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ARTICLE

Estimation of Natural and Anthropogenic Exposures to Gamma Ray from a High Agricultural Area in Jordan "Bani-Kananah District"

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Abstract: The activity concentrations of some artificial and natural radionuclides in some soil samples from high agricultural area, in North West Jordan "Bani-Kananah District", were measured by using gamma ray spectrometry. The activity concentrations of ^{137}Cs (Cesium), ^{40}K (Potassium), ^{238}U (Uranium) and ^{232}Th (Thorium) were measured in 38 soil samples which were collected from agricultural area. The radiation hazard indices of soil samples were also calculated. The results showed that the average values of either radionuclides activity concentrations or radiation hazard indices of all soil samples under study were in the internationally allowable and lower range. From the accumulated spectra, the activity concentrations were determined in (Bq/kg) to be on the average of 22.7 ± 15.2 for ^{232}Th, 20.4 ± 9.8 for ^{238}U, 160 ± 76 for ^{40}K and 4.6 ± 5.0 for ^{137}Cs. The mean value of the radium equivalent activity index (Ra_{eq}) was found to be 65.0 ± 27.8 Bq/kg, while the average value of the total absorbed dose (D) was 30.5 ± 13.1 nGy/h. In addition, the average value of the annual effective dose was 37.4 ± 16.0 μSv/y. The calculated values of external and internal radiation hazard indices (H_{ex} and H_{in}) were lower than unity. Results therefore emphasize that the radionuclide activity found in the surveyed area is nominal and does not pose any potential health hazard to the general public. This work can be added to other works on Jordan environment in order to establish baseline data for levels of radioactivity.

Keywords: Gamma ray spectrometry, Radionuclides, Hazard indices, Soil.
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Introduction

Environmental radioactivity and the correlated gamma radiation exposure appear at different levels in each area in the world [1]. Therefore, estimating a baseline level of gamma radiation is behind the extended surveys taken worldwide. In addition, the evaluation of radiation dose distribution is important for assessing the health risk to the general public and serves as a reference in environmental radioactivity [2], especially for humans that maybe exposed to irradiation by contamination of the food chain which happens as a deposition of radionuclides from contaminated soil, sediment or water on the plant leaves and root uptake [3].

Natural radionuclides are present mostly in soils since the foundation of earth; they are entering the human body during the food chain by the plant roots such as potassium radioisotope ^{40}K [4]. The main potential hazard of the natural radioactive series (uranium, thorium and actinium) is from external exposure; they enter in many building materials or by direct exposure to soil [5]. Artificial radionuclides, ^{137}Cs in particular, are released to the atmosphere from various sources such as medical waste, nuclear accidents like Chernobyl and Fukushima and

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nuclear weapons testing in the 1950s and1960s [5]. Since ^{137}Cs has a long half life time (30.2 y), it is a significant health pose when the level of internal exposure of human increases due to the intake of contaminated food stuff after the migration of radiocesium into soil [6].

Previous radioactivity studies assessed the natural and artificial radionuclides in soil samples around the world. However, the number of studies made on countries in the Mideast remains somewhat limited by comparison. In Jordan, several studies on soil radioactivity measurements in selected regions have been performed [5, 7-11]; among them, Ahmad et al., 1997 [7] have measured the concentration levels of indoor radon in a number of randomly selected houses and natural radioactivity in soil in different areas of Jordan using CR-39 based dosimeters. Al-Hamarneh et al., 2003 [8] studied surface and core soil samples from different regions of Jordan. They measured the concentration of artificial radionuclides (^{137}Cs). The estimation of the annual effective dose equivalent due to ^{137}Cs was more than 200 μSv. Al-Jundi, 2002 [9] has found that the concentration values of ^{40}K and ^{232}Th obtained from old phosphate mine of Russaifa city are normal compared to other worldwide standards in other countries, but the concentrations of ^{238}U are much higher than the worldwide range. Abusuni, et al., 2008 [10] studied the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil cores of Araba Valley. The mean concentrations of these radioactive nuclei were below than in other populated areas and the mean activity concentrations were decreased with depth. More recently, Abu Haija, 2012 [11] studied the natural radionuclide activity concentration in soil of Tafila city. The activities of the collected samples were below the world average activity rates. Ababneh et al., 2012 [5] studied the vertical distribution of both natural and anthropogenic radionuclides in heavy rainfall areas (Ras Muneef region). They found that ^{137}Cs has two types of depth profile depending on land use; Gaussian distribution and exponential distribution.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report [1] does not provide data concerning these radionuclides in Jordan. So, establishing a baseline for natural and artificial radioactivity is becoming essential to develop future guidelines in the country and the region for radiological protection of the population. Further investigations on the level of these radionuclides in the area, as no such study has been carried out, along with previous existing studies will contribute to establishing such a baseline level.

