International Journal of New Horizons in Physics

http://dx.doi.org/10.18576/ijnhp/030104

# Radiological Hazards Resulting from Natural Radioactivity in Sediments at Ras Gharib Coast, Red Sea, Egypt

*Hesham M. Zakaly*[1,*], *M. A. M. Uosif*[1], *Madkour.Hashim*[2], *Shams.issa*[1,3] *and Mahmoud tamam*[1].

[1] Faculty of Science, Al-Azhar University, Assuit branch, Egypt.
[2] National Institute of Oceanography and Fisheries, Hurghada, Egypt.
[3] Faculty of Science, Tabok University, Tabok, Saudi Arabia.

Received: 21 Feb. 2015, Revised: 22 Mar. 2015, Accepted: 24 Mar. 2015.
Published online: 1 Jan. 2016.

**Abstract:** Natural $^{226}$Ra, $^{232}$Th and $^{40}$K radionuclides concentration in beach Sediments along Ras Gharib coast of Red sea, Egypt has been measured by NaI (Tl) gamma spectrometry. The total average concentrations of radionuclides $^{226}$Ra, $^{232}$Th and $^{40}$K are 28±1.9, 23.9±2.8, and 381.4±21.4 Bqkg$^{-1}$, respectively. The total average absorbed dose rate is found to be 34 nGyh$^{-1}$, while, the annual effective dose rate has an average value of 42 µSvy$^{-1}$. In some locations, the concentration for the investigated heavy metals exceeds the permissible limits recommended by the Canadian Environmental Quality Guidelines, this indicated that the degree of metals pollution is caused by anthropogenic activities (Terrigenous sediments transported to marine environment by some wadis in General Beach area, oil spills as a result of exploration and extraction in General Company of Petroleum) and or by natural impacts like in El-Sakala area

**Keywords:** radiation hazard; radionuclides; natural radioactivity; Heavy metals ; Ras Gharib; Red Sea; Egypt; marine sediments.

## 1 Introduction

The Egyptian Red Sea coast is being stressed due to over exploitation and has become very vulnerable to human related activities. Generally, the main environmental problems and threats to the Red Sea geosystem and ecosystem contain recreation and tourism activities, landfilling, dredging, oil pollution, water pollution, solid waste disposal, navigation activities, phosphate shipment pollution and fishing activities. As a result of the human activities, pollution extends along the shore, and is discharged to the near shore waters. Some of these pollutants may directly or indirectly be captured by bottom sediments (Madkour, 2004). In the case of successive concentrations of these pollutants in bottom sediments, the later will act as a reservoir for pollutants. Therefore, studies of the recent sediments along the Red Sea shoreline is important in assessing potential environmental hazards originating from the irrational human activities.

The main aim of the radiation protection viewpoint is studying the concentrations of naturally activity of radionuclides and the extent of their exposure to population. Radionuclides present in the environmental media are generally found in low concentration. Detection and intensity measurements of weak gamma activities are playing a significant vital role in physics experiments and industrial investigations. The most important naturally occurring radionuclides exist in sediment are not uniformly distributed; the knowledge of their distribution in sea sediments plays an important role in radiation protection and measurement. In minerals, the incorporation of uranium and thorium into the crystal lattice depends on the abundance of these elements in the sediments during crystallization and on the matching of the chemicals properties and the atomic radii of hosts and substitutes. (Huy and Luyen, 2006).

The isotopes to interests are $^{226}$Ra, $^{232}$Th and $^{40}$K. $^{226}$Ra is chosen because the external exposure to the population is mostly by gamma rays emitted from its main daughters $^{214}$Pb and $^{214}$Bi. The contribution of these gamma rays to external dose encompasses ~ 98% of all γ-rays from all nuclides in the $^{238}$U series (Huy and Luyen, 2006).

## 2 Materials and Methods

### *2.1 Study regions*

***Ras Gharib City*** divided into three stations from south to north namly; El-Sakala area, General Beach area and the third station namely, General Company of Petroleum (Fig.1).

*Corresponding author e-mail: h.m.zakaly@azhar.edu.eg


**Fig 1**: Location map of Red Sea Governorate

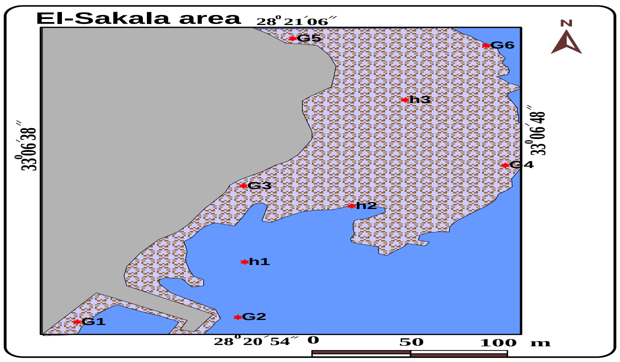


**Fig 2:** Sample locations in El-Sakala

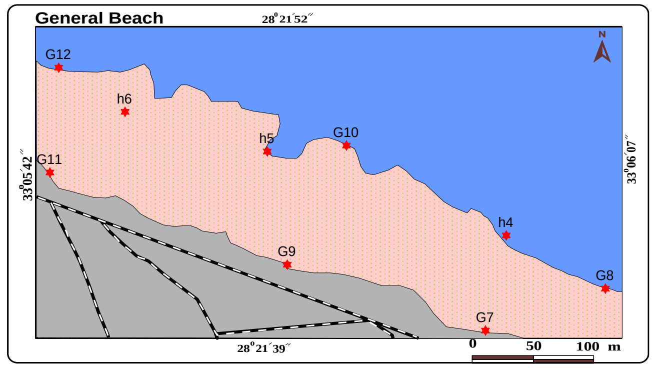


**Fig 3:** Sample locations in General Beach in Ras Gharib City.

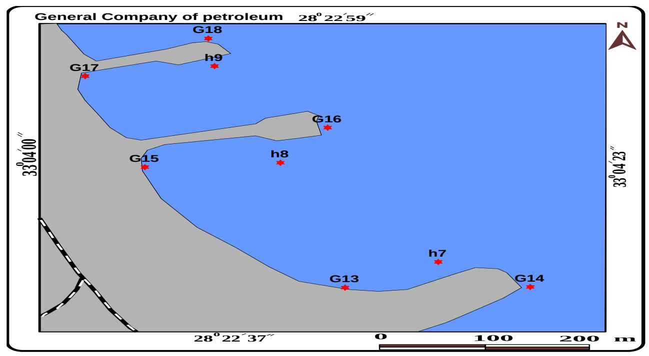


**Fig 4:** Sample locations in General Company of Petroleum

**Station IVV: El Sakala area** is lying at latitudes 28°21\ 00\\ N and longitudes 33° 06\ 40\\ E (Table 1; Fig. 2). Station IVV is characterized by the existence of a narrow intertidal zone about (50 – 100m). In the beach area and intertidal zone, the sands are accumulated as a small dunes which are covered by some vegetation. These dunes separate between the shore zone and sabkha evaporates. The gentle slope of this area produces a narrow sabkha basin, a narrow tidal flat, in the intertidal zone of this area.

**Station VVI: General Beach** is located between latitudes 28°21\ 41\\ N and longitudes 33° 05\ 50\\ E (Table 1; Fig, 3)**.** Sediments of terrigenous have been transported to marine environment by some vales especially in the southern part of Ras Gharib City.

