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THE ACTIVITY CONCENTRATIONS OF ^{226}Ra, ^{232}Th AND ^{40}K FOR THE BUILDING MATERIALS IN SOHAG REGION, EGYPT

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The specific activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in the building materials (sand, clay, limestone , limestone Issawi (Travertine) and cement) used in Sohag region, Egypt, were determined by using gamma-ray spectrometric technique based on high-resolution hyper-pure germanium detectors (HPGe). The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, radium equivalent (Ra_{eq}), external hazard index (H_{ex}), internal hazard index (H_{in}), gamma index (I_γ), alpha index (I_α), absorbed dose rates (D) and the annual effective doses (E) due to gamma radiation from the samples were calculated. The results for the samples are within the international recommendations, so the building materials are safe to use for construction of new buildings and do not pose any significant radiological hazards.

Keywords: *Building Materials, Gamma-ray Spectrometry, Radiological Hazards.*

INTRODUCTION

The building materials are produced from rocks and soil, so they contain various amounts of radionuclides specially ^{238}U and ^{232}Th chains members and ^{40}K. The external exposure is resulting from gamma emitting radionuclides due to decay of ^{238}U and ^{232}Th chains members and ^{40}K while the internal exposure is due to release radon gas isotopes from the construction materials into air .People spend about 80% of their time inside their houses and working places [1], so it's important to determine the radioactive concentrations and the associated radiological hazards from these materials .From these studies we can put rules and guidelines for the safe use of these materials. The aim of this study is to determine and estimate the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K and the associated radiological hazards from these materials used in Sohag region.

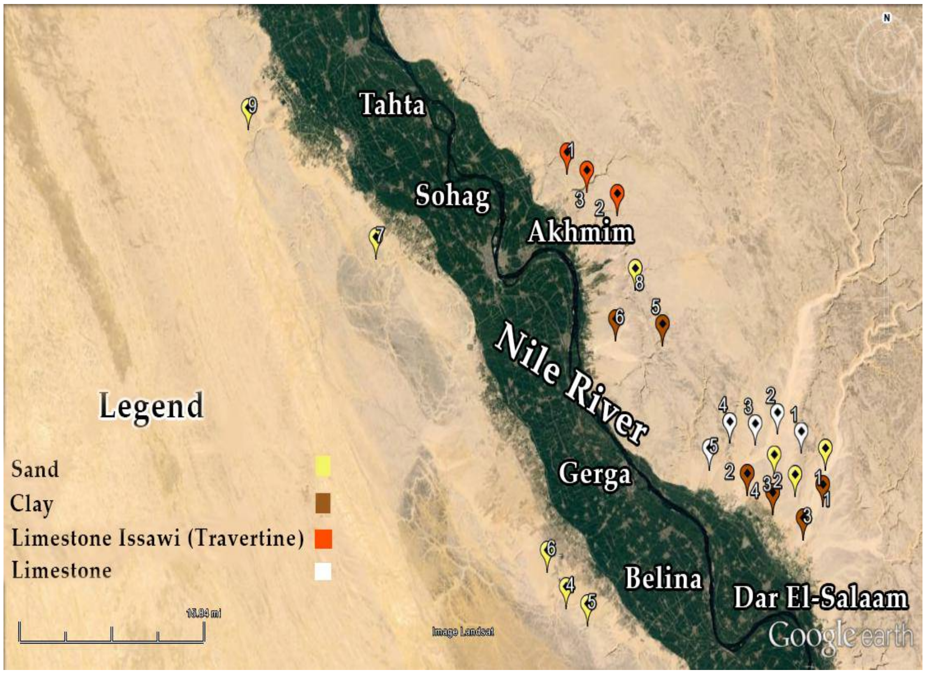

Figure 1. A satellite view of the samples locations

MATERIALS AND METHODS

1- Sample Collection

Twenty-seven represented samples of different types of building materials were included (9 sand, 6 clay, 5 limestone, 3 limestone Issawi (Travertine) and 4 cement). The sand samples were collected from nine quarries all over Sohag. The clay samples were collected from Dar El-Salaam region and from east of Akhmim region. The limestone samples were collected from Dar El-Salaam. The limestone Issawi samples were collected from east of Akhmim. Cement samples were collected from the local market. The locations of the collected samples are shown in figure (1).

