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Evaluation of Natural Radionuclide content in Nile River Sediments and Excess Lifetime Cancer Risk Associated with Gamma Radiation

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ABSTRACT

Introduction: This Study has was carried out to measure and detect the natural occurred radionuclide content including ^{226}Ra, ^{232}Th and ^{40}K in the Nile River sediments at various locations in Upper Egypt, from Aswan to El-Minya. Additionally, we determine the absorbed dose rate, the annual effective dose equivalent, and excess lifetime cancer risk also has been calculated.
Material and Methods: The gamma ray measurements were performed with a high resolution High-Purity Germanium detector, low background, and Personal Computer multichannel analyzer.
Results: In Aswan Governorate, the mean specific activities of radionuclide's (^{226}Ra, ^{232}Th and ^{40}K) 14.86, 13.78 and 175.4 in Bq/kg respectively. In Qena Governorate, the mean specific activities of mentioned radionuclides were 14.44 Bq/kg, 15.02 Bq/kg and 197.57 Bq/kg, respectively. These values were18.53 Bq/kg, 11.3 Bq/kg and 184.73 Bq/kg in Sohag Governorate, respectively. In Asyut Governorate the mean specific activities of the radionuclide's were 11.38 Bq/kg, 10.0 Bq/kg, and 164.715 Bq/kg, respectively. However, these values were 19.56 Bq/kg, 11.72 Bq/kg, and 239.92 Bq/kg in Minya Governorate, respectively. The hazard indices of gamma radiation such as Absorbed dose rate, annual effective dose equivalent and excess lifetime cancer risk were calculated.
Conclusion: According to the results, all the values were within the reported values by the United Nations Scientific Committee on the Effects of Atomic Radiation. In addition, there was no likelihood of radiological health hazards to the population living close to the Nile river.

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Introduction

Estimating the exposure of humans to various sources of radiation is very significant. Human beings have always been exposed to radiation from natural sources [1]. Such sources can comprise the ground people walk on, the air they breathe, and the food they eat [2]. Radiation can be found everywhere; people, intentionally or unintentionally, are being constantly exposed to the radiations found in the environment. The natural radiation associated with life on the earth is either from the terrestrial or extraterrestrial origin (cosmic rays).

They are emitted from terrestrial materials such as soil, rocks, as well as some singly occurring radionuclides including uranium, thorium, their isotopes, their decay products, as well as ^{40}K and ^{87}Rb [3-6]. A temporary sink of many materials might be the Nile river sediments, which pass through various aquatic chemical and biological cycles operating on the earth's surface. Therefore, the sediments are converted to an environmental host for numerous waste produced remains of the society [7].

The effects of this human-made interference can be sufficiently strong in some situations to highly affect the configuration of the deposited sediments. Once a substance is incorporated into sediment, its final destiny relies on very complex factors. An element can be believed to be permanently locked into a sediment component, or it may afterward be released to participate in various biogeochemical reactions [8-10].

This study was conducted to assess the natural radionuclides and to calculate the absorbed dose rate (D), the annual effective dose equivalent (AEDE), and the excess lifetime cancer risk of the Nile river sediments.

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Materials and Methods

Sampling Collection and Preparation

In this study, 26 samples of sediment were collected from 26 areas of Upper Egypt extend from Aswan to Minya. The samples were taken at the distance of 5 to 10 m from the riverside and the depth of 1-2 m. The sample weighed about 1 kg were placed in plastic bags and transported to the laboratory. The sampling map is shown in Figure 1. The sample codes, locations, and types are shown in Table 1.

Radioactivity measurements

The samples with the mean weight of 223 g were collected at the depth of 0-10 cm from the upper layer using a plastic cup and then they were put in plastic bags. Prior to the analysis, the samples were dried, crushed, and homogenized. Thereafter, before subjecting the samples to gamma spectrometer, the containers were sealed for a month to ensure the secular equilibrium between ^{226}Ra, ^{232}Th, and their progenies [11].

The samples were placed directly on the detector for the gamma analysis. The exposure time of each sample to the detector was 12 hours [12-16].

