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Study of the Radiological Doses in Karbala city

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▶ ***Short Report***

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ABSTRACT

Background: Man-made radionuclides, which are present in environment, have been created by human activities and added to the inventory of natural radionuclides for example ^{3}H, ^{131}I, ^{129}I, ^{137}Cs, ^{90}Sr and ^{239}Pu, in spite of the amount added is little compared to natural quantities. The aim of this study is to estimate the levels of radiological doses in the soil samples collected from different locations in Kerbala city, Iraq. ***Materials and Methods:*** Thirty soil samples were collected from different sites of Karbala city and gamma-ray spectroscopy system with NaI (Tl) "1.5×2" detector in low-background and 24 hours used to achieve the results. ***Results:*** The average values of absorbed gamma-ray dose rate, annual effective dose equivalent and annual gonadal dose equivalent were found to be 14.09±0.32, 19.59±0.39 and 112.81±2.25 respectively. The average values of gamma representative level index and external hazard index resulting from natural radionuclides for all samples in the study area were 0.25±0.005 and 0.09±0.002 respectively. ***Conclusion:*** The obtained results in current work were compared with some results of soil samples in literature over the world. They do not exceed the upper limit calculated by UNSCEAR reports.

Keywords: *Radiation, annual effective dose, absorbed dose, gonadal dose, NaI.*

INTRODUCTION

Naturally radionuclides materials that have very long half-lives include the ^{238}U, ^{235}U and ^{232}Th chains, which are distributed widely on land and in the ocean. They were already present when the earth was formed about 4.5 billion years ago and each of these nuclides terminates in stable isotopes of Pb nuclide(1). It is widely distributed on earth and is in measurable quantities in many building materials (2). Man-made radionuclides, which are also present in environment, have been created by human activities and added to the inventory of natural radionuclides, for example ^{3}H, ^{131}I, ^{129}I, ^{137}Cs, ^{90}Sr and ^{239}Pu, although the amounts added are low compared to the quantities of naturally occurring radionuclides. In 1996, International Atomic Energy Agency estimated that 20% of the radiation dose in the environment comes from cosmic rays and man-made processes while 80% is from natural radionuclides (3). The presence of the radionuclides depends on the geological and geographical conditions, so different levels of radionuclides are found in soil samples in different regions in the world (4).

The aim of this study is to estimate the levels of radiological doses as absorbed gamma-ray dose rate, annual effective dose equivalent and annual gonadal dose equivalent in soil samples collected from different locations in Kerbala, Iraq. Moreover, radiological hazard indices as gamma representative level index and external hazard index are calculated and compared with the results for different regions in the world.

MATERIALS AND METHODS

Description of the study area

Karbala is a city in central Iraq and the capital of Karbala Governorate. It is located about 100 km southwest of Baghdad between latitude 32° 37′ 0″ N and longitude 44° 2′ 0″ E. Many studies have been carried out to analyse the soil of Karbala city for its physical, chemical and mineralogical properties. The results of these studies suggest that Karbala soil consists of clay, silt, and sand in ratios of 8.7%, 20.2% and 71.1% respectively. Chemical analysis shows that the Calcium and Sulphate ions are most common followed by Bicarbonate, Chloride, Sodium, Magnesium and Potassium [5-6].

Samples collection and preparation

A total of 30 soil samples were collected from different sites in Karbala between October and November 2014. The samples were collected from random places, as in figure 1, with a depth of 5 cm. Table 1 show the sampling location in the area under study. The samples were crushed and dried to ensure that any significant moisture was removed. Next, a sieve with 500 μm diameter holes was used to obtain a homogeneous powder and then 1 kg of each sample was weighed out. The samples were packed into 1-liter polyethylene plastic Marinelli beakers. The beakers were sealed with tape and stored for about 1 month before analysis to allow secular equilibrium to be attained between ^{222}Rn and its parent ^{226}Ra in the uranium chain [7].