2- Preparation of the Samples

The clay samples were dried at 110 °C in a temperature controlled oven until there was no detectable change in the mass of the sample. The sand, clay, limestone and limestone Issawi samples were thoroughly crushed and pulverized to powder. The powder was sieved through 0.2 mm mesh, which is the optimum size enriched in heavy minerals. These samples in addition to the cement samples were transferred to polyethylene cans of 100 cc capacity. The cans were tightly sealed for 4 weeks to avoid the escape of ^{222}Rn and ^{220}Rn gases in order to ensure secular equilibrium between ^{226}Ra and ^{228}Ra, and their respective progenies [2].

EXPERIMENTAL SETUP

The samples were analyzed for their gamma emitters using a spectrometer based on hyper-pure germanium (HPGe) detector for 82,000 s. The HPGe detector is of CANBERRA model GC5019, with a 50 % relative efficiency and a 1.95 keV full width at half-maximum (FWHM) at the 1.332 MeV gamma transition of ^{60}Co.
The spectrometer was calibrated for absolute efficiency using certified reference materials (IAEA-326& IAEA-313]. The efficiency η of the gamma lines was calculated according to the following equation

$$\eta = \frac{C(E,n)}{t \times f(E,n) \times A} \qquad (1)$$

where C (E, n) is the net photo-peak count of gamma ray transition with energy E of radionuclide (n) , f (E, n) is the branching ratio, number of photon with energy (E) per hundred disintegration of radionuclide (n) , A is the activity concentration in Becquerel of radionuclide (n) and t is the counting time (s).
The spectra were evaluated manually with the use of a spread sheet (Microsoft Excel) to calculate the natural radioactivity. The average calculated activity concentration was based on the energy transitions of 295.1 keV (19.2 %) and 351.93 keV (37.1 %) of ^{214}Pb ; 609.3 keV (46.1 %) and 1764.5 keV (15.9 %) of ^{214}Bi for ^{226}Ra (^{238}U-seris); 338.4 keV (12.4 %) and 911.2 keV (29.0 %) of ^{228}Ac and 583.34 keV (30.9 %) of ^{208}Tl for ^{228}Ra (^{232}Th-series) and ^{40}K activity determined from the 1460.7 keV (10.7%) emissions gamma-lines. The specific activity concentration (Bq/kg) is based on the following equation.

$$A = \frac{C(E,n)}{(t \times (\eta \times M))} \qquad (2)$$

where M is the mass of the sample (kg).

RESULTS AND DISCUSSION

1- Radionuclide Concentrations

By using equation (2) the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the collected samples were calculated. The results are presented in table (1) and are shown in figures (2, 3).
As shown in table (1), the average specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for sand, clay and cement samples are 6.6±0.8, 8.6±1.2 and 214.7±7.1 Bq/kg (dry

weight), 28.7±1.9, 32.1±2.3 and 326.9±9.6 Bq/kg (dry weight); and 52.0±2.4, 15.1±2.2 and 162.4±8.4 Bq/kg (dry weight), respectively,

For limestone samples , the average specific activity concentration of ^{226}Ra is 10.2±1.1 Bq/kg, but the specific activity concentrations of ^{232}Th and ^{40}K were less than the detection limits (DL=0.7 Bq/kg) except for the sample number 3 with ^{40}K value 125±6 Bq/kg.

For limestone Issawi (Travertine) samples, the specific activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were less than the detection limits (<DL).

