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Assessment of the Level of Natural Radio Activity in Soil Samples Collected from El Minia, Egypt

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Abstract: The knowledge of natural radioactivity content of the various radionuclides in the soil play an important role in the health physics because of the population exposure to the radiation. The exposure depends on the activity concentration of the naturally occurring radionuclides (^{226}Ra, ^{232Th}, and ^{40}K) which distributed in the soil. The study is devoted to assess the specific activity and to examine the radiation hazard indices of naturally occurring radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in soil samples (reclaimed, and under reclamation) as well as Eastern desert from El-Minya governorate at different locations in El-Minya governorate. Measurements were carried out by γ-spectrometric method using 3 ″x 3 ″NaI(Tl) with 8192 multichannel analyzer(MCA). About 131 soil samples were collected, and stored in tight sealed containers for 4 weeks to reach seculer equilibrium. The results show that the activity concentrationfor reclaimed soil ranged from 9.39±0.46 Bq.kg^{-1} in Abo Qurqas to 20.78±1.04 Bq.kg^{-1} in Mattay with an average 13.92±0.71 Bq.kg^{-1} for ^{226}Ra, while ranged from 7.37±0.37 Bq.kg^{-1} in Bani Mazar to 16.79±0.86 Bq.kg^{-1} in Mattay with an average 11.91±0.63 Bq.kg^{-1} for ^{232}Th, and ranged from 124.68±6.23 Bq.kg^{-1} in Bani Mazar to 359.32±17.96 Bq.kg^{-1} in Mattay with average 193.55±9.67 Bq.kg^{-1} for ^{40}K. The activity concentrations for under reclamation soil samples ranged from 5.32±0.27 Bq.kg^{-1} in Maghagha to 17.23±0.85 Bq.kg^{-1} in Mattay with an average 11.93±0.59 Bq.kg^{-1} for ^{226}Ra, while ranged from 5.84±0.29 Bq.kg^{-1} in Abo Qurqas to 16.42±0.83 Bq.kg^{-1} in Mattay with an average 9.64±0.48 Bq.kg^{-1} for ^{232}Th, and ranged from 116.54±5.82 Bq.kg^{-1} in Abo Qurqas to 250.38±12.52 Bq.kg^{-1} in Samallot with average 159.28±9.57 Bq.kg^{-1} for ^{40}K. The activity concentrations of sandy soil ranged from 26.09±1.34 Bq.kg^{-1} to 37.47±1.97 Bq.kg^{-1} with an average 30.3±1.56 Bq.kg^{-1} for ^{226}Ra, while ranged from 8.16±0.41Bq.kg^{-1} to 9.18±0.46 Bq.kg^{-1} with an average 8.52±0.44 Bq.kg^{-1} for ^{232}Th, and ranged from 123.94±6.18 Bq.kg^{-1} to 148.03±7.39 Bq.kg^{-1} with average 136.93±6.83 Bq.kg^{-1} for ^{40}K. The average dose rates and other calculated hazard indices were lower than the average national and world recommended values, therefore, did not pose health risks to the population of the area.

Keywords: radiation, farm soil, radiological hazards.

1 Introduction

Since its genesis, the Earth's crust has contained radionuclides with long half-lives, such as 40K, 238U, and 232Th. As a result of their radioactivity, those radionuclides cause natural radiation [1]. Naturally occurring radionuclides contribute to a major portion to the effective dose of the worldwide population. Natural radionuclides in soil generate a significant component of the background radiation exposure of the population [2]. The natural radioactivity in soil mainly comes from the uranium and thorium decay series and potassium [3].

.A significant amount of man-made radionuclides ^{137}Cs, may also present in the environment as a result of testing of nuclear weapons in the atmosphere, accidents and the routine discharge of radionuclides from nuclear installations [4]. The specific level radiation in the crust varies from one region to another as the concentrations of these natural radioactive elements vary due to their non-uniform nature in soils and the types of rock from which the soil originates [5] The natural radionuclides like 238U, 232Th and 40K have been contained in volcanic geographic structures as well as rocks that are rich in phosphate, granite and salt [6]. When rocks are disintegrated by natural processes, radionuclides are transported to the soil by rain and low bottoms [7].

Radionuclides also occur naturally in rocks, soils are easily transported to the environment through plants and water [8,9]. The natural background radiation in soil comes from ^{226}Ra, ^{232}Th, ^{40}K and its about80% of the total radiation

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dose a person experiences in a year [10]. Radionuclide concentrations in soil and external exposure due to gamma radiation depend on geological and geographic conditions and appear at different levels in the soil of each region of the world [3]. Measurement of natural background radiation and radioactivity in soil has been carried out in many countries to establish the baseline data of natural radiation levels (11–13]

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Radionuclides also occur naturally in rocks, soils are easily transported to the environment through plants and water [8,9]. The natural background radiation in soil comes from 226Ra, 232Th, ^{40}K and its about80% of the total radiation dose a person experiences in a year [10]. Radionuclide concentrations in soil and external exposure due to gamma radiation depend on geological and geographic conditions and appear at different levels in the soil of each region of the world [3]. Measurement of natural background radiation and radioactivity in soil has been carried out in many countries to establish the baseline data of natural radiation levels (11–13]

2 Experimental Sections

2.1 Study area

The present study covered an area in El-Minya governorate from Deir Mawas (38° 37′ 34″ N ; 30° 98′ 03″ E) to Maghagha (38° 28′ 39″ N ; 30° 83′ 32″ E) about 139 km, and includes 8 regions: Deir Mawas (17 samples), Mallawy (17 samples), Abu-Qurqas (25 samples), Minya (15 samples), Samallot (16 samples), Mattay (10 samples), Bani Mazar (16 samples), and Maghagha (15 samples). Table and figure (1) show the locations of studied samples.

