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Measurement of Natural and Artificial Radioactive Elements in Soil at the Southern Al-Dora Region, Baghdad Governorate, Iraq

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Abstract: The specific activity of natural and artificial radioactive elements in nine soil samples at different locations of southern Al-Dora region, Baghdad governorate, Iraq were measured and analysed by using a gamma ray detector NaI (Tl). The average activity concentrations of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs are found to be 38.22 Bq/Kg, 42.99 Bq/Kg, 16.64 Bq/Kg and 2.92 Bq/Kg, respectively. Several radiological hazard indices including radium equivalent activity (Ra_{eq}), absorbed dose rate (D), internal (H_{in}) and external (H_{ex}) hazard indices, internal ($AEDE_{in}$) and external ($AEDE_{ex}$) annual effective dose equivalent and gamma ray index ($I\gamma r$) are calculated. The findings of all radiological hazard indices are lower than their international values. This study discloses that most locations in study area are safe from any radiological risks.

Keywords: Natural Radionuclide, Artificial Radionuclide, Activity Concentration, NaI (Tl) Detector, Baghdad governorate

حساب تركيز النظائر المشعة الطبيعية والصناعية لنماذج تربة جنوب منطقة الدورة في محافظة بغداد، العراق

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الملخص: تم قياس وتحليل النشاط المحدد للعناصر المشعة الطبيعية والاصطناعية في تسع عينات للتربة في مواقع مختلفة من منطقة الدورة الجنوبية، محافظة بغداد، العراق باستخدام كاشف أشعة كاما NaI (Tl). تم العثور على متوسط تركيزات النشاط من U^{238} وTh^{232} و K^{40} و C^{137} لتكون 38.22 بيكريل/ كغم و42.99 بيكريل/ كغم و16.64 بيكريل/ كغم و2.92 بيكريل/ كغم على التوالي. العديد من مؤشرات الخطر الإشعاعي بما في ذلك نشاط مكافئ الراديوم (Ra_{eq}) ، ومعدل الجرعة الممتصة (D) ، ومؤشرات الخطر الداخلية (H_{in})

والخارجية (H_{ex}) ، الداخلية ($AEDE_{in}$) والخارجية ($AEDE_{ex}$) المكافئ الفعال للجرعة السنوية ومؤشر أشعة كاما ($I\gamma_r$)) محسوبة. إن نتائج جميع مؤشرات الخطر الإشعاعي أقل من قيمها الدولية. تكشف هذه الدراسة أن معظم المواقع في منطقة الدراسة آمنة من أي مخاطر إشعاعية.

الكلمات المفتاحية: النويدات المشعة الطبيعية، النويدات المشعة الاصطناعية، تركيز النشاط، كاشف NaI (Tl) ، محافظة بغداد.

Introduction

Human beings are suffer from two types of radiation sources which are classified as natural sources (96%) and artificial sources (4%) (Elsaman, Omer, Seleem, & El-Taher, 2018; Taskin et al., 2009) . Naturally occurring radioactive materials (NORM) are common in numerous components of the earth's crust (UNSCEAR, 2011) . The concentration of natural radionuclides relies on geological condition (Elsaman et al., 2018) . The radionuclide of natural radioactive which individuals obtain largely from uranium-series of (^{238}U), thorium series of (^{232}Th) and their daughters resulting from decay in different radioactive series and potassium-40 (^{40}K) which is one of the natural radionuclides has non-series decay (Jitpukdee, Quinram, & Kranrod, 2019) . The radionuclides of ^{238}U, ^{232}Th and ^{40}K which have long half-lives comparable with the lifetime of the earth are excessive interest as they lead to radiological hazards due to gamma ray emissions (N. Ahmad, Jaafar, & Alsaffar, 2015) . Anthropogenic radionuclides such as ^{137}Cs (half-life time, 30 years) are released due to nuclear accidents (such as Chernobyl accident), military and medical applications (Sarkar, Ali, Paul, Bhuiyan, & Islam, 2011) . Artificial radionuclides discharged from nuclear accidents can be recollected in soil. It is vital to identify, quantify, evaluate and manage the radiological hazards of radioactivity (Alazemi, Bajoga, Bradley, Regan, & Shams, 2016) . Radiological risks of radioactivity can cause health problems for exposed individuals. There is therefore growing concern about the health risks associated with exposure to the natural sources of radiation in our environment. Several studies have been carried out about radiological health hazards assessment to achieve reliable database on the health problems of radiation (Akhtar, Tufail, Ashraf, & Iqbal, 2005; Alhiall & Alsalihi, 2018; Alsalihi & Abualhiall, 2019; Aswood, Abojassim, & Al Musawi, 2019; Bolca, Sac, Cokuysal, Karalı, & Ekdal, 2007; Jebur, Al-Sudani, & Fleifil, 2019; Jitpukdee et al., 2019; Kadhim & Ridha, 2019) . It is important for measuring the radiation parameters that affect the Iraqi population because the extreme exposure to radiation may cause main health complications such as carcinogenesis (Cember & Johnson, 2009) . The current research aims to measure concentration of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in soil and associated radiological risks in Al-Dora region, Baghdad, Iraq.