The natural and artificial radionuclides may transport to the human body through the food chain; i.e., mainly through the soil. Thus, in this work, the area of high agricultural use in the northwestern corner of Jordan, "Bani-Kananah District", was selected to investigate its radioactive content, calculating radium equivalent and examining the internal and external hazard indices. The area was chosen to be undisturbed away from the street, cultivated, uniform and inclusive of all regions in the area.

Materials and Methods

Sampling Area and Sample Collection

The area of the study lies within Bani-Kananah District in the northwestern corner of Jordan which covers an area of about 250 km^2 (Fig. 1). The area of agricultural use in Bani-Kananah District is 200 km^2 which is 80% of the total area. The area was chosen for this study because of the amount of rainfall and the type of soil making it suitable for agricultural use. The major crops grown are olives and pomegranate.

A total of 38 surface soil samples were collected from different sections at 0-10 cm depth level all over; (i.e., one sample for every section). The longitude and latitude for every sample position were taken using GPS. The samples were collected from agricultural, uniform, undisturbed and cultivated regions in the described area, packed in plastic bags and assembled in the laboratory. Then, the samples were oven dried for at least 2 hr at 100^{o}C until a constant weight is reached and sieved through 0.05 mm mesh to remove stones, pebbles and other impurities. Samples were then weighed and transferred to standard 100 ml cylindrical cups of 2 cm radius and 6 cm height. Thereafter, the samples were stored for at least 5 weeks before conducting gamma spectrometric analysis to ensure that secular equilibrium between ^{238}U and ^{232}Th and their respective daughters was reached.