It is noticed that these sediments are a relatively large under cutting effect of the violent water drive during heavy torrents. The sediments of beach are coarse sands and these sands are significant terrigenous fragments. The tidal flat is very narrow and extents smoothly and slopes gently seaward. The sediments covering the bottom topography of this area are of fine sand to sandy mud.

**Station VVII: General Company of petroleum** is laying at latitude 28° 22\ 37\\ N and longitude 33° 04\ 02\\ E (Table 1; Fig. 4). This station is similar morphologically the general beach but the beach and the big part of the intertidal zone is covered by heavy oil spills as a result of exploration and

**Table 1.** The hydrographic parameters of water mass in the studied areas

| Studied Station | position: Lat. ° ' " N | position: Long. ° ' " E | Sa. No. | Depth (m) | Tem (°C) | Sal. (%) | PH | SPC ms\cm | TDS (ppt) |
|---|---|---|---|---|---|---|---|---|---|
| south (El-Sakala area) | 28°21'00" | 33°06'40" | h1 | 0.3 | 17.4 | 40.6 | 8.8 | 60 | 30.2 |
| | | | H2 | 1.0 | 17.4 | 43.3 | 8.6 | 64 | 31.9 |
| | | | H3 | 1.5 | 17.3 | 43.2 | 8.6 | 64 | 31.9 |
| middle (General Beach) | 28°21'41" | 33° 5'50" | H4 | 0.3 | 17.4 | 43.3 | 8.6 | 64 | 32 |
| | | | H5 | 0.5 | 17.1 | 43.2 | 8.6 | 64 | 31.9 |
| | | | H6 | 0.3 | 18.2 | 43.2 | 8.7 | 64 | 31.8 |
| north (General Campony of Petroleum | 28°22'37" | 33°04'02" | H7 | 0.3 | 17.9 | 43.3 | 8.5 | 64 | 31.9 |
| | | | H8 | 0.5 | 17.5 | 43.2 | 8.5 | 64 | 31.8 |
| | | | H9 | 0.3 | 18.1 | 42.7 | 8.5 | 63 | 31.5 |

extraction activities of crude oil and flooding of some oil wells. Generally, the beach area of Ras Gharib is affected by oil spills.

***Sample collection and preparation***

Eighteen samples of sediment have been collected from Ras Gharib city coastline, Red sea. Samples collection was considered the locations throughout three Stations (El-Sakala, General Beach and General Campony of Petroleum) in Ras Gharib , Red sea governorate, Egypt, as shown in figure 1. 6 samples have been collected from El-Sakala (south town), also 6 samples from General Beach (Middle town) and 6 samples General Company of Petroleum (North town)). Table 1.

The location of collected samples and it's description of bottom characteristics are given in (Figures 2,3 and 4). Sediment samples have collected by using hand, grab sampler and scuba diving from three different environmental zones such as (i) beach, (ii) intertidal zone and (iii) offshore zone until 4 m water depth represent these localities. Scuba diving was used in region which rich in corals where grab sampler failed to collect samples

For gamma analysis, the samples were prepared as follows. Each sample (about1 kg) washed by distilled water and it was dried at about 110◦ C to ensure that moisture is completely removed. The samples were crushed, homogenized and sieved through a 200 mesh, the optimum size to be enriched in heavy minerals. Weighted samples were placed in a polyethylene beaker of 350 $cm^3$ volume. The beakers completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) (Uosif *et al* 2014, Mahmoud *et al* 2015). This step is necessary to ensure that radon gas confined within the volume and the progeny will remain in the sample

## 3 Results and Discussion

### *3.1 Environmental conditions*

Oceanographic situation prevailing along the shoreline have a commutable influence on the seaboard features. The oceanographic parameters influence the seaboard environment and simultaneously have an effect on the shore activities. Most oceanographic parameters were measured at the study regions listed in (Table 1). The salinity of seawater in El-Sakala area is high and varies between 40.6% at depth 0.3m and 43.3% at depth 0.5 m. The water temperature ranges between 17.3 ˚C at depth 1.5m and 17.4˚C at depth 0.3m in the winter season, Jan.,2012 (period of collecting samples ) (Table 1). The salinity of seawater in General Beach ranges between 43.2% at depth 0.5m and 43.3 at depth 0.3 m, and the water temperatures are between 17.1˚C at depth 0.5m and 18.2˚C at depth 0.3m in the winter season (Table 1). The salinity of the water in General Company of Petroleum is varies between 42.7% at depth 0.3m and 43.3 % at depth 0.3 m, while the water temperatures are between 17.5 ˚C at depth 0.5m and 18.1 ˚C at depth 0.3m in the winter season (Table 1).

### 3.2 *Radionuclide Activity Concentrations in Gharib City*

The measured activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in sediment samples from Gharib City are presented in Table 2, that shows the highest values observed for the specific activities of $^{226}$Ra, $^{232}$Th and $^{40}$K are 52±4, 45±5 and 1640±93 Bqkg$^{-1}$ (in General company of Petroleum), respectively, while the lowest observed values of the specific activities of the same radionuclides are 6±0.4 and 8±2 (in General Beach) and 86±5 Bqkg$^{-1}$ (in General company of Petroleum), respectively. As shown in Table 2, the activity of $^{226}$Ra ranged from 6 to 52 Bqkg$^{-1}$ with average is 28 Bqkg$^{-1}$. The activity concentration of $^{232}$Th varies from 8 to 45 Bqkg$^{-1}$, and it is average equal 24 Bqkg$^{-1}$. The activity concentration of $^{40}$K varies from 86 to 1640 Bqkg$^{-1}$, with average is 381 Bqkg$^{-1}$.

The average values are lower than the corresponding worldwide average values, which are 35, 30 and 400 Bqkg$^{-1}$ for $^{226}$Ra, $^{232}$Th and $^{40}$K respectively, (UNSCEAR, 2000). Figure 5 and 6 shows the Activity concentrations and (Mean, Max and Min) Distribution of $^{226}$Ra, $^{232}$Th and $^{40}$K for the sediment samples in **Gharib City.**

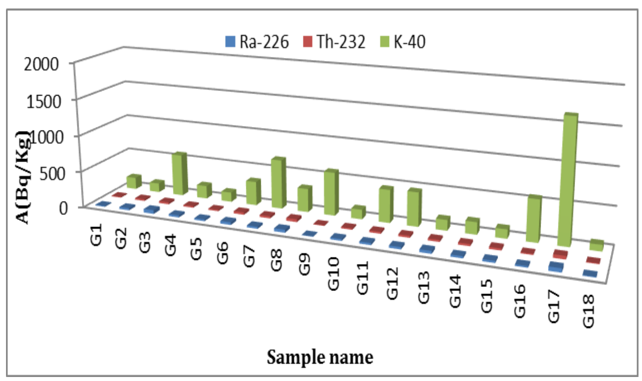


**Figure 5:** Activity concentrations of the radioelements (in Bqkg$^{-1}$) found in Gharib City samples.

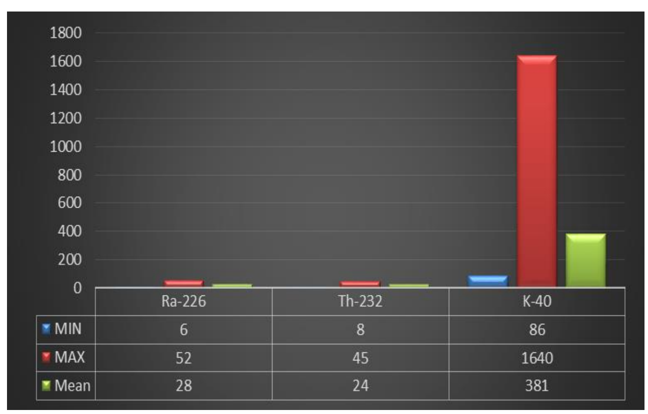


**Figure 6:** Distribution of $^{226}$Ra, $^{232}$Th and $^{40}$K in Gharib City.

The Frequency distributions of the radionuclides from Gharib samples were analyzed, and the histograms are given in Figs. 7-9. The graphs of $^{226}$Ra and $^{232}$Th show that these radionuclides show a normal (bell-shape) distribution. While $^{40}$K show that this radionuclides presented some degree of multi-modality. This multi-modal feature of the radio-elements elucidates the complexity of sediments samples