Table 1: The cities of investigated samples.

Location	Soil type	Samples naumber
Maghagha	Farm	9
	Reclaimed	3
	Under reclemation	3
Bani Mazar	Farm	9
	Reclaimed	3
	Under reclemation	3
Matay	Farm	10
	Reclaimed	3
	Under reclemation	3
Samalot	Farm	10
	Reclaimed	3
	Under reclemation	3
El-Minia	Farm	9
	Reclaimed	3
	Under reclemation	3
Abo Qurqas	Farm	5
	Reclaimed	5
	Under reclemation	4
Mallawy	Farm	9
	Reclaimed	3
	Under reclemation	3
Deir Mawas	Farm	9
	Reclaimed	3
	Under reclemation	3
Eastern desert	Deir Mawas road	10
road	Malawy road	10
	El-Minya	10

Fig.1: El-Minia governorate map of studied samples**.**

2.2 Samples Collection and Processing

Samples were collected according to the internationally established experience. For each soil sample collected, an area of about 50×50 cm^2 was marked and carefully cleared of debris to about 30 cm depth. Surface soil samples were taken from different places randomly within the marked and cleared areas and mixed together thoroughly in order to obtain a representative samples of that area. After collection, samples were dried in oven at 110°C for 3 hours to ensure that moisture is completely removed. The samples were crushed, homogenized, and sieved through a 200µm mesh, which is the optimum size enriched in heavy minerals [14].

About 150 gram of each sample were collected in tight plastic containers of 8 cm diameter and 5 cm hight. The containers were closed by screw caps and hermetically sealed with adhesive tape [15]. Finally soil samples were sealed for 4 weak to reach secular equilibrium when the rate of decay of the daughters becomes equal to that of the parent [16, 17]. Detailed γ- ray spectrometry analysis was performed on the soil samples.

2.3 Gamma Spectrometric Analysis

The gamma spectrometer consists of 3″×3″ NaI(Tl) scintillation well detector coupled to a photomultiplier tube (P.M.T). The photomultiplier tube is connected to an ORTEC photomultiplier base with preamplifier (model 276). The dynode pulses are fed to personal computer analyzer card set to 8192 channels through a spectroscopic amplifier (model 572). The block diagram of the gamma spectrometer is shown in figure (2.2) The detector had a photopeak efficiency of about 1.2×10^{-5} at 1332 kev and an energy resolution of 7.5 at 662 kev and operation bias voltage 1000 V dc. The detector is shielded with a 6 cm lead castle which was also shielded inside with a Cu sheet. The measured γ-ray spectrum was analyzed by software program Maestro 32.

The ^{60}Co source which has two known characteristic peaks at 1173.2 KeV and 1332.5 KeV and ^{137}Cs source which has one peak at 662 KeV are used for energy calibration.

The efficiency calibration was performed with marinelli beaker which has the same geometry of the detector contains satandard source sample which contain a known activity of one or more gamma ray emitters of the radionuclides ^{226}Ra (351.99, 609.32, and 1764.51 KeV) ,and ^{232}Th (238.63 KeV). The absolute efficiency has been calculated by relation [18]:

$$\eta_{Exp} = \frac{N_p \cdot 100}{I_\gamma . TOC . A_{BOC}} \quad (1)$$

Where N_P is the net peak area (counts $^{-1}$) at Eγ, I_γ is the intensity of emitted γ-ray (%), TOC is the time of counting, and A_{BOC} is the activity (Bq) of the calibrated source at the start of counting. Figure (2.2) shows Experimental and theoretical efficiency curves for 3″ x 3″ NaI(Tl) well detector :

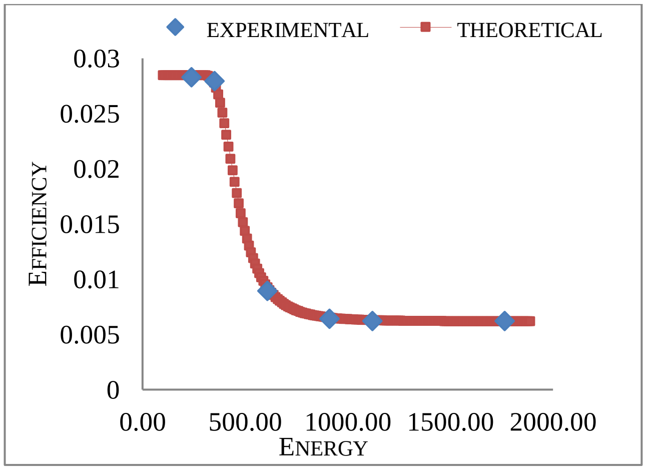

Fig. 2: Experimental and theoretical efficiency curves for 3″ x 3″ NaI(Tl) well detector.

