radon concentration and radium-226 and correlation for radon concentration between two types of detector that used in samples under study.

MATERIAL AND METHODS

Area of study and samples collection

Green zone is important in the regions of Al-Najaf province city and lies about 5 kilometers center of the Al-Najaf city. It is located $47^0 09' 02.01''$ E and $31^0 50.26' 09''$ N. The measure radiation hazard index in soil surface 20 soil samples were collected as fair distribution in at Green Zone in Al-Najaf, Iraq. One sample average from each point, was taken by digging a hole at a depth of 10-15 cm from the ground surface. The region was divided surveyed in the current investigation according to a systematic selection for radial distribution with sampling sites; samples were collected from the soil and located in areas of the green zone have been identified geographical location of the study area as indicated in Figure 1. Table 1 shows the sites studied that determined using GPS technical.

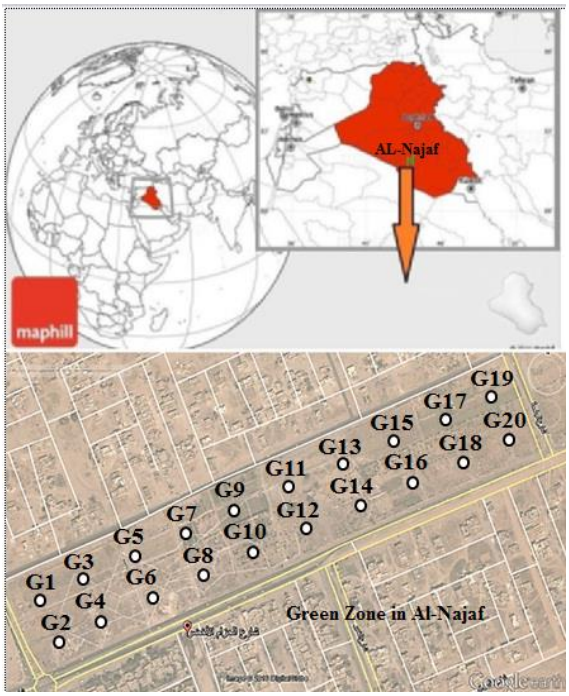

Figure 1. Location map for Green zone area

TABLE 1. Location and coordinate of samples

No.	Sample Code	Coordinates
1	G1	$44^0 19' 50.37'' E , 32^0 0.13' 56'' N$
2	G2	$44^0 19' 36.45'' E , 32^0 1.14' 02'' N$
3	G3	$44^0 20' 30.05'' E , 32^0 1' 62.03'' N$
4	G4	$44^0 20' 30.05'' E , 32^0 1' 25.10'' N$
5	G5	$44^0 20' 30.05'' E , 32^0 1' 29.09'' N$
6	G6	$44^0 20' 01.21'' E , 32^0 1' 59.15'' N$
7	G7	$44^0 20' 43.29'' E , 32^0 1' 43.16'' N$
8	G8	$44^0 20' 02.34'' E , 32^0 1' 92.17'' N$
9	G9	$44^0 20' 09.41'' E , 32^0 1' 53.22'' N$
10	G10	$44^0 20' 47.42'' E , 32^0 1' 69.18'' N$
11	G11	$44^0 20' 52.45'' E , 32^0 1' 43.23'' N$
12	G12	$44^0 20' 35.52'' E , 32^0 1' 23.23'' N$
13	G13	$44^0 20' 14.55'' E , 32^0 1' 87.25'' N$
14	G14	$44^0 21' 68.02'' E , 32^0 1' 54.25'' N$
15	G15	$44^0 20' 56.41'' E , 32^0 1' 94.23'' N$
16	G16	$44^0 21' 98.14'' E , 32^0 1' 70.34'' N$
17	G17	$44^0 21' 21.24'' E , 32^0 1' 72.33'' N$
18	G18	$44^0 21' 34.29'' E , 32^0 1' 32.37'' N$
19	G19	$44^0 21' 12.36'' E , 32^0 1' 89.39'' N$
20	G20	$44^0 21' 35.45'' E , 32^0 1' 92.40'' N$

