



## Assessment of Radioactivity in Various Types of Soil From Al-Obour City, Egypt.

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### Abstract

The distributions of natural radioactivity in various types of samples collected from several areas in Al-Obour city were determined using a high purity germanium (HPGe) detector. Four types of samples were investigated: soil, foundations, sand dunes and rock samples. The specific activities of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in soil; foundations; sand dunes and rock samples have a mean of  $(13.31\pm 3.59)$ ;  $(12.96\pm 3.63)$ ;  $(13.36\pm 4.32)$  and  $(26.74\pm 5.50)$ ,  $(6.49\pm 0.23)$ ;  $(3.71\pm 0.16)$ ;  $(3.87\pm 0.17)$  and  $(19.38\pm 0.64)$ ,  $(6.52\pm 0.55)$ ;  $(4.03\pm 0.46)$ ;  $(3.90\pm 0.45)$  and  $(25.91\pm 1.89)$  and  $(96.21\pm 1.60)$ ;  $(78.12\pm 1.46)$ ;  $(76.27\pm 1.43)$  and  $(215.71\pm 3.35)\text{Bq/kg}$ , respectively. It was also noticed that  $^{137}\text{Cs}$  is existed in some samples but is close to the background level. The hazard indices were also determined in all types of samples of the under study area. These values are important to establish baseline levels of this environmental radioactivity to detect any upcoming change for the local population.

**Indexing terms/Keywords** Gamma-spectroscopy, Heavy metals, Natural radioactivity, hazard indices

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## Introduction

The radionuclides are not uniformly distributed in soils and environmental radioactivity, and the associated external gamma exposure, depends strongly on geological and geographical conditions. The specific levels of terrestrial environmental radiation of a territory are usually related to its lithological composition and to the concentrations of thorium (Th), uranium (U) and potassium (K) of the rock from which the soils originated [1]. The natural terrestrial gamma dose rate is an important contributor to the average dose received by world's population [2]. The measurement of natural radioactivity due to gamma rays from the dose rate is needed to implement precautionary measures whenever the dose is found to be above the recommended limits [3]. The prime objective of this investigation is to determine natural ( $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$ ) and artificial ( $^{137}\text{Cs}$ ) radioactivity levels in soil, foundations, sand dunes and rock samples collected from the area under study. Also, the radiation hazard indices have been estimated and compared with the recommended limits. The results of this study will provide background data on natural and artificial radioactive isotopes and environmental pollution.

## 1. Materials and Methods

### 1.1. Location of the study area:

Al-Obour city is a newly constructed city located at 25km of Cairo. The city covers almost 210km<sup>2</sup>, and is characterized by significant variations in topography and geology [4]. It is bounded by Cairo-Ismailia high way from south and Cairo-Belbes road from the north, between latitude  $30^{\circ}10'12''$  and  $30^{\circ}18'36''$  N and longitude  $31^{\circ}26'00''$  and  $31^{\circ}31'12''$  E shown in [Fig.1].

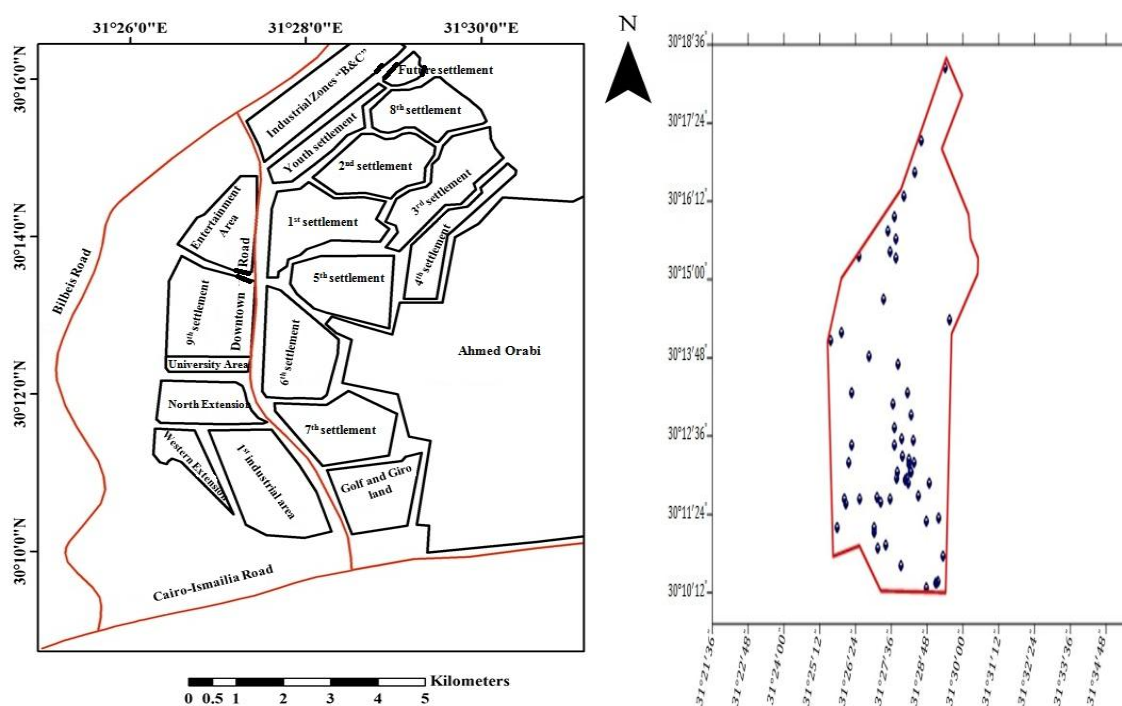


Fig.1: Map and locations of samples collected from Al-Obour city.

