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RESEARCH ARTICLE

ASSESSMENT OF RADIATION HAZARDS FOR SOIL SAMPLES FROM VICINITY OF AL-BAYDA CITY, YEMEN

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Abstract

In this work the radioactivity concentrations of the natural radioactive nuclides ^{226}Ra, ^{232}Th and ^{40}K were calculated in the surface soil samples from Al-Bayda governorate, middle of Yemen. Gamma spectroscopy is used to analyze the samples and the concentrations of radioisotopes were determined using hyper-pure germanium (HPGE) detector in Bq kg^{-1} dry-weight. The measured average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 27.657±1.7, 35.071±2.1 and 544.713±16.8 Bqkg^{-1}, respectively. Different hazard indices were also determined. The results showed that the average radium equivalent activity (Ra_{eq}), the absorbed dose rate (Dr), absorbed dose rate in indoor air, annual effective dose, the external hazard index (Hex), internal hazard index (H_{in}) and representation level index (I_{γ}) were: 119.75 Bqkg^{-1}, 56.42 nGyh^{-1}, 78.986 nGy h^{-1} , 46 µSv, 0.32, 0.40 and 45, respectively. The mean value of (Ra_{eq}) obtained in this study was in good agreement with that of the international value while the mean values of the other indices were found to be higher than the international reference values. The data were discussed and compared with those given in the literature.

Keywords: Annual effective dose, radiological parameter, soil, gamma spectroscopy.

1. Introduction

Knowledge of the distribution of radionuclides and radioactivity levels in the environment is important for assessing exposure of the population to the radiation. The two prominent sources of external radiation are cosmic rays and terrestrial gamma rays **[1]**. The concentrations of natural radioactivity such as radioactive series (^{238}U and ^{232}Th) and radioactive isotope ^{40}K and the related external exposure due to gamma radiation depend mainly on the geological and geographical conditions. Higher radioactivity in soil samples may be linked to the contribution of the parent materials that constitute the soil type. For instance, soil derived from granite will have a higher radioactivity than the soil derived from the other rock types **[2, 3]**.

Natural radioactivity is wide spread in the earth's environment. It exists in soil, plant, water, air, coal and phosphate fertilizers. Naturally occurring radioactive materials (NORMs) in soil are one of the components of external gamma-ray exposure to which persons are exposed to regularly.

Studies of soil radioactivity can provide reference data in observing the possible radiation hazards impact and associated radiological risk to human health. Radioisotopes that are present in soil significantly affect terrestrial gamma radiation levels. In the last decade, several studies were carried out to assess the average outdoor terrestrial gamma dose rate in air at 1 m from the ground **[4]**.

2. Experimental Section

2.1. Geologic Setting of the Area

The geology of Al-Bayda area is a part of the Precambrian basement complex of Yemen **[5]**.
The Republic of Yemen is located in the southern sector of the Arabian Peninsula. Yemen's land is covered with rocks whose ages date back to an era prior to the Cambrian. Some Cambrian rocks even date to a time before that era (that is, about 3 billion years ago). Geologically speaking, Yemen composes part of the Arabian Shield **[6]**. The area of Al Bayda governorate is about 10487 Km^2. The population is about 577369 person. Ab-Bayda governorate located between longitude 45.5771002 and latitude 13.9889146 Fig.(1) Shows a location map of the area under study.

2.2. Sampling and Samples Preparation

A total of 20 surface soils, at 5-cm depth, were collected using a stainless steel sampler. All samples were crushed to a fine powder and sieved through a 1- mm mesh, which is the optimum size enriched in heavy minerals. Each sample was dried in an oven at 110°C for 24 h to ensure that any significant moisture was removed from the samples **[7]**.

Weighed samples were placed in a polyethylene cylindrical beaker, of about 250-cm^3 volume each. These beakers have been sealed to prevent the escape of gaseous Rn^{222} from the samples and kept for about 30 days to ensure secular equilibrium between Ra^{226} and Th^{232} and their decay products, where the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) within the volume and the progeny will also remain in the sample **[8]**.