Sample Preparation

After collection samples each soil sample was kept in a plastic bag and labeled according to its location. The collected samples were transferred to labeled closed

polyethylene bags and taken to the laboratory of radiation detection and measurement in the physics department, faculty of science, university of Kufa. The prepared samples for analysis were dried in an oven at 100˚C and kept for 24 hours as moisture-free. The samples were mechanically crushed using electric mill of micro soil grinded. To obtain a suitable homogeneity, the samples were sieved through a 0.8mm pore size diameter sieve to get homogeneity. All soil samples under study were kept for about a month before counting, to allow secular equilibrium to be obtained between Radon-222 and its parent Radium-226 in uranium chain; each sample was put in face to face geometry over the detector for a long time measurement.

Sample measurements

In present study, there are two techniques were used to measure natural radioactivity (U-238, Th-232 and K-40) and radon concentrations stated as follows:

Gamma-ray spectroscopy

In this work using (1L) polyethylene Marinelli beaker of constant volume and samples were packed in it. Before use, the containers were washed with dilute hydrochloric acid and rinsed with distilled water. To remove the air completely from the sample the latter is pressed on by the light cap of the Marinelli beaker and sealed with a PVC tape. The respective net weights were measured and recorded with a high sensitive digital weighting balance with a percent of ±0.01%. After that less than about (1kg) of each sample was then packed in a standard Marinelli beaker that was hermetically sealed and dry weighted to get homogeneity. The gamma spectrum from each sample was recorded using a PC-based multichannel analyzer and processed using the MAESTRO-32 software. The soil samples were put on the detector and measured, the process took 24 hours. In order to conduct calculation for specific activity for each sample, the net area under the corresponding peaks in the energy spectrum was computed by subtracting count due to background sources from the net area of a certain peak using MAESTRO-32 data analysis package. The background spectrum was measured using empty one litter polyethylene plastic Marinelli beakers on the detector and was counted under the same time for the sample measurements; because of the poor resolution of NaI(Tl) detector, at low gamma energies which haven't well-separated photo-peaks. Thus, the measuring of the activity concentrations are possible at a good separated photo-peaks at high energies as that obtained in our results from the gamma rays emitted by the progenies of Uranium-238 and Thourium-232 which are in secular equilibrium with them while, Potasium-40 was estimated directly by its gamma-line of 1460 keV. Hence the specific activity of Uranium-238 was determined using the gamma-lines 1765 keV (Bismuth-214). The corresponding results of Thourium-232 were determined using the gamma-ray lines 2614 keV (Thallium-208).

Solid state nuclear track detectors

It used the integrated passive radon dosimeter to measure radon gas concentration in the same soil that measured using NaI(Tl) detector. Solid stated detectors CR-39 (USA, Charleswater.co.un, vermason.con.un, IEC61340-5-1) and LR-115 type II (Kodak Path, France) were used with dimensions of (1×1) cm^2. A specific number was engraved on the upper right corner of the detector to collect information more easily and recognize the detectors in the different sites. The detector was fixed at the bottom of a plastic container by a two sided adhesive tape. The distance between the surfaces of the sample and reagent was 5.5 cm and the sample height was 1cm as shown in Figure 2. The long-term method of 90 days exposure was applied. After collecting the samples from the soil and demounting the detectors, we had install the tracks resulted from alpha particles emitted from radon gas and progeny into the detectors material. In order to install the tracks, we used NaOH of concentration 6.25N for CR-39 detectors and 2.5N for LR-115 type II detectors, placed in a Pyrex in a water bath (Schwabach, Germany) and equipped with an electrical heater at 70±0.1˚C for 6 hours for case CR-39 detectors, while for case LR-115type II were placed inside Pyrex at 60±0.1˚C for 1.5 hours. After that the detectors were taken out of the bath, rinsed thoroughly with distilled water to remove digging leftover from the surface, then dried out. To count alpha particle tracks on the surface of the detector, we used an optical microscope, (Kruss-mbl 2000) at magnification power of 400X. The tracks were counted in at least 30 different scene for each detector; because of radiation produced by radon decay is a pure statistically random phenomena

