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**Research Article**

# ASSESSMENT OF RADIOACTIVITY LEVELS AND HAZARDS FOR SOME SEDIMENTARY ROCK SAMPLES IN DIFFERENT LOCALITIES SOUTHWESTERN, SINAI, EGYPT

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**ABSTRACT**

This study aimed to the assessment of the activity concentrations and radiation hazard indices with excess lifetime cancer risk (ELCR) in twenty one sedimentary rock samples obtained from three different localities, southwestern Sinai, Egypt. The natural radionuclides have been measured by using HPGe detector with a specially designed shield.

The results of this study showed that the activity concentrations of $^{238}U$, $^{226}Ra$, $^{232}Th$ and $^{40}K$ were higher than the world's average levels. The activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$, $^{226}Ra/^{238}U$, $^{238}U/^{235}U$ and $^{234}U/^{235}U$ were calculated to estimate the radioactive equilibrium / disequilibrium in the three localities.

The radium equivalent ($Ra_{eq}$) in Bq/Kg, external hazard index ($H_{ex}$), radioactivity level index (I $\gamma$), the absorbed dose rate (D) and the annual effective dose (AED) in outdoor environment were estimated. The excess lifetime cancer risk (ELCR) was found to be high for all samples due to high natural radioactivity concentrations in the area under investigation which represent radiological risk for the health of population.

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## INTRODUCTION

The knowledge of radionuclides distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and extraterrestrial sources. Terrestrial radiation is due to radioactive nuclides present in varying amounts in soils, building materials, water, rocks and atmosphere. Some of these radionuclides from these sources are transferred to man through food chain or inhalations, while the extraterrestrial radiation originates from outer space as primary cosmic rays [Keser *et al*., 2013]. The various geological formations play a predominant role in accumulating and transporting contaminants within a geographic area [Ramasamy *et al*., 2014]. Long-term exposure to radioactivity and inhalation of radionuclides could cause many health problems, such as acute leukopenia, anemia, leukemia, necrosis of the mouth, tooth fracture and cataracts as well as lung, pancreatic liver, hepatic, bone and kidney cancers [Taskin *et al*., 2009; Qureshi *et al*., 2014]. Human exposure to ionizing radiation is an important scientific subject that attracts sustained public attention.

The objective of this paper is to observe the distribution of $^{238}U$, $^{232}Th$, $^{226}Ra$ and $^{40}K$ activities in the surface sediment of the area under investigation and to evaluate the radiological hazards in this area by calculating the radium equivalent activity ($Ra_{eq}$), absorbed gamma dose rate (D), annual effective dose equivalent (AEDE), external hazard index ($H_{ex}$) and excess lifetime cancer risk (ELCR).

## MATERIALS AND METHODS

### *Study area*

The study area (Fig.1) is located in the southwestern Sinai, Egypt. Where the samples collected from three localities; Wadi Nasab is at the intersection of longitude 33° 26' 20" and latitude 29° 2', Wadi Sad El-Banat is at the intersection of longitude 33° 24' and latitude 29° 2' 30" and Wadi Um Hamd is at the intersection of longitude 33° 25' 45" and latitude 28° 57'.

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***Sampling***

Twenty one sedimentary rock grap samples were collected from three different locations (Fig.1) and different rock types; fourteen samples from Wadi Nasab, five samples from Wadi Sad El Banat and two samples from Wadi Um Hamd. These samples were prepared for $\gamma - Ray$ spectrometric analyses by HPGe detector where the samples first dried, crushed and sieved through -200 mesh size. Weighted samples were placed in polyethylene bottles of 250 $cm^3$ volume. The bottles were completely sealed for more than one month to allow radioactive equilibrium to be reached before measured by the gamma spectrometer. This step was necessary to ensure that radon gas is confined within the volume and the daughters still also remain in the sample.