After that period, the samples were measured using a closed end-coaxial Canberra p- type (model 707) high-purity germanium (HPGe) detector with a relative efficiency of 30%. The germanium crystal is located inside the lead shield.

2.3. Radiometric Analysis

For gamma spectrometry analysis, all samples were analyzed after collection by low-background gamma spectroscopy using HPGe detector (Canberra, GR4020 model) with relative efficiency 40% for 3″ x 3″ NaI (Tl) crystal, and energy resolution of 2 keV at the 1332 keV gamma of ^{60}Co. The detector was shielded in a 6.22 cm thick lead well internally lined with 0.6 mm Carbon composite. The detector output was connected to spectroscopy amplifier (Canberra, Model, 2002CSL). The energy calibration for the system is carried out using point sources of (Ba^{133}, Co^{60}, Cs^{13}, Mn^{54}, Na^{22}, and Zn^{65}). This spectrometer was equipped with LabSOCSs (Laboratory Source less Calibration Software). Basic calibration measurements had been done at the factory; results were used to establish the detector's characterization file. The LabSOCSs calibration tool takes into account the sample to detector geometry, sample density and composition, as well as measurement container properties. To validate and check the efficiency data supplied by LabSOCSs, measurements were performed in our laboratory by using a set of calibrated point sources,(Ba^{133}, Co60and Cs^{137}) positioned at a distance between 0 and 15 cm from the detector end-cap. The calculated results show good agreement between mathematical and empirical peak efficiencies with differences less than 10%.

For spectral analysis, the software Genie 2000 (Canberras, USA) has been used. The counting time of the measurements was 28800 s for activity or background. To determine the background radiation level, an empty cylindrical beaker was counted at the same time as the samples under identical geometry. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. The ^{226}Ra radionuclides have been estimated from the 351.9 keV (36.7 %) gamma peak of ^{214}Pb and 609.3 keV (46.1 %), 1120.3 keV (15 %) and 1764 keV (15.9 %) gamma peaks of ^{214}Bi. On the other hand the ^{232}Th radionuclide was estimated from the 911.2 keV (29 %) gamma peak of ^{228}Ac, the 238.6 keV (43.6 %) gamma peak of ^{212}Pb and 2614 keV gamma ray from 208Tl. While the ^{40}K radionuclide was estimated using the 1461 keV (10.7 %) gamma peak from ^{40}K itself.
Samples including soil were analyzed in nuclear physics and nuclear chemistry lab, Physics Department, Faculty of Science, Assiut University, Egypt.

2.4. Activity Concentration

The calculations of the activity concentration (A_c) values for radionuclides from the ^{238}U and ^{232}Th series and ^{40}K present in soil samples can be determined as **[9]**:

$$A_c=\frac{C_{net}}{\gamma\times\varepsilon\times m\times t} \quad \dots\dots\dots \quad (1)$$

Where C_{net} represents peak net counts, γ represents the emission probability of specific energy peak, ε is the absolute efficiency of the full energy peak of the detector, m is the mass sample in Kg and t is the time of count.

2.5. Assessment of Exposure Risk

2.5.1. Radium Equivalent Activity (Ra_{eq})

The radium equivalent activity (Raeq) is a weighted sum of activities of the ^{226}Ra. ^{232}Th and ^{40}K radionuclides based on the assumption that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of 232Th and 4810 Bq kg^{-1} of ^{40}K produce the same γ-ray dose rates **[10]**. Radium equivalent activity can be calculated from the following relation suggested by **[11]**.

$$Ra_{eq}=A_{Ra}+(A_{Th}\times 1.43)+(A_K\times 0.077) \quad \dots \quad (2)$$

Where A_{Ra} is the activity concentration of ^{226}Ra in Bq kg^{-1}, A_{Th} is the activity concentration of ^{232}Th in Bq kg^{-1} and A_K is the activity concentration of ^{40}K in Bq kg^{-1}.