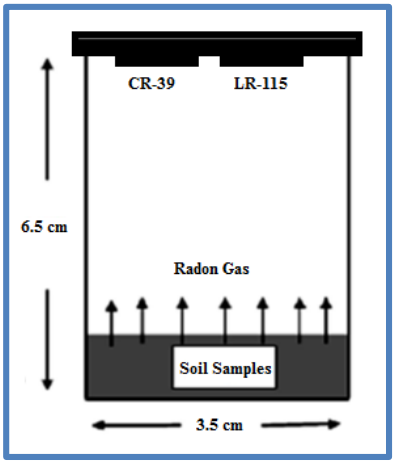

Figure 2. Schematic of the plastic container

Calculations

There are some nuclear parameters due to gamma and

alpha emitters for soil samples under study were determined stated as follows:

Gamma Emitters: specific activity for ^{238}U, ^{232}Th, ^{40}K and ^{235}U were measured in soil sample under study using gamma ray spectroscopy, as well as radiological parameters due to natural radioactivity (^{238}U, ^{232}Th and ^{40}K) also were calculated as following:

Specific Activity: The specific activity (activity concentration) of the gamma-emitting radionuclides in the sample can be calculated from the following equation [8.10]

$$A = \frac{N}{I_\gamma \, \varepsilon \, M \, T} \quad (1)$$

where, A is the specific activity of the radionuclide in the sample, N: is the net area under photo peak, ε: is the efficiency of the gamma-ray detector, I_γ: is the probability of gamma decay, M: is the weight of the measured sample in Kg , and T: is the live time for collecting the spectrum in seconds. Radionuclides ^{238}U (^{226}Ra), ^{232}Th and ^{40}K concentration obtained in different soil samples from sites in area under study. The calculated specific activity concentration for radionuclides is given by equation (1). But to calculate specific activity of ^{235}U, the following equation is used [12]:

$$A_{235_U} = \frac{A_{238_U}}{21.7} \quad (2)$$

Radium Equivalent Activity: This indices use to obtain the sum of those activities ^{238}U, ^{232}Th, and ^{40}K in (Bq/kg) and assess hazards associated with materials that it is mathematically defined as [13].

$$Ra_{eq} = A_{226_{Ra}} + 1.43\, A_{232_{Th}} + 0.077\, A_{40_K} \quad (3)$$

where A_{226Ra} , A_{232Th}, and $A_{40\,K}$ are the specific activities of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K, respectively

Hazard Index

The external hazard index (H_{ex}) for samples under investigation is given by the following equation [14]:

$$H_{ex} = \frac{A_{238_U}}{370} + \frac{A_{232_{Th}}}{259} + \frac{A_{40_K}}{4810} \quad (4)$$

Furthermore, the external irradiation radon and its short-run products pose several health hazards, in particular, for respiratory system. The health risks that the population is subject to be exposed to inside the environment result in mostly from the alpha-radioactive nuclides (radon, thorn and their decay products) exist in the air. The internal hazard index (H_{in}) can be calculated according to the following equation [15]:

$$H_{in} = \frac{A_{238_U}}{185} + \frac{A_{232_{Th}}}{259} + \frac{A_{40_K}}{4810} \quad (5)$$

Representative Level Index

Radiation hazards due to the specified radionuclides of ^{238}U(^{226}Ra), ^{232}Th and ^{40}K were assessed by another index called representative level index,($I_{\gamma r}$), The following equation can be used to calculate $I_{\gamma r}$ for soil samples under study.

$$I_{\gamma r} = \left(\frac{1}{150}\right) A_{226_{Ra}} + \left(\frac{1}{100}\right) A_{232_{Th}} + \left(\frac{1}{1500}\right) A_{40_K} \quad (6)$$

Absorbed Dose Rates

The absorbed dose rates due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) used for the description of terrestrial radiation and usually expressed in nGy/h, calculated by the following equation [10].

$$D_R = 0.462\, A_{226_{Ra}} + 0.604\, A_{232_{Th}} + 0.0417\, A_{40_K} \quad (7)$$