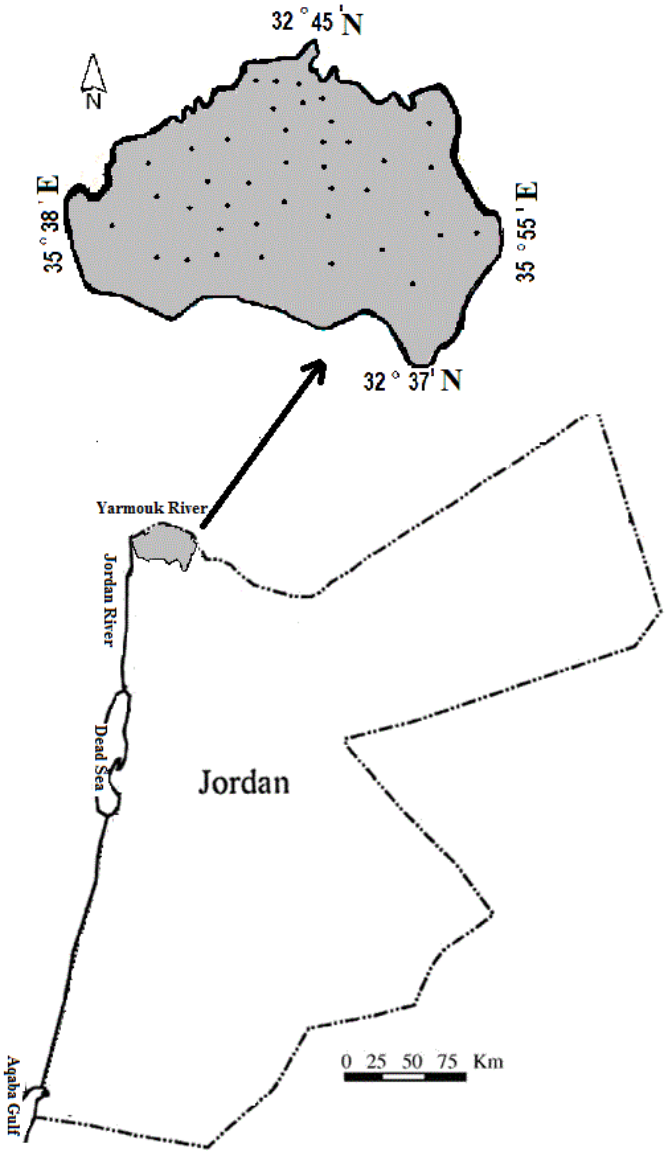

FIG. 1. Location map of the soil samples.

Activity Concentration Measurements

The radioactivity of the soil samples was measured using a low level counting system (gamma ray spectrometer) consisting of a high – purity germanium (HPGe) detector (GC2519) described elsewhere [12]. The detector has an active volume of 105.7 cm^3, a relative efficiency of 25% at 1.33 MeV of ^{60}Co gamma ray peak and a resolution of 1.9 keV at the same energy peak (Canberra, USA). To reduce background radiation, the detector is shielded by a 10 cm thick lead cylinder. A reference standard source (MGS-5, Canberra, USA) was used for energy and efficiency calibration, which emits gamma rays of 60-1461 keV. The standard sample consists of the radionuclides: ^{152}Eu, ^{57}Co, ^{113}Sn, ^{137}Cs, ^{54}Mn, ^{65}Zn and ^{40}K (Table 1). The detector signal was taken to the PC supplied with an MCA (Multi Channel Analyzer, model DSA-1000). Analysis of data was done using Genie 2000 software (Canberra, USA), containing peak search and nuclide identification modules. The prepared cups (samples) were placed on the detector end cap at a distance of 1 cm. Each sample was counted for 24 h to obtain good statistics with dead time smaller than 10% and quality control tests were performed using reference samples obtained from IAEA (IAEA-375 soil and IAEA-315 marine sediment) in the same geometry as the measured samples. Under identical conditions, empty cup measurements were also carried out to determine the background counts, which were later subtracted from the measured spectrum of each sample to get the net activities of the radionuclides. Fig. 2 shows the gamma ray spectrum for one of the soil samples.

TABLE 1. Data for radionuclides contained in standard sample used for energy and efficiency of calibration (MGS-5).

Nuclide	Energy (keV)	Activity (Bq)	Count rate (C/s)
^{155}Eu	60.0	2330	26
	86.5		722
	105.3		503
^{57}Co	122.1	5750	4920
	136.5		604
^{113}Sn	255.1	9600	202
	391.7		6230
^{137}Cs	661.6	2220	1880
^{54}Mn	834.8	7520	7520
^{65}Zn	1115.5	10800	5490
^{40}K	1460.8	798	85