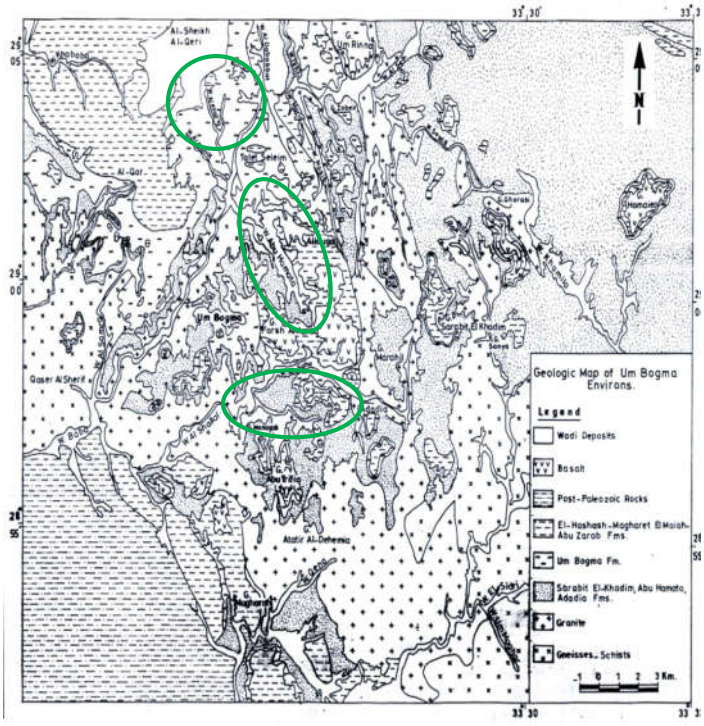


**Fig 1** Geologic map of the studied area in southwestern Sinai, Egypt [After El Aassy et al. 1986]

***Radioactivity measurements***

High purity vertical germanium was coupled to a PC-computer with a special electronic card to make it equivalent to a multichannel analyzer. The system also contains the usual electronic components of preamplifier, amplifier and power supply. The detector has resolution (FWHM) 0f 1.85 KeV for the 1332.5 KeV γ-ray line of $^{60}Co$.

The γ-ray spectrometer energy calibration was performed using $^{60}Co$, $^{226}Ra$ and $^{241}Am$ point sources. The detector was surrounded by a special heavy lead shield of about 10 cm thickness with inside dimension 28 cm diameter 40.5 cm height. The absolute detection efficiency of the HPGe detector was determined 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 [IAEA, 1987, Anjos *et al*., 2005]. The sample containers were placed on top of the detector for counting. The same geometry and size were used for both the samples and the reference materials [Pekala *et al*., 2010]. The primordial $^{238}U$ is the most abundant isotope of U (99.27 %) and the initial member of the $^{238}U$-decay chain with a long half-life time (4.4683 Ga). It decays to $^{234}Th$ with the emission of the $\alpha$ - particle. Through two consecutive $\beta$- transitions, $^{234}Th$ decays to $^{234}Pa$ (half-lives of 24.10 days and 6.69 h, respectively) and to $^{234}U$, with the half-life time of 245,250 years, which decays to $^{230}Th$ [Pekala *et al*., 2010]. Uranium-238 activity was determined indirectly from the gamma rays emitted by its daughter products ($^{234}Th$ and $^{234m}Pa$) whose activities are determined from the 63.3 (3.9%) and 1001(0.7%) keV photopeaks, respectively.