Table 2. Presents the basic statistics were used to describe the statistical characteristics of the radionuclide activities. SKEWNESS is a measure of the asymmetry of the probability distribution of a real-valued random variable. The normal distribution has a skewness of zero. However, in reality, data points may not be completely symmetric. Therefore, an understanding of the skewness of the data set indicates whether deviations from the mean are likely to be positive or negative. Skewness characterizes the degree of asymmetry of a distribution around its mean (Groeneveld and Meeden, 1984).presents the Positive skewness in Gharib samples, which, indicates a distribution with an asymmetric tail extending towards values that are more positive. The activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in this Gharib city are 0.2, 0.3 and 2.5, respectively; small skewness values (Table 2), which indicate that the distributions are asymmetric in nature.

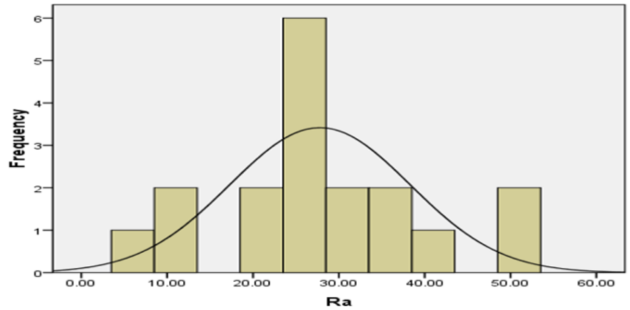


**Figure 7:** The frequency distributions of Ra-226 found in Gharib City samples.

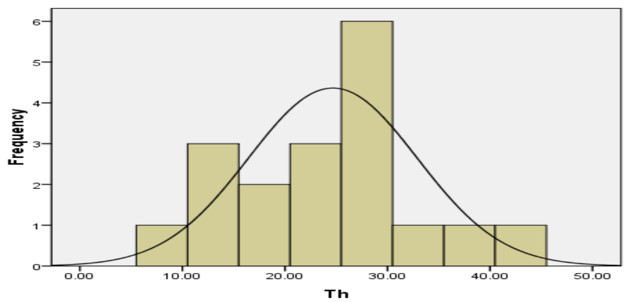


**Figure 8:** The frequency distributions of Th-232 found in Gharib City samples

**Table 2:** Activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K (in Bqkg$^{-1}$) found in Gharib City.

| Samples Location | Sample Name | Activity concentrations(Bqkg$^{-1}$) | | | Total | contribution% | | |
|---|---|---|---|---|---|---|---|---|
| | | $^{226}$Ra | $^{232}$Th | $^{40}$K | | Ra | Th | K |
| south ((El-Sakala area ) | G1 | 12±1 | 12±1 | 164±9 | 188 | 6 | 6 | 87 |
| | G2 | 28±2 | 23±3 | 126±7 | 177 | 16 | 13 | 71 |
| | G3 | 50±3 | 27±3 | 580±32 | 657 | 8 | 4 | 88 |
| | G4 | 29±2 | 21±2 | 180±10 | 229 | 12 | 9 | 78 |
| | G5 | 23±2 | 18±2 | 132±8 | 172 | 13 | 10 | 77 |
| | G6 | 36±2 | 32±4 | 329±18 | 397 | 9 | 8 | 83 |
| Middle (General Beach) | G7 | 26±2 | 29±3 | 676±38 | 732 | 4 | 4 | 92 |
| | G8 | 40±3 | 38±5 | 322±18 | 400 | 10 | 10 | 81 |
| | G9 | 6±0.4 | 8±2 | 592±34 | 605 | 1 | 1 | 98 |
| | G10 | 24±2 | 19±2 | 131±7 | 174 | 14 | 11 | 75 |
| | G11 | 27±2 | 25±3 | 450±25 | 502 | 5 | 5 | 90 |
| | G12 | 31±2 | 27±3 | 463±26 | 521 | 6 | 5 | 89 |
| North (General company of Petroleum) | G13 | 37±2 | 26±3 | 144±8 | 207 | 18 | 13 | 70 |
| | G14 | 27±2 | 28±3 | 166±9 | 222 | 12 | 13 | 75 |
| | G15 | 27±2 | 27±3 | 124±7 | 177 | 15 | 15 | 70 |
| | G16 | 20±1 | 14±2 | 562±32 | 597 | 3 | 2 | 94 |
| | G17 | 52±4 | 45±5 | 1640±93 | 1737 | 3 | 3 | 94 |
| | G18 | 10±1 | 11±2 | 86±5 | 107 | 9 | 10 | 81 |
| MIN | | 6 | 8 | 86 | 107 | 1 | 1 | 70 |
| MAX | | 52 | 45 | 1640 | 1737 | 18 | 15 | 98 |
| AVEG | | 28 | 24 | 381 | 433 | 9 | 8 | 83 |
| STDEV | | 12 | 10 | 371 | 382 | 5 | 4 | 9 |
| S.E | | 3 | 2 | 87 | 90 | 1 | 1 | 2 |
| SKEWNESS | | 0.2 | 0.3 | 2.5 | 2.5 | 0.1 | 0.03 | 0.01 |
| KURTOSIS | | 0.2 | 0.3 | 7.7 | 8.0 | -1.1 | -1.2 | -1.3 |

Kurtosis is a measure of the peakedness of the probability distribution of a real-valued random variable. It characterizes the relative peakedness or flatness of a distribution compared with the normal distribution (Ravisankar, at al., 2014). In Gharib city, the $^{226}$Ra, $^{232}$Th and $^{40}$K distributions have positive kurtosis value (Table 2), indicating peaked distribution.

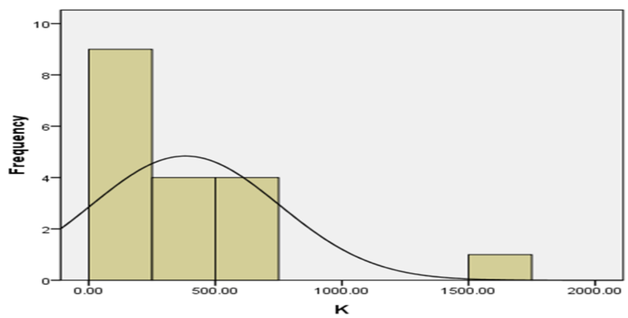


**Figure 9:** Frequency distributions of K-40 found in Gharib City samples

### *3.2.1 Correlation of Natural Radionuclides in Sediment Samples from Gharib City*

From the activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K given in table 2, the relationships between these radionuclides in sediments samples under investigation were diagrammatically plotted as shown in Figure 10.

Figure 10 shows strong correlation between $^{232}$Th and $^{226}$Ra while we found moderate correlation between $^{232}$Th and $^{40}$K with correlation coefficients (R=0.878 and 0.518) respectively. But between $^{40}$K and $^{226}$Ra we found relatively weak correlation with factor (R=0.476).