The Annual Effective Dose Equivalent: The annual effective dose equivalent (AEDE) can be calculated from the absorbed dose by applying the dose conversion factor of 0.7 (Sv/Gy) with an outdoor occupancy factor of 0.2 and 0.8 for indoor [16,17]

$$AEDE_{outdoor} = [D_r(mGy/h) \times 8760\, h \times 0.2 \times 0.7 Sv/Gy] \times 10^{-6} \quad (8)$$

$$AEDE_{indoor} = [\mathrm{D_r(mGy/h) \times 8760\ h \times 0.8 \times 0.7Sv/Gy}] \times 10^{-6} \quad (9)$$

Excess Lifetime Cancer Risk

This gives the probability of developing cancer over a lifetime at a given exposure level, considering 70 years as the average duration of life for human being. It is given as [8, 18]:

$$ELCR = AEDE \times DL \times RF \quad (10)$$

where AEDE is the total of Annual Effective Dose Equivalent ($AEDE_{outdoor}$ + $AEDE_{indoor}$), DL is the average Duration of Life (estimated to be 70 years) and RF is the Risk Factor (Sv) i.e. fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for the public.

Alpha Emitters

radon concentrations were measured in soil sample under study using solid state nuclear track detector CR-39 and LR-115 type II, as well as radiological parameters due to radon concentrations also were calculated as following:

Radon concentrations

Determination of radon concentration in soil samples are carried out using the following equations [19]:

$$C_{Rv} = \frac{\rho}{K \, . \, t} \quad (11)$$

where, ρ is track density on detectors by unit (tracks/cm^2), k is the calibration factor for detector in unit (track/cm^2.day per Bq/m^3) and *t* is exposure time (days) of distributed detectors.

The track density is given by the following formula [20]:

$$\rho = \frac{\text{Track number average}}{\text{Viewing area under the used light microscope}} = \frac{\bar{x}}{A} \quad (12)$$

While the calibration factor for CR-39 and LR-115 type II detectors determined by the equation (13) [21]:

$$k = \frac{1}{4}\, a\, cos\theta_c \left(2 - \frac{a_1}{a} - \frac{a}{a_o}\right) \quad (13)$$

where θ_c : is critical angle which it is equal 35° and 40° for CR-39 and LR-115 type II detectors respectively, a: is the radius of the can , $a_\circ = R_\circ \cos\theta_c, R_\circ = R - R_{\min}, a_1 = R_1 \cos\theta_c$ and $R_1 = R - R_{\max}$ .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) [22]. Consequently, K=0.0309 tracks/cm^2.day^{-1} per Bq/m^3 for LR-115 type II detector and k= 0.0328 tracks/cm^2.day^{-1} per Bq/m^3, where this calibration factor good near when compared with [23-26].

Radon exhalation rate

The radon exhalation rate in terms of area (E_A) and mass (E_M) were obtained from the following expression [27-29]:

$$E_A = \frac{C_{Rn}\, V\, \lambda}{A[t + \lambda^{-1}(e^{-\lambda t} - 1)]} \quad (14)$$

$$E_M = \frac{C_{Rn}\, V\, \lambda}{M[t + \lambda^{-1}(e^{-\lambda t} - 1)]} \quad (15)$$

where, V is the effective volume of the cup, λ is the decay constant for radon (^{222}Rn), A is the area of the cup and M is mass of the sample.

RESULTS AND DISCUSSION

Gamma spectrometry system and solid state nuclear track are used for the measuring emitted gamma rays and alpha particles from soil samples.