The samples were placed over the detector for at least 12 hours. The spectra were either evaluated with the computer software program Maestro 32. The activity of each sample was determined by using the total net counts under the selected photopeaks after substracting appropriate factors for photopeak efficiency, weight of the samples, and gamma intensity of radionuclides [19]. At the secular equilibrium between ^{232}Th and ^{226}Ra with their decay products, the concentration of ^{226}Ra was determined from the average concentrations of ^{214}Pb (352 keV) , ^{214}Bi (609, 1120 and 1765 keV). For ^{232}Th, it was determined from the average concentrations of ^{212}Pb (238 keV), ^{208}Tl (2615 keV) and ^{228}Ac (911 keV) in each sample under study, Since ^{40}K is directly γ-emitter, so its activity concentration could be determined from its single photopeak at 1460 kev [20].

The corresponding activity concentration (A) was then calculated by the following formula [20] :

$$A = \frac{N_p}{e \times \eta \times m} \quad (2)$$

Where N_P is the count per second, e is abundance of the γ-peak in a radionuclide, η is the measured efficiency for each gamma-ray peak observed for the same number of channels either for the sample or calibration source, and m is sample mass in kilograms.

3 Results and Discussion

As there is no suffecient data about radioactivity measurements and dose assessments have in El-Minia governorate, this study aimed to provide baseline data for radioactivity in El-Minia governorate which is essential for an accurate assessment of possible radiological risks to human health. γ-ray spectrometric analysis was used to assess the specific activity and to examine the radiation hazard indices of naturally occurring radionuclides ^{226}Ra,

^{232}Th, and ^{40}K in soil samples (reclaimed, and under reclamation) as well as Eastern desert from El-Minya governorate.
A total of 131 different soil samples (reclaimed, under reclamation, and sandy soil) have been collected in El-Minya governorate including 9 sites: Maghagha, BaniMazar, Mattay, Samallot, El-Minia, Abo Qurqas, Mallawy, Deir Mawas and Eastern desert from El-Minya to Deir Mawas.

3.1 Activity Analysis

Table (2) shows that the activity concentration of ^{226}Ra ranged from 12.43±0.62 Bq.kg^{-1} in Deir Mawas to 30.15±1.51 Bq.kg^{-1} in Sam allot with an average 20.58±1.04 Bq.kg^{-1}, while ranged from 7.27±0.35Bq.kg^{-1} in in Abo Qurqas to 25.74±1.28 Bq.kg^{-1} in El-Minya with an average 14.37±0.75 Bq.kg^{-1} for ^{232}Th, and ranged from 149.24±7.45Bq.kg^{-1} in Deir Mawas to 270.94±13.59 Bq.kg^{-1} in Maghagha with an average 270.94±13.59 Bq.kg^{-1} for ^{40}K.
Figure (3) shows that the average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentration in farm soil. It can be seen that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil but vary from region to another.
The largest contribution to the total activity comes from ^{40}K in the study region. This may be attributed to excessive use of Potassium containing fertilizers [21] and it is common occurrance in normal geological materials. The variations of the activity concentration depends on the radionuclide distribution in rocks from which they originate and on the processes through which the soils are concentrated [22].

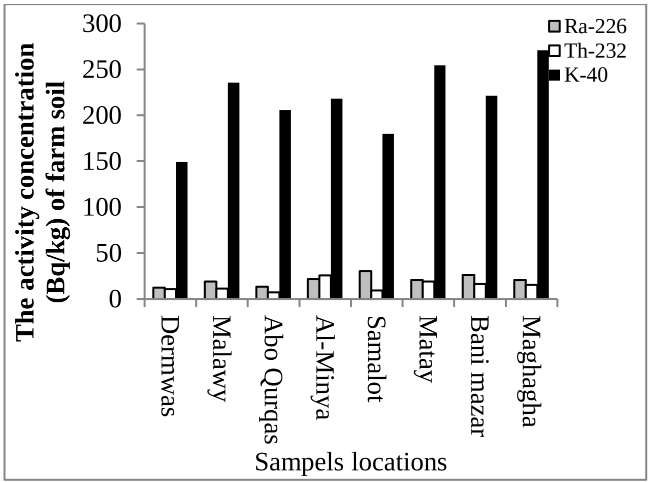

Fig.3: Average values 0f ^{226}Ra, ^{232}Th and ^{40}K activity concentration in farm soil.

Table (3) shows the activity concentration of reclaimed soil, 226Ra ranged from 9.39±0.46 Bq.kg^{-1} in Abo Qurqas to 20.78±1.04 Bq.kg^{-1} in Mattay with an average 13.92±0.71 Bq.kg^{-1}, while ranged from 7.37±0.37Bq.kg^{-1} in Bani Mazar to 16.79±0.86Bq.kg^{-1} in Mattay with an average 11.91±0.63 Bq.kg^{-1} for ^{232}Th, and ranged from 124.68±6.23 Bq.kg^{-1} in Bani Mazar to 359.32±17.96 Bq.kg^{-1} in Mattay with average 193.55±9.67 Bq.kg^{-1} for ^{40}K.