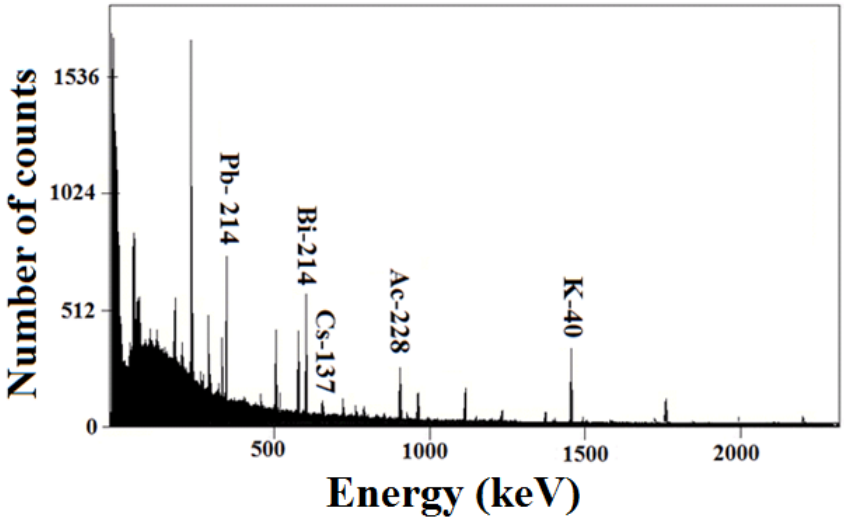

FIG. 2. The gamma ray spectrum for one of the soil samples (S 9).

The determination of ^{137}Cs and ^{40}K measured activity concentrations for the collected samples from Bani-Kananah District is based upon the detection of their gamma lines (gamma yields) of 662 keV (0.85) and 1461 (0.11) keV, respectively. For ^{232}Th radionuclide, the activity was determined using gamma line of 911 keV (0.29) of its daughter ^{228}Ac. The determination of ^{238}U activity concentration was based on the detection of gamma rays emitted using weighted mean activity concentration of its first daughter ^{234}Th of 63.3 keV (0.048).

The minimum detectable activities of (MDAs) for ^{137}Cs, ^{40}K, ^{238}U and ^{232}Th were 0.18, 8.4, 4.5 and 0.7 Bq/kg, respectively. The MDAs were calculated using the following equation:

$$MDA = \frac{2.71 + 4.65\sqrt{B}}{\varepsilon \times P_\gamma \times m} \quad (1)$$

where B is the true mean of the blank, P_γ is the gamma yield of the nuclide at given energy, ε is the efficiency of the detector at the peak and m is the mass of the sample.

Calculation of Radiation Hazard Indices

The radium equivalent activity index (Ra_{eq}) in Bq/kg represents the specific activity levels of materials containing different concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K, taking into account the hazards of radiation correlated with each component. It can be calculated according to the following equation [1]:

$$Ra_{eq} = C_{Ra} + 1.423\ C_{Th} + 0.077\ C_K \quad (2)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K, respectively. The above equation is based on the estimate that 1 Bq/kg of ^{226}Ra (^{238}U), 0.7 Bq/kg

of ^{232}Th and 13 Bq/kg of ^{40}K produce the same gamma ray dose rate.

The total absorbed dose rate (D) at 1 m above the ground surface due to gamma radiation in air has been calculated by assuming uniform distribution of the natural radionuclides ^{226}Ra (^{238}U), ^{232}Th and ^{40}K using the following equation [1]:

$$D(nGy/h) = 0.429C_{Ra} + 0.662C_{Th} + 0.0427C_K \quad (3)$$

To estimate the annual effective dose rate (D_{eff}), the conversion coefficient from absorbed dose in air to effective dose is 0.7 Sv/Gy and an outdoor occupancy factor of (0.2) is used. The annual effective doses are calculated from the following equation [1]:

$$Deff\ (\mu Sv/y) = D(nGy/h) \times 8760(h/y) \times 0.2 \times 0.7(Sv/Gy) \times 10^{-3} \quad (4)$$

The external and internal hazard indices (H_{ex} and H_{in}), respectively, are widely used and defined as follows [1]:

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_k/4810 \quad (5)$$

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_k/4810 \quad (6)$$

The values of these indices must be less than unity for the radiation hazard to be negligible.

Results and Discussion

The activity concentrations of the radionuclides ^{137}Cs, ^{40}K, ^{232}Th and ^{238}U detected in soil samples were reported in Table 2 which shows low level activity concentrations. All concentrations were reported as Bq/kg dry weight. Based on Table 2, the activity concentration values ranged from 5.7 to 32.1 with an average (±SD) of 22.7 ± 15.2 for ^{232}Th, 12.2 to 34.6 with an average (±SD) of 20.4 ± 9.8 for ^{238}U, 62.0 to 240.2 with an average (±SD) of 160 ± 76 for ^{40}K and 1.5 to 12.4 with an average (±SD) of 4.6 ± 5.0 for ^{137}Cs.