Gamma ray emitters and radiological parameters: The specific activity for twenty soil samples collected from different sites from of green zone in Al-Najaf city, were measured for ^{238}U, ^{232}Th, ^{40}K and ^{235}U as data shown in Table 2. The specific activities values for 238U of the samples ranged from 7.94±1.38 Bq/kg to 35.74±2.59 Bq/kg with an average value of 17.48±7.43 Bq/kg The minimum value had been found in sample (G5) while the maximum value in sample (G8). The average value of the current work is less than the worldwide average value (35 Bq/kg) calculated by defined method [30]. The specific activities of ^{232}Th were estimated to be in range from 2.79±0.52 Bq/kg to 15.56±1.17 Bq/kg with average value of 8.59±3.18 Bq/kg as it is clear from this table. The minimum value had been found in sample (G18) and the maximum value in sample (G5). The average value of the current work is less than those mentioned in literature (45 Bq/kg) [30]. The specific activities obtained for ^{40}k, were listed in Table 2. It which in turn shows the minimum value of 113.92±5.66 Bq/kg in sample (G16) and the maximum value of 423.56±10.21 Bq/kg in sample (G14). The average value was found to be 298.31±76.22 Bq/kg which is less than the average world-wide concentration (412 Bq/kg) [30].While the values of ^{235}U have been found to lie in the range of 0.23 Bq/kg to 1.64 Bq/kg with an average value of 0.80±0.07 Bq/kg. The radium equivalent activities were calculated using equation (3) and listed in Table 3. The results show that, the values lie between 22.67Bq/kg and 73.35 Bq/kg with an average value of 52.74±2.64 Bq/kg. The minimum and maximum values were found in samples (G16) and (G17). Since the acceptable value is 370 [13] therefore, the maximum value in this study lies in the acceptable level. To calculated values of Hazard index (external and internal index) and representative level index for the soil samples respectively in equations (4), (5) and (6) listed in Table 3. The average values of H_{ex}, H_{in} and $I_{\gamma r}$ in all samples under study were 0.14±0.01, 0.18±0.01 and 0.40±0.02. The hazard indexes (external and internal) and representative level index of all values for all samples studied in this work is less than unity which is the maximum value of the permissible safety limit recommended by UNSCEAR [16]. The equation (7) has been used to calculate the absorbed dose rate in air, the values obtained are listed in the table (3). The values ranged from 11.01 nGy/h to 35.69 nGy/h with an average value of 25.70±1.26 nGy/h. The population-weighted value of the absorbed dose rate in outdoor that calculated by UNSCEAR 2000 was 57 nGy/h [16] which is higher than our average value. The annual effective dose equivalent for outdoor and indoor depends directly on absorbed dose rate in air and evaluated from equations (8) and (9). The average values of $AEDE_{outdoor}$ and $AEDE_{indoor}$ were 0.031±0.001 mSv/y and 0.12±0.006 mSv/y shown in Table 3, while the worldwide average value calculated by UNSCEAR 2008 were outdoor 0.07 mSv/y and indoor 0.41 mSv/y respectively [30]. The Excess Lifetime Cancer Risk ELCR was calculated using equation (10) as shown in Figure 3. It is found that, ELCR values varies from 0.23×10^{-3} to 0.76×10^{-3} with an average value of $(0.55\pm0.02)\times10^{-3}$. Thus, the average of ELCR is higher than the world permissible value of 0.29×10^{-3} [31]. The specific activity of Uranium-238, Thourium-232 and Potasium-40 in soil samples from the studied areas was compared with those from resembling studies conducted in other countries and summary results were shown in Table 4. The comparison indicates that the values of soils under consideration are extremely low in accordance with others. It has been reached that the mean value of Thourium-232 in the current study was lower than for all countries. While Uranium-238 is found that it is lower than for all countries but it is higher to Kuwait. Among the value of Potasium-40 concentration, the value is high comparing with Oman, Jordan and Syria but it is

lower than other counters as shown in Table 4. The disparities in the radioactivity concentrations that are present in the soil of many locations all over the world depend upon the geological and geographical conditions of that area and the extent of fertilizer applied to the agriculture lands. From the results above such as specific activity and radiological parameters, it can be concluded according to the report of European Commission in Radiation Protection that the area of the current study is safe and harmless and posing no significant radiological threat to the population [32].

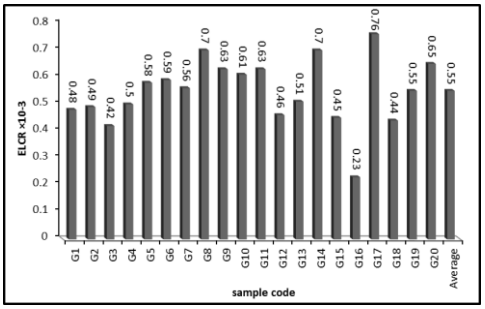

Figure 3. ELCR in soil samples under study

TABLE 2. Specific activity of radionuclides in soil samples collected from study area