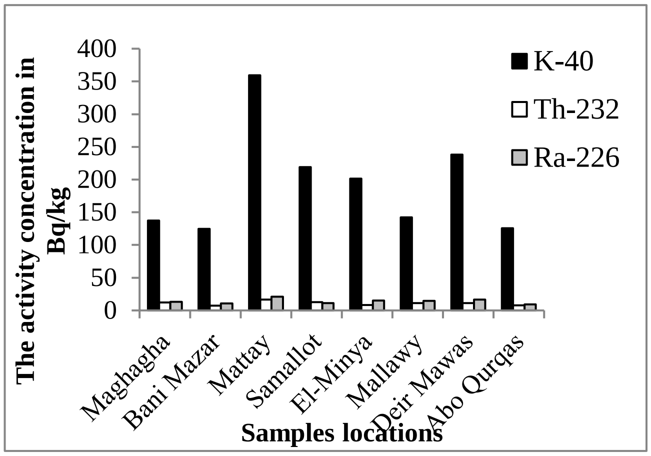

Fig.4: Average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentration in the reclaimed soil.

Figure (4) shows that the average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentration in reclaimed soil, it can be seen that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil and vary from region to another. The largest contribution to the total activity comes from ^{40}K in the study region.This may be attributed to excessive use of Potassium containing fertilizers [21] and it is common occurrance in normal geological materials. The variations of the activity concentration are associated with the radionuclide distribution in rocks from which they originate and on the processes through which the soils are concentrated [22].

Table (3-2) shows the the activity concentration of under reclamation soil, ^{226}Ra ranged from 5.32±0.27 Bq.kg^{-1} in Maghagha to 17.23±0.85 Bq.kg^{-1} in Mattay with an average 11.93±0.59 Bq.kg^{-1}, while ranged from 5.84±0.29 Bq.kg^{-1} in Abo Qurqas to16.42±0.83 Bq.kg^{-1} in Mattay with an average 9.64±0.48 Bq.kg^{-1} for ^{232}Th, and ranged from 116.54±5.82 Bq.kg^{-1} in Abo Qurqas to 250.38±12.52 Bq.kg^{-1} in Samallot with an average 159.28±9.57 Bq.kg^{-1} for ^{40}K.
Figure (5) shows that the average values 0f ^{226}Ra, ^{232}Th and ^{40}K activity concentration in under reclamation soil, it can be seen that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil and vary from region to another. The largest contribution to the total activity comes from ^{40}K in the study region. This may be attributed to excessive use of Potassium containing fertilizers [21] and it is common occurrance in normal geological materials. The activity concentration of 226Ra, ^{232}Th, and ^{40}K in under reclamation soil are less than The activity concentration of 226Ra, ^{232}Th, and ^{40}K in the reclaimed soil. The variations of the activity concentration are associated with the radionuclide distribution in rocks from which they originate and on the processes

Table 2: Activity concentrations (BqKg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in farm soil samples.

Samples locations	Number of samples		activity concentration (Bq.kg^{-1})	
		^{226}Ra	^{232}Th	^{40}K
Maghagha	9			
Min		8.53±0.42	6.57±0.33	111.55±5.57
Max		33.03±1.67	28.19±1.41	492.27±24.61
Average		20.67±1.14	15.52±0.77	270.94±13.59
Bani Mazar	10			
Min		12.6±0.64	8.03±0.41	115.12±5.75
Max		35.86±1.81	29.07±1.45	432.32±21.61
Average		26.24±1.32	16.54±0.83	221.27±10.99
Mattay	10			
Min		9.6±0.49	7.08±0.35	138.01±6.9
Max		36.41±1.82	34.87±1.74	440.04±22
Average		20.84±1.04	18.82±0.94	254.32±13.15
Samallot	10			
Min		20.83±1.04	4.57±0.23	112.38±5.61
Max		51.89±2.6	17.88±0.89	308.88±15.44
Average		30.15±1.51	9.33±0.46	179.80±8.98
El-Minya	9			
Min		13.48±0.67	18.96±0.96	127.53±6.37
Max		31.98±1.59	34.51±1.72	335.30±16.76
Average		21.85±1.08	25.74±1.28	218.13±10.87
Abo Qurqas	19			
Min		8.25±0.41	3.06±0.15	102.15±5.11
Max		21.1±1.05	11.72±0.58	274.03±13.7
Average		13.35±0.66	7.27±0.35	152.16±7.61
Mallawy	11			
Min		11.85±0.59	6.91±0.34	207.47±10.37
Max		31.09±1.57	17.27±0.89	340.36±17.02
Average		19.15±0.96	11.29±0.8	235.75±11.82
Deir Mawas	11			
Min		6.34±0.31	5.24±0.26	102.22±5.11
Max		18.5±0.92	14.42±0.72	282.91±14.14
Average		12.43±0.62	10.5±0.53	149.24±7.45
Min		12.43±0.62	7.27±0.35	149.24±7.45
Max		30.15±1.51	25.74±1.28	270.94±13.59
Average		20.58±1.04	14.37±0.75	210.20±10.55

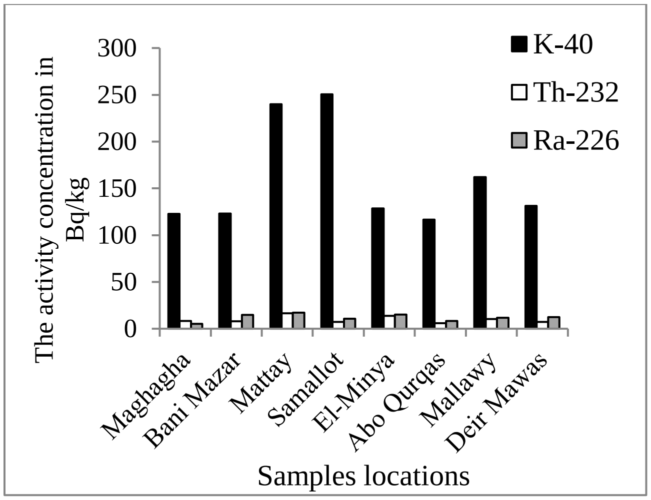

Fig.5: Average values 0f ^{226}Ra, ^{232}Th and ^{40}K activity concentration in under reclamation soil.