The gamma-ray transitions of $^{228}Ac$ (338.4 (12.3%), 911 (29%)) KeV, $^{212}Bi$ (727.3 KeV (7%)) and $^{208}Tl$ (583.1 KeV (30%)) were used to evaluate the specific activity of $^{232}Th$ [Technical Reports Series, 1989]. $^{226}Ra$ activity concentration was measured from 186.1 KeV (3.29 %) after the subtraction of the 185.7 KeV (54 %) of $^{235}U$. The concentrations of $^{214}Pb$ and $^{214}Bi$ were measured from (295.1(18.7%), 351.9 (35.8%)) KeV and (609.3 (45%), 1120.3(14.9%),1238.1(5.96%), 1764.5(16.07%)) KeV. For the actinium series gamma energies of 143.8 KeV (10.5 %), 163.4 KeV (4.8 %), 185.7 KeV (54 %) and 205.3 KeV (4.7%) were taken to represent the $^{235}U$ concentrations. $^{40}K$ was determined directly from the 1460 KeV (10.7%) peak energy. $^{234}U$ activity was determined directly from the gamma rays emitted from this nuclide at energies of 53.2 (0.123%) keV and 120.9 (0.034%) keV. For the measurement of the $^{230}Th$ activity, the $\gamma$-ray emission at 67.7 (0.37%) keV is used [Technical Reports Series, 1989].

## RESULT AND DISCUSSION

The measured activity concentrations of $^{238}U$, $^{234}U$, $^{235}U$, $^{230}Th$, $^{226}Ra$, $^{232}Th$ and $^{40}K$ are shown in table (1). These data represent three localities and four rock types. The sandy dolomite K9 from Wadi Nasab records the highest measurements of $^{238}U$, $^{234}U$, $^{235}U$, $^{230}Th$ and $^{226}Ra$ and the lowest $^{232}Th$ and $^{40}K$. The siltstone K10 from Wadi Nasab also record the lowest measurements of $^{238}U$, $^{234}U$, $^{235}U$, $^{230}Th$ and $^{226}Ra$ table (1).

The three different locations indicate that the rocks contain significant specific activities and concentrations of $^{238}U$ and its progenies. It is clear from (Fig. 2) that the activity concentrations of $^{238}U$ and $^{226}Ra$ for all the samples are more higher than the typical world average value of 33 and 32 Bq/Kg, respectively [UNSCEAR, 2010]. For $^{232}Th$ (Fig.3) six samples of Wadi Nasab are higher than the permissible level 45 Bq/Kg (K4, K5, K6, K7, K12 and K14) [UNSCEAR, 2010]. All the samples of Wadi Sad El Banat are higher than the permissible level 45 Bq/Kg, except one sample K17. All the samples of Wadi Um Hamd are higher than the permissible level 45 Bq/Kg. Also the results show the activity concentrations of $^{40}K$ (Fig.4) for Wadi Nasab are less than the permissible level 412 Bq/Kg [UNSCEAR, 2010], except five samples K5, K6, K7, K12 and K14. All the samples of Wadi Sad El Banat are higher than the permissible level except two samples K15 and K17. Also the samples of Um Hamd are higher than the permissible level.

**Table 1** The activity concentrations in (Bq/Kg) of $^{238}U$, $^{234}U$, $^{235}U$, $^{230}Th$, $^{226}Ra$, $^{232}Th$ and $^{40}K$