The world average radioactivity concentrations and their ranges for ^{226}Ra, ^{232}Th and ^{40}K in soils and rocks are 32 (17-60) Bq/kg, 45 (11-64) Bq/kg and 420 (140-850) Bq/kg (UNSCEAR 2000, 2008) [1, 3], respectively.

It is clear that the radioactivity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in the building materials samples are normal and fall within the world average [1, 3]. Tables (2 and 3) show the comparison between the current results and the results of other countries on the same types of samples.

Sand, clay and limestone enter the cement industry as a clinker, so it is important to study the effect of the industry on the radiological concentrations of the raw materials as called technologically enhanced naturally occurring radioactive materials (TENORM).

Based on the results presented in table (1) and shown in figures (2,3) we note that the higher radioactivity concentrations of cement will not lead to hazardous high radioactivity concentrations of the building mixtures used in constructions, if we take in account the percentages of cement in these mixtures.

Table 1. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the collected building materials samples.

Sample Type	Sample Number	Activity concentration (Bq/kg) dry weight		
		^{226}Ra	^{232}Th	^{40}K
Sand	1	2.5± 0.8	4.9± 0.9	147.8± 6.1
	2	4.5± 0.3	6.5± 0.9	149.0± 7.0
	3	6.4 ± 0.7	13.0± 1.7	284.5± 8.5
	4	9.8 ±1.6	10.3± 2.0	380.0 ±9.7
	5	5.3± 0.4	5.9± 0.8	163.6± 7.0
	6	8.3± 0.4	8.7± 0.6	201.4± 8.7
	7	5.5± 0.7	6.4 ±1.0	196± 4.7
	8	9.4± 0.9	12.0 ±1.1	261.9 ±5.4
	9	7.6±1.1	9.2±1.2	147.7±6.6
	Average	6.6±0.8	8.6±1.2	214.7±7.1
Clay	1	24.1±2.0	36.6±2.3	296.2±10.6
	2	19.8±2.8	26.7±3.3	451.6±13.7
	3	28.1±1.6	32.3±1.9	324.3±7.0

	4	29.4±2.1	22.9±1.9	236.9±10.1
	5	32.1±1.4	38.0±1.8	288.8±5.9
	6	38.5±1.3	35.9±2.4	364.0±10.5
	Average	28.7±1.9	32.1±2.3	326.9±9.6
Limestone	1	10.2±0.8	<DL	<DL
	2	9.0±1.3	<DL	<DL
	3	11.9±0.9	<DL	125.0±6.0
	4	10.8±1.2	<DL	<DL
	5	9.2±1.2	<DL	<DL
	Average	10.2±1.1	<DL	<DL
Cement	1	61.6± 2.5	15.0± 2.1	203.9± 8.8
	2	52.6± 1.7	17.9 ±3.0	216.0± 11.5
	3	56.7± 3.1	14.6± 1.6	64.6± 6.1
	4	37.3±2.2	12.9±2.0	165±7.2
	Average	52.0±2.4	15.1±2.2	162.4±8.4