Through which the soils are concentrated [22].

Table (5) shows that the activity concentration of ^{226}Ra ranged from 26.09±1.34 Bq.kg^{-1} to 37.47±1.97 Bq.kg^{-1} with an average 30.3±1.56 Bq.kg^{-1}, while ranged from 8.16±0.41Bq.kg^{-1}to 9.18±0.46 Bq.kg^{-1} with an average 8.52±0.44 Bq.kg^{-1} for ^{232}Th, and ranged from 123.94±6.18Bq.kg^{-1}to 148.03±7.39 Bq.kg^{-1} with an average 136.93±6.83 Bq.kg^{-1} for ^{40}K.

Figure (6) shows that the average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentration in sandy soil, it can be seen that the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in soil but vary from region to another. The largest contribution to the total activity comes from ^{40}K in the study region. This may be attributed to excessive use of Potassium containing fertilizers [21] and it is common occurrance in normal geological materials. The Activity concentration of ^{232}Th, and ^{40}K in the sandy soil are less than the activity concentration of^{232}Th, and ^{40}K in

Table 3: Activity concentrations ($BqKg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K in reclaimed soil.

Samples locations	Number of samples		activity concentration ($Bq.kg^{-1}$)	
		^{226}Ra	^{232}Th	^{40}K
Maghagha	3			
Min		11.32±0.56	10.92±0.55	126.23±6.32
Max		14.96±0.75	13.86±0.7	146.27±7.31
Average		13.17±0.65	12.09±0.61	137.54±6.87
BaniMazar	3			
Min		9.81±0.5	6.43±0.33	121.62±6.08
Max		11.73±0.60	7.95±0.41	128.35±6.41
Average		10.66±0.54	7.36±0.37	124.68±6.23
Mattay	3			
Min		15.31±0.77	11.01±0.57	290.26±14.51
Max		26.70±1.34	22.14±1.12	419.84±20.99
Average		20.78±1.04	16.79±0.86	359.32±17.96
Samallot	3			
Min		9.29±0.51	11.81±0.6	211.3±10.56
Max		13.63±0.72	13.41±0.67	229.12±11.45
Average		11.35±0.61	12.67±0.64	219.22±10.95
El-Minya	3			
Min		12.93±0.64	5.82±0.22	192.86±9.64
Max		16.08±0.8	10.5±0.52	211.57±10.57
Average		14.98±0.74	8.32±0.39	201.47±10.07
Abo Qurqas	3			
Min		8.38±0.42	6.08±0.3	116.81±5.84
Max		10.71±0.53	8.29±0.42	131.9±6.59
Average		9.39±0.46	7.37±0.36	125.74±6.28
Mallawy	3			
Min		12.84±0.67	10.54±0.58	127.04±6.35
Max		16.62±0.85	12.46±0.67	152.97±7.64
Average		14.54±0.75	11.41±0.62	142.38±7.11
DeirMawas	*3*			
Min		12.33±0.65	10.34±0.58	224.2±11.21
Max		18.84±0.96	11.97±0.64	253.28±12.66
Average		16.55±0.85	11.33±0.62	238.11±11.9
Min		9.39±0.46	7.36±0.37	124.68±6.23
Max		20.78±1.04	16.79±0.86	359.32±17.96
Average		13.92±0.71	11.91±0.63	193.55±9.67

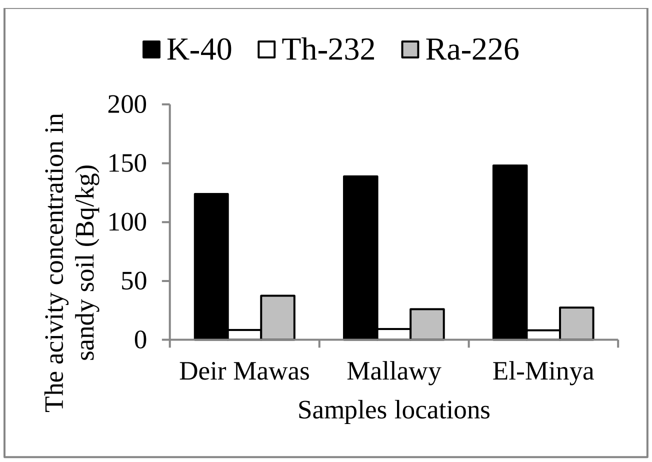

Fig.6: Average values of ^{226}Ra, ^{232}Th and ^{40}K activity concentration in sandy soil.

the reclaimed, and under reclamation soil but the activity concentration of ^{226}Ra in sandy soil is higher than the activity concentration of ^{226}Ra in the reclaimed, and under reclamation soil. The variations of the activity concentration are associated with the radionuclide distribution in rocks from which they originate and on the processes through which the soils are concentrated [22]. Table (6) shows that, Comparison between literature values (the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K) and present value. The activity concentration of ^{226}Ra, ^{232}Th and ^{40}K for all types of soil samples under study are lower than USA, India, Japan, Malaysia, Turkey, Vietnam and Pakiastan and higher than Egypt, and Saudi. It is clear that, the average measured activity concentration for all soil samples in the investigated area are within and lower than world's average concentration.