Research Methodology

Sample collection and preparation

Nine soil samples were collected from different locations (AL-Mokhabrat, Abo desheer 1, Abo desheer 2, Kafaat AL-Saha, AL_Saha, AL_Umarat, 60 Street, AL-Mekanic and AL-Shurta1) in southern Al-

Dora region, Baghdad governorate, Iraq. All nine samples were collected in August 2018. Each collected sample was about 1kg in weight and kept in a plastic bag with label of sample information (sample weight, sample code, sample location). After that, all nine soil samples were dried in an oven at 100 ^{0}C for 10 hours to remove any moisture. Dried samples were ground, homogenized and sieved through a 200 μm mesh size. Each sample was put in Marinelli beaker with weight of 1 kg and stored for about 4 weeks in order to achieve secular equilibrium.

Experimental technique

Radioactivity measurement of soil samples was carried out using gamma ray spectrometer with 3x3 inch NaI (Tl) detector. The detector which was totally insulated by lead shield was calibrated for an hour as explained in previous work (Rejah, 2017) . The ^{238}U and ^{232}Th were detected by utilizing their daughters ^{214}Pb (351.93 keV) and ^{212}Pb (238.63 keV), respectively. For ^{40}K (1460.81 keV) and ^{137}Cs (661.65 keV) were determined directly by the detector. Marinelli beaker filled with 1 kg of prepared soil sample was placed over the NaI (Tl) detector within the lead shielding and counted for 3600 seconds.

Measurement Parameters

Specific activity (As)

The specific activity (As) of each radionuclide was determined by Eq.1 [8]:

$$A_s(\frac{Bq}{Kg}) = \frac{N}{t \times P_\gamma \times \varepsilon \times m} \quad \text{... (1)}$$

Where: N is the net count, t is time measurement (1 hour), P_γ is gamma-ray emission probability, ε is detector efficiency and m is sample mass (1 Kg).

Radium equivalent activity (Ra_{eq})

Radium equivalent activity is applied to determine the risks related with samples that have ^{226}Ra, ^{232}Th and ^{40}K and is introduced by Eq.2 (Jebur et al., 2019) .

$$Ra_{eq}(\frac{Bq}{Kg}) = A_U + 1.43A_{Th} + 0.077A_k \quad \text{... (2)}$$

Where, A_U, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K in Bq/kg, respectively.

The gamma absorbed dose rates

The equation of gamma adsorbed dose rate in air is giving by Eq.3 (A. Y. Ahmad, Al-Ghouti, AlSadig, & Abu-Dieyeh, 2019) .

$$D(\frac{nGy}{h}) = 0.462A_U + 0.604A_{Th} + 0.0417A_k \quad ... (3)$$

The external (H_{ex}) and internal (H_{in}) hazard indices

The equations of external and internal hazard indices are given by Eq.4 and Eq.5 (Salih, 2018) .

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad ... (4)$$

$$H_{in} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad ... (5)$$

The internal ($AEDE_{in}$) and external ($AEDE_{ex}$) annual effective dose equivalent

$$AEDE_{ex}(\frac{msv}{y}) = D \times 8760 \times 0.7 \times 0.2 \times 10^{-6} \quad ... (6)$$

$$AEDE_{in}(\frac{msv}{y}) = D \times 8760 \times 0.7 \times 0.8 \times 10^{-6} \quad ... (7)$$

The radiological risk of gamma index ($I\gamma$)

$$I_{\gamma} = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad ... (8)$$

The representative gamma index is 0.696 which is less than the acceptable value of unity (Al-Hamidawi, 2014; United Nations Scientific Committee on the Effects of Atomic Radiation, 2000) .

