

# Radiation Hazard Assessment by Measuring of Soil Radioactivity Levels in Al-anbar (Al-fallujah District) and Wasit Governorate in Iraq

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**Abstract:** Soil samples were collected from two region Al-anbar (Al-fallujah district) and Wasit of Iraq with an aim to determine the activity concentration using a coaxial high purity germanium (HPGe) detector based on high-resolution gamma spectrometry system.  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , the primordial radionuclide  $^{40}\text{K}$ , and the artificial radionuclide  $^{137}\text{Cs}$  were measured in the soil of the study area. The mean radioactivity concentration in Al-anbar (Al-fallujah district) and Wasit region due to  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  was (20.36, 11.08, 226.97, and 1.01 Bq kg<sup>-1</sup>) and (23.01, 14.45, 290.64, and 2.22 Bq kg<sup>-1</sup>), respectively. Radium equivalent activity ( $\text{Ra}_{\text{eq}}$ ), representative level index ( $I_{\gamma}$ ), absorbed gamma dose rate (D) in air, total annual effective dose equivalent (AEDE) from the terrestrial gamma radiation, the external and internal hazard index were estimated. The mean of six hazard index values came out to be (53.67 Bq kg<sup>-1</sup>, 0.38 Bq kg<sup>-1</sup>, 24.78 Bq kg<sup>-1</sup>, 0.15 mSv y<sup>-1</sup>, 0.14 Bq kg<sup>-1</sup>, and 0.19 Bq kg<sup>-1</sup>) in Al-anbar (Al-fallujah district) and (66.17 Bq kg<sup>-1</sup>, 0.49 Bq kg<sup>-1</sup>, 32.08 Bq kg<sup>-1</sup>, 0.2 mSv y<sup>-1</sup>, 0.18 Bq kg<sup>-1</sup>, and 0.24 Bq kg<sup>-1</sup>) in Wasit, respectively. Present data have been compared with the published data for other regions of the world near from the study area and found to be safe for public and environment.

**Keywords:** Radiation Hazard, Annual Effective Dose, Gamma Spectrometry

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## 1. Introduction

Human beings have always been exposed to natural radiations arising from within and outside the earth. The primordial radionuclides have radioactive decay half-lives that are approximately earth's age. The exposure to ionizing radiations from natural sources occurs because of the naturally occurring radioactive elements in the soil and rocks, cosmic rays entering the earth's atmosphere from outer space and the internal exposure through incorporation of these radionuclides into the body by inhalation or ingestion. These radionuclides and their radioactive decay products are an important source of earth's radioactivity [1, 2]. The natural radioactivity in soil primarily comes from  $^{238}\text{U}$  and  $^{232}\text{Th}$  series and natural  $^{40}\text{K}$ . Artificial radionuclides can also be present such as  $^{137}\text{Cs}$ , resulting from fallout from weapons testing and from accidents such as Chernobyl. The radiological

implication of these radionuclides is due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters. The great number of decay products of  $^{238}\text{U}$  and  $^{232}\text{Th}$  series and  $^{40}\text{K}$  are the main components of external gamma radiation originating from soil. Therefore, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population [1]. The average annual radiation dose to world population is 2.8 mSv approximately 85% (2.4 mSv) of this comes from natural radionuclides of both terrestrial and cosmogenic origin [3].  $^{137}\text{Cs}$  is regarded as the most important constituent of worldwide radioactive fallout. Sixty percent of the collective effective dose equivalent commitment from external radiation associated with past atmospheric

nuclear weapon testing may be attributed to  $^{137}\text{Cs}$ . In the case of an accidental release of fission products from a nuclear power plant, cesium isotopes are especially significant due to their volatility and large inventory that builds up in the reactor over time. Therefore, measurement of  $^{137}\text{Cs}$  levels in soil is necessary in the environment of a studied area as such a data would serve as the baseline data. Its presence in soil would be an indicator that the area under study might have received some fallout radioactivity in the past [4]. The specific levels are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks, such as granite, and lower levels with sedimentary rocks [1]. The present study deals with the measurement of specific activities of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$ , calculation of the radium equivalent activity, external and internal hazard indices, absorbed dose and annual effective dose equivalent for the studied area. This data will help to decide whether the studied region is in an area of normal or high background radiation and will set a baseline for the determination of radioactivity level in the region [4].