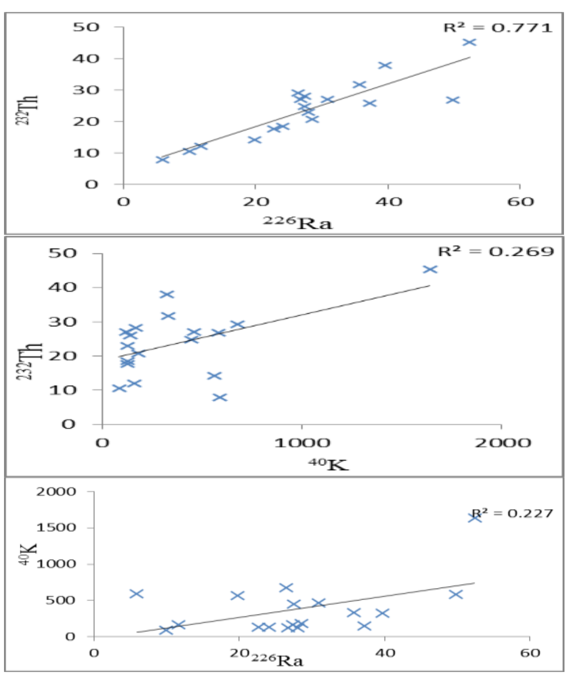


**Figure 10:** Correlation between natural radionuclides in sediment samples from Hurghada city

### *3.3 Radiological Characterization of Ras Gharib.*

### *3.3.1 Radium equivalent activities ($Ra_{eq}$)*

Radium equivalent ($Ra_{eq}$) index in Bq kg$^{-1}$ is an exceedingly used radiological hazard index. It is a suitable index to compare the specific activities of samples including different concentrations of $^{226}$Ra, $^{232}$Th ($^{228}$Ra) and $^{40}$K. It was defined on the assumption that 10Bqkg$^{-1}$ of $^{226}$Ra, 7 Bqkg$^{-1}$ of $^{232}$Th and 130Bqkg$^{-1}$ of $^{40}$K produce the same gamma dose rate. It was calculated as follows (El Taher and Uosif, 2006).

$$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.077 C_{k} \quad (1)$$

Where $C_{Ra}$,$C_{Th}$ and $C_k$ are the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg-1, respectively. The calculated values of $Ra_{eq}$ for Gharib samples under investigation are given in Table 3.. These values were ranged from 32 to 244 with average value of 92 Bqkg$^{-1}$; these results indicate all average values of $Ra_{eq}$ are less than the upper limit 370 Bqkg$^{-1}$ (Beretka, and Mathew, 1985) this mean that, it is safe , if it use as building materials.

Figure 11; show the relative contribution to $Ra_{eq}$ owing to $^{226}$Ra, $^{232}$Th and $^{40}$K. for sediment samples under investigation in Gharib city. It's noticed that the contribution owing to $^{226}$Ra, $^{232}$Th and $^{40}$K were ranged between (9% to 44%), (18% to 52%) and (13% to 72%) for sediment samples under investigation respectively. Figure 12, shows the average relative contribution of $^{226}$Ra, $^{232}$Th and $^{40}$K contents of $Ra_{eq}$ for samples under consideration, the average relative contribution to $Ra_{eq}$ owing to $^{226}$Ra, $^{232}$Th and $^{40}$K are 32%, 39% and 29%, respectively. It is evident that the contribution from $^{232}$Th is the highest one where the contribution from $^{40}$K is the smallest.

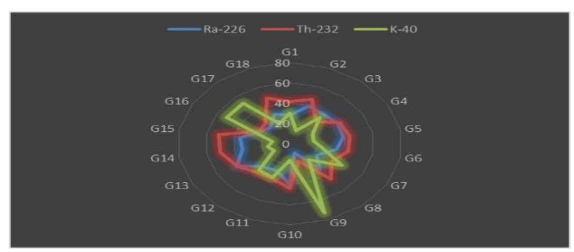


**Figure 11:** The relative contribution (%) of $^{226}$Ra, $^{232}$Th and $^{40}$K to Radium equivalent in ($H_{ex}$) in every sample from Gharib City.

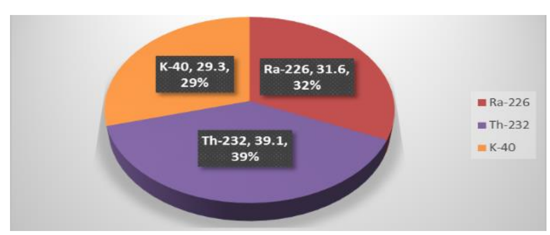


**Figure 12:** The average relative contribution to Radium equivilant activity ($Ra_{eq}$) due to $^{226}$Ra, $^{232}$Th and $^{40}$K in sediment samples from Gharib city.

### 3.3.2 Absorbed gamma dose rate (D)

The natural radionuclides contribution to the absorbed dose rate in air ($D_R$) depends on the natural specific activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K. If a radionuclide activity is known then its exposure dose rate in air at 1 m above the ground can be calculated (Ravisankar *et al.*, 2014; Issa et al., 2015) The conversion factors used to compute absorbed gamma dose rate ($D_R$) in air per unit activity concentration in Bqkg$^{-1}$ (dry weight) corresponds to 0.462 nGyh$^{-1}$ for $^{226}$Ra, 0.604 nGyh$^{-1}$ for $^{232}$Th and 0.0417 nGyh$^{-1}$ for $^{40}$K. Therefore $D_R$ can be calculated as follows (UNSCEAR,2000):

$$D_R(\text{nGy h}^{-1}) = 0.462\, C_{Ra} + 0.604\, C_{Th} + 0.0417 C_K \qquad (2)$$

Where $C_{Ra}$, $C_{Th}$ and $C_k$ are the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq kg$^{-1}$, respectively. From Table 3, values of absorbed dose (D) were ranged from 15 to 119 with average value of 43 nGy h$^{-1}$, these average value is less than the world average value of D is 57 nGy.h$^{-1}$ (UNSCEAR, 2000).

The relative contribution (%) of $^{226}$Ra, $^{232}$Th and $^{40}$K to absorbed dose rate in every sample from Gharib City can be seen in Figure 13. From it, one can notice that the contribution absorbed dose rate (D) owing to $^{226}$Ra, $^{232}$Th and $^{40}$K in sediment samples under investigation were ranged between (9% to 44%), (15% to 48%) and (15% to 78%) for sediment samples under investigation respectively.

Figure 14, shows the average relative contribution to (**D**) owing to $^{226}$Ra, $^{232}$Th and $^{40}$K are 31%, 36% and 33%, respectively. It is evident that the contribution from $^{232}$Th is the highest one where the contribution from $^{226}$Ra is the smallest; these indicate that the contribution to (**D**) is owing to $^{232}$Th followed by $^{40}$K followed by $^{226}$Ra.

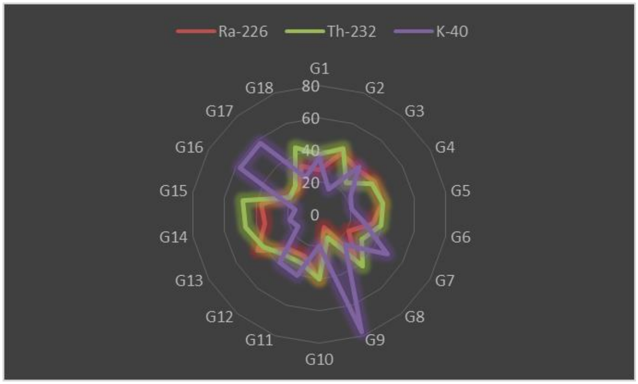


**Figure 13:** The relative contribution (%) of $^{226}$Ra, $^{232}$Th and $^{40}$K to absorbed dose rate in every sample from Gharib City.