2.5.2. Absorbed Dose Rate

The absorbed dose rate in air (Dr) in (nGy h^{-1}), resulting from the natural specific activity concentration of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}) at a height of 1m above the ground was calculated by the following equation **[12, 13, 14, 15]**.

$$D(nGyh^{-1})=0.462A_{Ra}+0.604A_{Th}+0.042A_K \quad \dots \quad (3)$$

Where: A_{Ra}, A_{Th} and A_K are the mean activity concentrations of ^{226}Ra, ^{232}Th and 40K, respectively, in Bq kg^{-1} **[15]**.

2.5.3 Annual Effective Dose

To estimate annual effective doses, the following must be considered: (a) the conversion coefficient from absorbed

dose in air to effective dose and (b) the indoor occupancy factor. The annual, estimated, average, effective- dose equivalent received by a member is calculated using a conversion factor of 0.7 Sv Gy^{-1}, which is used to convert the absorbed rate to human effective dose equivalent with an outdoor occupancy of 20% and 80% for indoors **[16]**.

The annual effective doses are determined as follows:

Effective dose rate ($\mu Sv.yr^{-1}$) = Absorbed dose (nGy h^{-1}) × 8760 h.yr^{-1} ×0.7 ……. (4)

2.5.4. Annual Gonadal Dose Equivalent (AGDE)

The gonads, the active bone marrow and the bone surface cells are considered as the organs of interest by UNSCEAR **[13].** Therefore, the AGDE (mSv yr^{-1}) owing to the specific activities of ^{226}Ra, ^{232}Th and ^{40}K were calculated using the following formula **[17, 18]:**

$$AGDE=(3.09\times A_{Ra}+4.18\times A_{Th}+0.314\times A_K)\times 10^{-3} \ldots (5)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq kg^{-1}. The world average value is 0.30 mSv reported by Zaidi et al., **[17]** for soil.

2.5.5. External and Internal Hazard

The external hazard index (H_{ex}) considers only the external exposure due to the emitted gamma-ray and corresponds to a maximum Ra_{eq} of 370 Bq kg^{-1} for the materials **[19]**. The value of this index must be less than unity for the radiation hazard to be negligible.

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad ..... \quad (6)$$

Where A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K, respectively. The calculated average external hazard index was found to be less than unity.

2.5.6. Internal Hazard Index

In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs. To assess the internal exposure to ^{222}Ra gas and its daughter products the internal hazard index has been defined by Beretka and Mathew **[11]** as:

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad ..... \quad (7)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. For the safe use of a material in the construction of dwelling, H_{in} should be less than unity.

2.5.7. Gamma Index (I_γ)

Radioactivity level index is used to estimate the level of γ-radiation hazards associated with the natural radionuclides. The level index I_γ is calculated by the equation given by Beretka and Mathew, **[11]**:

$$I_{\gamma r} = \frac{1}{300}A_{Ra} + \frac{1}{200}A_{Th} + \frac{1}{3000}A_K \quad \ldots (8)$$

Where: A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}), respectively.

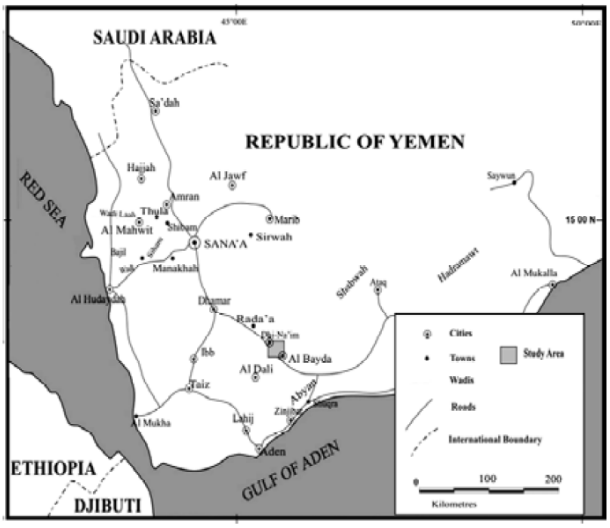

Figure 1: Location study of area

3. Results and Discussion

Activity Concentrations and Radiological Hazards

The results for the activity concentrations of U-238 series (Ra-226), Th-232 series (Th-232), as well as K-40, expressed in Bq kg^{-1} were determined using γ-spectrometry.