## 2. Materials and Methods

### 2.1. Description of Study Area

Soil sampling was carried out in 2011. The geological locate of the two governorate Al-anbar (Al-fallujah district) and Wasit at west and middle of Iraq. Soil samples were collected from three selected sites at Al-anbar (Al-fallujah district) governorate and six selected sites at Wasit governorate, which were chosen for two reasons: first record rise in cancers and birth defects rates in the surrounding residential areas of sites according to the information that has been obtained from hospital near the sites or from the governorate council and the second that these areas have seen some of them military operations were reconstruction and other division is the remnants of the wreckage of vehicles and wheels military destroyer and some rubble of buildings. The description of the study area has been reported elsewhere in reference [5]. Tables 1 & 2 were shown the description of the study area at Al-anbar (Al-fallujah district) and Wasit governorate respectively while Figure 1 was shown the soil sampling locations on map of Al-anbar (Al-fallujah district) and Wasit governorate respectively.

**Table 1.** The description of the study area at Al-anbar (Al-fallujah district) governorate.

Sample No.	Sample ID	Location description	Latitude	Longitude
1	B.G.S1	Golan background (its far 1000 m from Golan selected area).	33.36684	43.76478
2	S1-1	Golan district near the railroad tracks (rubble, with height 2m and area $(400 \times 1000) \text{ m}^2$ ).	33.36830	43.75455
3	S1-2	Golan district-residential neighborhood (rubble, with height 2m and area $(250 \times 400) \text{ m}^2$ ).	33.35956	43.75394
4	S1-3	Golan district-rivers edge (rubble, with height 2m and area $(4 \times 100) \text{ m}^2$ ).	33.35384	43.7591
5	B.G.S2	Al-shuhada district background (its far 1000 m from Al-shuhada selected area).	33.33219	43.80234
6	S2-1	Al-shuhada district-residential region (rubble, with height 2m and area $(250 \times 600) \text{ m}^2$ ).	33.32848	43.79225
7	S2-2	Al-shuhada district-land region (rubble, with height 2m and area $(20 \times 25) \text{ m}^2$ ).	33.33928	43.79327
8	B.G.S3	Jubail district background (its far 1000 m from Jubail selected area).	33.33281	43.77237
9	S3-1	Jubail district-dam way (rubble, with height 1m and area $(25 \times 50) \text{ m}^2$ ).	33.32701	43.78090
10	S3-2	Jubail district-Fliah Revir area (residential district).	33.33965	43.77910
11	S3-3	Jubail district.	33.34213	43.76955

**Table 2.** The description of the study area at Wasit governorate.

Sample No.	Sample ID	Location description	Latitude	Longitude
1	B.G.S1	Governorate office background (its far 1000 m from selected area).	32.51353	45.81960
2	S1	Governorate council office (This site is subjected to a military strike, which has been reconstruction, and there are some debris and soil is left in strike place).	32.50436	45.82496
3	B.G.S2	Alsharqiya Alkhajah region background (its far 1000 m from selected area).	32.52886	45.78931
4	S2	Alsharqiya Alkhajah region (residual wreckage of military vehicle).	32.52956	45.80229
5	B.G.S3	Taba healthy center background (its far 1000 m from selected area).	32.51252	45.81259
6	S3	Taba healthy center.	32.50632	45.81761
7	B.G.S4	Shield factory background (its far 1000 m from selected area).	32.91072	45.06351
8	S4	Shield factory in Alaziziya region (surface radiological survey / rubble, with height 1m and area $400 \text{ m}^2$ ).	32.90719	45.07164
9	B.G.S5	Saad abn maath school background (its far 1000 m from selected area)	32.90509	45.05841
10	S5	Saad abn maath school in Alaziziya region (surface radiological survey for land of school which used as military replacement site)	32.91008	45.05025