### 1.2. Geology of Al-Obour city:

The study area has a relatively low relief, except its northern part that comprises more rugged relief. The low relief area includes three geomorphic landforms: sand dunes, plains and wadies. On the other hand, the rugged area comprises other two geomorphic landforms: structural high-table lands and flat topped hills. The sand dunes cover about 10% of the study area. Their presence is restricted in two fields. The first occupies the western border of the area and is known as G. El-Asfar dune belt while the second occupies a strip located just



north Cairo-Ismailia highway, in addition to a few locations within Al-Obour city. The sand dunes in the study area are of two types which are sief and barchan dunes. Plains cover about 72.5% of the study area. They occupy the extreme north of the study area. The southern plains are covered with thick deposits of Nonmarine Miocene while the northern ones are occupied mainly by the Nonmarine Miocene and, in places, by the Oligocene sands. Both types of plains have streaks of Quaternary sand filling the dry wadi streams. Wadies cover about 1.25% of the study area. They present the channel paths of old stream which were running through the area in the past or during the present temporary rainfall episodes. The high topographic lands represented by flat topped hills are occupying a few locations to the south and southeast of the northern part of El-Obour City. These hills are capped by the dolomite beds of the Miocene rock Subnit (M2) forming the northern and western dip slope sides, while the claystone and sandstones form the eastern and southern steep wall sides of these hills[5].

### **1.3.Samples description and preparation technique:**

19 soil samples were collected from the first industrial area and industrial zones "B&C" of Al-Obour city. The samples were sandy silt, clayey sand, silty sand, grayish white, friable to soft, calcareous in parts and rich in plant debris. 21 foundations samples were collected from the 6th, 7th, 9th settlements and the entertainment area. They were sand, medium to fine, friable, loose, yellowish white and clayey in parts. Also, 25 sand dunes samples were collected from the northern, western extensions and the golf and Giro land area. They were sief and barchan dunes samples. Finally, 17 rock samples were collected from two sections located in the 4th and 5th settlements and they were mainly claystone and sandstone rocks. A Global Positioning System (GPS) was used to determine geographical coordinates shown in Fig.1.

The samples were dried, pulverised, homogenized, weighed and sieved to pass through 2mm mesh size and the meshed soil samples were transferred to Marinelli beakers having volumes of 250 and 100 ml and sealed for a period of about four weeks before counting by gamma spectrometry in order to allow  $^{226}\text{Ra}$  and its short-lived progenies to reach secular radioactive equilibrium and to ensure that radon gas is confined within the volume and the daughters also remain in the sample [6].

### **1.4.Analytical techniques:**

The activity concentrations of  $^{238}\text{U}$ ,  $^{232}\text{Th}$ ,  $^{40}\text{K}$  and  $^{137}\text{Cs}$  in the samples were measured for all samples using a high purity germanium (HPGe) detector, model (GEM-50210-P), a P-type crystal, from EG&G ORTEC. It has a resolution (FWHM) of 1.9keV for the 1332keV gamma- ray line of  $^{60}\text{Co}$  and a relative efficiency of about 50%.The efficiency calibration was performed by using three well-known reference materials obtained from the International Atomic Energy Agency for U, Th and K activity measurements: RGU-1, RGTh-1 and RGK-1[7,8]. Absolute efficiency calibration of the gamma spectrometry system was carried out using the radionuclide specific efficiency method in order to reduce the uncertainty in gamma-ray intensities, as well as the influence of coincidence summation and self-absorption effects of the emitting gamma photons [9].The gamma-ray transitions of  $^{228}\text{Ac}$  (338.4, 911keV),  $^{212}\text{Bi}$  (727.3, 1620.7keV) and  $^{208}\text{Tl}$  (583.1, 2614.4keV) were used to evaluate the specific activities of Th-series radionuclides. The activity concentrations of  $^{238}\text{U}$  were measured from gamma-ray transition of  $^{234\text{m}}\text{Pa}$  (1001keV) while  $^{226}\text{Ra}$  was determined from (186.1keV),  $^{214}\text{Pb}$  from (351.1, 295.1keV) and (609.3, 1120.3, 1764.5 keV) for  $^{214}\text{Bi}$ .  $^{40}\text{K}$  was determined from the 1460keV photo peak and the activity concentration of  $^{137}\text{Cs}$  was determined from 661.66 keV gamma-ray transition [10].

For soil samples, the soil solution was analyzed for the determination of heavy metals using the Inductively Coupled Plasma-Optical (ICP-OES) with ultrasonic nebulizer (USN), this nebulizer decrease the instrumental detection limits, which is Perkin Elmer Optima 3000, USA which is existed in the Desert Research Center in Cairo, Egypt.



### 1.5. Radioactivity counting:

The samples were counted for a counting time of about 24h. The net area count after background corrections in each photo peak was used in the computation of the activity concentration  $C$  (Bqkg<sup>-1</sup>) for each of the radionuclides in the samples using the expression [11]:

$$C(\text{Bq/kg}) = \frac{C_n}{\epsilon P_\gamma M_s} \quad (1)$$

where  $C_n$  is the count rate under each photo peak due to each radionuclide,  $\epsilon$  is the detector efficiency for the specific  $\gamma$ -ray,  $P_\gamma$  is the absolute transition probability of the specific  $\gamma$ -ray and  $M_s$  is the mass of the sample (kg). The LLD values obtained were 9.347, 1.310, 1.344 and 0.025 Bqkg<sup>-1</sup> for 40K, 238U, 232Th and 137Cs, respectively.