| Locality | Rock Type | Sample | $^{238}U$ | $^{234}U$ | $^{235}U$ | $^{230}Th$ | $^{226}Ra$ | $^{232}Th$ | $^{40}K$ |
|---|---|---|---|---|---|---|---|---|---|
| Wadi Nasab | Shale | K1 | 8053.55 ± 107.2 | 6843.91 ± 1586 | 371.21±7.3 | 7239.35±180 | 7637.09±21.9 | 30.12±3.3 | 211.16±11.8 |
| | | K2 | 6836.6 ± 94.8 | 6930.34 ± 583.3 | 318.67±6.3 | 5223.6±157.5 | 5613.8±20.1 | 37.499±2.3 | 263.85±11.2 |
| | | K3 | 3732.52 ± 153.7 | 4747.17 ± 402.5 | 176.62±7.4 | 11544.3±168.2 | 12040.1±36.8 | 28.82±2.7 | 342.6±20.1 |
| | | K4 | 8517.75 ± 98.1 | 8816.64 ± 479.9 | 416.37±7.8 | 6699.92±131.8 | 6765.07±22.3 | 54.02±3.1 | 165.44±11.2 |
| | | K5 | 1237.68 ± 49.9 | 1276.91 ± 368.5 | 57.141±3.5 | 1232.78±89.7 | 1242.68±12.5 | 67.45±4.4 | 537.9±14.1 |
| | | K6 | 1176.73 ± 53.8 | 1129.4 ± 298.4 | 54.14±3.0 | 1110.2±94.3 | 1137.57±11.4 | 62.168±3.8 | 584.04±13.1 |
| | | K7 | 1195.33 ± 43.4 | 1188.43 ± 67.1 | 54.794±3.1 | 1106.08±101 | 1062.92±10.2 | 100.26±4.2 | 641.84±12.5 |
| | Sandy dolomite | K8 | 2855.1 ± 53.2 | 2872.47 ± 361.9 | 140.41±4.1 | 2512.63±73.6 | 2433.12±12.1 | 19±1.4 | 183.51±7.1 |
| | | K9 | 15341.28±101.7 | 15367.42±911.2 | 717.4±8.1 | 15252.54±247.3 | 15164.28±29.6 | 4.861±1.6 | 146.119±11.3 |
| | Siltstone | K10 | 371.33 ± 22.3 | 358.42 ± 110 | 17.46±1.9 | 414.25±49.5 | 447.55±6.3 | 30.91±1.3 | 239.82±7.1 |
| | | K11 | 3294.811 ± 72.8 | 4705.66 ± 366.7 | 161.4±6.5 | 5882.94±184.8 | 6127.87±23.3 | 12.79±1.8 | 119.006±9.8 |
| | Claystone | K12 | 1251.84 ± 52.9 | 1265.66 ± 263.6 | 58.3±3.4 | 1159.68±107.8 | 1261.84±13.1 | 67.12±4.1 | 554.58±14.4 |
| | | K13 | 1501.95 ± 36.2 | 1308.7 ± 356.6 | 71.003±2.5 | 3687.4±119.3 | 6747.01±17.4 | 29.624±1.3 | 223.053±6.6 |
| | | K14 | 1424.39 ± 48.4 | 1321.51 ± 207.8 | 66.025±3.5 | 1456.42±99.8 | 1989.93±15.9 | 51.712±3.4 | 469.76±13.7 |
| | | K15 | 1041.71 ± 37.9 | 1233.1 ± 71.8 | 47.95±3.5 | 994.291±82.7 | 1215.53±10.5 | 106.09±2.8 | 182.71±8.9 |
| Wadi Sad El Banat | Siltstone | K16 | 1609.9 ± 48.8 | 1488.53 ± 386.2 | 72.96±3.4 | 1404.27±100.2 | 1355.38±10.5 | 86.363±2.1 | 570.075±11.1 |
| | | K17 | 496.32 ± 25.1 | 492.56 ± 40 | 23.997±1.9 | 474.11±48.1 | 555.98±6.9 | 18.81±1.3 | 249.52±7.4 |
| | Sandstone | K18 | 454.91 ± 30.1 | 462.47 ± 122.2 | 22.038±2.2 | 495.73±66.1 | 543.01±7.2 | 62.42±2.1 | 622.83±10.9 |
| | Variegated shale | K19 | 713.37 ± 33.4 | 673.3 ± 157.8 | 34.82±2.4 | 440.69±59.4 | 534.35±6.5 | 67.35±2.3 | 776.6±11.4 |
| Wadi Um Hamd | Siltstone | K20 | 8579.77 ± 104 | 8863.57 ± 201 | 422.005±8.7 | 8584.45±244 | 8862±27.6 | 84.717±4.3 | 1000.46±19.6 |
| | | K21 | 8630.84 ± 70.8 | 8550.92 ± 342.9 | 403.26±5.6 | 8640.25±155.7 | 10020.2±20.5 | 62.34±2.4 | 819.37±12.8 |