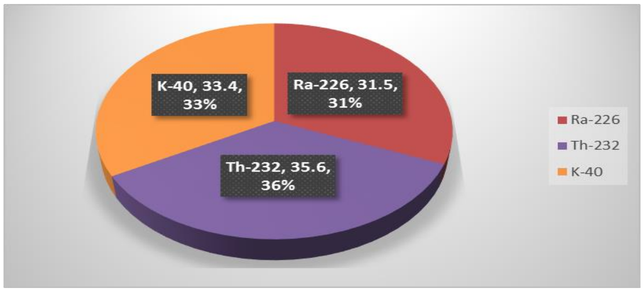


**Figure 14:** The average relative contribution to absorbed dose rate (D) due to $^{226}$Ra, $^{232}$Th and $^{40}$K in sediment samples from Gharib city.

### 3.3.3 Internal radiation hazard (Hin)

The using of internal hazard index ($H_{in}$) to control the internal exposure to $^{222}$Rn and its progeny (Al-Trabulsy et al., 2011).The internal exposure to radon and its Girondist products is quantified by the internal hazard index ($H_{in}$), which is given by the next equation (Krieger, 1981):

$$H_{in} = (C_{Ra}/185 + C_{Th}/259 + C_k/4810) < 1 \qquad (3)$$

Where $C_{Ra}$, $C_K$ and $C_{Th}$ are the activity concentrations of $^{226}$Ra, $^{40}$K and $^{232}$Th in Bq kg$^{-1}$, respectively. Values of internal hazard index ($H_{in}$), ranged from 0.1 to 0.8 with average value 0.3 as given in Table 3, for samples under investigation, which were lower than the unity, acceptable level (Beretka, and Mathew, 1985).Figure 15, shows the relative contribution of ($H_{in}$) owing to $^{226}$Ra, $^{232}$Th and $^{40}$K in all measured samples. The contribution to ($H_{in}$) owing to $^{226}$Ra, $^{232}$Th and $^{40}$K ranged from 17% to 61%, from 16% to 38% and from 9% to 66% for sediment samples under investigation respectively. Figure 16, shows the average relative contribution to (**$H_{in}$**) owing to $^{226}$Ra, $^{232}$Th and $^{40}$K are 47%, 30% and 23%,

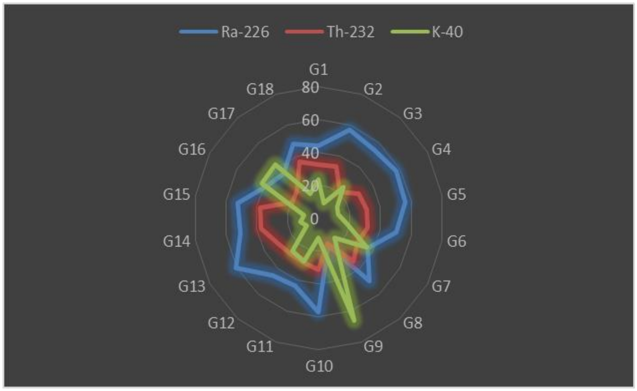


**Figure 15:** The relative contribution (%) of $^{226}$Ra, $^{232}$Th and $^{40}$K to internal hazard index ($H_{in}$) in every sample from Gharib City.

respectively. It is evident that the contribution from $^{226}$Ra is the highest one where the contribution from $^{40}$Kis the smallest; these indicate that the contribution to (**$H_{in}$**) is owing to $^{226}$Ra followed by $^{232}$Th followed by $^{40}$K.

**Table 3:** Radium equivalent ($Ra_{eq}$), the dose rate (D), hazard indices ($H_{ex}$ and $H_{in}$), annual effective dose rate (AEDE), excess lifetime cancer risk (ELCR), Gamma index ($I_\gamma$) and annual gonadal dose equivalent (AGDE) for Gharib city.

| Sample Location | Code no. | $Ra_{eq}$ Bqkg$^{-1}$ | D | $H_{in}$ | $H_{ex}$ | AEDE μSvy$^{-1}$ | ELCR ($10^{-6}$) | ($I_\gamma$) | AGDE μSv y$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | nGy h$^{-1}$ | | | | | | |
| south ((El-Sakala area ) | G1 | 42 | 19 | 0.1 | 0.1 | 24 | 83 | 0.1 | 138 |
| | G2 | 71 | 32 | 0.3 | 0.2 | 39 | 137 | 0.2 | 222 |
| | G3 | 133 | 63 | 0.5 | 0.4 | 77 | 271 | 0.4 | 449 |
| | G4 | 72 | 33 | 0.3 | 0.2 | 41 | 142 | 0.2 | 231 |
| | G5 | 58 | 27 | 0.2 | 0.2 | 33 | 114 | 0.2 | 185 |
| | G6 | 106 | 49 | 0.4 | 0.3 | 60 | 211 | 0.4 | 346 |
| middle (General Beach) | G7 | 120 | 58 | 0.4 | 0.3 | 71 | 247 | 0.4 | 416 |
| | G8 | 119 | 54 | 0.4 | 0.3 | 67 | 234 | 0.4 | 382 |
| | G9 | 63 | 32 | 0.2 | 0.2 | 39 | 136 | 0.2 | 237 |
| | G10 | 61 | 28 | 0.2 | 0.2 | 34 | 119 | 0.2 | 193 |
| | G11 | 98 | 46 | 0.3 | 0.3 | 57 | 198 | 0.3 | 330 |
| | G12 | 105 | 50 | 0.4 | 0.3 | 61 | 213 | 0.4 | 354 |
| north (General Company of petroleum) | G13 | 85 | 39 | 0.3 | 0.2 | 48 | 166 | 0.3 | 269 |
| | G14 | 81 | 37 | 0.3 | 0.2 | 45 | 157 | 0.3 | 255 |
| | G15 | 75 | 34 | 0.3 | 0.2 | 41 | 145 | 0.3 | 235 |
| | G16 | 84 | 41 | 0.3 | 0.2 | 50 | 175 | 0.3 | 298 |
| | G17 | 244 | 119 | 0.8 | 0.7 | 146 | 510 | 0.8 | 866 |
| | G18 | 32 | 15 | 0.1 | 0.1 | 18 | 63 | 0.1 | 102 |
| | MIN | 32 | 15 | 0.1 | 0.1 | 18 | 63 | 0.1 | 102 |
| | MAX | 244 | 119 | 0.8 | 0.7 | 146 | 510 | 0.8 | 866 |
| | AVEG | 92 | 43 | 0.3 | 0.2 | 53 | 185 | 0.3 | 306 |
| | RANGE | 32-244 | 15-119 | 0.1-0.5 | 0.1-0.7 | 18-146 | 63-510 | 0.1-0.8 | 102-866 |

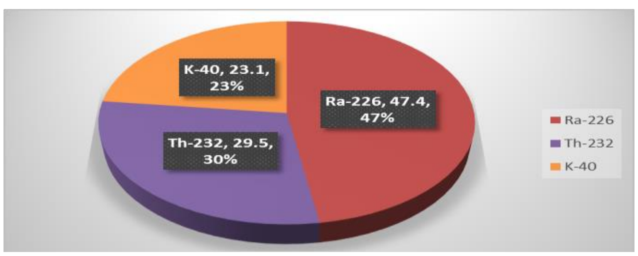


**Figure 16:** The average relative contribution to internal hazard index ($H_{in}$) due to $^{226}Ra$, $^{232}Th$ and $^{40}K$ in sediment samples from Gharib city.