### 1.6. Hazard indices:

The activity concentrations of 40K, 238U and 232Th measured in each of the studied samples indicate the quantity of radioactivity present but do not provide a measure of radiation risks in the form of an absorbed dose rate. The absorbed dose rate,  $D$  (nGyh<sup>-1</sup>) in air at 1m above ground level due to the presence of 238U, 232Th and 40K in the studied samples at each studied site was calculated using the following equation [12]:

$$D = aC_U + bC_{Th} + cC_K + dC_{Cs} \quad (2)$$

where  $a$  is the dose rate per unit 238U activity concentration ( $4.27 \times 10^{-10}$  Gyh<sup>-1</sup>/Bqkg<sup>-1</sup>),  $C_U$  is the concentration of 238U in the sample (Bqkg<sup>-1</sup>),  $b$  is the dose rate per unit 232Th activity concentration ( $6.62 \times 10^{-10}$  Gyh<sup>-1</sup>/Bqkg<sup>-1</sup>),  $C_{Th}$  is the concentration of 232Th in the sample (Bqkg<sup>-1</sup>),  $c$  is the dose rate per unit 40K activity concentration ( $0.43 \times 10^{-10}$  Gyh<sup>-1</sup>/Bqkg<sup>-1</sup>),  $C_K$  is the concentration of 40K (Bqkg<sup>-1</sup>),  $d$  is the dose rate per unit 137Cs activity concentration ( $0.30 \times 10^{-10}$  Gyh<sup>-1</sup>/Bqkg<sup>-1</sup>),  $C_{Cs}$  is the concentration of 137Cs in the sample (Bqkg<sup>-1</sup>) [13, 11].

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7) and outdoor occupancy factor (0.2) proposed by UNSCEAR (2000) were used. The effective dose rate in units of mSv per year was determined using the following formula:

$$\text{Out door annual effective dose} = D_{\text{air}} \times 8760\text{h} \times 0.7\text{SvGy}^{-1} \times 0.2 \times 10^{-6} \quad (3)$$

The radium equivalent activity is a weighted sum of activities of 226Ra, 232Th and 40K based on the presumption that 10Bqkg<sup>-1</sup> of 226Ra, 7Bqkg<sup>-1</sup> of 232Th or 130Bqkg<sup>-1</sup> of 40K produce the same gamma-ray dose rates. Hence it is defined as follows:

$$Ra_{\text{eq}} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (4)$$

where  $A_{Ra}$ ,  $A_{Th}$  and  $A_K$  are activities of 226Ra, 232Th and 40K, respectively, in Bqkg<sup>-1</sup>. The maximum value of  $Ra_{\text{eq}}$  must be < 370 Bqkg<sup>-1</sup> [14] in order to keep the external dose < 1.5 mGy/y.

A modified quantity of radium equivalent activity is the external hazard index  $H_{\text{ex}}$ , which is defined as follows:

$$H_{\text{ex}} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (5)$$

The value of  $H_{\text{ex}}$  must be lower than unity in order to keep the radiation hazard insignificant. The maximum value of unity for  $H_{\text{ex}}$  corresponds to the limit of 370 Bqkg<sup>-1</sup> for  $Ra_{\text{eq}}$  [15].



The annual gonadal dose equivalent (AGED) is the genetic relevance of the dose equivalent received each year by the reproductive organs of the exposed population can be calculated according the following equation [16] :

$$AGDE(\mu Sv/y) = 3.09C_{Ra} + 4.18C_{Th} + 0.314C_K \quad (6)$$

The activity utilization index is the dose rate in air from different combinations of the three original radionuclides present in soil samples are expressed by the activity utilization index, AUI. AUI is calculated by applying the appropriate conversion factors, along with the radioactivity concentrations of the three respective radionuclides from the following equation [17]

$$AUI = \frac{c_{Ra}}{50 \text{ Bq/kg}} f_{Ra} + \frac{c_{Th}}{50 \text{ Bq/kg}} f_{Th} + \frac{c_K}{500 \text{ Bq/kg}} f_K \quad (7)$$

Where  $C_{Ra}$ ,  $C_{Th}$  and  $C_K$  are the concentration of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in  $\text{BqKg}^{-1}$  respectively.  $f_{Ra}$ ,  $f_{Th}$  and  $f_K$  are the respective fractional contributions from the actual activities of radionuclides  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  which equal 0.462, 0.0604 and 0.041 respectively.

Consequent according the evaluation of annual effective dose equivalent (AEDE) the excess lifetime cancer risk factor (ELCR) was estimated using equation [17]

$$ELCR = AED \times DL \times RF \quad (8)$$

where: DL and RF are the duration of life (70 year) and risk factor  $0.05 \text{ Sv}^{-1}$

## 2. Results and Discussion

The specific activity concentrations for  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$  in the samples are shown in Table 1.

Table1.: The specific activity concentrations for  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$  ( $\text{Bq/kg}$ ) in Al-Obour city.

Type	Location	No. of samples	$^{238}\text{U}$	$^{226}\text{Ra}$	$^{232}\text{Th}$	$^{40}\text{K}$
Soil	First industrial area and industrial zones "B&C"	19	$13.31 \pm 3.59$ (3.74-17.07)	$6.49 \pm 0.23$ (3.12-11.41)	$6.52 \pm 0.55$ (3.41-12.65)	$96.21 \pm 1.60$ (60.33-177.91)
Foundations	6th,7th,9th settlements and the entertainment area	21	$12.96 \pm 3.63$ (9.92-16.69)	$3.71 \pm 0.16$ (2.33-7.62)	$4.03 \pm 0.46$ (2.38-5.70)	$78.12 \pm 1.46$ (49.93-109.02)
Sand dunes	Northern, western extensions and golf and Giro land area	25	$13.36 \pm 4.32$ (9.99-18.69)	$3.87 \pm 0.17$ (2.09-8.24)	$3.90 \pm 0.45$ (2.51-6.88)	$76.27 \pm 1.43$ (52.89-106.33)
rock	4th and 5th settlement	17	$26.74 \pm 5.50$ (4.34-66.59)	$19.38 \pm 0.64$ (9.00-37.66)	$25.91 \pm 1.89$ (5.08-48.94)	$215.71 \pm 3.35$ (56.17-322.72)