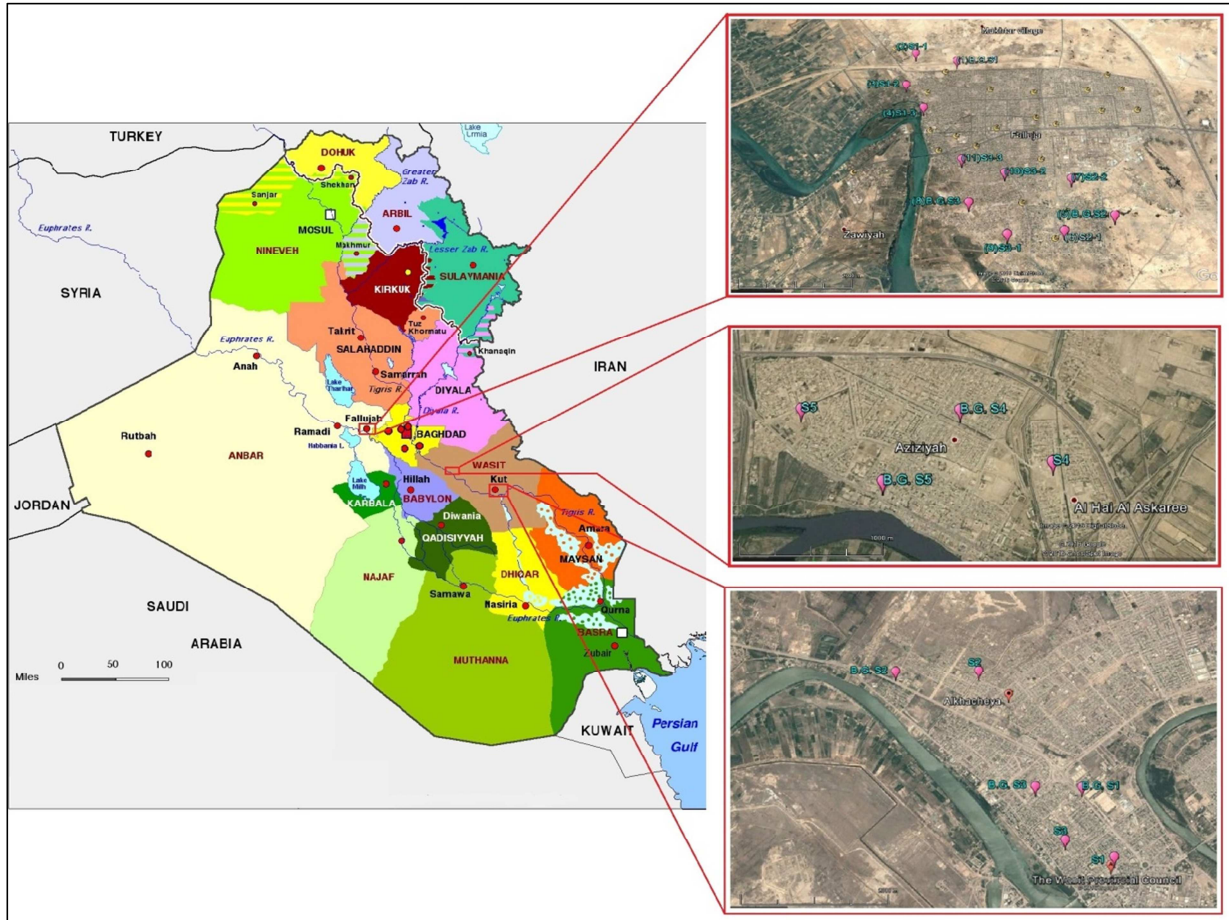


Figure 1. Sampling location map in Al-anbar (Al-fallujah district) and Wasit governorate.

## 2.2. Sample Preparation

At each site, samples were taken from layer down to 25 cm depth. Fine quality of the sample was obtained using sieve of 9 mesh size (2 mm particle size). An average 0.5 kg of soil was used per sample. Before measurement samples were dried in an oven at a temperature of 80°C for 8 hr. These samples were packed and sealed in a marinelli beaker and kept for about 3 week period to allow radioactive equilibrium among the daughter products of radon, thoron and their short lived decay products [6].