No.	Sample code	U-238	Th-232	K-40	U-235
1	G1	8.177±1.34	5.06±0.64	373.79±9.48	0.37
2	G2	9.24±1.46	12.20±1.0	277±8.35	0.42
3	G3	5.15±10.9	8.74±0.9	288.79±8.58	0.23
4	G4	15.88±1.97	5.95±0.7	305.53±9.01	0.73
5	G5	7.94±1.38	15.56±1.2	338.71±10.09	0.36
6	G6	13.93±1.87	12.04±1.0	335.96±9.29	0.64
7	G7	15.08±1.96	6.89±0.8	363.67±10.02	0.69
8	G8	35.74±2.59	8.80±0.8	267.73±7.42	1.64
9	G9	22.35±1.95	8.36±0.8	335.27±8.54	1.02
10	G10	19.77±2.21	9.22±0.9	334.14±9.48	0.91
11	G11	18.84±1.87	8.54±0.7	375.54±8.72	0.86
12	G12	13.09±1.78	7.25±0.8	272.83±8.48	0.60
13	G13	16.32±1.78	10.76±0.8	235.95±7.06	0.75
14	G14	18.54±2.04	10.69±0.9	423.56±10.21	0.85
15	G15	22.28±2.11	5.41±0.6	184.74±6.35	1.02
16	G16	9.81±1.59	2.86±0.5	113.92±5.66	0.45
17	G17	27.94±2.58	10.59±0.9	393.07±10.11	1.28
18	G18	15.37±2.03	2.79±0.5	283.84±9.13	0.70
19	G19	24.61±2.41	10.75±0.9	193.80±7.07	1.13
20	G20	29.61±2.62	9.39±0.9	268.41±8.25	1.36
Average± S.D		17.48±7.43	8.59±3.2	298.31±76.22	0.80±0.07

TABLE 3. Radiological parameters due to gamma ray emitters for samples in study area

No.	Sample Code	Ra_{eq} (Bq/kg)	Hazard Index		$I_{\gamma r}$	Dr (nGy/h)	AEDE (mSv/y)	
			H_{ex}	H_{in}			Outdoor	Indoor
1	G1	44.19	0.11	0.14	0.35	22.42	0.027	0.10
2	G2	48.01	0.12	0.15	0.36	23.18	0.028	0.11
3	G3	39.88	0.10	0.12	0.31	19.70	0.024	0.09
4	G4	47.91	0.12	0.17	0.36	23.67	0.029	0.11
5	G5	56.27	0.15	0.17	0.43	27.19	0.036	0.13
6	G6	57.01	0.15	0.19	0.43	27.71	0.033	0.13
7	G7	52.93	0.14	0.18	0.41	26.29	0.032	0.12
8	G8	68.93	0.18	0.28	0.50	32.99	0.040	0.16
9	G9	60.12	0.16	0.22	0.45	29.35	0.036	0.14
10	G10	58.68	0.15	0.21	0.44	28.63	0.035	0.14
11	G11	59.96	0.16	0.21	0.46	29.52	0.036	0.14
12	G12	44.46	0.12	0.15	0.34	21.80	0.026	0.10
13	G13	49.87	0.13	0.17	0.37	23.87	0.029	0.11
14	G14	66.44	0.17	0.22	0.51	32.68	0.048	0.16
15	G15	44.24	0.11	0.17	0.32	21.26	0.026	0.10
16	G16	22.67	0.06	0.08	0.16	11.01	0.013	0.05
17	G17	73.35	0.19	0.27	0.55	35.69	0.043	0.17
18	G18	41.21	0.11	0.15	0.31	20.62	0.025	0.10
19	G19	54.90	0.14	0.21	0.40	25.94	0.031	0.12
20	G20	63.70	0.17	0.25	0.47	30.54	0.037	0.14
Average±S.D		52.74±2.64	0.14±0.01	0.18±0.01	0.40±0.02	25.70±1.26	0.031±0.001	0.12±0.006

TABLE 4. Comparison of activity concentration levels in different area of the world

No.	Country	Average of specific Activity (Bq/kg^{-1})			Ref.
		^{238}U	^{232}Th	^{40}K	
1	Oman	29.7	15.9	225	[33]
2	Kuwait	13.3	10	370	[34]
3	Jordan	49	27	291	[35]
4	Egypt	37	18	320	
5	Iran	28	22	640	[16]
6	Syria	23	20	270	
7	Present study	17.48	8.59	298.31	---------