DL (for ^{226}Ra) = 0.7 Bq/kg, DL (for ^{40}K) = 3 Bq/kg

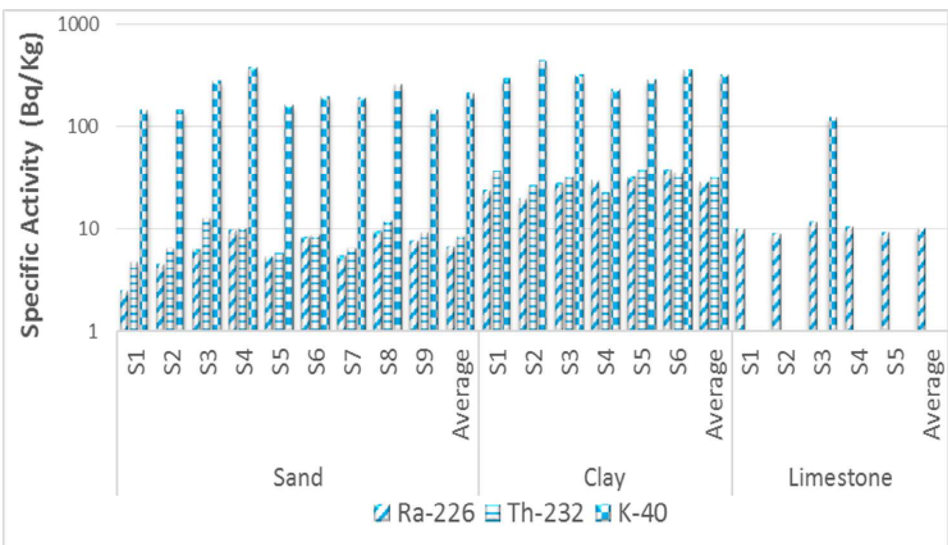

Figure 2. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the collected raw building materials samples.

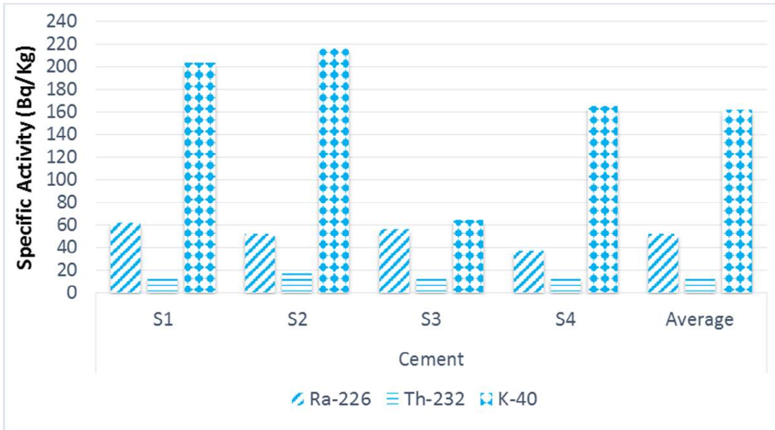

Figure 3. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in the collected cement samples.

Table 2. Comparison between the specific activity concentrations of the raw building materials samples with that of other countries of the World.

Sample Type	Country	Activity concentration (Bq/kg) dry weight			
		^{226}Ra	^{232}Th	^{40}K	Reference
Sand	Egypt (Sohag)	6.6	8.6	214.7	This Study
	Pakistan	23	40.2	429.7	4
	Hong Kong	24.3	27.1	841	5
	Brazil	14.3	18	807	6
	Zambia	25	26	714	7
	Kuwait	7.4	7.2	360	8
	India	43.7	64.4	455.8	9
	Bangladesh	14.1	25	158.4	10
	Malaysia	60	13	750	11

	Algeria	12	7	74	12
Clay	Egypt (Sohag)	28.7	32.1	326.9	This Study
	Norway	104	62	1058	13
	Sweden	96	127	962	14
	Finland	78	62	962	14
	Australia	40.7	88.8	681	15
Limestone	Egypt (Sohag)	10.2	<DL	<DL	This Study
	Brazil	24.3	7	205	6
	Bangladesh	68	107	1660	16
	Algeria	16	13	36	12
	Italy	11	2	22	17
Worldwide	UNSCEAR, 2000	32	45	420	1

Table 3. Comparison between the specific activity concentrations of cement samples with that of other countries of the World.