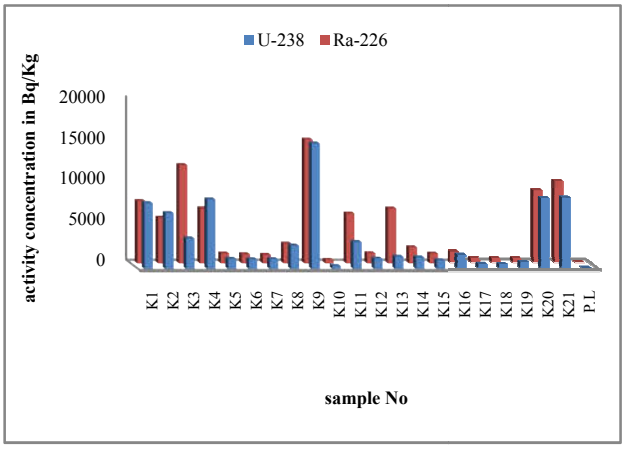


**Fig 2** the Activity Concentration of $^{238}U$ and $^{226}Ra$

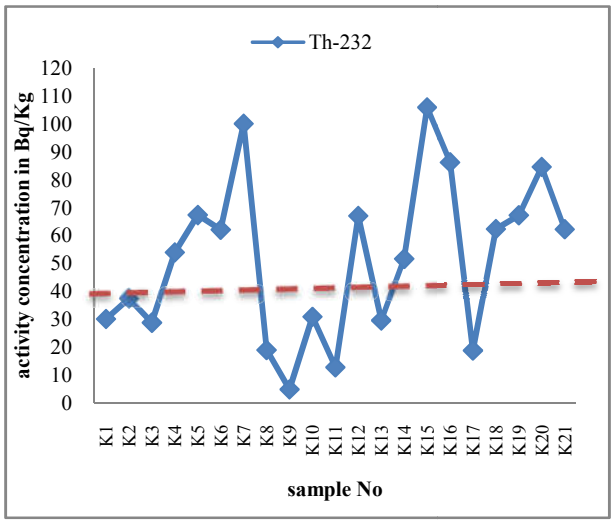


**Fig 3** the Activity Concentration of $^{232}Th$.

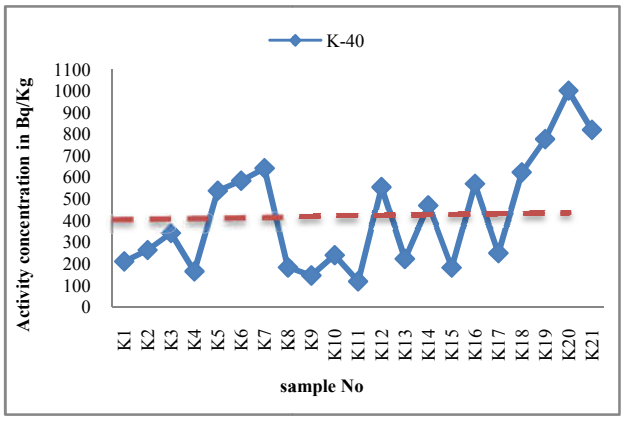


**Fig 4** the Activity Concentration of $^{40}K$

### *Activity Ratios*

$^{234}U$ and $^{238}U$ have similar chemical behavior and should therefore not be fractionated by chemical weathering of minerals, several authors have shown that this assumption is not verified in nature. The reason why $^{234}U/^{238}U$ activity ratios of weathered solids are lower than unity is known as the *α*-recoil effect and is explained by the preferential leaching of $^{234}U$ from *α*-recoil-damaged lattice sites in minerals. Conversely, the solid phase is enriched in $^{238}U$ [Brantley *et al.*, 2008].