## 2.3. Sample Analysis

The samples were analyzed at MOST Gamma Ray Spectrometry laboratory. Using high- resolution gamma spectrometry system consists of coaxial High Purity Germanium (HPGe) detector. The detector has resolution of 2.0 keV and relative efficiency of 40% for 1.33 MeV gamma energy of Co-60. The detector was shield with lead of thickness 10 cm and internally lined with 3 mm copper to reduce the environmental gamma background radiation. The efficiency calibration of the system was employed by reference materials. The gamma ray spectrum was recorded using software GENIE-2000.  $^{226}\text{Ra}$  was assessed through the photo peaks of its daughters:  $^{214}\text{Pb}$  (352 keV) and  $^{214}\text{Bi}$  (609keV) furthermore the concentration of  $^{232}\text{Th}$  was

determined through the photo peaks of  $^{228}\text{Ac}$  (911keV) and  $^{212}\text{Pb}$  (238.6 keV).  $^{40}\text{K}$  and  $^{137}\text{Cs}$  were measured directly from their 1460.8, 662 keV gamma ray peaks [5].

## 2.4. Radiation Hazard Indices

### 2.4.1. Radium Equivalent Activity

To represent their specific activities levels of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  by a single quantity which take into calculation the radiation hazards related with them, a common radiological index has been used which is radium equivalent ( $Ra_{eq}$ ). To define  $Ra_{eq}$  activity, it can be assumed that 1 Bq/kg of  $^{226}\text{Ra}$ , 0.7 Bq/kg of  $^{232}\text{Th}$  or 13 Bq/kg of  $^{40}\text{K}$  give the same dose of gamma ray.

The mathematically defined by Eq. (1) [4 & 7]

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \leq 370 \quad (1)$$

Where  $C_{Ra}$ ,  $C_{Th}$ , and  $C_K$  are the activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in Bq/kg

### 2.4.2. Representative Level Index ( $I_\gamma$ )

The representative level index ( $I_\gamma$ ) used for the calculation of gamma radiation associated with the natural radioactive materials in the soil. It is calculated using Eq. (2). The safety value for this index is  $\leq 1$  [8 & 9]

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500} \leq 1 \quad (2)$$

#### 2.4.3. Air Absorbed Radiation Dose Rate

Absorbed dose rate in air at a height of about 1 meter above the ground surface due to gamma radiations for uniform distribution of the naturally occurring radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  is calculated using Eq. (3). The conversion factor of 0.462 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup> for  $^{226}\text{Ra}$ , 0.621 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup> for  $^{232}\text{Th}$ , 0.0417 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup> for  $^{40}\text{K}$ , and 0.136 nGy h<sup>-1</sup>/Bq kg<sup>-1</sup> for  $^{137}\text{Cs}$  equilibrium is assumed between  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  series with all their daughter and the effect of  $^{90}\text{Sr}$  and  $^{235}\text{U}$  decay series can be neglected because of their small contribution to the whole dose from background. [4 & 7]

$$D(\text{nGy h}^{-1}) = 0.462C_{\text{Ra}} + 0.621C_{\text{Th}} + 0.0417C_{\text{K}} + 0.136C_{\text{Cs}} \quad (3)$$

#### 2.4.4. Annual Effective Dose Rate

The annual effective dose rates expected to be received by the general public due to the radioactivity in soil was calculated using Eq. (4 & 5) the conversion coefficient from absorbed dose rate in air to effective dose (0.7 Sv Gy<sup>-1</sup>) and an outdoor occupancy factor (20%) proposed by UNSCEAR 2000 are used [1, 4, 7].

$$\text{Indoor}(\text{mSv/y}) = (\text{Absorbeddose})\text{nGyh}^{-1} \times 8760 \text{ h. yr}^{-1} \times 0.8 \times 0.7 \times (10^3 \text{mSv}/10^9 \text{nGy}) \quad (4)$$

$$\text{Outdoor}(\text{nSv/y}) = (\text{Absorbeddose})\text{nGyh}^{-1} \times 8760 \text{ h} \times 0.2 \times 0.7 \times (10^3 \text{mSv}/10^9 \text{nGy}) \quad (5)$$