The world-wide average concentration values of the natural radionuclides ^{238}U, ^{232}Th and ^{40}K are 40, 40 and 370 Bq/kg, respectively [1]. Our data in general agree well and are lower than international reported limits. The artificial source ^{137}Cs in the samples can be considered as being due to nuclear weapons, bomb tests and accidents. The ^{137}Cs concentration is attributed to global fallout.

The correlation between ^{232}Th and ^{40}K shown in Fig. 3 is linear, which is in agreement with other studies [5,9], while there is no theoretical basis for this calculation.

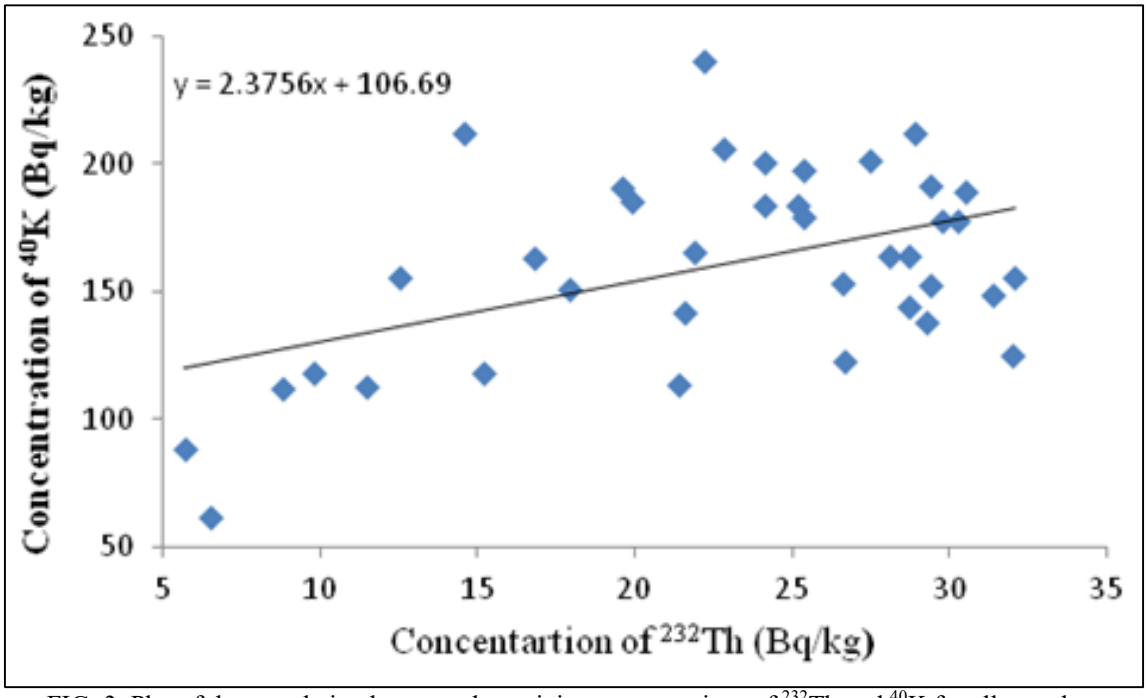

FIG. 3. Plot of the correlation between the activity concentrations of ^{232}Th and ^{40}K for all samples.

TABLE 2. Locations and activity concentrations of ^{238} U, ^{232}Th, ^{40}K and^{137} Cs in Bq/kg in the studied soil samples.