The specific activities of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in soil; foundations; sand dunes and rock samples have a mean of  $(13.31 \pm 3.59)$ ;  $(12.96 \pm 3.63)$ ;  $(13.36 \pm 4.32)$  and  $(26.74 \pm 5.50)$ ,  $(6.49 \pm 0.23)$ ;  $(3.71 \pm 0.16)$ ;  $(3.87 \pm 0.17)$  and  $(19.38 \pm 0.64)$ ,  $(6.52 \pm 0.55)$ ;  $(4.03 \pm 0.46)$ ;  $(3.90 \pm 0.45)$  and  $(25.91 \pm 1.89)$  and  $(96.21 \pm 1.60)$ ;  $(78.12 \pm 1.46)$ ;  $(76.27 \pm 1.43)$  and  $(215.71 \pm 3.35)$  Bq/kg, respectively. According to UNSCEAR 2000, the worldwide average concentrations for  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  are 35, 30 and 400 Bqkg<sup>-1</sup>, respectively, which reveals that the activity of  $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  measured for soil, foundations and sand dunes samples in the area under study are much lower than the world wide values. In the rock samples, the specific activity concentrations for  $^{238}\text{U}$  is much higher than the recommended limits in 6 samples and for  $^{232}\text{Th}$  is also high in 9 samples, while the activity concentrations for  $^{40}\text{K}$  are low comparing to the recommended limits. The high values of  $^{238}\text{U}$  and  $^{232}\text{Th}$  radioactivity is noticed to be in the claystone rocks. Clay minerals are mainly composed of plate-like secondary aluminum silicate with small particle size and have a negatively charged surface. Therefore, clay particles have the ability to adsorb cations on their surface [18]. The distribution of specific activities of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  and  $^{40}\text{K}$  is also described using SPSS statistical computer program for the samples as shown in Table 2 and Fig. 2(a, b, c and d).

Table 2.: The activity concentrations distribution of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$  series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$  in samples of Al-Obour city (in Bq/kg) .

	<b><math>^{238}\text{U}</math></b>	<b><math>^{226}\text{Ra}</math></b>	<b><math>^{232}\text{Th}</math></b>	<b><math>^{40}\text{K}</math></b>
<b>Mean</b>	16.02	7.65	9.10	110.27
<b>S.D</b>	10.43	7.56	11.31	72.79
<b>Skewness</b>	2.84	2.28	2.41	1.97
<b>Kurtosis</b>	8.93	5.01	4.75	2.69
<b>Range</b>	3.74-66.59	1.90-37.66	2.38-48.94	47.99-326.61
<b>Frequency-distribution</b>	Log-normal	Log-normal	Log-normal	Log-normal

The table gives the statistics of the values corresponding to their activity values corresponding as measured for  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in 82 samples of the area under study. It lists the respective mean value, range, skewness, kurtosis coefficients and the type of theoretical frequency distribution that best fits each empirical distribution [19].