#### 2.4.5. External and Internal Hazard Index [9 & 10]

The external hazard index ( $H_{\text{ex}}$ ) is widely used to reflect to external exposure and can be calculated by Eq. (6):

$$H_{\text{ex}} = \frac{C_{\text{Ra}}}{370} + \frac{C_{\text{Th}}}{259} + \frac{C_{\text{K}}}{4810} < 1 \quad (6)$$

In addition to the external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal hazard indexes ( $H_{\text{in}}$ ) used to reflect to

internal exposure to radon and its daughter, which is given by Eq. (7):

$$H_{\text{in}} = \frac{C_{\text{Ra}}}{185} + \frac{C_{\text{Th}}}{259} + \frac{C_{\text{K}}}{4810} < 1 \quad (7)$$

The values of the indices of external and internal radiation hazard index must be less than unity for the radiation hazard to be negligible.

### 3. Results and Discussion

The data in Table (3 & 4) are summarized of measurements of natural and manmade radionuclide ( $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$ ) concentration and radium equivalent in the collected soil samples from Al-anbar (Al-fallujah district) and Wasit governorate, respectively. The mean activity concentration at Al-anbar (Al-fallujah district) due to  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  was 20.36, 11.08, 226.84, and 1.01 Bq kg<sup>-1</sup>, respectively. In Wasit governorate, the mean activity concentration due to  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  was 23.01, 14.54, 290.64, and 2.22 Bq kg<sup>-1</sup>, respectively.  $^{137}\text{Cs}$  concentration was detected very low at most of the places. Its concentration at Al-anbar (Al-fallujah district) governorate ranged from 0.00 to 2.3 Bq kg<sup>-1</sup> with an average value of 1.01 Bq kg<sup>-1</sup> and at Wasit governorate was ranged from 0.70 to 5.06 Bq kg<sup>-1</sup> with an average value of 2.22 Bq kg<sup>-1</sup> and these concentration survey low at most of the places for that they don't have any radiological important. The activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in soil samples of studied area was compared with the value reported by other countries near from study area as shown in Table (5). The measured activity concentration of  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  was close to the Syria and Iran for Al-anbar (Al-fallujah district) and Wasit. While the measured activity concentration of  $^{40}\text{K}$  was closed to Southern Jordan and Syria for two governorates. Furthermore, the world average concentrations for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in soil sample are 35, 30, 400 Bq/kg, respectively [7].

**Table 3.** Activity concentrations of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  and radium equivalent activity in soil samples from Al-anbar (Al-fallujah district) governorate.

Sample ID	A.Conc. of $^{226}\text{Ra}$ Bq/kg	A.Conc. of $^{232}\text{Th}$ Bq/kg	A.Conc. of $^{40}\text{K}$ Bq/kg	A.Conc. of $^{137}\text{Cs}$ Bq/kg	Ra <sub>eq</sub> (Bq/kg)
B.G.S1	21.8	13.5	280.5	1.2	62.70
S1-1	17.4	5.6	137.02	0.85	35.96
S1-2	21.6	14.8	278.4	0	64.20
S1-3	22.5	15.2	271.6	0.5	65.15
B.G.S2	21.3	13.02	306	1.9	63.48
S2-1	19.8	6.9	134.2	0.32	40.00
S2-2	19.4	11.8	233.8	1.7	54.28
S2-3	27.7	19	371	0	83.44
B.G.S3	14.4	9.6	247	0.3	47.15
S3-1	23.2	4.6	113.8	1.18	38.54
S3-2	14.7	9.5	177.4	2.3	41.94
S3-3	20.5	9.4	172	1.9	47.19
Mean value	20.36	11.08	226.89	1.01	53.67
Min value	14.40	4.60	113.80	0.00	35.96
Max value	27.70	19.00	371.00	2.30	83.44
Worldwide background soil standard	10-50	10-50	100-700		≤ 370

**Table 4.** Activity concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ , and  $^{137}\text{Cs}$  and radium equivalent activity in soil samples from Wasit governorate.