## *3.3.4 External radiation hazard (Hex)*

The external hazard index ($H_{ex}$) represents the external radiation exposure associated with gamma irradiation from radionuclides of concern. The value of $H_{ex}$ should not exceed the maximum acceptable value of one in order to keep the hazard insignificant. The external hazard index ($H_{ex}$) is defined by equation (Jankovic et al., 2008):

$$H_{ex} = (C_u/370 + C_{Th}/259 + C_k/4810) \leq 1 \quad (4)$$

Where $C_{Ra}$, $C_K$ and $C_{Th}$ are the concentration in (Bq Kg$^{-1}$) of radium, potassium and thorium respectively. The External hazard index ($H_{ex}$), values ranged from 0.1 to 0.7 with mean value 0.2 as given in Table 3, for samples under investigation, which were lower than the unity, acceptable level (Beretka, and Mathew, 1985).

Figure 17, shows the relative contribution of ($H_{ex}$) owing to $^{226}Ra$, $^{232}Th$ and $^{40}K$ in all measured samples. The contribution to ($H_{in}$) owing to $^{226}Ra$, $^{232}Th$ and $^{40}K$ ranged between (9% to 44%), (18% to 52%) and (13% to 72%) for sediment samples under investigation respectively.

Figure 18, shows the average relative contribution to (**$H_{ex}$**) owing to $^{226}Ra$, $^{232}Th$ and $^{40}K$ are 32%, 39% and 29%, respectively. It is evident that the contribution from $^{232}Th$ is the highest one where the contribution from $^{40}K$ is the smallest; these indicate that the contribution to (**$H_{ex}$**) is owing to $^{232}Th$ followed by $^{226}Ra$ followed by $^{40}K$.

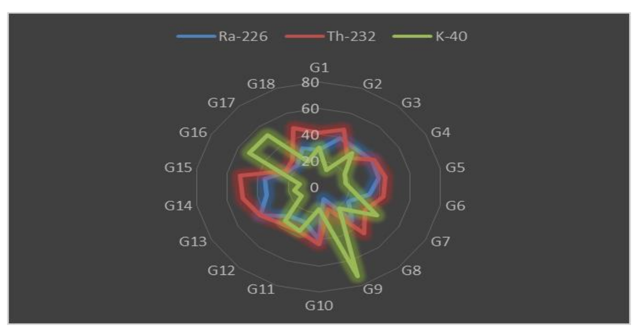


**Figure 17:** The relative contribution (%) of $^{226}Ra$, $^{232}Th$ and $^{40}K$ to External hazard index ($H_{ex}$) in every sample from Gharib City.

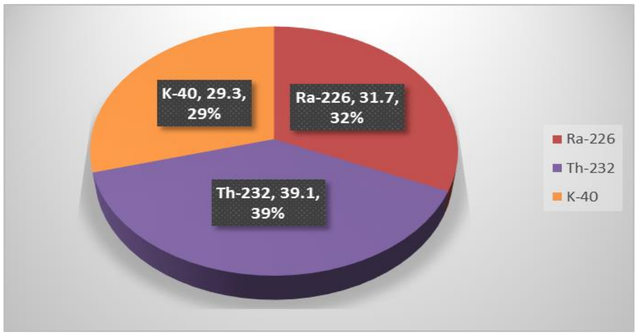


**Figure 18:** The average relative contribution to External hazard index ($H_{ex}$) due to $^{226}Ra$, $^{232}Th$ and $^{40}K$ in sediment samples from Gharib city

### *3.3.5 Annual effective dose (µSvy-1)*

The annual effective dose equivalent (AEDE) outdoors in units of ($mSvy^{-1}$), resulting from natural radionuclides of $^{226}Ra$, $^{40}K$ and $^{232}Th$. was calculated by the following formula (UNSCEAR, 2000)

$$AEDE(m\frac{Sv}{y}) = D_R(0.2 * 365.25d * 24h) * (0.7 * 10^{-3}) \quad (5)$$

Where, $D_R$ is dose rate in (nGy/h), (0.2*24h*365.25d) is the outdoor occupancy time and ($0.7 * 10^{-3}$ ) is the conversion coefficient in Sv/Gy (Uosif, 2011).

Table 3, shows the annual effective doses outdoors from measured sediment samples. It can see that the annual outdoor effective dose of samples under investigation from Gharib city varied from 18 to 146 µSv, with average value of 53 µSv.

It evident that the obtained average annual effective doses for outdoor in this study are smaller than the world average 70 µSv reported in UNSCEAR (2000).

The distribution patterns of (AEDE) at Ras Gharib City (Figure 19-a, b and c) divided into three stations from south to north the first one; El-Sakala area, which characterized by the existence of a narrow intertidal zone in the beach area and intertidal zone. AEDE Increasing at the center toward the beach and decreases on both sides, perhaps due to the formation of lagoon allow the entry of water and do not allow to get out as shown in (Figure19-a). while in General Beach area we can see increasing of (AEDE) in the southern part, may be this result from Terrigenous sediments were transported to marine environment by some vales specially in the southern part that, may be have contain natural radioactive materials (figure 19-b). But in General Company of Petroleum (figure 19-c). The (AEDE) recorded high values compared with other stations, this due to , the existing of a big part of the intertidal zone is covered by heavy oil spills as a result of exploration and extraction activities of crude oil and flooding of some oil wells. Generally, the beach area of Ras Gharib is affected by oil spills.

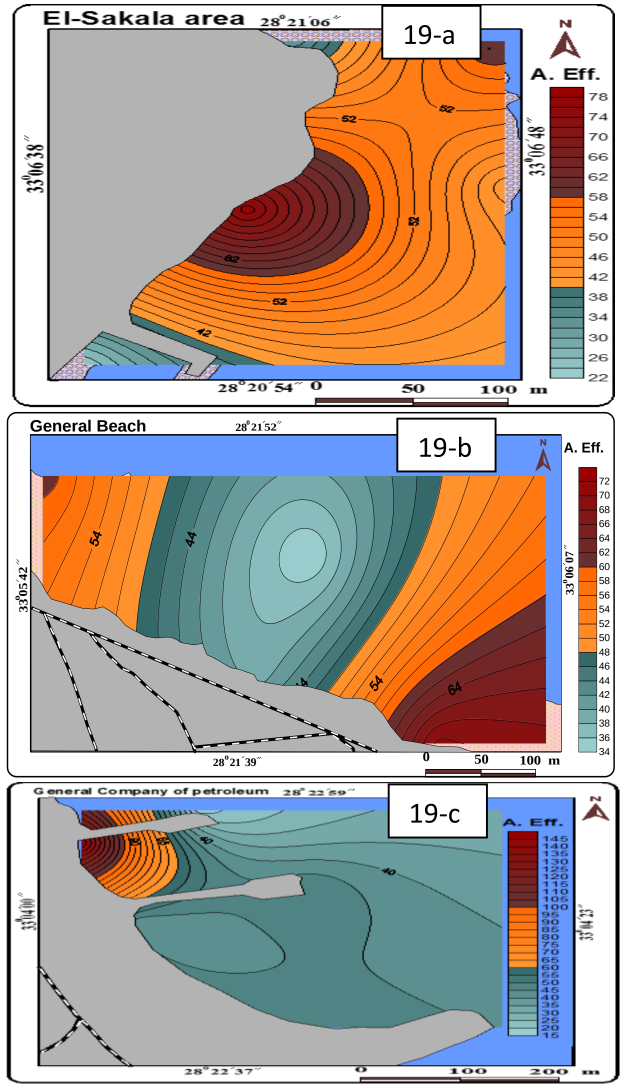


**Figure 19:** The distribution patterns of AEDE at Ras Gharib city

### *3.3.6 Gamma index (Iγ)*

The representative level index (Iγ) is used to assessment the level of γ-radiation hazard associated with the natural radionuclides in specific study samples. Iγ index is used to correlate the annual dose rate due to the excess external gamma radiation caused by superficial materials. It is used only as a screening tool for identifying materials that might become health concerns when used as construction materials (Ravisankar, et al. 2014). The **γ**-radiation hazard level of the samples associated with natural radionuclides was calculated by using the following equation, which was based on the radiation hazard index Iγ. (Beretka and Mathew, 1985):