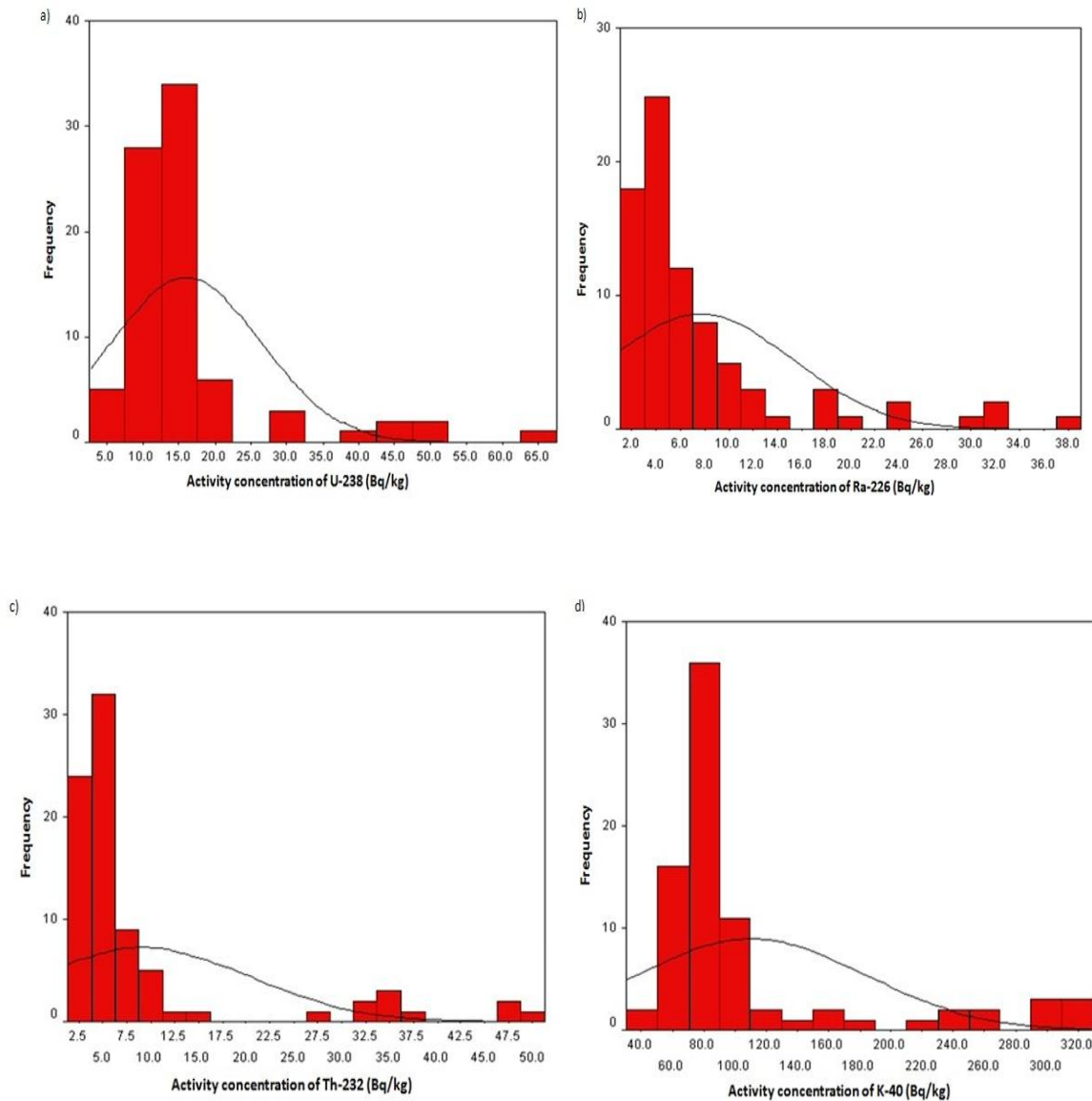


Fig.2: The activity concentrations distribution of 238U, 226Ra series, 232Th series and 40K in samples of Al-Obour city (in Bq/kg).

Skewness coefficient is a measure of the asymmetry of the probability distribution of a real-valued random variable. It can be positive or negative, or even undefined. Qualitatively, a negative skew indicates that the tail on the left side of the probability density function is longer than the right side and the bulk of the values lie to the left of the mean. A zero value indicates that the values are relatively evenly distributed on both sides of the mean, typically but not necessarily implying a symmetric distribution [20]. Kurtosis coefficient is any measure of the "peakedness" of the probability distribution of the real valued random variable. It is a descriptor of the shape of a probability [21]. It can be noticed from Fig.2 that 238U, 226Ra, 232Th and 40K fitted a log-normal distribution as the positive values of kurtosis coefficient for them indicate that their distributions are higher and narrower than normal.



Table 3: The Pearson correlation between radionuclide isotopes and heavy metals measured in soil samples of the understudy area.

<b>Variables</b>	<b>Cd</b>	<b>Co</b>	<b>Cr</b>	<b>Cu</b>	<b>Fe</b>	<b>Mn</b>	<b>238U</b>	<b>226Ra</b>	<b>232Th</b>	<b>40K</b>
<b>Cd</b>	1.00									
<b>Co</b>	-0.15	1.00								
<b>Cr</b>	-0.09	0.96*	1.00							
<b>Cu</b>	-0.02	0.58	0.64*	1.00						
<b>Fe</b>	-0.18	0.97*	0.93*	0.56	1.00					
<b>Mn</b>	-0.04	0.78*	0.77*	0.43	0.88*	1.00				
<b>238U</b>	0.34	0.40	0.38	0.13	0.34	0.31	1.00			
<b>226Ra</b>	0.05	0.55	0.57	0.18	0.59	0.70*	0.47	1.00		
<b>232Th</b>	-0.14	0.75*	0.71*	0.22	0.77*	0.73*	0.50	0.87*	1.00	
<b>40K</b>	-0.29	0.65*	0.61*	0.12	0.62*	0.49	0.34	0.61*	0.84*	1.00

\*. Correlation is significant at 0.05 level.

Table 3: Continued.

<b>Variables</b>	<b>Ni</b>	<b>Pb</b>	<b>Stronium</b>	<b>Vanadium</b>	<b>Zn</b>	<b>238U</b>	<b>226Ra</b>	<b>232Th</b>	<b>40K</b>
<b>Ni</b>	1.00								
<b>Pb</b>	0.23	1.00							
<b>Stronium</b>	0.44	0.46	1.00						
<b>Vanadium</b>	0.75	0.14	0.36	1.00					
<b>Zn</b>	0.01	0.03	-0.02	-0.05	1.00				
<b>238U</b>	0.29	0.34	0.41	0.44	-0.08	1.00			
<b>226Ra</b>	0.41	0.13	0.29	0.80*	0.05	0.47	1.00		
<b>232Th</b>	0.62	0.16	0.24	0.87*	0.12	0.50	0.87*	1.00	
<b>40K</b>	0.57	0.13	0.16	0.62	0.02	0.34	0.61*	0.84*	1.00

\*. Correlation is significant at 0.05 level.

Table3 shows the correlations between radioactive isotopes and heavy metals measured in 19 soil samples collected from the industrial areas in Al-Obour city. It has been noticed that there are a very good correlations between 226Ra, 232Th and 40K with Fe and Mn. Radium has been shown to absorb strongly to Fe(III) oxyhydroxides and MnO<sub>2</sub> impregnated filtration has been used to extract both radium and thorium isotopes [22]. Also a good correlation between 232Th and 40K with Co and Cr. 226Ra and 232Th has a good correlation with Vanadium. From all of that we can see that 238U has week correlation with heavy metals while 226Ra,





$^{232}\text{Th}$  and  $^{40}\text{K}$  have nearly the same behavior and good correlation with some of these heavy metals. These correlations are existed mainly due to the clay minerals in soil samples. Generally, clay minerals are mainly composed of plate-like secondary aluminum silicate with small particle size and have a negatively charged surface. Therefore, clay particles have the ability to absorb the cations on their surface and raise the level of radionuclide and heavy metal concentrations [23].