Gamma-ray spectrometry

A gamma spectrometry system was used to measure the gamma rays emitted from the soil samples. The system consists of a NaI (TI) scintillation detectorfrom Leybold Didactic GmbH (Germany); it is surrounded by a shield of lead of 4 cm thickness to reduce the background gamma radiation to a minimum. The detector was energy-calibrated using a set of standard gamma-ray radioactive sources including ^{137}Cs (661.66 keV), ^{22}N (511, 1274 keV) and ^{60}Co (1173.24 and1332.5 keV) to cover a sufficient range of photo peaks.

The energy and efficiency calibration for the detector were achieved using the above sources. The energy calibration showed a straight line with excellent correlation (100%) as illustrated in figure 2(A), while the efficiency calibration showed an exponential relationship with correlation of (99.7%) as in figure 2(B). The photo peaks of ^{214}Bi (609 keV), ^{228}Ac (338 keV) and ^{40}K (1460 keV) were used to specifying the activity of ^{238}U, ^{232}Th and ^{40}K in the soil samples.

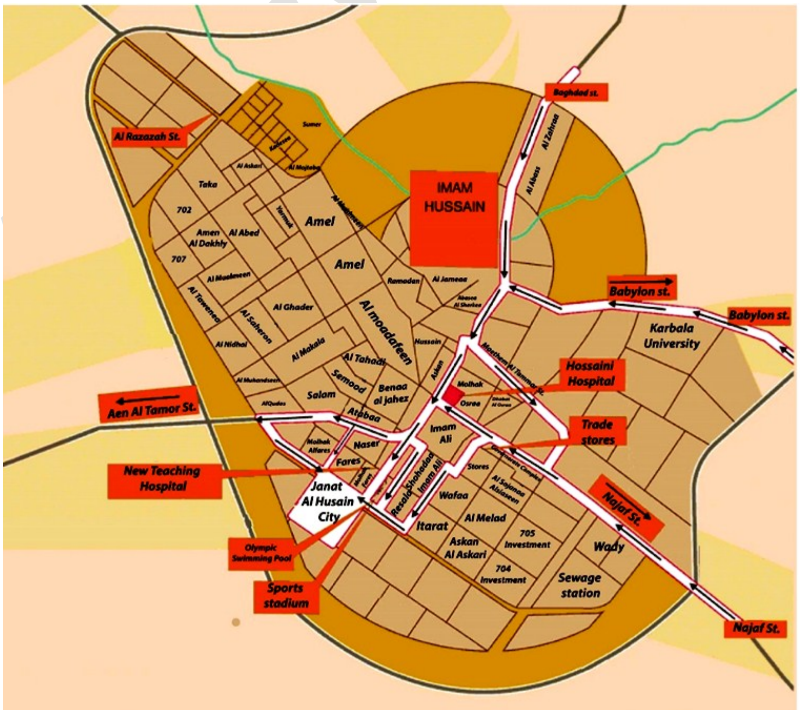

Figure 1. Distribution of sample collection in Karbala.

Table 1. Location of the thirty soil samples collected from different districts of Karbala city.

Sample No.	Sample Code	Position		Location
		Longitude	Latitude	
1	Sa1	44.015944	32.614226	Jameaa
2	Sa2	44.017038	32.587162	Benaa Jahez
3	Sa3	43.997273	32.593584	Semood
4	Sa4	44.004239	32.592088	Tahady
5	Sa5	44.007504	32.576145	Naser
6	Sa6	44.012931	32.560085	Resala
7	Sa7	43.979555	32.614472	Askaree
8	Sa8	44.001885	32.622182	Moalmeen
9	Sa9	44.022197	32.589249	Askan
10	Sa10	44.041735	32.590336	Molhak
11	Sa11	44.042898	32.575158	Industrial City
12	Sa12	44.0228829	32.578023	Imam Ali
13	Sa13	44.021574	32.554645	Itarat
14	Sa14	44.019797	32.572244	Shohadaa Imam Ali
15	Sa15	44.003453	32.601484	Shohadaa Moadafeen
16	Sa16	44.006756	32.603366	Moadafeen
17	Sa17	43.966443	32.618725	Amen dakhly
18	Sa18	44.032509	32.584459	Osraa
19	Sa19	44.01807	32.635158	Abass
20	Sa20	43.986353	32.627845	Amel
21	Sa21	44.003696	32.565916	Fares
22	Sa22	43.999718	32.58.265	Atebaa
23	Sa23	43.99763	32.584237	Salam
24	Sa24	44.048823	32.641497	Zahraa
25	Sa25	44.026011	32.56712	Wafaa
26	Sa26	44.011411	32.604433	Ramadan
27	Sa27	43.968185	32.638977	Taka
28	Sa28	43.98178	32.639969	Kadesea
29	Sa29	43.987539	32.580592	Qudos
30	Sa30	43.990035	32.641174	Mojtaba