The gamma-ray measurements were performed by using High Purity Germainum gamma spectrometer (HPGe) model CS20-A31CL. Liquid Nitrogen (-196c°) is used to the cool the detector for operating

The model of HPGe detector (CS20-A31CL) of the closed-end coaxial type with sensitive volumes of

108 cm^3 ,diameter 5.4 cm, and lead shield with the thickness of 10 cm. The relative efficiency was 24.5% for 1332 keV for the line of ^{60}Co related to NaI (3×3) inch with the source-detector distance (25) cm,the data were gathered , stored and analyzed by using Multi-Channel Analyzer(MCA) [17-20].

Quality control

Three types of calibrations including energy, resolution, and efficiency calibrations were performed for gamma spectrometer**.** The ^{152}Eu standard source was used for efficiency calibration which was produced in Amersham International plc (U.K.). The parallel measurements of the International Atomic Energy Agency (IAEA) inter comparison sediment samples (IAEA-300 and IAEA-315) were used for checking the precision and accuracy. An empty polyethylene container with the same geometry and measuring conditions as those used for the samples to determine the background due to the existence of natural radionuclides in the environment. The uncertainties in the calibration of the peak areas of these photopeaks were±2% [21].

Figure 1. Study context

Table 1. Sample codes, locations and types

Code No.	Governorate	Description	Sediment type
1	Aswan	old Aswan Dam	Clay
2	Aswan	Kima area	Sand
3	Aswan	Kom Ombo	Sand
4	Aswan	Edfu	Sand
5	Aswan	El-Sibayia	Clay
6	Qena	Isna – Tourism area	Clay
7	Qena	Isna	Clay
8	Qena	Luxor – Awameya	Sand
9	Qena	Luxor	Clay
10	Qena	Qus – before paper company	Sand
11	Qena	Qus – after paper company	Sand
12	Qena	Qena	Clay
13	Qena	Nag Hammadi	Clay
14	Sohag	El-Balyana	Clay
15	Sohag	Gerga	Clay
16	Sohag	Sohag	Sand
17	Sohag	El -Maragha	Clay
18	Asyut	Asyut	Sand
19	Asyut	Mangabad	Clay
20	Minya	Der Mawas	Loam
21	Minya	Malawi	Sand
22	Minya	Minya	Clay
23	Minya	Samalut	Loam
24	Minya	Matai	Sand
25	Minya	Beni Mazar	Clay
26	Minya	Maghagha	Loam

Radiological Hazards

Absorbed dose rate (D)

The measured activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K were converted into doses by applying the conversion factors 0.462, 0.604, and 0.0417, respectively. These factors were used to calculate the total dose rate (nGy/h) using the following equation: [22]

$$D\ (nGy/h) = 0.462A_{Ra}+0.604\ A_{Th}+0.0417A_K \quad (1)$$

In the mentioned equation, A_{Ra}, A_{Th}, and A_K stand for the specific activities of corresponding radionuclides.

Annual effective dose equivalent

The annual effective dose equivalent (AEDE) is determined using the following equation [23].

$$(AEDE)_{outdoor}=D\ (nGy/h)\times 8.760\ (h/y)\times 0.2\times 0.7\ Sv/G\times 10^{-3} \quad (2)$$

The highest value of outdoor annual effective dose equivalent $(AEDE)_{out}$ in the studied samples was equal to 46.81 µSv/y, while the lowest value of outdoor annual effective dose equivalent which was equal to 15.57 µSv/y with an average value of 29.68 µSv/y.

Excess lifetime cancer risk:

Excess lifetime cancer risk (ELCR) can be defined as the excess probability of developing cancer at a lifetime due to the radiation exposure levels. The ELCR is calculated using the below equation [24].

$$ELCR= AEDE\times DL\times RF \quad (3)$$

In this equation, DL is the average duration of life (estimated to be 70 years), and RF is the risk factors such as fatal cancer risk (% per sievert). The International Commission on Radiological Protection (ICRP) uses RF values of 0.05 for the public in the case of stochastic effects [25].