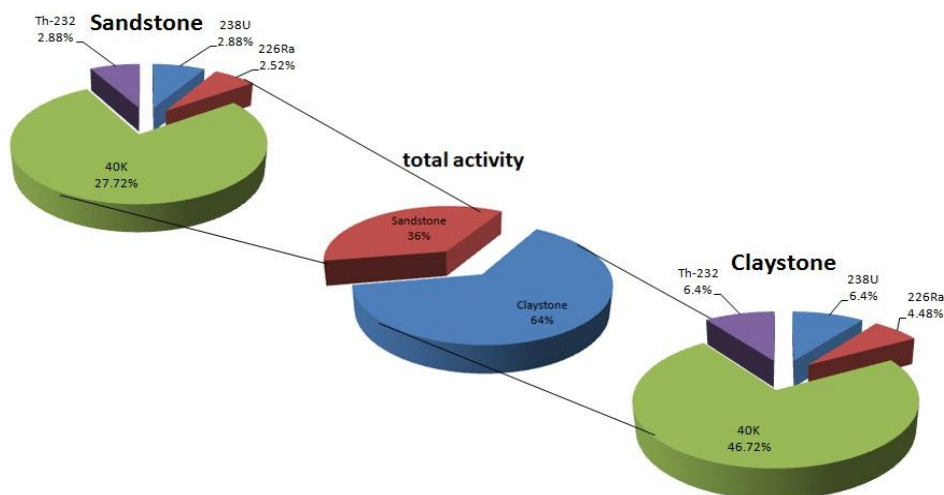


Fig.3: The distribution of natural radioactivity in the rock samples of Al-Obour city.

Fig.3 shows the distribution of natural radioactivity in the rocks samples of Al-Obour city. It has been seen that most the activity is concentrated in the claystone rocks (64%) and most the radioactivity in the rocks is coming from  $^{40}\text{K}$  (73%) in claystone rocks and (77%) in sandstone rocks.

Table 4. shows the ratios between the different isotopes in  $^{238}\text{U}$  series and  $^{232}\text{Th}$  series for each type of samples collected from the area under study. It can be noticed that for soil, foundations and sand dunes samples, the activity ratio of  $^{238}\text{U}/^{226}\text{Ra}$  is greater than 1 with averages of 2.03, 3.51 and 3.50 and ranges from 0.94 to 4.03, 1.75 to 5.98 and 1.51 to 6.74, respectively, which indicates that there is a state of disequilibrium between the two radionuclides in the U-series. This is explained by the difference in geochemical properties between the two radionuclides. Uranium has greater mobility than radium in the environment and  $^{238}\text{U}$  is rapidly transferred to deeper soil where it accumulates [10]. On the other hand, The activity ratios of  $^{238}\text{U}/^{226}\text{Ra}$  in rock samples range from 0.31 to 1.76 with average of 1.22 which is close to unity indicating a state of equilibrium in the samples. It also noticed that the ratios  $^{226}\text{Ra}/^{214}\text{Pb}$  and  $^{214}\text{Pb}/^{214}\text{Bi}$  have averages of 1.12 and 0.98, 1.18 and 0.96, 1.15 and 0.97 and 1.05 and 1.01 for soil, foundations, sand dunes and rock samples, respectively. It is obvious that the values are close to unity which shows a state of secular equilibrium within the  $^{226}\text{Ra}$  series. The ratio  $^{228}\text{Ac}/^{212}\text{Bi}$  and  $^{212}\text{Bi}/^{208}\text{Tl}$  in the  $^{232}\text{Th}$  series have the averages of 1.00 and 1.08, 1.05 and 1.04, 1.04 and 0.99 and 1.00 and 1.02 for soil, foundations, sand dunes and rock samples, respectively. The values are close to unity which also indicates a state of secular equilibrium in the  $^{232}\text{Th}$  series.



Table 4.: The ratios of  $^{238}\text{U}$  and  $^{232}\text{Th}$  series in samples collected from the area under study.

Sample no.		238U-series			232Th-series	
		238U/226Ra	226Ra/214Pb	214Pb/214Bi	228Ac/212Bi	212Bi/208Tl
Soil	Average	2.03	1.12	0.98	1.00	1.08
	Range	(0.94-4.03)	(0.99-1.29)	(0.95-1.08)	(0.86-1.15)	(0.79-1.57)
Foundations	Average	3.51	1.18	0.96	1.05	1.04
	Range	(1.75-5.98)	(0.85-1.62)	(0.88-1.98)	(0.89-1.54)	(0.58-1.36)
Sand dunes	Average	3.50	1.15	0.97	1.04	0.99
	Range	(1.51-6.74)	(0.87-1.45)	(0.92-1.05)	(0.80-1.36)	(0.85-1.23)
Rock	Average	1.22	1.05	1.01	1.00	1.02
	Range	(0.31-1.76)	(0.98-1.19)	(0.97-1.05)	(0.90-1.03)	(0.90-1.14)

The distribution of  $^{238}\text{U}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  in the whole city of Al-Obour is as shown in Fig.4(a, b, c and d) using Surfer 9. computer program. It shows that  $^{238}\text{U}$  is concentrated in northwest of the city, while  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  have nearly the same distribution and concentrated in the middle of the city. Hence, Ra and Th are low solubility in soil. It was concluded that radium does not migrate through the soil, except for dispersed or dissolved  $^{226}\text{Ra}$ . Even then, adsorption in the soil solid phase leads to a very low average migration [24]. Uranium is mobile under oxidizing conditions whereas radium and thorium are essentially immobile in the surficial environment, the differing mobility's of these radionuclides has previously been identified as causing disequilibrium in young organic uranium deposits [25]. This explains difference in behavior and distribution of uranium comparing with radium and thorium.