Statistical analysis

All statistical analysis was performed using two software programs which are SPSS Version 19.0 statistic software package (IBM Corp., USA) for Windows TM 7 and Microsoft Excel 2010 for Windows TM7.

Results and Discussion

The average specific activities of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in southern Al-Dora region, Baghdad governorate are 38.22 Bq/Kg, 42.99 Bq/Kg, 16.64 Bq/Kg and 2.92 Bq/Kg, respectively as shown in the Table (**1**. The results of average specific activity are compared with the international values which are 33 Bq/kg, 45 Bq/kg, 412 Bq/kg and 101 Bq/kg for ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs, respectively (Al-Hamidawi, 2014; Alhiall & Alsalihi, 2018; Poschl & Nollet, 2006; UNSCEAR, 2010) . The average specific activity of ^{238}U is higher than the international value whereas the average specific activities of ^{232}Th, ^{40}K and ^{137}Cs are lower than the international value. The specific activity values of ^{238}U in five of nine locations including AL-Mokhabrat (37.90 Bq/kg), Abo desheer 1 (55.10 Bq/kg), Abo desheer 2 (63.80 Bq/kg), AL_Saha (60.90 Bq/kg) and 60 Street (50.30 Bq/kg) are higher than the international value. On the other hand, the specific activity values of ^{238}U in four of nine locations including Kafaat AL-Saha (27.20 Bq/kg), AL_Umarat (9.30

Bq/kg), AL-Mekanic (13.90 Bq/kg) and AL-Shurta 1 (25.60 Bq/kg) are less than the international value. The specific activity of ^{137}Cs determined in the soil samples are illustrated in **Figure**. The specific activity values of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs in soil samples varied within the Dora region because of the variances of environmental structures. This variation is related to specific activity in soil. The specific activity of natural radionuclides such as ^{238}U and ^{232}Th are not always at constant level in soil (Taskin et al., 2009) .

Table (1) The specific activities of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs calculated in soil samples

Locations	Average U-238 Bq/Kg	Average Th-232 Bq/Kg	Average K-40 Bq/Kg	Average Cs-137 Bq/Kg
AL-Mokhabrat	37.90	44.80	16.30	1.20
Abo desheer 1	55.10	67.98	12.20	2.88
Abo desheer 2	63.80	81.97	21.90	3.44
Kafaat AL-Saha	27.20	57.60	8.10	3.93
AL_Saha	60.90	8.20	25.95	0.60
AL_Umarat	9.30	32.20	32.01	4.26
60 Street	50.30	52.10	5.97	4.99
AL-Mekanic	13.90	23.20	24.01	1.98
AL-Shurta 1	25.60	18.90	3.30	3.01
Average	38.22	42.99	16.64	2.92
International	33	45	412	101

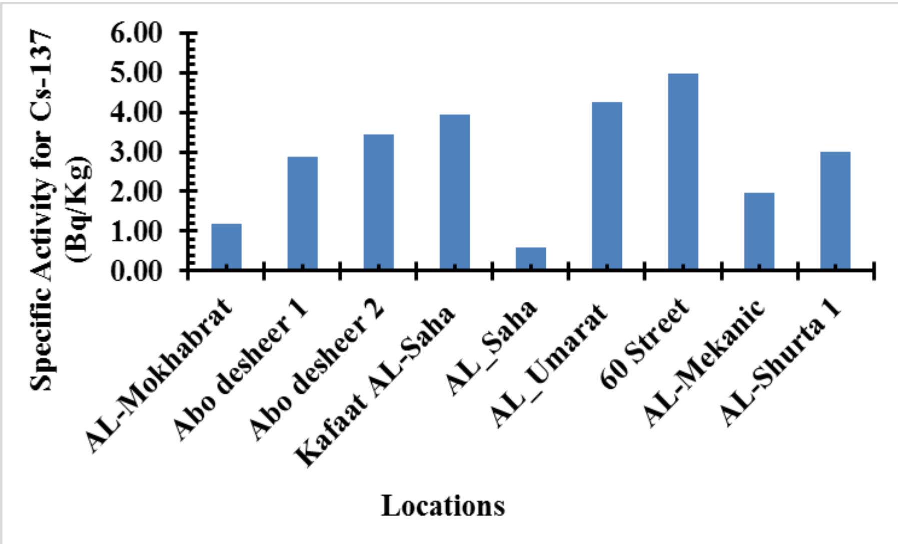

Figure (2) The specific activity of ^{137}Cs determined in the soil samples

The average value of radium equivalent activity in studied samples is 101 Bq/kg as shown in **Table** and **Figure**. The obtained result is lower than the recommended value which is 370 Bq/kg (Devi, Kumar, & Chauhan, 2019; M. et al., 2018) .