Results

Radioactivity Analysis

The specific activities of radionuclides ^{226}Ra, ^{232}Th and ^{40}K were measured in selected sediment samples from different locations along the Nile River from Aswan to El-Minia and their radiation hazard parameters are listed in table 2. The comparison between the activity concentrations in Bqkg^{-1} for all the samples is showed in Figure 2 . In Aswan governorate, the specific activity of ^{226}Ra ranged from 3.83±1.54 Bq/kg in Edfu area to 34.94±4.01 Bq/kg in El Sibayia with the mean value of 14.86 Bq/kg. However, the specific activity of ^{232}Th varied from 2.88±1.08 Bq/kg in Kimma area to 30.10± 1.83Bq/kg in After the old Aswan Dam area with the mean value of 15.026 Bq/kg. In addition, these values were 133.48 ± 6.29 Bq/kg in El Sibayia and 253.97±8.05 in old Aswan Dam area with the mean value of 175.4 Bq/kg for ^{40}K .

In Qena governorate, the specific activity of ^{226}Ra ranged from 4.18±1.97 Bq/kg in Qus – before paper company to 28.24±4.00 Bq/kg in Qena with the mean value of 14.44 Bq/kg while they were 6.15±1.97 Bq/kg in Qus – before paper company to 22.03±1.79 Bq/kg in Nag Hammadi with the mean value of 15.022 Bq/kg for ^{232}Th. Additionally, these values varied ranged from 158.84±6.35 Bq/kg in Qus – after paper company to 273.41±9.46 in Luxor with the mean value of 197.57 Bq/kg for ^{40}K.

In Sohag governorate, the specific activity of ^{226}Ra ranged from 12.16±2.57 Bq/kg in El Balyana area to 34.25±2.68 Bq/kg in Gerga with the mean value of 18.53 Bq/kg. Moreover, the specific activity of^{232}Th ranged from 6.73±1.28 Bq/kg in Sohag to 16.44±1.69 Bq/kg in El_Balyana with the mean value of 11.3 Bq/kg. These values were 137.15±5.68 Bq/kg in Sohag and 248.80±8.73 Bq/kg in El Balyana with the mean value of 184.73 Bq/kg for ^{40}K.

In Asyut governorate, the specific activity of ^{226}Ra ranged from 9.07±2.60 Bq/kg in Mangbad to 13.70±2.35 Bq/kg in Asyut city with the mean value of 11.38 Bq/kg, while ^{232}Th had the specific activities of 9.88±1.88 Bq/kg in Mangbad and 10.13±1.12 Bq/kg in Asyut with the mean value of 10 Bq/kg. Furthermore, these values were 112.31±4.77 Bq/kg in Asyut and 217.12±8.19 Bq/kg in Mangabad with the mean value of 164.71 Bq/kg for ^{40}K

In Minya governorate, the activity concentration of ^{226}Ra ranged from 7.90±3.23 Bq/kg in Matai to 33.64±3.59 Bq/kg in Mangabad with the mean value of 19.56 Bq/kg, while they ranged from 4.88±2.06 Bq/kg in Maghagha to 20.79±2.18 Bq/kg in Der Mawas with the mean value of 10.34 Bq/kg for ^{232}Th. These values varied from 188.47±8.78 Bq/kg in Matai to 312.98±12.2 Bq/kg in Samalut with the mean value of 239.92 Bq/kg for ^{40}K.

The absorbed dose rate (D) values ranged from 12.73 nGy/h in sample No. 10 (Qus- before paper company area) to 38.17 nGy/h in sample No. 1 (after Old Aswan Dam) with the mean value of 24.17 nGy/h (Table 3).

The values of ELCR ranged from 0.054×10^{-3} to 0.163×10^{-3} with the mean value of 0.100×10^{-3} (Table 3). The relative contributions to the radiological hazards (D, AEDE, and ELCR) owing to ^{226}Ra, ^{232}Th, and ^{40}K for the sediment samples are demonstrated in Fig.2 . It is worth mentioning that ^{226}Ra and ^{40}K are the main contributors to D, AEDE, and ELCR in the samples.