	Position	Height above sea level (m)	^{137}CS	^{40}K	^{232}Th	^{238} U
S1	(32 ° 44′ 02″ N, 35° 46′ 32″ E)	360	5.0±0.4	200.8±16.0	24.1±2.3	17.0±2.8
S2	(32 ° 43′ 43″ N, 35° 47′ 52″ E)	368	2.2±0.3	153.1±13.6	26.6±2.7	20.6±3.0
S3	(32 ° 43′ 38″ N, 35° 48′ 42″ E)	367	4.1±0.3	185.7±15.2	19.9±2.2	29.7±4.2
S4	(32 ° 43′ 39″ N, 35° 49′ 11″ E)	344	11.3±0.7	118.2±12.2	15.2±2.0	34.6±2.2
S5	(32 ° 42′ 53″ N, 35° 49′ 52″ E)	395	1.5±0.4	184.1±15.0	24.1±1.9	14.2±2.9
S6	(32 ° 42′ 37″ N, 35° 52′ 21″ E)	410	2.1±0.2	184.2±15.0	25.2±2.4	21.1±3.1
S7	(32 ° 40′ 45″ N, 35° 52′ 35″ E)	438	2.6±0.4	211.9±16.5	28.9±2.4	20.3±3.0
S8	(32 ° 38′ 59″ N, 35° 51′ 11″ E)	502	5.4±0.4	240.2±18.0	22.2±2.2	25.2±3.6
S9	(32 ° 38′ 57″ N, 35° 53′ 10″ E)	475	2.5±0.4	177.7±14.7	29.8±2.4	18.7±2.8
S10	(32 ° 37′ 13″ N, 35° 53′ 05″ E)	515	2.8±0.3	189.3±15.3	30.5±2.5	27.0±3.6
S11	(32 ° 37′ 31″ N, 35° 52′ 41″ E)	493	6.5±0.5	212.3±16.6	14.6±2.1	18.7±3.0
S12	(32 ° 37′ 37″ N, 35° 51′ 26″ E)	497	4.9±0.5	179.6±15.0	25.4±2.3	27.5±3.9
S13	(32 ° 38′ 07″ N, 35° 51′ 50″ E)	520	4.1±0.4	206.0±16.1	22.8±2.3	19.8±2.8
S14	(32 ° 40′ 29″ N, 35° 51′ 27″ E)	482	6.3±0.6	151.1±13.3	17.9±2.0	22.7±3.3
S15	(32 ° 42′ 26″ N, 35° 49′ 48″ E)	304	4.9±0.5	112.7±11.8	11.5±1.9	15.6±2.7
S16	(32 ° 41′ 30″ N, 35° 49′ 37″ E)	423	2.5±0.3	148.9±13.9	31.4±2.5	16.5±2.7
S17	(32 ° 38′ 27″ N, 35° 50′ 03″ E)	569	3.5±0.4	201.8±16.0	27.5±2.4	25.3±3.6
S18	(32 ° 39′ 37″ N, 35° 48′ 54″ E)	483	4.5±0.3	155.6±13.7	12.5±1.9	20.7±3.1
S19	(32 ° 40′ 10″ N, 35° 49′ 22″ E)	516	4.5±0.3	137.8±13.0	29.3±2.4	17.9±2.8