The overall results show that the ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil, but the radioactivity varies, often greatly, over a distance of some meters.

The results of activity concentrations for soil samples are present in Table 1. From the table the range of Ra-226 values were from 36.21±2.2 to 19.83±1.2 with the average concentration of 27.657±1.7. The values for Th-232 were from 43.73±2.6 to 26.59±1.6 with the average concentration of 35.071±2.1. While the values for K-40 were from 591.07±18.3 to 487.88±15.1 with the average concentration of 544.713±16.8. The distribution of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations in all samples is given in Figure 2.

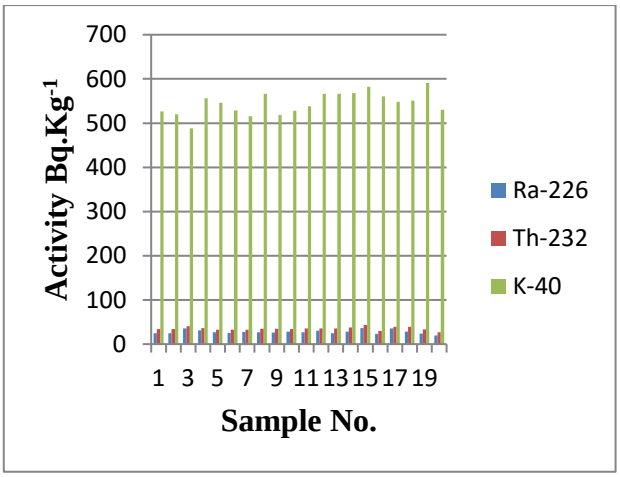

Figure 2: Activities concentration of ^{226}Ra, ^{232}Th and ^{40}K in soil samples from Al-Bayda governorate area, Yemen

From the results we noted that the activity concentrations of samples close to the city were the highest values of radioactivity (samples No. 3 and 15), while the lowest activity concentrations were in samples No. 19 and 20 far from the city.

The activity concentrations of Ra-226 in all sites under study are lower than the worldwide mean values that recorded by UNSCEAR, **[15]**, (40 Bq kg^{-1}). Except samples No. 3, 4, 12, 15 and 17 are higher than the Worldwide.

The values activity concentrations of ^{232}Th for samples were from 26.59 ±1.6 to 43.73±2.6 with average activity concentration of 35.071±2.1 Bq kg^{-1}.

The activity concentrations of ^{232}Th are higher than the activity concentrations of ^{226}Ra in all investigated samples, these results agree with the fact the concentrations of ^{232}Th radionuclide in earth crust is more abundance (7.4 µg g^{-1}) compared with concentrations of ^{238}U radionuclides (2.8 µg g^{-1}) **[15]**.

The activity concentrations of 40K in soil samples were from 487.88±15.1 to 591.07±18.3 with average activity concentration of 544.713 Bq kg^{-1}, this value is higher than the worldwide average (412 Bqkg^{-1}) reported by UNSCEAR **[20]**.

The activity concentrations of ^{40}K in soil are higher than that of 226Ra and ^{232}Th, this is also in accordance with the well-known fact that potassium in the earth's crust is of the order of percentage whereas uranium and thorium are in ppm level **[13]**.

To assess the radiological hazard of soil samples from Al-Bayda governorate, Yemen, the radium equivalent activities (Ra_{eq}), the absorbed dose rate, the absorbed dose rate in indoor air, Annual Gonadal Dose Equivalent, Gamma radiation hazard index, external hazard index, and internal hazard index were calculated and listed in Table 2.