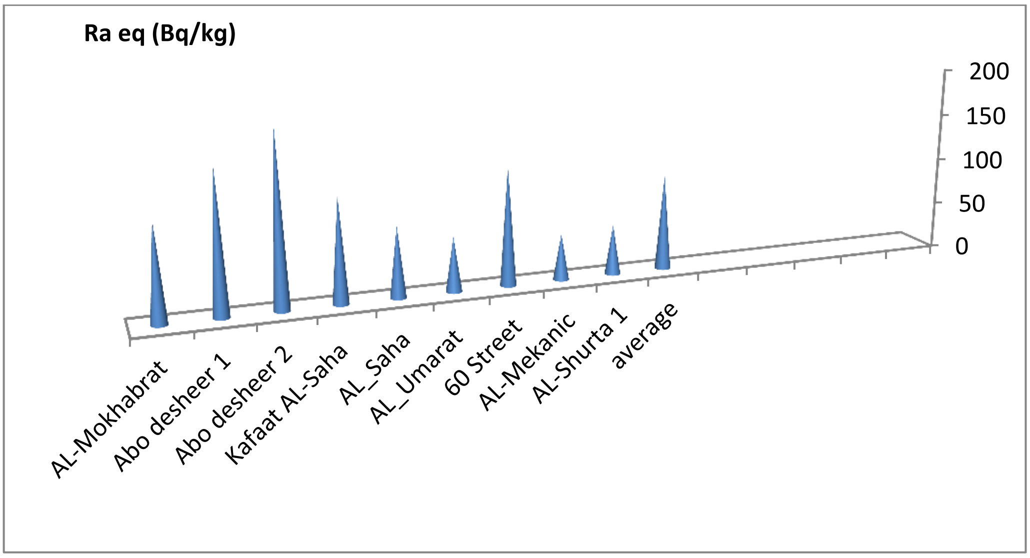

Figure (2) Radium equivalent activity in soil samples

The average value of gamma adsorbed dose rate in soil samples is 45.1 nGy/h, as shown in **Table**, and it is lower than the international value which is 58 nGy/h (Al-Hamidawi, 2014; United Nations Scientific Committee on the Effects of Atomic Radiation, 2000) .

The average values of external and internal hazard indices are 0.273 and 0.376, respectively, as shown in **Table** and **Figure** . These results are safe because they are lower than the world permissible value of unity (Al-Hamidawi, 2014; M. et al., 2018; United Nations Scientific Committee on the Effects of Atomic Radiation, 2000) . The significant correlations were measured for external and internal hazard indices with the gamma adsorbed dose rate (R^2=0.9996) and (R^2=0.9599), respectively.