Sample Type	Country	Activity concentration (Bq/kg) dry weight			
		^{226}Ra	^{232}Th	^{40}K	Reference
Portland Cement	Egypt(Sohag)	52	15.1	162.4	This Study
	Egypt	35	19	93	18
	Egypt	36.6	43.2	82	19
	Albania	55	17	179.7	20
	Turkey	41	26	267	21
	Greece	92	31	310	22

	China	51.7	32	207.7	23
	Slovakia	11.8	18.4	156.5	24
	Algeria	41	27	422	12
Worldwide	UNSCEAR,2000	32	45	420	1

2- Radium Equivalent Activity (Ra_{eq})

The most widely used radiation hazard index Ra_{eq} is called the radium equivalent activity. It can be calculated from the following relation

$$Ra_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \qquad (3)$$

where A_{Ra} is the activity concentration of ^{226}Ra in Bq/kg, A_{Th} is the activity concentrations of ^{232}Th in Bq/kg and A_K is the activity concentration of ^{40}K in Bq/kg. The Ra_{eq} is related to the external gamma dose and internal dose due to radon and its daughters and must be $\leq$ 370 Bq/ kg for safe uses [25].

By using equation (3), as presented in table (4) the calculated Radium equivalent activity (Ra_{eq}) for sand, clay, limestone and cement samples are ranged from 20.9 to 53.8 Bq/kg, from 80.5 to 117.9 Bq/kg, from 9.0 to 21.5 Bq/kg and from 68.4 to 98.8 Bq/kg with average values 35.4 Bq/kg, 92.2 Bq/kg, 12.2 Bq/kg and 86.2 Bq/kg, respectively.

All the current (Ra_{eq}) values of the studied samples follow the condition ($Ra_{eq} \leq$370 Bq/kg) therefore we conclude that the materials are safe for use and do not pose any significant health hazards.

3- Assessment of Radiological Hazards

To examine the analyzed building material samples for the radiological hazards, which may occur when used in in dwelling constructions, we will deal with some different indices, namely External Hazard Index (H_{ex}), Internal Hazard Index (H_{in}), Alpha Index (I_α) and Gamma Index (I_γ).

3.1- External Hazard Index (H_{ex})

In order to assess the external radiological hazards we use the index (H_{ex}) expressed as

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (4)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively. To limit the external gamma radiation dose from the samples below 1.5 mGy/y the external hazard index, H_{ex} should obey the following relation $H_{ex} \leq 1$ [26]. External hazard indices for sand, clay, limestone and cement samples, are ranged from 0.06 to

0.15, from 0.22 to 0.32, from 0.02 to 0.06 and from 0.19 to 0.26, with average values of 0.10, 0.27, 0.03 and 0.23, respectively. The external hazard index for the studied samples as presented in table (4) is less than unity and therefore these building materials are safe to be used.

3.2- Internal Hazard Index (H_{in})

The internal radiation hazards due to the inhalation of radon and its short-lived products are assessed using similar criterion to that used for the external hazard index. In this regard, the materials would be safe if H_{in} of the following relation is ≤1.

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively. The Internal hazard index for sand, clay, limestone and cement samples is ranged from 0.06 to 0.17, from 0.3 to 0.42, from 0.05 to 0.09 and from 0.28 to 0.43 with average values of 0.11, 0.35, 0.06 and 0.37, respectively. The internal hazard index for the building samples as presented in table (4) is less than unity which indicates that the studied materials are safe to be used.

3.3- Alpha Index (I_α)

The excess alpha radiation due to the radon inhalation originating from the materials is assessed through the alpha index (I_α) which is defined as follows

$$I_\alpha = A_{Ra} /200 \qquad (6)$$

where A_{Ra} is the specific activity of ^{226}Ra.The recommended limit concentration of ^{226}Ra is 200 Bq/kg, for which $I_\alpha = 1$. The values of I_α for sand, clay, limestone and cement samples are ranged from 0.01 to 0.05, from 0.10 to 0.19, from 0.05 to 0.06 and from 0.19 to 0.31 with average values of 0.03, 0.14, 0.05 and 0.26, respectively. These observed values as presented in table (4) are less than unity showing that these construction materials are safe to be used.

3.4- Gamma Index (I_γ)

European Commission has suggested a gamma activity concentration index, I_γ for defining radiation risk from excessive gamma exposure by the following relation.