Alpha particles emitters and radiological parameters

To achieve the aim of this study, we studied radon gas concentrations in soil samples of Green Zone in Al-Najaf, Iraq using two types of Solid state nuclear track detector. We measured radon concentrations in same of the soil samples of in order to establish a correlation between radon concentrations using CR-39 and LR-115 type II detectors Also, we calculated some of radiological parameters due to radon in soil samples under study. The following are the results of the current study: The results of radon concentrations in the soil for selected in area of study using CR-39 detectors, LR-115 type II and average are shown in Table (5). Figure 4) shows the relationship of the radon concentrations in soil using CR-39 detector and LR-115 Type II detector. From presentation of data in Figure 4, it is found that a very good correlation exist between them (r=0.93). Therefore, it may be used the average value of radon concentrations for two detectors. The average of radon concentrations ranged between 308.15 Bq/m^3 in sample (G3) to 940.16 Bq/m^3 in sample (G8) with an average value of 579.65±33.30 Bq/m^3. The obtained values of all samples were lower than the accordable limit, usually ranges from 0.4 to 40 kBq/m^3 [36]. Variation was given, in values concentrations of radon in the soil of the study area, because of the nature of the soil and its components, which may vary from one area to another, as well as the difference in the concentrations of uranium and radium since they are the main source of radon.

TABLE 5. Radon concentrations in study area using CR-39 &LR-115 type II

Sample Code	Radon Concentrations (Bq/m^3)		
	CR-39	LR-115	Average
G1	429.70±25.32	431.49±20.57	430.60
G2	441.63±25.66	470.72±21.48	456.18
G3	310.34±21.51	305.97±17.32	308.15
G4	513.25±27.67	564.87±23.53	539.06
G5	463.12±26.28	407.96±20.00	435.54
G6	513.25±27.67	596.25±24.18	554.75
G7	537.12±28.30	533.49±22.87	535.30
G8	931.02±37.27	949.29±30.51	940.16
G9	575.32±29.29	525.64±22.70	550.48
G10	692.29±32.13	525.64±22.70	608.97
G11	596.81±29.84	564.87±23.53	580.80
G12	572.93±29.23	580.56±23.86	576.75
G13	763.91±33.76	690.39±26.02	727.15
G14	561.00±28.93	588.40±24.02	574.70
G15	680.36±31.86	651.17±25.27	665.76
G16	405.83±24.60	392.27±19.61	399.05
G17	763.91±33.76	784.54±27.73	774.23
G18	537.12±28.30	572.71±23.69	554.92
G19	620.68±30.43	635.48±24.96	628.08
G20	728.10±32.95	776.69±27.59	752.40
	Average± S.D		**579.65±33.30**

Table 6 shows the values of radon exhalation rates in terms of area (E_A) and radon exhalation rates in terms mass (E_M). From this table, it is found that the values of E_A vary from 219.79 mBq/m^2.h in sample (G3) to 670.59 mBq/m^2.h in sample (G8) with a mean value of 413.44±22.85 mBq/m^2.h; while, the E_M vary from 23.48 mBq/kg.h in sample (G3) to 57.34 mBq/kg.h in sample (G20) with a mean value of 38.51±1.85 mBq/kg.h. The values of E_A and E_M of radon reported in Table 6 are less than the values reported in the world average (118.8 Bq/m^2.h) [16]