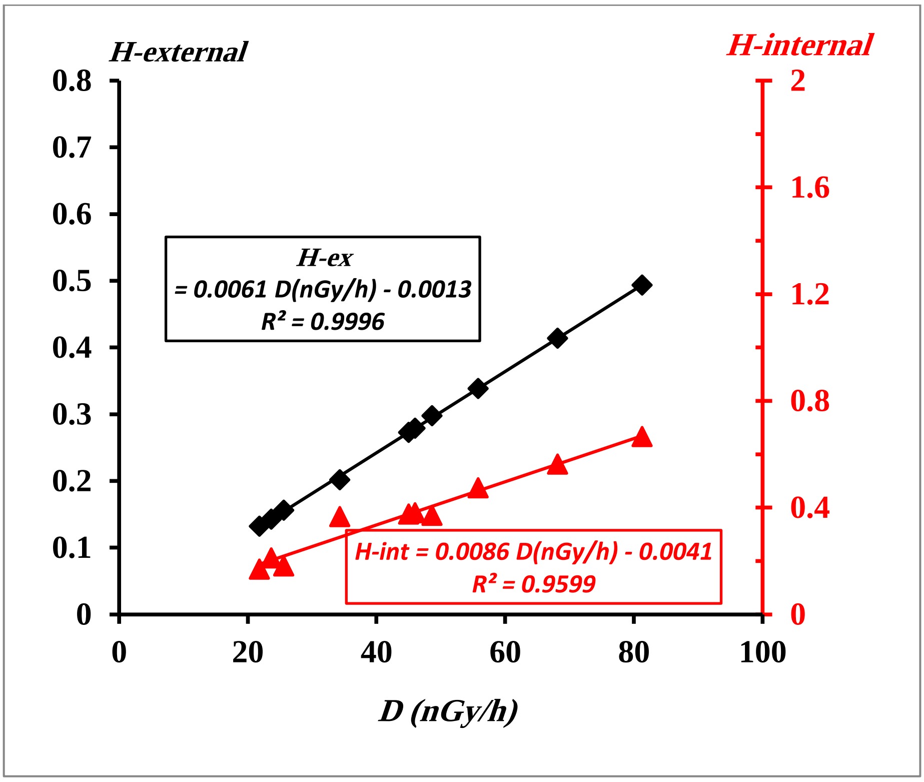

Figure (3) Correlation of external and internal hazard indices with the gamma adsorbed dose rate

The $AEDE_{in}$ and $AEDE_{ex}$ are 0.221 mSv/y and 0.055 mSv/y, respectively as presented in **Table**. The results are less than recommended average value of $AEDE_{in}$ and $AEDE_{ex}$ annual effective dose equivalent which are 0.34 mSv/y and 0.07 mSv/y, respectively (United Nations Scientific Committee on the Effects of Atomic Radiation, 2000) . The significant correlations (R^2=1) were measured for $AEDE_{in}$ and $AEDE_{ex}$ with the gamma adsorbed dose rate, respectively as demonstrated in **Figure**.

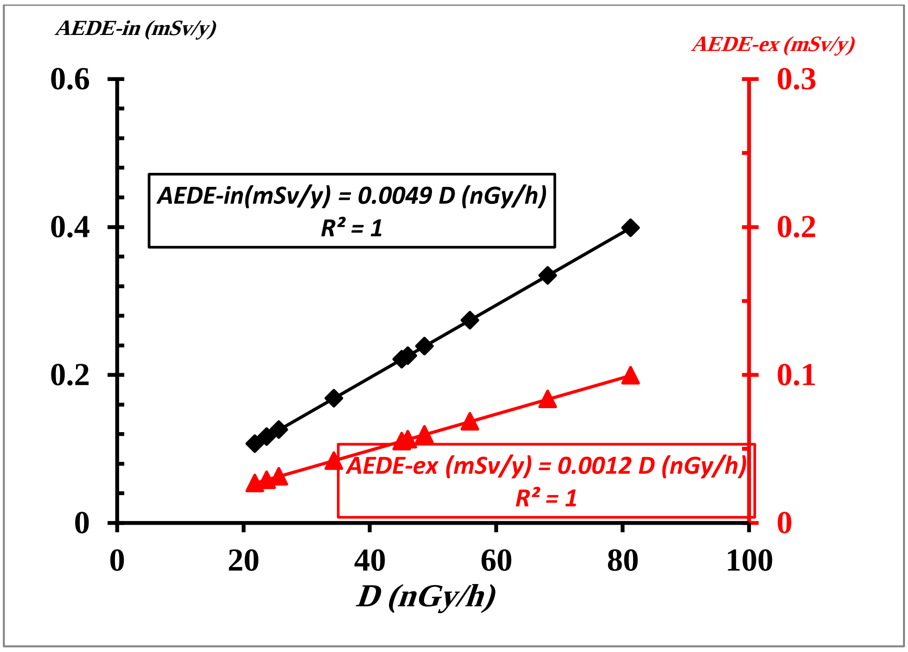

Figure (4) Correlation between measurement of AEDE ($_{\text{in and ex}}$) and the gamma adsorbed dose rate in soil samples

The significant correlation of radium equivalent activity and representative gamma index with the gamma adsorbed dose rate (R^2= 0.9996) and (R^2= 0.9988), respectively as illustrated in **Figure**.