S20	(32 ° 39′ 21″ N, 35° 47′ 24″ E)	493	2.2±0.4	164.1±14.2	28.7±2.4	22.5±3.2
S21	(32 ° 39′ 59″ N, 35° 46′ 41″ E)	458	7.6±0.5	141.5±13.1	21.6±2.2	21.5±3.1
S22	(32 ° 41′ 06″ N, 35° 50′ 10″ E)	440	8.0±0.6	113.4±12.0	21.4±2.2	16.0±2.6
S23	(32 ° 43′ 15″ N, 35° 48′ 11″ E)	201	6.9±0.5	112.0±11.8	8.8±1.9	12.8±2.1
S24	(32 ° 42′ 41″ N, 35° 44′ 10″ E)	355	2.9±0.4	164.0±14.2	28.1±5.5	16.7±3.8
S25	(32 ° 42′ 14″ N, 35° 45′ 16″ E)	393	2.5±0.4	191.9±15.4	29.4±2.5	15.9±2.5
S26	(32 ° 41′ 12″ N, 35° 46′ 56″ E)	442	4.4±0.5	125.1±12.6	32.0±2.5	22.7±3.3
S27	(32 ° 41′ 21″ N, 35° 46′ 13″ E)	415	5.8±0.5	144.5±13.2	28.7±2.5	20.3±2.9
S28	(32 ° 40′ 47″ N, 35° 46′ 47″ E)	450	4.9±0.4	156.0±13.8	32.1±2.6	18.8±2.9
S29	(32 ° 40′ 08″ N, 35° 48′ 38″ E)	481	5.7±0.5	163.6±14.1	16.8±1.7	18.9±2.8
S30	(32 ° 39′ 38″ N, 35° 45′ 20″ E)	468	5.9±0.4	62.0±10.0	6.5±1.7	14.8±2.4
S31	(32 ° 39′ 04″ N, 35° 44′ 23″ E)	421	12.4±0.7	165.6±14.3	21.9±2.2	22.6±3.2
S32	(32 ° 38′ 59″ N, 35° 39′ 40″ E)	328	1.8±0.4	197.3±15.8	25.4±2.4	12.3±2.2
S33	(32 ° 38′ 08″ N, 35° 38′ 28″ E)	199	2.5±0.4	191.0±15.5	19.6±2.2	12.2±2.1
S34	(32 ° 39′ 20″ N, 35° 50′ 23″ E)	537	3.4±0.5	177.5±14.7	30.3±2.5	24.8±3.5
S35	(32 ° 41′ 20″ N, 35° 48′ 16″ E)	218	1.7±0.4	152.5±13.7	29.4±2.4	23.5±3.5
S36	(32 ° 39′ 27″ N, 35° 41′ 01″ E)	180	2.1±0.4	118.2±12.1	9.8±1.9	19.8±3.0
S37	(32 ° 40′ 35″ N, 35° 39′ 59″ E)	-50	4.9±0.5	88.5±11.2	5.7±1.9	21.9±3.2
S38	(32 ° 40′ 23″ N, 35° 44′ 53″ E)	425	6.4±0.5	123.0±12.3	26.7±2.3	23.7±3.4
	MIN.		1.5	62.0	5.7	12.2
	MAX.		12.4	240.2	32.1	34.6
	AVERAGE		4.6	160	22.7	20.4
	SD		2.5	38	7.6	4.9