Table (3.2): Activity concentrations ($BqKg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K in under reclamation soil samples.

Samples locations	Number of samples		activity concentration ($Bq.kg^{-1}$)	
		^{226}Ra	^{232}Th	^{40}K
Maghagha	3			
Min		4.39±0.22	5.15±0.26	113.27±5.66
Max		6.32±0.32	11.31±0.56	132.24±6.61
Average		5.32±0.27	8.37±0.42	122.71±6.13
BaniMazar	3			
Min		11.46±0.57	6.2±0.31	113.07±5.65
Max		19.41±0.97	10.29±0.51	131.4±6.57
Average		14.81±0.73	8.03±0.40	123.15±6.15
Mattay	3			
Min		9.69±0.48	12.23±0.63	229.24±11.46
Max		25.78±1.28	20.91±1.05	258.01±12.90
Average		17.23±0.85	16.42±0.83	239.89±11.99
Samallot	3			
Min		7.94±0.43	5.48±0.27	226.25±11.32
Max		13.66±0.71	9.3±0.47	279.04±13.95
Average		10.59±0.56	7.4±0.37	250.38±12.52
El-Minya	3			
Min		11.46±0.57	7.30±0.41	111.43±5.57
Max		19.36±0.96	23.23±1.16	148.08±7.4
Average		15.04±0.75	13.62±0.69	128.51±6.42
Abo Qurqas	3			
Min		7.13±0.35	5.6±0.28	102.3±5.11
Max		9.16±0.45	6.31±0.31	129.12±6.45
Average		8.34±0.41	5.84±0.29	116.54±5.82
Mallawy	3			
Min		10.56±0.52	6.17±0.32	122.18±6.11
Max		13.63±0.68	8.23±0.42	142.26±7.11
Average		12.35±0.61	7.14±0.36	131.13±6.55
DeirMawas	3			
Min		6.22±0.31	6.71±0.34	114.58±5.72
Max		8.19±0.41	8.59±0.43	129.28±6.46
Average		11.84±0.59	10.37±0.53	161.97±8.09
Min		5.32±0.27	5.84±0.29	116.54±5.82
Max		17.23±0.85	16.42±0.83	250.38±12.52
Average		11.93±0.59	9.64±0.48	159.28±9.57

Table (5): Activity concentrations ($BqKg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K in sandy soil samples.

Samples locations	Number of samples		activity concentration ($Bq.kg^{-1}$)	
		^{226}Ra	^{232}Th	^{40}K
Deirmawas	10			
Min		17.06±0.87	5.64±0.28	108.37±5.41
Max		54.03±2.73	10.85±0.54	147.07±7.35
Average		37.47±1.97	8.23±0.41	123.94±6.18
Mallawy	10			
Min		19.2±1.01	4.44±0.22	105.26±5.26
Max		36.52±1.85	14.64±0.73	174.11±8.7
Average		26.09±1.34	9.18±0.46	138.84±6.93
El-Minya	10			
Min		13.54±0.68	5.56±0.27	110.26±5.51
Max		39.56±1.98	11.26±0.56	191.54±9.57
Average		27.35±1.36	8.16±0.41	148.03±7.39
Min		26.09±1.34	8.16±0.41	123.94±6.18
Max		37.47±1.97	9.18±0.46	148.03±7.39
Average		30.3±1.56	8.52±0.44	136.93±6.83

Table (6): The average value of activity concentrations in ($BqKg^{-1}$) for all soils samples collected from Egypt (EL-Minya) and with data in the world.

country	^{226}Ra	^{232}Th	^{40}K	References
Nigeria	55.3	26.4	505.1	[23]
Tayma, Saudi Arabia	30.77	27.59	161.82	[24]
India Amritsar	54.45	78.31	301.80	[25]
Egypt	17	18	320	[3]
USA	40	35	370	[3]
Vietnam	42.77	59.84	411.93	[26]
Japan	33	28	310	[3]
Malaysia	127	304	302	[27]
India	29	64	410	[3]
Saudi Arabia	15	11	225	[28]
Nigeria	19.3	8.5	214.6	[29]
Turkey	48.35	20.48	744.76	[30]
Punjab,Pakistan	35	41	615	[31]
Worldwide Average	35	30	400	[3]

3.2 The Radiological Hazards

Radiation hazard due to specified radionuclide ^{226}Ra, ^{232}Th, and ^{40}K were assessed by different indices according to UNSCEAR,2000 to arrive at a safe conclusion on the health status of an exposed person or environment. To assess the radiation hazards associated with soil samples, seven indices have been considered, which are Radium equivalent activity (Ra_{eq}), Absorbed dose rate (D_r), External and Internal hazards indices (H_{ex}, H_{in}), Annual Effective Dose Equivalent (AEDE), and Exess Life Time Cancer (ELCR).