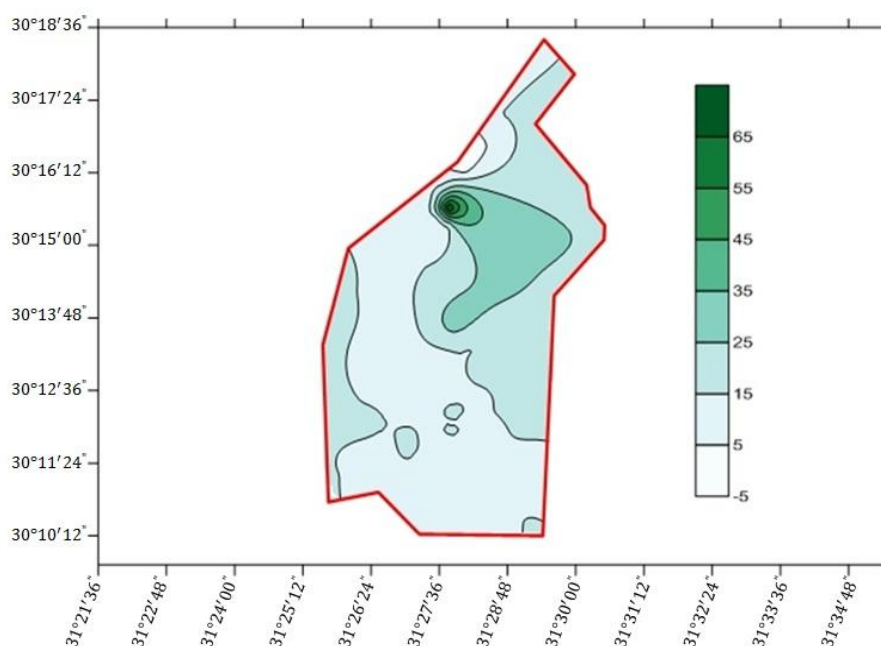


Fig.(4-a): The distribution of  $^{238}\text{U}$  in Al-Obour city.

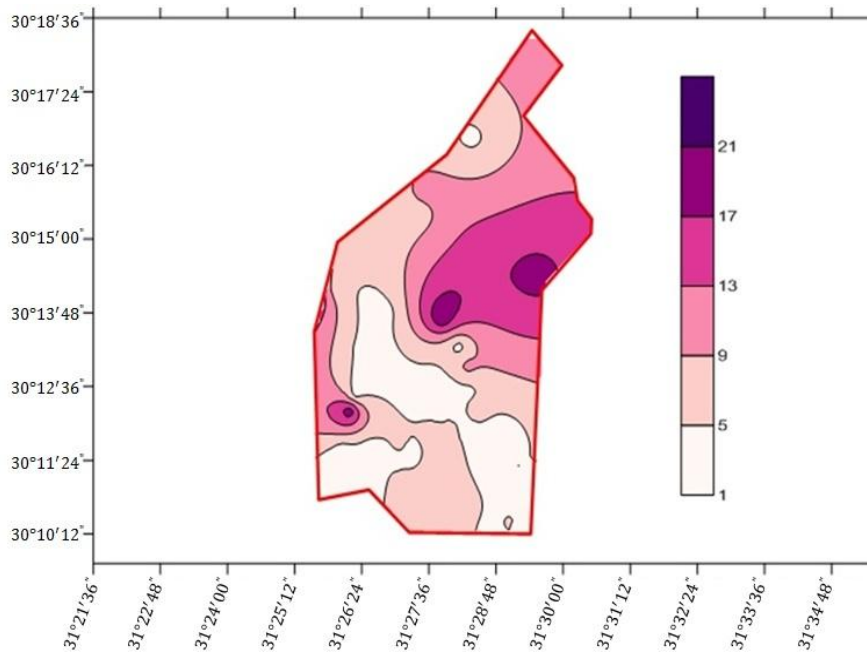


Fig.(4-b): The distribution of  $^{226}\text{Ra}$  in Al-Obour city.

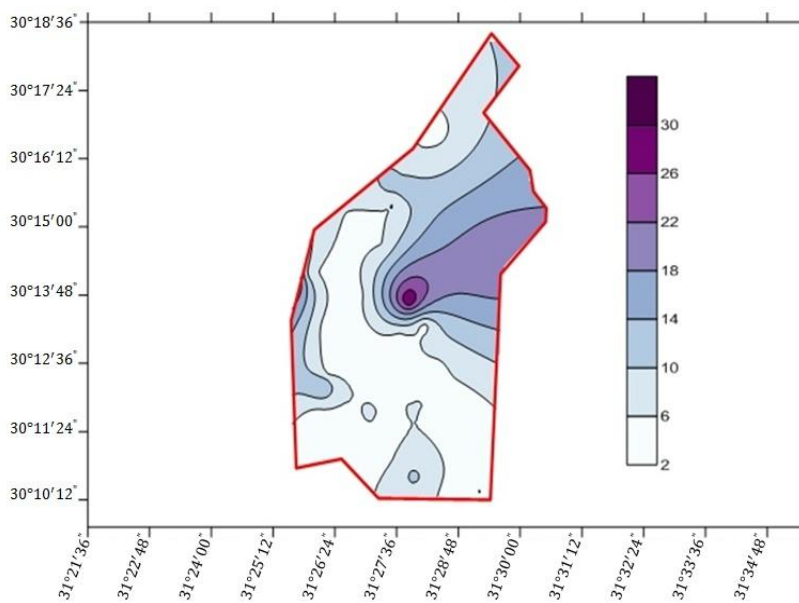


Fig.(4-c): The distribution of  $^{232}\text{Th}$  in Al-Obour city.