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \qquad (7)$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively. Values of index $I_\gamma \leq 2$ corresponds to a dose rate criterion of 0.3 mSv/y, whereas $2 \leq I_\gamma \leq 6$ corresponds to a criterion of 1 mSv/y. Thus the material with $I\gamma > 6$ should be avoided to use as building material. By using equation (7), we found that the values of I_γ for sand, clay, limestone and cement samples are ranged from 0.08 to 0.21, from 0.29 to 0.43, from 0.03 to 0.08 and from 0.24 to 0.35 with average values of 0.14, 0.37, 0.04 and 0.30, respectively. All the current I_γ values of the studied samples as presented in table (4) follow the criterion ($I_\gamma \leq 2$) therefore the building materials are safe to be used and does not pose any significant health hazards. The ranges of the abovementioned indices are summarized in Table (4).

Table (4). The radium equivalent activity and the radiological hazards indices of the collected samples.

Sample Type	Sample Number	Ra_{eq}	H_{ex}	H_{in}	I_{α}	I_{γ}
Sand	1	20.9	0.06	0.06	0.01	0.08
	2	25.3	0.07	0.08	0.02	0.10
	3	46.9	0.13	0.14	0.03	0.18
	4	53.8	0.15	0.17	0.05	0.21
	5	26.4	0.07	0.09	0.03	0.10
	6	36.4	0.10	0.12	0.04	0.14
	7	29.9	0.08	0.10	0.03	0.12
	8	46.8	0.13	0.15	0.05	0.18
	9	32.2	0.09	0.11	0.04	0.12
	Average	35.4	0.10	0.11	0.03	0.14
Clay	1	99.3	0.27	0.33	0.12	0.36
	2	92.8	0.25	0.30	0.10	0.35
	3	99.5	0.29	0.34	0.14	0.36
	4	80.5	0.22	0.30	0.15	0.29
	5	108.8	0.29	0.38	0.16	0.39
	6	117.9	0.32	0.42	0.19	0.43
	Average	92.2	0.27	0.35	0.14	0.37
Limestone	1	10.2	0.03	0.06	0.05	0.03
	2	9.0	0.02	0.05	0.05	0.03
	3	21.5	0.06	0.09	0.06	0.08
	4	10.8	0.03	0.06	0.05	0.04
	5	9.2	0.03	0.05	0.05	0.03
	Average	12.2	0.03	0.06	0.05	0.04
Cement	1	98.8	0.27	0.43	0.31	0.35
	2	94.9	0.25	0.39	0.26	0.33
	3	82.6	0.22	0.37	0.28	0.28
	4	68.4	0.19	0.28	0.19	0.24
	Average	86.2	0.23	0.37	0.26	0.30

4- Dosemetric Estimation

To estimate the external exposure to population from the terrestrial radionuclides, it's common to use the external absorbed dose rate in air and the annual effective dose rate (UNSCEAR 2000, 2008) [1, 3].

4.1- External Gamma Absorbed Dose Rates

4.1.1- The outdoor external absorbed dose rates

The external absorbed dose rates D (nGy/h), in outdoor air at 1 m above the ground surface, can be calculated from the following formula

$$D_{outdoor} = A_E * C_f \quad (8)$$

where A_E is the specific activity concentrations in Bq/Kg and C_f is the dose conversion factors in units of nGy/h per Bq/Kg. The conversion factors for ^{226}Ra, ^{232}Th and ^{40}K are C_{Ra} =0.4551, C_{Th}= 0.5835 and C_K = 0.0429 [3]. So the above equation can be written as

$$D_{outdoor} = 0.4551\ A_{Ra} + 0.5835\ A_{Th} + 0.0429\ A_K \quad (9)$$

By using equation (9), $D_{outdoor}$ values for sand, clay, and limestone and cement samples are ranged from 10.3 to 26.8, from 36.9 to 54.1, from 4.1 to 10.8 and from 31.6 to 45.6 nGy/h with average values of 17.2, 45.8, 5.7 and 39.5 nGy/h, respectively.