$$I_{\gamma r} = (C_{Ra}/300 + C_{Th}/200 + C_k/3000) \quad (6)$$

Where $C_{Ra}$, $C_K$ and $C_{Th}$ are the specific activities (Bq $kg^{-1}$) of $^{226}Ra$, $^{40}K$ and $^{232}Th$, respectively. Gamma index ($I_\gamma$) was estimated for sediments under test and the derived values are presented in Table 3. It can be see that, gamma activity index values were ranged from 0.1 to 0.8 with average value of 0.3. It is observed that, all samples have gamma index $I_\gamma < 2$ which indicates gamma dose contribution from these sediment samples was not exceed 0.3 $mSv.y^{-1}$

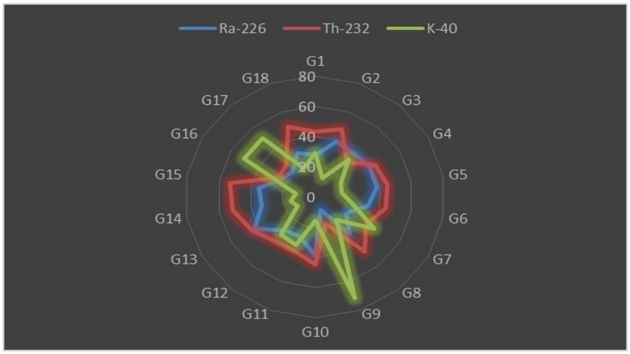


**Figure 20:** The relative contribution (%) of $^{226}$Ra, $^{40}$K and $^{232}$Th to Gamma activity index (**$I_\gamma$**) in every sample from Gharib City.

Figure 20, shows the relative contribution to gamma index $I\gamma$ owing to $^{226}$Ra, $^{232}$Th and $^{40}$K, where they ranged between (10% to 43%), (19% to 53%) and (12% to 71%) for sediment samples under investigation respectively. Figure 21, shows the average relative contribution to $I_\gamma$ owing to $^{226}$Ra, $^{232}$Th and $^{40}$K are 31%, 41% and 28%, respectively. It is evident that the contribution from $^{232}$Th is the highest one where the contribution from $^{40}$K is the smallest; these indicate that the contribution to $I_\gamma$ is owing to $^{232}$Th followed by $^{226}$Ra followed by $^{40}$K.

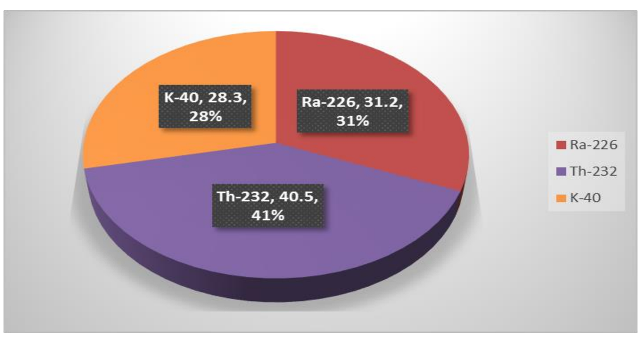


**Figure 21:** The average relative contribution to Gamma activity index (**$I_\gamma$**) due to $^{226}$Ra, $^{232}$Th and $^{40}$K in sediment samples from Gharib city

### *3.3.7 Excess lifetime cancer risk (ELCR)*

Excess lifetime cancer risk (ELCR) defined as the excess probability of developing cancer at a lifetime due to exposure level of human to radiation. (ICRP-60, 1991**)**: Excess lifetime cancer risk (ELCR) calculated using the following formula and presented in Table 5.

$$\mathrm{ELCR} = \mathrm{AEDE} * \mathrm{DL}\ (70\mathrm{y}) * \mathrm{Rf}(0.5\ \mathrm{SV}^{-1}) \qquad (7)$$

Where AEDE, DL and RF are the annual effective dose equivalent, duration of life (70 y) and risk factor (Sv-1), fatal cancer risk per Sievert. The obtained values of ELCR for the studied samples are summarized in Table 3. As we shown in Table 3, ELCR values ranged from 63 × $10^{-6}$ to 510 × $10^{-6}$ with average value of 185× $10^{-6}$.

The distribution patterns of (ELCR) at Ras Gharib city show three patterns (Figure 22). The first one for, El-Sakala area we can see that the (ELCR) increasing at the center and decreases on both sides as shown in Figure (22-a), while (ELCR) in General Beach area Increase at the southern region and decreases in the direction of the north as illustrated in figure (22-b). In General Company of Petroleum are the (ELCR) recorded high value especially around the marine as shown in figure (22-c). The reasons we have explained previously in (AEDE).

### *3.3.8 Annual gonadal dose equivalent (AGDE)*

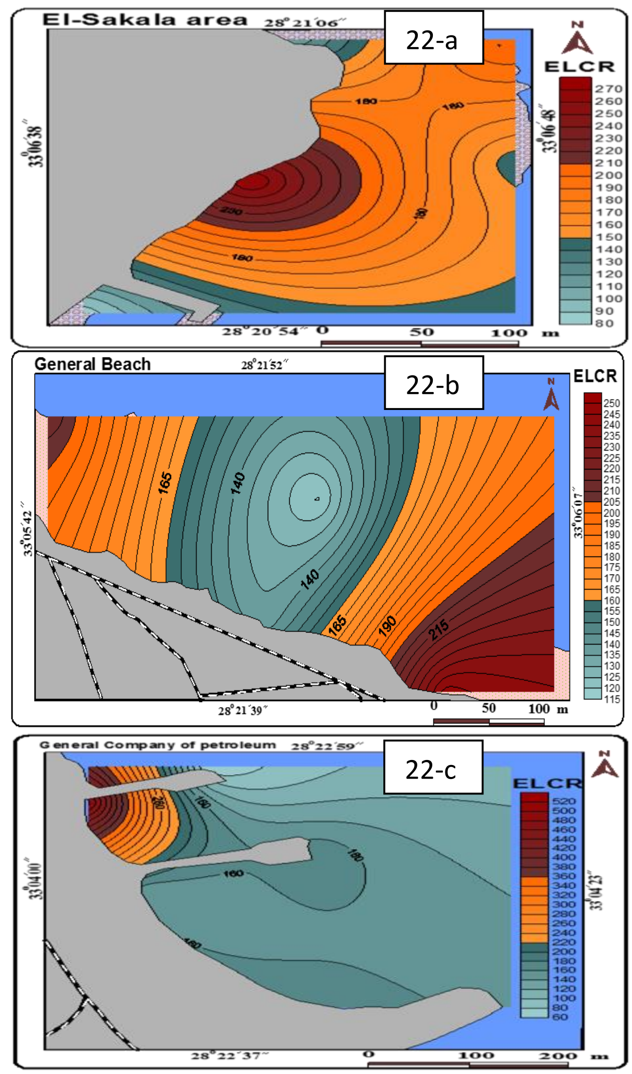


**Figure 22:** The distribution patterns of ELCR at Ras Gharib city.

AGDE is a measure of the genetic significance of the yearly dose equivalent received by the population's reproductive organs (gonads) (Ravisankar, at al., 2014 and Shams ISSA et al., 2013). In the same context, the activity bone marrow and the bone surface cells are considered as the organs of interest by (UNSCEAR, 1988). Therefore, the annual gonadal dose equivalent (AGDE) due to the specific activities of $^{226}$Ra, $^{232}$Th and $^{40}$K was calculated using the next equation (Mamont-Ciesla etal.,1982)