From the results the radium equivalent was ranged from 98.7 to143.6 Bq kg^{-1} with average activity of 119.75 Bq kg^{-1}.

The absorbed dose rate in nGr h^{-1} was from 47.282 to 66.964 nGr h^{-1} with average value 56.42 nGr h^{-1}. The average value of absorbed dose rate in soil samples under study agrees with that the world average value (57 nGyh^{-1}) **[15]**.

Values of indoor dose rate for soil are varying from 93.750 to 66.195 with an average value of 78.986 nGy h^{-1}. The values of indoor dose rates in soil samples under test are lower than the world range reported in UNSCEAR **[20]**.

The annual gonadal dose equivalent (AGDE) was from 0.34 to 0.48 with average value 0.40 mSv y^{-1}. This result is slightly higher than the permissible safety limit of 0.3 mSv year^{-1} **[17]**.

The calculated values of representative level index, $I_{\gamma r}$, for soil samples ranged from 0.4 to 0.5 with an average value of 0.45, which indicates gamma dose contribution from these soils were less than the highest value of dose rate in air 1 mSv yr^{-1} **[14]**, recommended for population **[20]**.

For the safe use of the material under investigation in the construction of dwellings, H_{in} and H_{ex} must be less than unity **[21]**. The calculated values of H_{ex} and H_{in} for the studied samples range from 0.3 to 0.4 and from 0.3 to 0.5 respectively, as it appears in Table 2, all these values are less than unity.

The results show that the activity concentrations and radiological parameter for soil samples under study were in the range of worldwide values reported in the UNSCEAR **[20]**, and we can conclude that the area under investigation has a normal background radiation and may be not pose radiological risks to the population owing to harmful effects of ionizing radiation from the naturally occurring radionuclides in soil. Also the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in samples from the study area were compared with similar investigations in other countries and the summary of results is given in table (3).

Table (3) represents a comparison of ^{226}Ra, ^{232}Th and ^{40}K activity concentrations (Bq kg^{-1}) for different types of soil samples under study with other values in the world. Table (3) shows that ^{226}Ra activity concentrations in our study for soil samples matches with those of other countries, except in the cases of Bangladesh **[22]**, India **[23],** Srilanka **[24]** and Jordan (Ma'an) (Saleh and Shageb **[25]**, which are higher than the present work.

Table 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq kg^{-1}) in soil samples from Al-Bayda governorate area.

S.No	Latitude	Longitude	Activity concentrations		
			Ra-226	Th-232	K-40
1	13°58'34.57"N	45°34'34.49"E	24.25±1.5	33.97±2.0	526.33±16.3
2	13°58'23.44"N	45°34'26.34"E	24.70±1.5	33.91±2.0	519.97±16.1
3	13°58'20.70"N	45°34'26.37"E	35.15±2.2	40.60±2.4	487.88±15.1
4	13°58'19.39"N	45°34'27.95"E	31.35±1.9	36.15±2.2	556.19±17.2
5	13°58'17.45"N	45°34'25.15"E	26.75±1.6	32.60±2.0	545.68±16.9
6	13°58'15.51"N	45°34'22.03"E	25.27±1.6	32.39±1.9	528.58±16.3
7	13°58'13.31"N	45°34'24.75"E	27.70±1.7	32.38±1.9	515.63±16.3
8	13°58'15.84"N	45°34'15.68"E	26.80±1.6	34.95±2.1	566.36±17.5
9	13°58'14.47"N	45°34'6.51"E	25.72±1.6	34.78±2.1	518.57±16.0
10	13°58'19.08"N	45°34'37.70"E	27.93±1.7	34.12±2.0	528.01±16.3
11	13°58'26.15"N	45°34'50.25"E	26.74±1.6	35.25±2.1	537.77±16.6
12	13°58'35.64"N	45°35'10.24"E	30.41±1.9	35.61±2.1	566.14±17.5
13	13°58'41.14"N	45°35'23.44"E	24.61±1.5	35.13±2.1	566.05±17.5
14	13°58'45.40"N	45°35'35.53"E	28.53±1.8	37.90±2.3	568.02±17.5
15	13°58'4.57"N	45°33'45.75"E	36.21±2.2	43.73±2.6	582.02±18.0
16	13°59'6.73"N	45°35'38.59"E	23.33±1.4	29.34±1.8	560.57±17.3
17	13°59'9.12"N	45°35'25.27"E	35.34±2.2	39.44±2.4	548.01±16.9
18	13°59'1.67"N	45°35'54.27"E	28.53±1.8	39.02±2.3	551.28±17.0
19	13°59'10.27"N	45°36'43.84"E	23.99±1.5	33.56±2.0	591.07±18.3
20	13°59'19.20"N	45°38'23.79"E	19.83±1.2	26.59±1.6	530.12±16.4
Average			**27.657±1.7**	**35.071±2.1**	**544.713±16.8**
Max			**36.21±2.2**	**43.73±2.6**	**591.07±18.3**
Min			**19.83±1.2**	**26.59±1.6**	**487.88±15.1**