4.1.2- The indoor external absorbed dose rates

According to the worldwide values, the indoor contribution is 1.4 times higher than the outdoor dose, so the indoor dose rate was calculated from the following formula (UNSCEAR 2000, 2008)[1,3]

$$D_{indoor} = 1.4 * D_{outdoor} \quad (10)$$

By using equation (10), D_{indoor} values for sand, clay, limestone and cement samples are ranged from 14.5 to 37.5, from 51.7 to 75.7, from 5.8 to15.1 and from 44.2 to 63.8 nGy/h, with average values of 24.1, 64.1, 8.0 and 55.2 nGy/h, respectively.

From the previous results for the outdoor and indoor external absorbed dose rates we found that:

According to the average worldwide value for the outdoor and indoor external absorbed dose rates (58 (50-59) nGy/h and 84 (20-200) nGy/h (UNSCEAR 2000, 2008) [1, 3]), respectively, as presented in table (5) the average and range values of the outdoor and indoor external absorbed dose rates for our study are lower than the average worldwide value.

4.2- Annual Effective Dose

In the UNSCEAR 2000 and UNSCEAR 2008 Report [1,3], the committee used 0.7 Sv/ Gy for the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.8 for the indoor occupancy factor, i.e. the fraction of time spent indoors and outdoors is 0.8 and 0.2, respectively. Therefore, the annual effective doses outdoors and indoors received by adults were determined as follows:

$$\text{Outdoors: } D_{out}\ (nGy/h) \times 8760\ (h) \times 0.7 (Sv/Gy) \times 0.2 \quad (11)$$
$$\text{Indoors: } D_{in}\ (nGy/h) \times 8760\ (h) \times 0.7\ (Sv/\ Gy) \times 0.8 \quad (12)$$

The resulting worldwide average of the annual effective dose is 0.48 mSv, with typical ranges (0.3-0.6 mSv) according to UNSCEAR 2000 [1] (0.3-1.0 mSv) according to UNSCEAR 2008 [3]. For children and infants, was taken into account the numerical values, 0.8 and 0.9, respectively [1, 3].
By using equation (11, 12), the values of annual outdoor and indoor effective doses of the samples for infants, children and adults are presented in table (5). From the results of the annual outdoor and indoor effective doses we found that:
According to the average worldwide values of the annual outdoor and indoor effective doses for infants, children and adults (0.09, 0.08 and 0.07 mSv, respectively) and (0.53, 0.46 and 0.41 mSv, respectively), respectively, as reported in UNSCEAR 2000 and 2008 [1,3], the average and range values of the annual outdoor and indoor effective doses for the collected samples for all ages are lower than the average worldwide values.

Table (5). The absorbed dose rates and the annual effective doses of the collected samples.

Sample Type	Sample Number	Absorbed Dose Rates (nGy/h)		Annual Effective Doses (mSv/y)					
		$D_{outdoor}$	D_{indoor}	Outdoor			Indoor		
				Infants	Children	Adults	Infants	Children	Adults
Sand	1	10.3	14.5	0.02	0.01	0.01	0.09	0.08	0.07
	2	12.3	17.2	0.02	0.02	0.02	0.12	0.1	0.08
	3	22.7	31.8	0.04	0.03	0.03	0.2	0.18	0.16
	4	26.8	37.5	0.04	0.04	0.03	0.24	0.21	0.18
	5	12.9	18.1	0.02	0.02	0.02	0.11	0.1	0.09
	6	17.5	24.6	0.03	0.02	0.02	0.16	0.14	0.12
	7	14.7	20.6	0.02	0.02	0.02	0.13	0.12	0.1
	8	22.6	31.6	0.04	0.03	0.03	0.2	0.18	0.16
	9	15.2	21.3	0.02	0.02	0.02	0.13	0.12	0.1
	Average	17.2	24.1	0.03	0.02	0.02	0.15	0.14	0.12
Clay	1	45.1	63.1	0.07	0.06	0.06	0.4	0.35	0.31
	2	43.9	61.6	0.07	0.06	0.05	0.38	0.35	0.3
	3	45.6	63.9	0.07	0.06	0.06	0.4	0.36	0.31
	4	36.9	51.7	0.06	0.05	0.05	0.33	0.29	0.25
	5	49.2	68.9	0.08	0.07	0.06	0.43	0.39	0.34
	6	54.1	75.7	0.09	0.08	0.07	0.48	0.42	0.37
	Average	45.8	64.1	0.07	0.06	0.06	0.41	0.36	0.32
limestone	1	4.6	6.5	0.007	0.006	0.005	0.04	0.04	0.03
	2	4.1	5.8	0.006	0.005	0.005	0.04	0.03	0.03