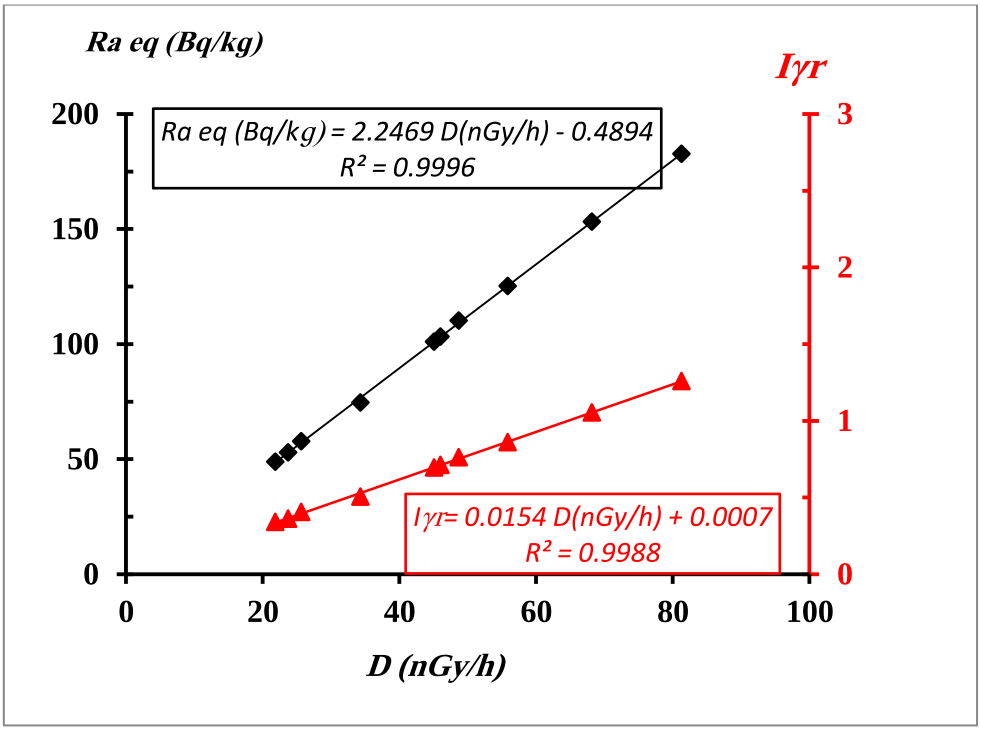

Figure (5) Correlation of radium equivalent activity and representative gamma index with the gamma adsorbed dose rate in soil samples

Table (2) The radiological hazards including radium equivalent activity (Ra_{eq}), absorbed dose rate (D), internal (H_{in}) and external (H_{ex}) hazard indices, internal ($AEDE_{in}$) and external ($AEDE_{ex}$) annual effective dose equivalent and gamma ray index (Iγr)

Locations	Ra_{eq} Bq/kg	D (nGy/h)	H_{ex}	H_{in}	$AEDE_{in}$ (mSv/y)	$AEDE_{ex}$ (mSv/y)	$I_{\gamma r}$
AL-Mokhabrat	103.2	46.0	0.279	0.381	0.226	0.056	0.712
Abo desheer 1	153.3	68.2	0.414	0.563	0.334	0.084	1.055
Abo desheer 2	182.7	81.3	0.493	0.666	0.399	0.100	1.260
Kafaat AL-Saha	110.2	48.7	0.298	0.371	0.239	0.060	0.763
AL_Saha	74.6	34.3	0.202	0.366	0.168	0.042	0.505
AL_Umarat	57.8	25.6	0.156	0.181	0.126	0.031	0.405
60 Street	125.3	55.8	0.338	0.474	0.274	0.068	0.860
AL-Mekanic	48.9	21.8	0.132	0.170	0.107	0.027	0.341
AL-Shurta 1	52.9	23.7	0.143	0.212	0.116	0.029	0.362
Average	101.0	45.1	0.273	0.376	0.221	0.055	0.696

The variations in the specific activity of radionuclides and all radiological parameters in the studied soil samples varied within the Dora region. This may due to the variances of environmental structures (Ibraheem, El-Taher, & Alruwaili, 2018) . This variation is related to specific activity in soil. The specific activity of natural radionuclides such as 238U and 232Th are not always at constant level in soil (Taskin et al., 2009) .

Conclusion

A gamma ray detector NaI (Tl) is applied to calculate the specific activity of four radionuclides in soil at nine locations of southern Al-Dora region, Baghdad governorate, Iraq. The average activity concentration of ^{238}U, was found to be 38.22 Bq/Kg that is higher than the international value. The average activity concentration of ^{232}Th, ^{40}K and ^{137}Cs were found to be 42.99 Bq/Kg, 16.64 Bq/Kg and 2.92 Bq/Kg, respectively. These results are lower than the international value. All radiological hazards factors including radium equivalent activity (Ra_{eq}), absorbed dose rate (D), internal (H_{in}) and external (H_{ex}) hazard indices, internal ($AEDE_{in}$) and external ($AEDE_{ex}$) annual effective dose equivalent and gamma ray index ($I\gamma r$) were found to be lower than their recommended values.

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