Table (2) shows the activity ratios of different radionuclides in different rock types. For Wadi Nasab locality; the activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for shale samples ranges between (0.8498-1.272), (0.764-3.093), (0.754-2.432) and (0.794-3.226) and all the samples around the unity which referred secular equilibrium except one sample K3 where all the ratios greater than unity and deviating from secular equilibrium.

**Table 2** The activity ratios of different radionuclides in studied samples

| Locality | Rock Type | Sample | $\frac{^{238}U}{^{235}U}$ | $\frac{^{234}U}{^{235}U}$ | $\frac{^{234}U}{^{238}U}$ | $\frac{^{230}Th}{^{238}U}$ | $\frac{^{226}Ra}{^{238}U}$ | $\frac{^{230}Th}{^{234}U}$ |
|---|---|---|---|---|---|---|---|---|
| Wadi Nasab | Shale | K1 | 21.696 | 18.437 | 0.8498 | 0.899 | 0.948 | 1.058 |
| | | K2 | 21.454 | 21.748 | 1.014 | 0.764 | 0.821 | 0.754 |
| | | K3 | 21.133 | 26.878 | 1.272 | 3.093 | 3.226 | 2.432 |
| | | K4 | 20.457 | 21.175 | 1.035 | 0.787 | 0.794 | 0.759 |
| | | K5 | 21.660 | 22.347 | 1.032 | 0.996 | 1.004 | 0.965 |
| | | K6 | 21.734 | 20.859 | 0.959 | 0.943 | 0.967 | 0.983 |
| | Sandy Dolomite | K7 | 21.815 | 21.689 | 0.994 | 0.925 | 0.889 | 0.931 |
| | | K8 | 20.334 | 20.458 | 1.006 | 0.880 | 0.852 | 0.875 |
| | | K9 | 21.386 | 21.422 | 1.002 | 0.994 | 0.988 | 0.993 |
| | Siltstone | K10 | 21.262 | 20.523 | 0.965 | 1.116 | 1.205 | 1.156 |
| | | K11 | 20.414 | 29.156 | 1.428 | 1.786 | 1.859 | 1.250 |
| | Claystone | K12 | 21.474 | 21.711 | 1.011 | 0.926 | 1.008 | 0.916 |
| | | K13 | 21.153 | 18.432 | 0.871 | 2.455 | 4.492 | 2.818 |
| | | K14 | 21.573 | 20.015 | 0.928 | 1.022 | 1.397 | 1.102 |
| Wadi Sad El Banat | Siltstone | K15 | 21.724 | 25.715 | 1.184 | 0.954 | 1.167 | 0.719 |
| | | K16 | 22.066 | 20.403 | 0.925 | 0.872 | 0.842 | 0.943 |
| | | K17 | 20.682 | 20.526 | 0.992 | 0.955 | 1.120 | 0.963 |
| | Sandstone | K18 | 20.640 | 20.980 | 1.017 | 1.090 | 1.194 | 1.072 |
| | Variegated shale | K19 | 20.489 | 19.338 | 0.944 | 0.618 | 0.749 | 0.655 |
| Wadi Um Hamd | Siltstone | K20 | 20.331 | 21.003 | 1.033 | 1.0005 | 1.033 | 0.968 |
| | | K21 | 21.403 | 21.205 | 0.991 | 1.001 | 1.161 | 1.0104 |

The activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for sandy dolomite samples are around the unity which referred secular equilibrium. The activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for siltstone samples are around the unity which referred secular equilibrium except K11 where all the ratios greater than unity and deviating from secular equilibrium. While the activity ratios, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for sample (K13 claystone) greater than unity and $^{234}U/^{238}U$ <1 which means preferential migration out/ or mobilization of $^{234}U$, but sample (K14 claystone) referred secular equilibrium and all the ratios around the unity. For Wadi Sad El Banat; the activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for all the samples, are around the unity which referred secular equilibrium except two samples; (K15 siltstone and K19 variegated shale) (Fig.5). For Wadi Um Hamd; the two samples show secular equilibrium where all the ratios are around the unity. (Fig.5) demonstrates that the $^{230}Th/^{238}U$, $^{230}Th/^{234}U$, $^{226}Ra/^{238}U$ and $^{234}U/^{238}U$ activity ratios for all studied samples for the three locations.