	3	10.8	15.1	0.016	0.015	0.013	0.1	0.08	0.07
	4	4.9	6.9	0.007	0.006	0.006	0.04	0.04	0.03
	5	4.2	5.9	0.006	0.005	0.005	0.04	0.03	0.03
	Average	5.7	8.0	0.009	0.008	0.007	0.05	0.05	0.04
Cement	1	45.6	63.8	0.07	0.06	0.06	0.4	0.36	0.31
	2	43.6	61.1	0.07	0.06	0.05	0.39	0.34	0.3
	3	37.1	51.9	0.06	0.05	0.05	0.33	0.29	0.25
	4	31.6	44.2	0.05	0.04	0.04	0.28	0.25	0.22
	Average	39.5	55.2	0.06	0.05	0.05	0.35	0.31	0.27

CONCLUSSION

From the above discussions we found that:

- The radioactivity concentrations for ^{226}Ra, ^{232}Th and ^{40}K in the building materials are normal and fall within the world averages.
- All the current radium equivalent activity Ra_{eq} values of the studied samples follow the condition ($Ra_{eq} \leq 370$ Bq/kg). For the values of external hazard H_{ex} index, the internal hazard index H_{in} and alpha index $I\alpha$ are less than unity. All the current gamma index $I\gamma$ values follow the criterion ($I\gamma \leq 2$).
- The average and range values of the outdoor and indoor external absorbed dose rates for the samples are lower than the average worldwide value 58 (50-59) nGy/h and 84 (20-200) nGy/h.
- The average and range values of the annual outdoor and indoor effective doses for the collected samples for all ages are lower than the average worldwide values.

Therefore from the radiological concentrations and hazards for the samples we can conclude that the building materials are safe to use in the construction of new dwellings and does not pose any significant health hazards.

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قيم تركيز النشاط الإشعاعي لنظائر الراديوم-226 والثوريوم-232 والبوتاسيوم-40 في مواد البناء المستخدمة في منطقة سوهاج، مصر

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تم قياس قيم تركيز النشاط الإشعاعي للنويدات المشعة الطبيعية للراديوم-226 والثوريوم-232 والبوتاسيوم-40 في مواد البناء (الرمل والطين والحجر الجيري والحجر الجيري العيساوي (الترافرتين) والاسمنت) المستخدمة في منطقة سوهاج، مصر K، وذلك باستخدام تقنية التحليل الطيفي لأشعة جاما بكاشف الجرمانيوم عالي النقاوة (HPGe) عالي الدقة. وتم حساب قيم نشاط الراديوم المكافئ (Ra_{eq}) ومؤشر الخطر الخارجي (H_{ex}) ومؤشر الخطر الداخلي (H_{in}) ، ومؤشر جاما (I_{γ})، ومؤشر ألفا (I_{α})، ومعدل الجرعة الممتصة (D) و الجرعة الفعالة السنوية (E) الناتجة عن أشعة جاما من العينات. وقد وجد أن النتائج تقع ضمن حدود القيم الموصى بها دوليا، وبالتالي فإن مواد البناء المدروسة آمنة للاستخدام لتشييد المباني الجديدة ولا تشكل أية مخاطر إشعاعية محسوسة.

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