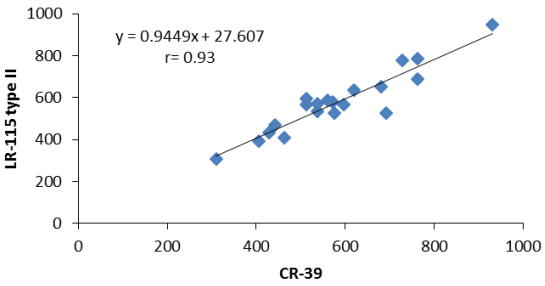

Figure 4. Correlation between CR-39 and LR-115 type II detectors

TABLE 6. Radon Exhalation rates for the soil samples collected from study area

Sample Code	Radon Exhalation rates	
	E_A (mBq/m^2.h)	E_M (mBq/m^2.kg)
G1	307.13	28.12
G2	325.38	29.79
G3	219.79	23.48
G4	384.50	33.61
G5	310.66	29.87
G6	395.69	36.23
G7	381.81	34.96
G8	670.59	53.73
G9	392.64	39.74
G10	434.36	37.97
G11	414.27	36.21
G12	411.38	39.55
G13	518.66	47.50
G14	409.92	35.83
G15	474.87	39.70
G16	284.63	26.06
G17	552.24	50.57
G18	395.81	44.77
G19	447.99	45.34
G20	536.67	57.34
Average± S.D	413.44±22.85	38.51±1.85

The average of all values of soil gas radon concentration in Green Zone in Al-Najaf, Iraq are lower than that found in India [37], Saudi Arabia [38], Egypt [39], Sudan [40] Iraq [41] and Turkey [42]. Based on above results, data plotted in Figure 5, have very good linear correlation (r= 0.91) between activity concentrations of 238U and 222Rn. The results of the present work indicate that it is possible to estimate the specific activity of 238U radon concentrations (222Rn) in soil under investigation using specific activity of 238U according to radon concentrations (222Rn) given by the linear equation: $^{238}U = 0.05\ ^{222}Rn - 11.56$

The results for gamma emissions (238U, 232Th, 40K and 235U) and alpha emissions (222Rn) were varied in all soil samples of area under study were lower than worldwide average levels. So, the Soil of Green Zone in Al-Najaf, Iraq do not pose any health hazards to the residents.

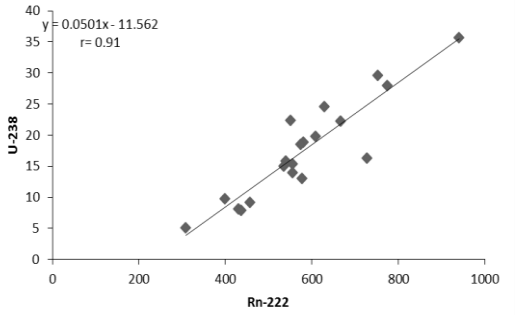

Figure 5. Correlation between Average value of Uraniun-238 and Radon-222 concentrations

CONCLUSION

The twenty soil samples collected from Green Zone in Al-Najaf, Iraq were analyzed using gamma-ray spectrometry (NaI(Tl) detector) and solid state nuclear track (CR-39 and LR-115 type II detectors). It is found that the average values of specific activities for 238U, 232Th and 40K were less than the world-wide values for UNSCEAR [16, 30]. Moreover, Raeq is another good indicator, which is less than acceptable value (370 Bq/kg), and the mean value of annual effective dose equivalent 20.92±0.397 ⁄ which is less than the average value of UNSCEAR [30]. The values of the hazard indices for all soil samples were less than unity for all soil samples. The mean value of AEDE for indoor and outdoor were less than the average value of UNSCEAR [30], But value obtained for ELCR were within the permissible limits of 0.29×10-3. All results of radon concentrations in the soil of area under study were much lower than the studies globally conducted in Arabic countries. The radon exhalation rate in the samples is less than the allowed maximum level of 118.8 Bq/m2.h [16]. Avery good correlation for measuring radon concentrations in soil were found by two detectors CR-39 and LR-115 type II. The correlation between radon concentration in soil and specific activity of uranium-238 which is equal r=0.91. Finally, it is concluded that these results of gamma emitters and alpha emitters in soil of Green Zone in Al-Najaf, Iraq do not constitute a health risk to the resident.

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Persian Abstract

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چکیده

در این مقاله میزان تشعشعات رادیواکتیو شامل اورانیوم، توریم، پتاسیم و ... رسیده به مردم در ناحیه امن شهر نجف مورد بررسی قرار گرفته است. در این تحقیق سه تکنولوژی جهت اندازه گیری تشعشعات مورد استفاده قرار گرفت. همچنین میزان خطر مورد ارزیابی قرار گرفت. با توجه به داده‌های بدست آمده میزان تشعشعات در این شهر در حد مجاز بوده و خطری مردم این ناحیه را تحدید نمی‌کند.