Table 2. Activity concentrations (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K with their uncertainties in the Nile River Sediments collected from the Upper Egypt area

Sample code No.	Governorate	Activity concentration (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
1	Aswan	17.04±3.15	30.10±1.83	253.97±8.05
2		7.83±2.32	2.88±1.07	172.64±5.82
3		10.68±1.97	9.16±1.18	162.29±6.04
4		3.83±1.54	7.16±1.14	154.62±5.92
5		34.94±4.01	19.63±1.98	133.48±6.29
6	Qena	7.88±2.83	18.88±1.81	230.44±8.43
7		8.99±2.82	19.46±1.69	173.59±6.79
8		15.23±3.43	15.20±1.64	185.07±7.61
9		20.69±3.62	17.81±1.80	273.41±9.46
10		4.18±1.97	6.15±1.08	159.00±6.11
11		10.95±2.19	10.03±1.33	158.84±6.35
12		28.24±4.00	10.62±2.01	210.58±8.19
13		19.39±3.41	22.03±1.79	189.70±7.78
14	Sohag	12.16±2.75	16.40±1.69	248.80±8.73
15		34.25±2.68	10.81±1.45	196.60±6.68
16		12.56±2.00	6.73±1.28	137.15±5.68
17		15.15±2.24	11.26±1.20	156.39±6.29
18	Asyut	13.70±2.35	10.13±1.12	112.31±4.77
19		9.07±2.60	9.88±1.88	217.12±8.19
20	Minya	18.34±3.41	20.70±2.18	213.75±9.02
21		10.62±3.45	11.00±1.76	150.89±7.77
22		27.80±3.66	14.75±2.42	249.11±10.8
23		25.39±4.41	9.10±1.79	312.98±12.2
24		7.90±3.23	10.29±1.57	188.47±8.78
25		13.26±3.70	11.34±1.86	278.06±9.82
26		33.64±3.59	4.88±2.06	286.21±10.9
Mean		16.30±2.80	12.94±1.57	200.21±7.14
Max.		34.94±4.01	30.10±1.83	312.98±12.2
Min.		3.83±1.54	2.88±1.07	112.31±4.77

Table 3. Absorbed Dose Rate , Annual Effective Dose and Excess Lifetime Cancer Risk for the Nile River Sediment samples

Sample code No.	**Governorate**	Description	Absorbed Dose Rate (nGy/h)	AEDE (μSv/y)	ELCR×10^{-3}
1	Aswan	old Aswan Dam	38.17±1.55	46.81	0.163
2		Kima area	12.71±0.96	15.57	0.0545
3		Kom Ombo	17.63±1.00	21.62	0.0756
4		Edfu	13.05±0.91	16.00	0.0560
5		El-Sibayia	33.68±1.71	41.30	0.144
6	Qena	Isna – Tourism area	25.82±1.50	31.67	0.110
7		Isna	24.22±1.42	29.70	0.104
8		Luxor – Awameya	24.56±1.45	30.12	0.105
9		Luxor	32.44±1.59	39.78	0.139
10		Qus – before paper company	12.73±0.94	15.61	0.0546
11		Qus – after paper company	18.18±1.12	22.29	0.0780
12		Qena	28.19±1.75	34.57	0.120
13		Nag Hammadi	31.06±1.55	38.09	0.133
14		El-Balyana	26.80±1.42	32.86	0.115
15	Sohag	Gerga	30.28±1.25	37.13	0.129
16		Sohag	15.74±1.06	19.30	0.0675
17		El--Maragha	20.68±1.04	25.36	0.0887
18	Asyut	Asyut	17.41±0.99	21.35	0.0747
19		Mangabad	19.79±1.50	24.27	0.0849
20	Miniya	Der Mawas	30.77±1.80	37.73	0.132
21		Malawi	18.34±1.54	22.49	0.0787
22		Miniya	32.40±1.89	39.73	0.139
23		Samalut	30.38±1.64	37.26	0.130
24		Matai	18.32±1.39	22.46	0.0786
25		Beni Mazar	25.18±1.64	30.88	0.108
26		Maghagha	29.96±1.76	36.74	0.128
Mean			24.17± 7.30	29.68	0.100
Max.			33.68	41.30	0.163
Min.			12.71	15.57	0.0545