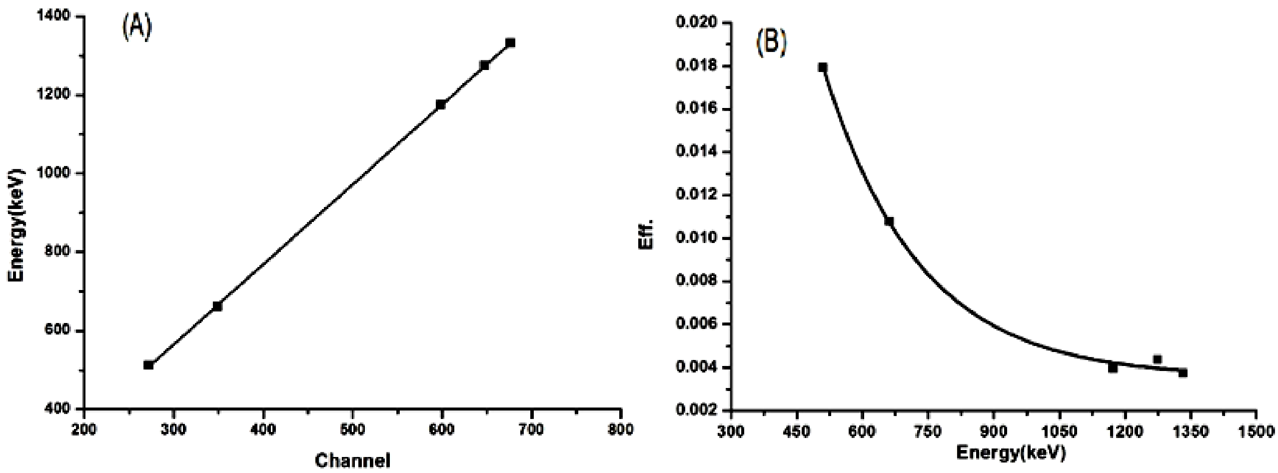

Figure 2. (A) Energy calibration for NaI detector. **(B)** The efficiency calibration for NaI detector.

Background measurement

Before the analysis of the samples, the gamma background was determined with an empty Marinelli beaker for 24 hours in the same manner as that used for samples. The background was subtracted from the measured gamma- ray spectrum of each sample.

Absorbed gamma-ray dose rate (D)

The main contribution to the absorbed dose rate in the air comes from terrestrial gamma-ray radionuclides present in trace amounts in the soil. The measurements of the dose rate depends on measurements of specific activity concentrations of radionuclides, mainly ^{238}U, ^{232}Th and ^{40}K families. The United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) report explained that the absorbed dose rate D in air 1 meter above the ground surface can be given by [8]:

$$D(nGy/h) = 0.462\, A_{^{238}U} + 0.604\, A_{^{232}Th} + 0.0417\, A_{^{40}K} \quad (1)$$

Where $A_{^{238}U}$, $A_{^{232}Th}$ and $A_{^{40}K}$ are the specific activities of ^{238}U, ^{232}Th and ^{40}K families in (Bq/kg) respectively. The dose convention factors of ^{238}U, ^{232}Th and ^{40}K are 0.462, 0.604 and 0.0417 in (nGy/h)/(Bq/kg) respectively.