Sample ID	A.Conc. of $^{226}\text{Ra}$ Bq/kg	A.Conc. of $^{232}\text{Th}$ Bq/kg	A.Conc. of $^{40}\text{K}$ Bq/kg	A.Conc. of $^{137}\text{Cs}$ Bq/kg	$\text{Ra}_{\text{eq}}$ (Bq/kg)
B.G.S1	28.8	16.9	351.1	2.7	80.00
S1	19.5	13.3	303.7	2.4	61.90
B.G.S2	20.5	12.3	240.2	0.9	56.58
S2	17.2	10.7	203.2	2.4	48.15
B.G.S3	34.7	24.3	344.6	5.06	95.98
S3	25.5	17.7	442.1	4.4	84.85
B.G.S4	23.05	16.9	299.05	0.9	70.24
S4	15.7	7.78	172.2	1.45	40.08
B.G.S5	21.6	13	315.1	1.3	64.45
S5	23.5	12.5	235.1	0.7	59.48
Mean value	23.01	14.54	290.64	2.22	66.17
Min value	15.70	7.78	172.20	0.70	40.08
Max value	34.70	24.30	442.10	5.06	95.98
Worldwide background soil standard	10-50	10-50	100-700		$\leq 370$

**Table 5.** Activity concentration ( $\text{Bq kg}^{-1}$ ) of natural radionuclides reported by various countries.

Country	$^{226}\text{Ra}$	$^{232}\text{Th}$	$^{40}\text{K}$	reference
Syria	19 (6-69)	24 (3-50)	336 (85-735)	10
Southern Jordan	42.5	26.7	291.1	2
Turkey	79	62	574	4
Istanbul	27.7	32.5	388	10
Iran	28	22	640	1
World average	35	30	400	7
Present study Al-anbar (Al-fallujah district) governorate	20.36	11.08	226.89	5
Present study Wasit governorate	23.01	14.54	290.64	5

Radium equivalent activity ( $\text{Ra}_{\text{eq}}$ ) in  $\text{Bq kg}^{-1}$  for these soil samples were shown in Table 3 and 4. The mean radium equivalent activity in Al-anbar (Al-fallujah district) is 53.67 and in Wasit is 66.17  $\text{Bq kg}^{-1}$  which is less than the safe limit ( $370 \text{ Bq kg}^{-1}$ ) recommended by Organization for Economic Cooperation and Development [7].

Tables (6) and (7) were shown the five radiation hazard indices for soil samples for Al-anbar (Al-fallujah district) and Wasit governorate, respectively. The values of representative level index ( $I_\gamma$ ) of soil samples ranged from 0.26 to 0.48  $\text{Bq kg}^{-1}$  with a mean value of 0.38  $\text{Bq kg}^{-1}$  for Al-anbar (Al-fallujah district) governorate and ranged from 0.3 to 0.7  $\text{Bq kg}^{-1}$  with a mean value of 0.49  $\text{Bq kg}^{-1}$  for Wasit governorate. All values were lower the unity permissible limit. Equations (3, 4, and 5) were used to calculate the absorbed dose rate  $D(\text{nGy h}^{-1})$  and the effective dose rate ( $\text{mSv/y}$ ) in outdoor