Table 2: Radium equivalent activity,Ra_{eq}, absorbed dose rate, annual effective dose(AED), absorbed dose rate in indoor air, Annual Gonadal Dose Equivalent, gamma activity concentration index, $I_{\gamma r}$, external hazard index, H_{ex}, and internal hazard index, H_{in}, for soil samples.

Sample No.	Ra_{eq} (Bq kg^{-1})	Dr(nGy h^{-1})	(AED) (µSv)	Indoor dose (nGy h^{-1})	AGDE (mSv y^{-1})	$I_{\gamma r}$	H_{ex}	H_{in}
1	113.4	53.437	0.43	74.812	0.38	0.4	0.3	0.4
2	113.2	53.334	0.43	74.668	0.38	0.4	0.3	0.4
3	130.8	60.617	0.49	84.864	0.43	0.5	0.4	0.4
4	125.9	59.221	0.48	82.910	0.42	0.5	0.3	0.4
5	115.4	54.606	0.44	76.448	0.39	0.4	0.3	0.4
6	112.3	53.076	0.43	74.306	0.38	0.4	0.3	0.4
7	113.7	53.621	0.43	75.069	0.38	0.4	0.3	0.4
8	120.4	56.887	0.46	79.642	0.41	0.5	0.3	0.4
9	115.4	54.246	0.44	75.944	0.39	0.4	0.3	0.4
10	117.4	55.272	0.45	77.380	0.39	0.4	0.3	0.4
11	118.6	55.808	0.45	78.131	0.40	0.4	0.3	0.4
12	124.9	58.905	0.48	82.468	0.42	0.5	0.3	0.4
13	118.4	55.982	0.45	78.375	0.40	0.4	0.3	0.4
14	126.5	59.467	0.48	83.253	0.42	0.5	0.3	0.4
15	143.6	66.964	0.54	93.750	0.48	0.5	0.4	0.5
16	108.5	51.786	0.42	72.500	0.37	0.4	0.3	0.4
17	133.9	62.606	0.51	87.649	0.45	0.5	0.4	0.5
18	126.8	59.402	0.48	83.163	0.42	0.5	0.3	0.4
19	117.5	55.857	0.45	78.200	0.40	0.4	0.3	0.4
20	98.7	47.282	0.38	66.195	0.34	0.4	0.3	0.3
Average	**119.75**	**56.42**	**0.46**	**78.986**	**0.40**	**0.45**	**0.32**	**0.40**

To compare the natural radioactivity of Al-Bayda soil with the Yemeni soils in other areas **[26]**, studied the natural radioactivity of ^{40}K, ^{226}Ra, and ^{232}Th in rock and soil samples collected around Juban town in Yemen. The study shows that the average radioactivity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for soil samples were 44.4, 58.2, and 822.7 Bq kg^{-1}, respectively. Also **[27]**, reported that the average specific activities in soil samples collected from Alsalamia-Al-Homira area in Abyan governorate were (41.46 ± 5.6, 68.68 ±6 and 1224.7 ± 31 Bq kg^{-1})

and (80.77 ± 4.5, 211.5 ± 14 and 1004.8 ± 40 Bq kg^{-1}), for clay and sandy soil, for ^{226}Ra, ^{232}Th and ^{40}K, respectively.