Annual effective dose equivalent (AEDE)

The calculation of effective dose equivalent depends on the value of the absorbed dose rate in air. To accomplish these calculations, account must be taken of the conversion coefficient from the absorbed dose rate in air to the effective dose equivalent received by an adult and the occupancy fraction. The value of these two parameters vary depending on the climate at the area under consideration and the average age of the population. In the UNSCEAR 2008 report, the indoor and outdoor conversion coefficient is 0.7 Sv/Gy for both males and females and the 0.2 for the outdoor occupancy fraction. Therefore, the outdoor AEDE can be given as follows [8]:

$$AEDE(\mu Sv/y)=D(nGy/h)\times 8760(h)\times 0.2\times 0.7(Sv/Gy)\times 10^{-3} \quad (2)$$

Annual gonadal dose equivalent (AGDE)

The organs of interest by UNSCEAR include the thyroid, lungs, bone marrow, bone surface cell, gonads and the female breast [8]. Hence, the annual gonadal dose equivalent can be given by [9]:

$$AGDE(\mu Sv/y) = 3.09\, A_{^{238}U} + 4.18\, A_{^{232}Th} + 0.314\, A_{^{40}K} \quad (3)$$

Gamma representative level index (I_{yr})

The gamma radiation representative level index associated with natural radionuclides was evaluated using the following equation [10]:

$$I_{yr} = \frac{A_{^{238}U}}{150} + \frac{A_{^{232}Th}}{100} + \frac{A_{^{40}K}}{1500} \quad (4)$$

Hazard index (H_{ex})

The external hazard index, is defined as [11]:

$$H_{ex} = \frac{A_{^{238}U}}{370} + \frac{A_{^{232}Th}}{259} + \frac{A_{^{40}K}}{4810} \leq 1 \quad (5)$$

The value of this index must be less than unity in order to keep the radiation hazard insignificant. A hazard index equal to unity corresponds to the upper limit of radium equivalent activity of 370 (Bq/kg).

RESULTS AND DISCUSSION

The absorbed dose rate values for the samples were calculated and are listed in table 2. They ranged from 9.16±0.28 to 24.44±0.37 nGy/h with an average value of 14.09±0.32 nGy/h. In the literature, the average absorbed dose rate was reported to be 37.15 nGy/h in Jordan [12], and 64.5±27.1 nGy/h in Thailand [13] and 28.90±2.1 nGy/h in the Fuel Fabrication Facility in AlTuwaitha, Iraq [14]. The population-weighted value of the outdoor absorbed dose rate given by UNSCEAR 2000 was 59 nGy/h.

The AEDEs for the soil samples from different areas are shown in table 2. The values varied from 11.23±0.34 to 29.97±0.45 µSv/y with a mean value and standard deviation of 19.59±0.39 µSv/y. The average AEDEs were calculated for soil sample in other countries, including 136 µSv/y in Turkey [15], and 32.33 µSv/y in Saudi Arabia [16]. The worldwide average value given by UNSCEAR 2008 was 70 µSv/y.

Moreover, the obtained values of annual gonadal dose equivalent are listed in table 2. The values varied from 63.32±1.96 to 172.56±2.62 µSv/y with mean value and standard deviation of 112.81±2.25 µSv/y. In the literature, mean values of soil samples where reported to be 2398 µSv/y for Egypt [17], and 182.52 µSv/y for Saudi Arabia [16].

Furthermore, table 2 shows the obtained values of gamma index results for our samples. The minimum, maximum and mean values for this index were 0.15±0.004, 0.39±0.006 and 0.25±0.005 (Bq/kg), respectively. The literature values varied from 0.248 and 2.735 (Bq/kg) for India [18] and 0.09 to 0.72 (Bq/kg) for Nigeria [19]. It is clear that our values do not exceed the upper limit for I_{yr}, which is unity [20].

Finally, the hazard index varied from 0.06±0.002 to 0.14±0.002 with a mean of 0.09±0.002, which are less than 1safe limit (see table 2). The mean hazard values index for soil samples were reported to be 0.25±0.01 for Jordan [12], 0.38±0.16 for Thailand [13], and 0.13 for Saudi Arabia [16].

Table 2. The radiological doses and hazard indices for all soil samples.