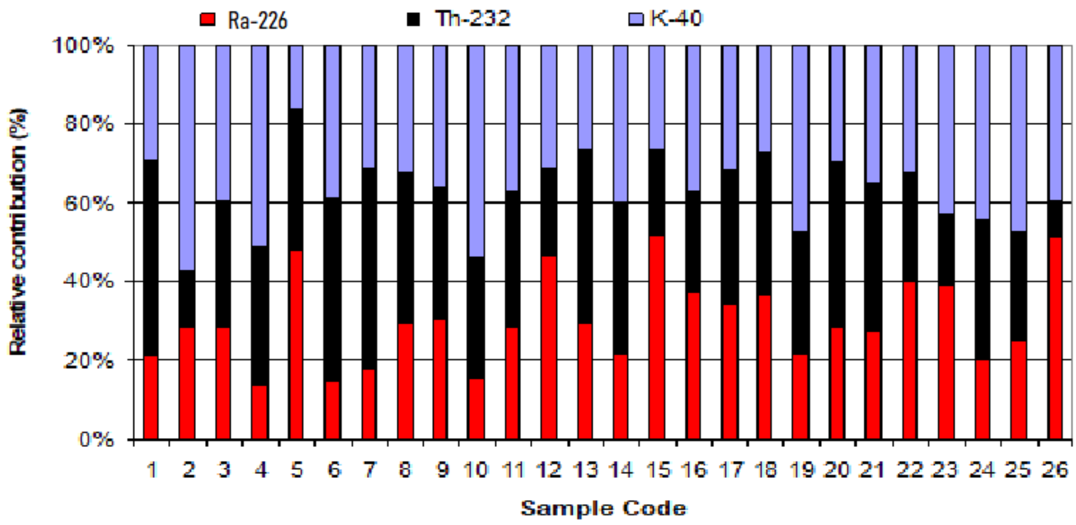

Figure 2. The relative contribution (%) of ^{226}Ra, ^{232}Th, and ^{40}K to absorbed dose rate, annual effective dose equivalent, and excess lifetime cancer risk in the Nile river sediment samples.

Table 4. Comparison of the activity concentrations of the studied Nile river sediment samples with the results of other studies in various countries

Country	Activity concentration (Bq/kg)			References
	^{226}Ra	^{232}Th	^{40}K	
Egypt	26 (5–58)	19 (4-33)	458(430-602)	[26]
Saudi Arabia	11.68	6.21	169.40	[27]
Libya	7.5	4.2	27.5	[28]
Egypt	28.82	38 (34-110)	419 (214–641)	[5]
Egypt	27	31.4	427.5	[29]
Ghana	31.4	42.6	109.5	[30]
Iran	23	31	453	[31]
Egypt	66(51-76)	71(17–141)	493 (272–866)	[6]
Turkey	37	40	667	[32]
Iran	33.35	38.28	430.27	[33]
World average (soil)	33	45	420	[22]
Egypt	16.30±2.80	12.94±1.57	200.21±7.14	Present study

Discussion

The results of specific activity in natural radionuclides for the studied samples were lower than the world average according to The United Nations Scientific Committee on the Effects of Atomic Radiation 2008, which were 33 Bq/kg, 45 Bq/kg, and 420 Bq/kg for ^{226}Ra, ^{232}Th, and ^{40}K, respectively. The mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the Nile river sediments were compared with those obtained in similar investigations in other countries. The summary of their results is provided in Table 4.

Regarding the results of the present study, the values of AEDE in all studied samples were less than the acceptable value of (1 mSv/y) for the outdoor annual effective dose equivalent given by the United Nations Scientific Committee on the Effects of Atomic Radiation 2008. At last, the ELCR obtained in this study was less than the mean value of the world (0.29×10^{-3}). Therefore, it may be decided that the risk of cancer is negligible [34].

Conclusion

The level of naturally occurring radioactivity in the Nile river sediment samples was evaluated using HPGe gamma-ray spectrometry**.** The obtained results revealed that the level of measured radioactivity in the Nile river sediment samples could not pose any radiological threat to the people living near it. Moreover, the obtained values when compared to the world permissible values were below acceptable standard and hence the risk of developing cancer by the people will be low.

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