Table 3: Comparison of mean activity concentrations (Bq kg^{-1}) in soil with other countries of the world

Country	^{226}Ra (Bq kg^{-1})	Th^{232} (Bq kg^{-1})	^{40}K (Bq kg^{-1})	References
Lebanon	4-73	5-50	57-554	[28]
Egypt (Assiut)	46.15±9.69	30.57±4.90	553.14±23.19	[29]
Bangladesh	84	141	1944	[22]
India	44.97	59.7	217	[23]
Yemen (Juban)	44.4	58.2	822.7	[26]
Yemen (Assalamia-Al-Homira) clay	41.46	68.68	1224.7	[27]
Syria	19	24	336	[30]
Egypt (Qena)	13.7	12.3	162.8	[31]
Jordan (northern Jordan)	42.5	26.7	291.1	[32]
Jordan (Ma'an)	57.7	18.1	138.1	[25]
Malaysia	12-968	11-1210	12-2450	[33]
Saudi Arabia (Taif)	23.8	18.6	162.8	[34]
Qassim, KSA	13.1(2.1-22.9)	17.5 (3.3 – 31.7)	151(221- 1212)	[35]
Srilanka	35	72	585	[24]
Al-Bayda	27.657±1.7	35.071±2.1	544.713±16.8	Present study
World wide	**32**	**45**	**412**	**[20]**

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مقالة بحثية

تحديد المخاطر الإشعاعية لعينات من التربة من جوار مدينة البيضاء، اليمن

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الملخص

لقد تم في هذا البحث دراسة تركيز النويدات ذات النشاط الإشعاعي الطبيعي لعناصر الراديوم-226 والثوريوم-232 ونظيرالبوتاسيوم-40 لعشرين عينة من عينات التربة تمَّ جمعها من مواقع مختلفة في محافظة البيضاء في اليمن. استخدمت تقنية مطيافية جاما لتحليل العينات باستخدام كاشف الجرمانيوم عالي النقاوة، وحساب تركيز النظائر المشعة بوحدات بيكريل/كغم. لقد وجد إن متوسط تركيز هذه النويدات 27.657، 35.071 و544.713 بيكريل/كغم للنويدات الراديوم-226 والثوريوم-232 والبوتاسيوم-40 على التوالي.
لقد تم تقدير الأضرار الإشعاعية الناجمة عن النشاط الإشعاعي الكلي، وذلك بحساب بعض المعاملات الإشعاعية المختلفة. أظهرت النتائج إن معدلات نشاط الراديوم المكافئ (Ra_{eq}) معدل الجرعة الممتصة (Dr)، الجرعة الممتصة في الهواء الداخلي، الجرعة المكافئة السنوية، معامل الخطر الإشعاعي الخارجي (H_{ex})، معامل الخطر الإشعاعي الداخلي (H_{in})، ومعامل مستوى الإشعاع (I_γ) هي: 119.75 بيكريل/كغم، 56.42 نانوجراي/ساعة، 46 ملي سفرت/سنة، 0.32، 0.40 و45 على التوالي. وبإجراء مقارنة علمية وجدنا أن متوسط قيمة نشاط اليورانيوم المكافئ متوافق مع القيم العالمية، بينما متوسط القياسات لجميع المعاملات الأخرى أعلى من الحدود العالمية. كما تم مقارنة تركيز النويدات الطبيعية الناتجة مع دراسات أخرى في العديد من دول العالم.

الكلمات الرئيسية: الجرعة الفعالة السنوية، المعامل الإشعاعية، تربة، التحليل الطيفي لجاما.