3.2.1 Radium Equivalent Activity (Ra_{eq})

For the purpose of comparing the radiological effect or activity of materials that contain ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common index termed the radium equivalent activity (Ra_{eq}) is used. This activity index provides a useful guideline in regulating the safety standards on radiation protection for the general public residing in the area under investigation. The Ra_{eq} index represents a weighted sum of activities of the above mentioned natural radionuclides and is based on the estimation that 1 $Bq\cdot kg^{-1}$ of ^{226}Ra, 0.7 $Bq\cdot kg^{-1}$ of ^{232}Th, and 13 $Bq\cdot kg^{-1}$ of ^{40}K produce the same gamma radiation dose rate [32].

Radium equivalent activity can be calculated from the following relation suggested by (Beretka and Mathew, 1985).

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

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

The published maximal admissible (permissible) Ra_{eq} is 370 Bq/kg [3].

3.2.2 The Absorbed Dose Rate (D_r):

The contribution of natural occurred radionuclides to the absorbed dose rate in the air depends on the radionuclides in the soil. It was found that there is a direct relation between the emitted gamma radiation and the concentration of radionuclides in the soil [33].

If the activities of radionuclides in the soil is known then its exposure dose rate in the air at 1m above the ground can be calculated using conversion factor of 0.427 $nGyh^{-1}/Bq.kg^{-1}$ for ^{226}Ra, 0.662 $nGyh^{-1}/Bq.kg^{-1}$ for ^{232}Th and 0.0423 $nGyh^{-1}/Bq.kg^{-1}$ for ^{40}K [34].

The contribution of the terrestrial gamma radiation to the absorbed dose rate in the air (nGy/h) can be calculated using the formula of [34] and [35].

$$D = 0.427\ A_{Ra} + 0.662A_{Th} + 0.0423\ A_K \quad (4)$$

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

3.2.3 The Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent (*AEDE*) to the population can be calculated using the conversion coefficient from absorbed dose in air to effective dose received by an adult must be considered. This value is published in [3] and [36] to be 0.7 SvGy-1 for environmental exposure to gamma rays of moderate energy. The indoor to outdoor ratio (1.4), the occupancy factor for the outdoor and the indoor are 0.2 and 0.8 respectively [3]. Therefore, the annual effective doses outdoors and indoors equivalent are calculated by using the following formula [26,32]

$$AEDE_{outdoor}\ (mSv/yr) = [\ D_r.\ (mGy/hr) \times 24\ hr \times 365.25\ d \times 0.2 \times 0.7\ Sv/Gy\ ] \times 10^{-6} \quad (5)$$

$$AEDE_{indoor}\ (mSv/yr) = [\ D_r.\ (mGy/hr) \times 24\ hr \times 365.25\ d \times 1.4 \times 0.8 \times 0.7\ Sv/Gy\ ] \times 10^{-6} \quad (6)$$

The corresponding worldwide values of D_{out} and D_{in} and D_{tot} are 0.08, 0.42 and 0.50 $mSv{\cdot}y^{-1}$, respectively [3].

3.2.4. The External and Internal Hazard Index (H_{ex}, H_{in}):

The external (H_{ex}) and internal (H_{in}) hazard index due to the emitted γ-rays of the soil samples were calculated and examined according to the following formula:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leqslant 1 \quad (7)$$

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (8)$$

The value of H_{ex} must be lower than unity for the radiation hazard from building material to be insignificant. This is the radiation exposure due to the radioactivity from a construction material, limited to 1.5 $mGy{\bullet}y^{-1}$. For the maximum values of H_{ex} to be less than unity the maximum value of Raeq must be less than 370 $Bq{\bullet}kg^{-1}$. [37].

3.2.5. Excess Lifetime Cancer Risk (ELCR):

Excess Lifetime Cancer Risk *(ELCR)* is calculated using below formula [37]:

$$ELCR = AEDE \times DL \times RF \quad (9)$$

Where AEDE, DL and RF are the total annual effective dose equivalent (in $\mu Sv{\cdot}yr^{-1}$), duration of life (70 years) and risk factor (Sv^{-1}), fatal cancer risk per sievert. For stochastic effects, ICRP 60 uses values of 0.05 for the public [38].

Table 7: Radium equivalent (Ra_{eq}), Absorbed dose rate (D_r), External and Internal hazard indices (H_{ex}), (H_{in}), Annual effective dose equivalent (AEDE) and Excess lifetime cancer risk (ELCR) in the farm soil.

Samples locations	Number of samples	Ra_{eq} $Bq.kg^{-1}$	D_r $nGy.h^{-1}$	H_{ex}	H_{in}	AEDE (tot)	ELCR $\times10^{-3}$
Maghagha	3	65.81	31.45	0.17	0.23	240.14	0.840
BaniMazar	3	66.96	31.52	0.18	0.25	119.15	0.417
Mattay	3	68.05	32.5	0.18	0.24	285.09	0.997
Samallot	3	57.36	26.67	0.15	0.23	118.23	0.413
El-Minya	3	75.35	35.55	0.2	0.26	130.35	0.456
Abo Qurqas	3	35.48	16.96	0.14	0.13	128.75	0.450
Mallawy	3	53.47	25.63	0.145	0.17	160.31	0.561
DeirMawas	3	38.95	18.58	0.1	0.13	120.42	0.421
Average	24	57.67	27.35	0.15	0.205	162.80	0.569

Table 8: Radium equivalent (Ra_{eq}), Absorbed dose rate (D_r), External and Internal hazard indices (H_{ex}), (H_{in}), Annual effective dose equivalent (AEDE) and Excess lifetime cancer risk (ELCR) in the reclaimed soil.