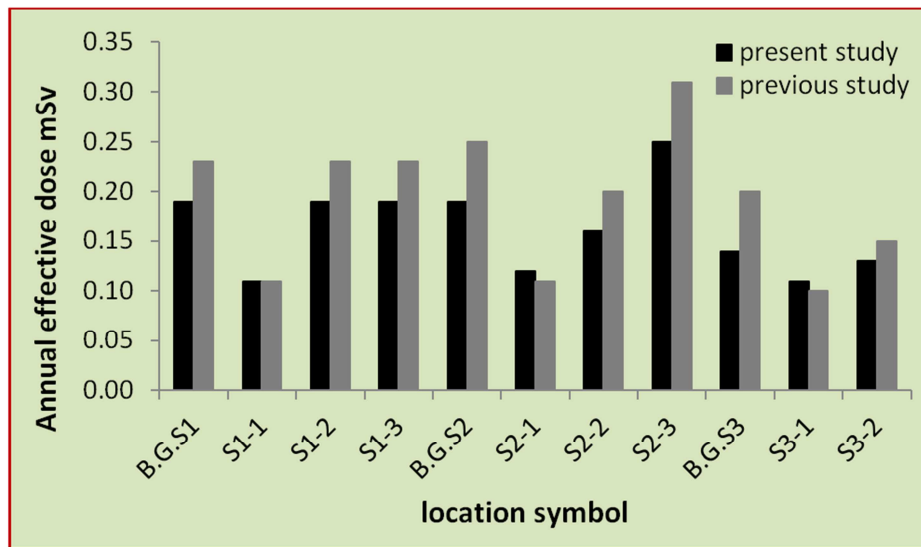
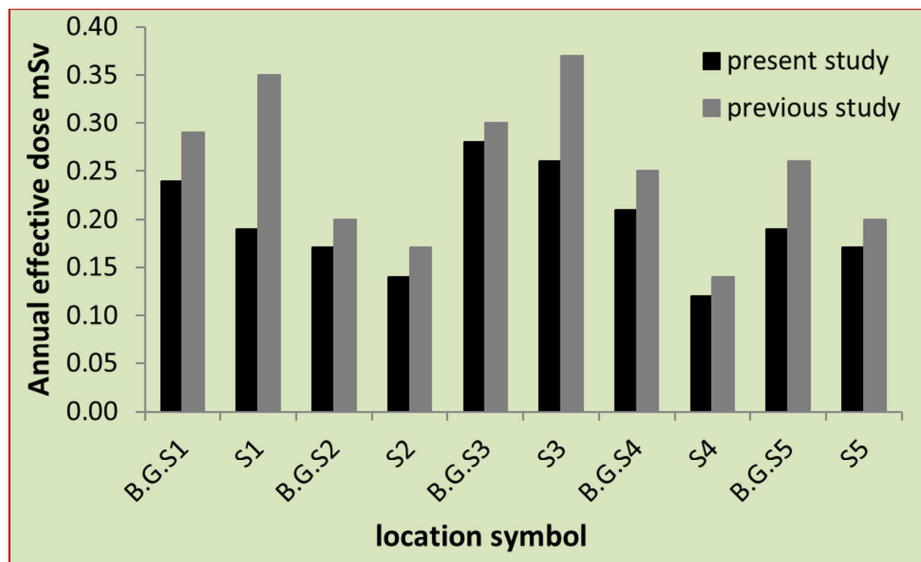
and indoor air for Al-anbar (Al-fallujah district) and Wasit governorate, as shown in Tables (6) and (7) respectively. The values of the total absorbed dose rate ranged from 17.35 to 31.23  $\text{nGy h}^{-1}$  with a mean value of 24.78  $\text{nGy h}^{-1}$  for Al-anbar (Al-fallujah district) governorate and ranged from 19.46 to 46.18  $\text{nGy h}^{-1}$  with a mean value of 32.08  $\text{nGy h}^{-1}$  for Wasit governorate. All values are lower than the world average value of 60  $\text{nGy h}^{-1}$  given by UNCEAR 2000 [7]. All calculated values of the effective dose rate for two governorates are far lower than the 1.0  $\text{mSv.y}^{-1}$  recommended by UNSCEAR 2000. Furthermore the calculated values are near from the values which were calculated in the previous study [9] using ReCLAIM program version 3.0 as shown in Figures (2 and 3) for Al-anbar (Al-fallujah district) and Wasit governorate, respectively.