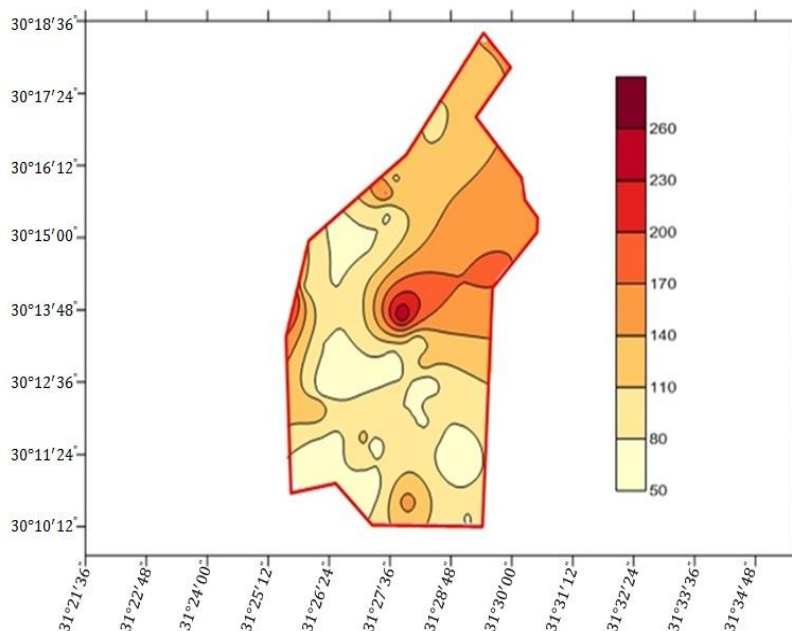


Fig.(4-d): The distribution of 40K in Al-Obour city.

It is very important to estimate the hazard indices of the samples to be sure about the safety of the area under study and see if there are percussions needed while working or living in or around the area under study. The hazard indices in soil samples of Al-Obour city is shown in Table 5.

Table 5: The range and average of dose rate, the annual effective dose(AED), radium equivalent and external index.

Hazard indices	soil		foundations		Sand dunes		rock	
	range	average	range	average	range	average	range	Average
<b>D(nGy/h)</b>	9.16-23.08	14.14	9.42-15.27	11.56	9.66-15.70	11.57	8.05-71.62	37.85
<b>AED(mSv/y)</b>	0.01-0.03	0.02	0.01-0.02	0.01	0.01-0.02	0.01	0.01-0.09	0.05
<b>Raeq(Bq/kg)</b>	13.04-36.57	23.23	9.93-24.82	15.48	9.77-26.27	15.32	20.59-126.95	73.04
<b>Hex</b>	0.04-0.11	0.06	0.03-0.07	0.04	0.03-0.07	0.04	0.06-0.34	0.20

The dose rate was found to be 14.14, 11.56, 11.57 and 37.85nGy/h with ranges of 9.16 to 23.08, 9.42 to 15.27, 9.66 to 15.70 and 8.05 to 71.62nGy/h for soil, foundations, sand dunes and rock samples, respectively. All the samples collected from Al-Obour city were found to be within the recommended limits except for 2 claystone rock samples which have higher dose rates. The annual effective dose (AED), Raeq and Hex were noticed to be within the limits recommended by UNSCEAR,2000. Fig.5 shows the dose rate distribution in the samples collected from the area under study comparing with the worldwide.

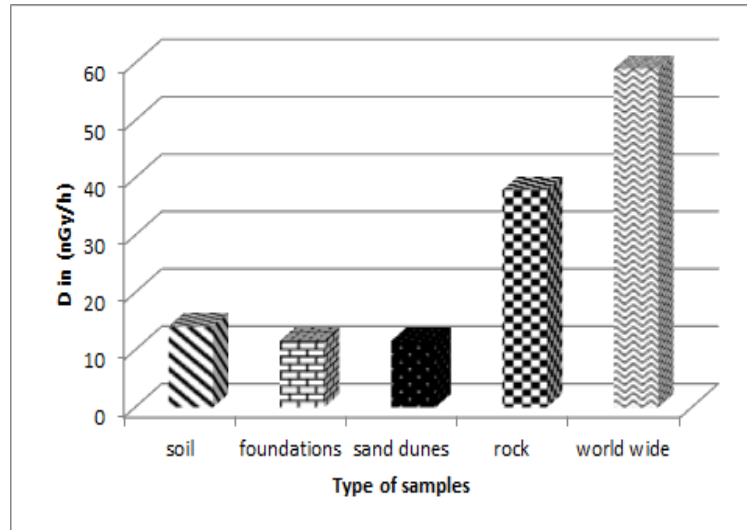


Fig.5: The dose rate distribution in Al-Obour city.

Table 6: The calculated AGED, AUI and ELCR for all samples

Type	Location	No. of samples	AGED	AUI	ELCR
Soil	First industrial area and industrial zones "B&C"	19	0.077±.003.	0.15±0.009	0.049
Foundations	6th,7th,9th settlements and the entertainment area	21	0.052±0.002	0.09±0.007	0.040
Sand dunes	Northern, western extensions and golf and Giro land area	25	0.052±0.002	0.09±0.007	0.040
rock	4th and 5th settlement	17	0.235±0.011	0.52±0.031	0.132

It is important to assess the annual gonadal dose equivalent (AGDE), activity utilization index (AUI) and excess lifetime cancer risk (ELCR). These parameters indicate the human risk due to the natural radiation emitted to the sensitive organs. The permissible values of these ELCR parameters should be less than unity, but the results in table (6) show that the values are less than unity, this leads to a safety region for people staying.



### 3. Conclusions

The results of this study will provide background data on natural and artificial radioactive isotopes and environmental pollution. The distribution of natural radioactivity was determined and showed that the radioactivity in all types of samples was very low except for the rock. The claystone samples in rock showed much higher radioactivity for  $^{238}\text{U}$  and  $^{232}\text{Th}$ .  $^{137}\text{Cs}$  is existed in some samples but is close to the background level. The hazards were determined for all samples and the area is considered to be safe for human activities.

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