$$\mathrm{AGDE} = 3.09\mathrm{C_{Ra}} + 4.18\mathrm{C_{Th}} + 0.314\mathrm{C_k}(\mu\mathrm{Svy}^{-1}) \quad (8)$$

The obtained values of AGDE for the studied samples are summarized in Table 3. As we shown in Table 3, AGDE values ranged from 102 to 866 with average value of 306 $\mu$Svy$^{-1}$, the average AGDE value is higher than the world average values for soil 0.298 mSvy$^{-1}$ (Zaidi et al., 1999). The annual gonadal dose equivalent results exceed the permissible recommended limits, indicating that the hazardous effects of the radiation are serious.

## 4 Conclusions

The conclusion of our study can be summarized in the following points:

- The results show that the average activity of $^{226}$Ra and $^{232}$Th are less than the compared worldwide average while and $^{40}$K is higher than the compared worldwide average value of these radionuclides in the sediment (UNSCEAR, 2000)
- The internal and external hazard indices ($H_{in}$, $H_{ex}$), representative level index (Iγr) for all samples under study are below unity. The annual effective dose ($D_{eff}$) is well below the recommended value (1 mSv/y). Therefore, the use of these materials for all purposes of human needs is considered be safe.
- General Company of Petroleum recorded high values of (AEDE) and ELCR compared with other stations, this due to , the existing of a big part of the intertidal zone is covered by heavy oil spills as a result of exploration and extraction activities of crude oil and flooding of some oil wells.
- Generally, the beach area of Ras Gharib is affected by oil spills.

## Acknowledgements

This work was carried out using the nuclear analytical facilities at Physics Department, Faculty of Sciences, Al-Azhar University, Assiut, Egypt. And analytical facilities National Institute of Oceanography and Fisheries, Red Sea Branch.

## References

[1] Al-Trabulsy, H. A.; Khater, A. E. and Habbani, F.I., (2011). Radioactivity levels and radiological hazard indices at the Saudi coastline of the Gulf of Aqaba. Radiation Physics and Chemistry 80: 343–348

[2] Beretka, J., Mathew, P.J., (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products. Health Physics 48, 87–95

[3] El-Taher and M A M Uosif, (2006). The assessment of the radiation hazard indices due to uranium and thorium in some Egyptian environmental matrices. J. Phys. D: Appl. Phys.39, 4516–4521

[4] Groeneveld, R.A., Meeden, G., (1984). Measuring skewness and kurtosis. The Statistician. 33, (4), 391–399.

[5] Huy, N.Q. and Luyen, T.V., (2006). "Study in external exposure doses from terrestrial radioactivity in Southern Vietnam." Radiation protection Dosimetry Journal,118 (3), 331-336.

[6] ICRP, (1993). International Commission on Radiological Protection ICRP Publication 65.Ann. ICRP 23(2).Pergamon Press

[7] Issa, Shams AM, AMA Mostafa, and Abd El-Salam M Lotfy. (2015). 'Radiological impacts of natural radioactivity in phosphate rocks from El-Sibaiya and Red Sea coast mines, Egypt', *Journal of Radioanalytical and Nuclear Chemistry*, 303: 53-61.

[8] Jankovic, M.; Todorovic, D. and Savanovic, M., (2008). Radioactivity measurements in soil samples collected in the Republic of Srpska.Radiation Measurements, 43: 1448-1452

[9] Krieger, R., (1981). Radioactivity of construction materials. Betonwerk Fertigteil Tech 47,468–473.

[10] Madkour, H.A., (2004). Geochemical and environmental studies of recent marine sediments and some invertebrates of the Red Sea, Egypt. Ph.D. Thesis, South Vally Univ., Qena p 317 .

[11] Mahmoud A. Dar, Mahmoud A. Uosif, Lamyaa I. Mohamadeenc, Abeer A. El Sahartyd, Hesham M. Hamed and Fekry A. Murad, (2015). The semi-annual variations of the bio-available heavy metals and natural radionuclides in Timsah Lake sediments, Egypt, International Journal of Scientific & Engineering Research, 6: 1697-1712

[12] Mamont-Ciesla, K., Gwiazdowski, B., Biernacka, M. and Zak, A., (1982). Radioactivity of building materials in Poland.In: Vohra, G., Pillai, K. C. and Sadavisan, S., Eds. Natural Radiation Environment. Halsted Press, p. 551.

[13] Ravisankar, R., Vanasundari, K., Suganya, M., Raghu, Y., Rajalakshmi, A., Chandrasekaran, A., Sivakumar, S., Chandramohan, J., Vijayagopal, P., Venkatraman, B., (2014). Multivariate statistical analysis of radiological data of building materials used in Tiruvannamalai, Tamilnadu, India. Appl. Radiat. Isot. 85, 114–127.

[14] Ravisankar, R, S Sivakumar, A Chandrasekaran, J Prince Prakash Jebakumar, I Vijayalakshmi, P Vijayagopal, and B Venkatraman. (2014). 'Spatial distribution of gamma radioactivity levels and radiological hazard indices in the east coastal sediments of Tamilnadu, India with statistical approach', Radiation Physics and Chemistry.

[15] Shams ISSA, Mohamed UOSIF, Reda ELSAMAN, (2013).

Gamma radioactivity measurements in Nile River sediment samples. Turkish J Eng Env Sci 37: 109 – 122

[16] UNSCEAR, (2000). United Nations Scientific Committee on effects of Atomic Radiation. Exposures from natural radiation sources.UNSCEAR Report.United Nations.

[17] UNSCEAR United Nations Scientific Committee on the Effects of Atomic Radiation, (1988). Sources, Effects and Risks of Ionizing Radiation. UnitedNations,NewYork.

[18] Uosif, MAM, AMA Mostafa, Reda Elsaman, and El-sayed Moustafa. (2014). 'Natural radioactivity levels and radiological hazards indices of chemical fertilizers commonly used in Upper Egypt', Journal of Radiation Research and Applied Sciences, 7: 430-37

[19] Uosif, Mohamed Amin Mahmoud, (2011). Specific Activity of $^{226}Ra$, $^{232}Th$ and $^{40}K$ for Assessment of Radiation Hazards from Building Materials Commonly Used in Upper Egypt. SDU Journal of Science (E-Journal), 6 (2): 120-126

[20] Zaidi, J.H., Arif, M., Ahmed, S., Fatima, I. and Qureshi, I. H., (1999). "Determantion of natural radioactivity in Building materials used in the Rawalpindi/ Islamabad area by γ-ray spectrometry and instyumental neutron activation analysis." Applied Radiation and Isotopes Journal, 51, 559-564.