Samples locations	Number of samples	Ra_{eq} $Bq.kg^{-1}$	D_r $nGy.h^{-1}$	H_{ex}	H_{in}	AEDE (tot)	ELCR $\times10^{-3}$
Maghagha	3	39.68	18.79	0.11	0.14	240.14	0.840
BaniMazar	3	30.81	14.71	0.083	0.11	119.15	0.417
Mattay	3	72.48	35.19	0.19	0.25	285.09	0.997
Samallot	3	30.37	14.59	0.082	0.102	118.23	0.413
El-Minya	3	34.53	16.09	0.093	0.13	130.35	0.456
Abo Qurqas	3	33.26	15.89	0.089	0.115	128.75	0.450
Mallawy	3	41.83	19.79	0.113	0.15	160.31	0.561
DeirMawas	3	30.89	14.86	0.083	0.107	120.42	0.421
Average	24	39.23	18.74	0.105	0.138	162.80	0.569

Table 9: Radium equivalent (Ra_{eq}), Absorbed dose rate (D_r), External and Internal hazard indices (H_{ex}), (H_{in}), Annual effective dose equivalent (AEDE) and Excess lifetime cancer risk (ELCR) in the under reclamation soil.

Samples locations	Number of samples	Ra_{eq} Bq.kg^{-1}	D_r nGy.h^{-1}	H_{ex}	H_{in}	AEDE (tot)	ELCR ×10^{-3}
Maghagha	3	26.76	13.01	0.072	0.086	189.09	0.661
BaniMazar	3	35.78	16.85	0.096	0.13	136.51	0.477
Mattay	3	59.204	28.38	0.15	0.21	229.91	0.804
Samallot	3	31.75	15.19	0.085	0.11	123.1	0.430
El-Minya	3	44.42	20.88	0.11	0.16	169.13	0.591
Abo Qurqas	3	25.73	12.39	0.06	0.092	100.35	0.351
Mallawy	3	32.67	18.79	0.088	0.12	125.99	0.440
DeirMawas	3	27.81	13.44	0.075	0.094	108.88	0.381
Average	24	35.51	17.36	0.092	0.124	147.87	0.517

Table 10: Radium equivalent (Ra_{eq}), Absorbed dose rate (D_r), External and Internal hazard indices (H_{ex}), (H_{in}), Annual effective dose equivalent (AEDE) and Excess lifetime cancer risk (ELCR) in the sandy soil.

Samples locations	Number of samples	Ra_{eq} Bq.kg^{-1}	D_r nGy.h^{-1}	H_{ex}	H_{in}	AEDE (tot)	ELCR ×10^{-3}
Deir Mawas	10	60.50	27.42	0.16	0.26	222.15	0.777
Mallawy	10	49.91	23.09	0.13	0.20	187.05	0.654
El-Minya	10	51.89	24.02	0.14	0.21	194.58	0.681
Average	**24**	54.10	24.84	0.14	0.22	201.26	0.704

Tables (7),(8),(9) and (10) show the radiological hazards in farm, reclaimed, under reclamation, and sandy soil samples respectively.

- The radium equivalent activity value in all types of soil under study is less than the permissible limits of 370 Bq·kg$^{–1.}$
- The absorbed dose rate values are less than the allowed limit 59 nGyh^{-1}.
- the annual Effective Dose Rate is lower than the international limit for public exposure control 0.50 mSv·y$^{−1}$ and Excess lifetime cancer risk for all samples are lower than the international limit for public exposure
- The calculated average values of the external hazards were less than the acceptable value 1.
- The calculated average values of the internal hazards were less than the acceptable value 1
- The average dose rates and other calculated hazard indices were lower than the average national and world recommended values, therefore, did not

4 Conclusions

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K have been measured by gamma spectroscopy (sodium iodide NaI(Tl) detector) in One hundred and sixty seven soil samples(reclaimed, under reclemation, and sandy soil) collected from EL-Minya governorate (Nine regions) with an aim of evaluating the environmental radioactivity and radiation hazard**.** The concentration of radioactive elements depends on soil formation and transport processes that were involved since soil formation. It is known that the chemical and biochemical interactions influence the distribution patterns of ^{226}Ra, ^{232}Th, and ^{40}K. The activity concentration of ^{40}K in the farm soil is higher than the activity concentration of ^{40}K in reclaimed, under reclemation, and sandy soil. In all soil samples the largest contribution to the total activity comes from ^{40}K in the study region. The obtained mean values of the activity concentrations lower than the recommended value of the world average. (30 Bq.kg^{-1} for ^{226}Ra, 35 Bq.kg^{-1} for ^{232}Th, and ^{370} Bq.kg^{-1} for ^{40}K). The average dose rates and other calculated hazard indices were lower than the average national and world recommended values, therefore, did not pose health risks to the population of the area.

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