Sample code	D (nGy/h)	AEDE (µSv/y)	AGDE (µSv/y)	I_{yr} (Bq/kg)	H_{ex}
Sa1	20.69±0.35	25.37±0.43	145.64±2.47	0.33±0.006	0.12±0.002
Sa2	13.38±0.30	16.41±0.37	94.18±2.13	0.21±0.005	0.08±0.002
Sa3	15.49±0.32	19.00±0.39	109.76±2.27	0.25±0.005	0.09±0.002
Sa4	14.13±0.31	17.33±0.38	99.57±2.17	0.22±0.005	0.08±0.002
Sa5	15.06±0.31	18.47±0.38	106.66±2.21	0.24±0.005	0.09±0.002
Sa6	16.66±0.32	20.43±0.39	118.14±2.28	0.27±0.005	0.10±0.002
Sa7	9.16±0.28	11.23±0.34	63.32±1.96	0.15±0.004	0.06±0.002
Sa8	16.04±0.32	19.67±0.39	113.28±2.25	0.25±0.005	0.09±0.002
Sa9	19.21±0.34	23.56±0.42	135.06±2.41	0.30±0.005	0.11±0.002
Sa10	17.71±0.32	21.72 ±0.39	126.21±2.30	0.28±0.005	0.10±0.002
Sa11	12.67±0.30	15.54±0.37	89.39±2.13	0.20±0.005	0.07±0.002
Sa12	24.44±0.37	29.97±0.45	172.56±2.62	0.39±0.006	0.14±0.002
Sa13	14.22±0.31	17.44±0.38	100.70±2.17	0.23±0.005	0.08±0.002
Sa14	15.56±0.31	19.08±0.38	109.59±2.23	0.25±0.005	0.09±0.002
Sa15	17.05±0.32	20.91±0.39	121.41±2.28	0.27±0.005	0.10±0.002
Sa16	12.66±0.30	15.53±0.37	89.31±2.13	0.20±0.005	0.07±0.002
Sa17	15.77±0.32	19.34±0.39	111.97±2.25	0.25±0.005	0.09±0.002
Sa18	14.14±0.31	17.34±0.38	99.59±2.18	0.22±0.005	0.08±0.002
Sa19	24.17±0.37	29.64±0.45	169.96±2.61	0.38±0.006	0.14±0.002
Sa20	9.84±0.28	12.07±0.34	69.75±1.96	0.16±0.004	0.06±0.002
Sa21	17.58±0.33	21.56±0.40	123.76±2.32	0.28±0.005	0.10±0.002
Sa22	13.87±0.30	17.01±0.37	97.89±2.14	0.22±0.005	0.08±0.002
Sa23	13.30±0.30	16.31±0.37	94.28±2.16	0.21±0.005	0.08±0.002
Sa24	21.71±0.35	26.63±0.43	152.52±2.51	0.34±0.006	0.13±0.002
Sa25	19.56±0.34	23.99±0.42	138.49±2.43	0.31±0.005	0.11±0.002
Sa26	16.03±0.32	19.66±0.39	112.98±2.28	0.25±0.005	0.09±0.002
Sa27	16.22±0.32	19.89±0.39	114.67±2.26	0.26±0.005	0.09±0.002
Sa28	17.48±0.33	21.44±0.40	123.53±2.35	0.28±0.005	0.10±0.002
Sa29	11.04±0.28	13.54±0.34	78.54±2.00	0.17±0.004	0.06±0.002
Sa30	14.35±0.31	17.60±0.38	101.70±2.18	0.23±0.005	0.08±0.002
Min	9.16±0.28	11.23±0.34	63.32±1.96	0.15±0.004	0.06±0.002
Max	24.44±0.37	29.97±0.45	172.56±2.62	0.39±0.006	0.14±0.002
Mean±S.D.	14.09±0.32	19.59±0.39	112.81±2.25	0.25±0.005	0.09±0.002

CONCLUSION

The radiological doses (absorbed gamma-ray dose rate, AEDE and annual gonadal dose equivalent) from soil samples collected from Karbala were measured. The values obtained were within the recommended safety limits. Since the representative level index and the external hazard index less than unity, there is no significant radiological hazard for any of the soil samples in the study area.

Conflicts of interest: *Declared none.*

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