**Table 6.** The value of calculated radiation indices of soil samples for Al-anbar (Al-fallujah district) governorate.

Sample ID	$I_\gamma$	D $\text{nGy h}^{-1}$	$D_{\text{out}}$ $\text{mSv.y}^{-1}$	$D_{\text{in}}$ $\text{mSv.y}^{-1}$	$D_{\text{total}}$ $\text{mSv.y}^{-1}$	$H_{\text{ex}}$	$H_{\text{in}}$
B.G.S1	0.47	30.32	0.04	0.15	0.19	0.17	0.23
S1-1	0.26	17.35	0.02	0.09	0.11	0.10	0.14
S1-2	0.48	30.78	0.04	0.15	0.19	0.17	0.23
S1-3	0.48	31.23	0.04	0.15	0.19	0.18	0.24
B.G.S2	0.48	30.94	0.04	0.15	0.19	0.17	0.23
S2-1	0.29	19.07	0.02	0.09	0.12	0.11	0.16
S2-2	0.4	26.27	0.03	0.13	0.16	0.15	0.2
S2-3	0.62	40.07	0.05	0.2	0.25	0.23	0.3
B.G.S3	0.36	22.96	0.03	0.11	0.14	0.13	0.17
S3-1	0.28	18.48	0.02	0.09	0.11	0.10	0.17
S3-2	0.31	20.40	0.03	0.10	0.13	0.11	0.15
S3-3	0.35	22.74	0.03	0.11	0.14	0.13	0.18
Mean field soil value	0.38	24.78	0.03	0.13	0.15	0.14	0.19
Min	0.26	17.35	0.02	0.09	0.11	0.10	0.14
Max	0.48	31.23	0.05	0.20	0.19	0.18	0.24

**Table 7.** The value of calculated radiation indices of soil samples for Wasit governorate.

Sample ID	( $I_\gamma$ )	D nGy h <sup>-1</sup>	D <sub>out</sub> mSv.y <sup>-1</sup>	D <sub>in</sub> mSv.y <sup>-1</sup>	D <sub>total</sub> mSv.y <sup>-1</sup>	Hex	Hin
B.G.S1	0.60	38.81	0.05	0.19	0.24	0.22	0.29
S1	0.47	30.26	0.04	0.15	0.19	0.17	0.22
B.G.S2	0.42	27.25	0.03	0.13	0.17	0.15	0.21
S2	0.36	23.39	0.03	0.11	0.14	0.13	0.18
B.G.S3	0.70	46.18	0.06	0.23	0.28	0.26	0.35
S3	0.64	41.81	0.05	0.21	0.26	0.23	0.30
B.G.S4	0.52	33.74	0.04	0.17	0.21	0.19	0.25
S4	0.30	19.46	0.02	0.10	0.12	0.11	0.15
B.G.S5	0.48	31.37	0.04	0.15	0.19	0.17	0.23
S5	0.44	28.52	0.03	0.14	0.17	0.16	0.22
Mean field soil value	0.49	32.08	0.04	0.16	0.20	0.18	0.24
Min	0.30	19.46	0.02	0.10	0.12	0.11	0.15
Max	0.70	46.18	0.06	0.23	0.28	0.26	0.35

**Figure 2.** The annual effective dose comparison for Al-anbar (Al-fallujah district) governorate.**Figure 3.** The annual effective dose comparison for Wasit governorate.

## 4. Conclusions

1. The measured activity concentration of <sup>226</sup>Ra and <sup>232</sup>Th

was close to the Syria and Iran for Al-anbar (Al-fallujah district) and Wasit while the measured activity concentration of <sup>40</sup>K was closed to Southern Jordan and

Syria for two governorates. Furthermore, the world average concentrations for  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$  in soil sample are 35, 30, 400 Bq/kg respectively.

2.  $^{137}\text{Cs}$  concentration was detected very low at most of the places. Its concentration at Al-anbar (Al-fallujah district) governorate ranged from 0.00 to 2.3 Bq kg<sup>-1</sup> with an average value of 1.01 Bq kg<sup>-1</sup> and at Wasit governorate was ranged from 0.70 to 5.06 Bq kg<sup>-1</sup> with an average value of 2.22 Bq kg<sup>-1</sup> and these concentration survey low at most of the places for that they don't have any radiological important
3. The results obtained have shown that the effective dose rate values due to natural radioactivity of soil samples are far lower than the average world recommended value of 1.0 mSv.y<sup>-1</sup> and near from the values were calculated using ReCLAIM program version 3.0.

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