From Table 3, the radium equivalent activity index (Ra_{eq}) in the soil samples ranges from 28.77 to 84.93 Bq/kg with a mean value of 65.0 ± 27.8 Bq/kg, which is less than the safe limit (370 Bq/kg) recommended by the Organization for Economic Cooperation and Development (OECD) (1979) [13]. The total absorbed dose (D) in the study area ranged between 13.21 and 39.65 nGy/h with an average value of 30.5 ± 13.1 nGy/h, which is lower than the range of values given in UNSCEAR (2000) {57(24-160) nGy/h}.

TABLE 3. External hazard indices (H_{ex}), internal hazard indices (H_{in}), radium equivalent (R_a), total absorbed dose (D) and annual effective dose (AEDE) in the studied soil samples.

Sample	H_{ex}	H_{in}	Ra_{eq} (Bq/kg)	D (nGy/h)	D_{eff} (μSv/y)
S1	0.18	0.23	66.76	31.65	38.84
S2	0.19	0.25	70.19	32.81	40.27
S3	0.20	0.28	72.27	33.64	41.28
S4	0.18	0.27	65.37	29.82	36.59
S5	0.17	0.21	62.64	29.73	36.49
S6	0.19	0.25	71.14	33.43	41.02
S7	0.21	0.27	77.69	36.68	45.01
S8	0.20	0.27	75.24	35.52	43.60
S9	0.20	0.25	74.74	35.15	43.14
S10	0.23	0.30	84.93	39.65	48.66
S11	0.15	0.20	55.82	26.57	32.60
S12	0.21	0.28	77.47	36.10	44.30
S13	0.18	0.24	68.06	32.18	39.49
S14	0.16	0.22	59.76	27.87	34.20
S15	0.11	0.15	40.59	18.99	23.30
S16	0.20	0.24	72.65	34.09	41.83
S17	0.22	0.28	79.92	37.46	45.98
S18	0.14	0.19	50.42	23.63	29.00
S19	0.19	0.24	70.15	32.81	40.26
S20	0.21	0.27	75.93	35.48	43.54
S21	0.17	0.23	63.08	29.40	36.08
S22	0.15	0.19	55.18	25.76	31.62
S23	0.09	0.13	33.90	15.97	19.60
S24	0.19	0.23	69.31	32.62	40.03
S25	0.20	0.24	72.46	34.29	42.08
S26	0.21	0.27	77.82	36.11	44.32
S27	0.20	0.25	72.27	33.74	41.40
S28	0.21	0.26	76.44	35.81	43.95
S29	0.15	0.20	55.35	26.04	31.95
S30	0.08	0.12	28.77	13.21	16.21
S31	0.18	0.24	66.46	31.08	38.14
S32	0.17	0.21	63.59	30.33	37.22
S33	0.15	0.18	54.75	26.19	32.14
S34	0.22	0.29	81.53	38.08	46.74
S35	0.21	0.27	77.08	35.90	44.06
S36	0.12	0.17	42.80	19.89	24.40
S37	0.10	0.16	36.83	16.84	20.67
S38	0.19	0.26	71.12	32.94	40.43
MIN.	0.08	0.12	28.77	13.21	16.21
MAX.	0.23	0.30	84.93	39.65	48.66
AVERAGE	0.18	0.23	65.0	30.5	37.4
SD	0.04	0.04	13.9	6.53	8.01

The annual effective dose in this study area ranged from 16.21 to 48.66 μSv/y with an average value of 37.4 ± 16.0 μSv/y. It's clear that the average value of the annual effective dose (0.037 mSv/y) is lower than the worldwide average value for outdoor effective dose of 0.07 mSv/y, reported by UNSCEAR (2000) [1].

The calculated values of H_{ex} for the soil samples studied ranged from 0.08 to 0.23 with an average value of 0.18 ± 0.08. In addition, the calculated values of H_{in} ranged from 0.12 to 0.30 with an average value of 0.23 ± 0.08. Since these values are lower than unity, the soil in the study area is safe and can be used for agriculture

without posing any radiological threat to the population.

The activity concentrations and dose rates of natural radionuclides of soil samples in different regions around the world are shown in Table 4.

TABLE 4. Summary of activity concentrations and dose rates of natural radioisotopes in soil samples in some of the world regions.

Region / Country	^{238}U	^{232}Th	^{40}K	Dose rate (nGy/h)	Reference
Karak, Jordan	228.9	27.2	410.2	-	[7]
Amman, Jordan	56.4	28.8	501.3	-	[7]
Russifa, Jordan	48.3-523.2	8.7-27.1	44-344	97.50	[9]
Northern Jordan	49.9	26.7	291.1	51.5	[14]
Tafila, Jordan	22.03	27.91	285.02	40.12	[11]
Ras Muneef, Jordan	10-73.2	5.8-30.8	108.8-325.6	44.2	[5]
Zarqa, Jordan	41.3	Low	390.8	34.66	[15]
Syria	19	24	336	-	[16]
Istanbul, Turkey	21	37	342	65	[17]
Pakistan	37	18	320	22	[18]
Bushehr, Iran	12-75	8-33	108-520	30.56	[19]
Cyprus	25	20	360	56	[20]
Greece	49	51	840	84	[20]
Spain	42	17	285	30	[19]
Russia	-	33	470	76	[20]
United States	35	35	370	47	[20]
Worldwide Average	40	40	370	57	[20]
Present study	20.4	22.7	160.6	30.46	

Conclusions

The activity concentrations of ^{137}Cs,^{40}k, ^{238}U and ^{232}Th in soil samples collected from north west Jordan (Bani-Kananah) have clearly shown the existence of low level activity. The calculated average radium equivalent activity index (Ra_{eq}), the mean external (H_{ex}) and internal hazard indices (H_{in}), the total absorbed dose rate and the annual effective dose in this study show that the radioactivity of radionuclides found in the surveyed area is below the world activity values. It is nominal and does not pose any potential health hazard to the general public.

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