Until very recently it was assumed that the current $^{238}U/^{235}U$ activity ratio was a constant value (= 21.7) in our Solar System because uranium was thought to be too heavy to undergo significant isotope fractionation [Fujii *et al.*, 1989, Abdel Gawad and Ibrahim, 2015, and Schauble, (2006, 2007)]. The activity ratio of $^{238}U/^{235}U$ for Wadi Nasab samples ranged from 20.33 to 21.81, while for Wadi Sad El Banat samples ranged from 20.49 to 22.07 and for Wadi Um Hamd ranged from 20.33 to 21.403. From these results the activity ratio of $^{238}U/^{235}U$ for all the samples of the three locations were varied from 20.33 to 22.07 reflect little deviation from the natural ratio 21.7 may be due to mathematical error (±) as shown in (Fig.6). Although significant variations in the $^{238}U/^{235}U$ ratio are recent discovery, much larger variations in the $^{234}U/^{235}U$ ratio in the terrestrial variations have long been observed. The ocean, for example, contains elevated abundances of $^{234}U$ [Abdel Gawad and Ibrahim, 2015]. Specifically, the increased mobility of $^{234}U$ relative to other U isotopes reflects production from $^{238}U$ by $\alpha$-decay and subsequent emplacement in crystal sites damaged by $\alpha$-recoil. Aqueous weathering of materials containing U results in preferential leaching of $^{234}U$ from these $\alpha$-damaged crystal sites [Brennecka *et al.*, 2010]. The $^{234}U/^{235}U$ ratio in Wadi Nasab samples range between 18.43 to 29.16, which showed ten samples in the normal ratio and the other four samples deviated (Fig.7)

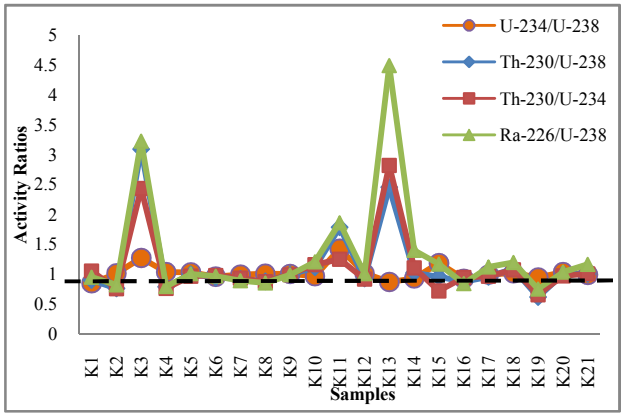


**Fig 5** Variations of $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ activity ratios in the studied samples of the three locations

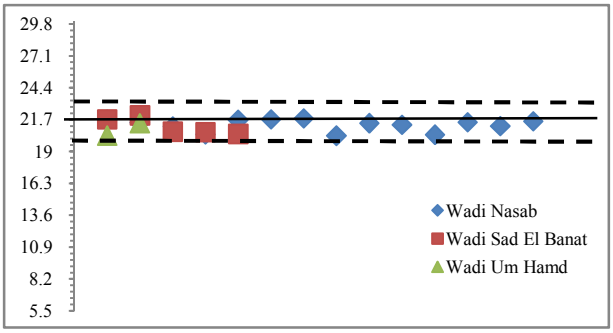


**Fig 6** Variations of the $^{238}U/^{235}U$ activity ratio in studied samples. The certified value of $^{238}U/^{235}U$ activity ratio is 21.7

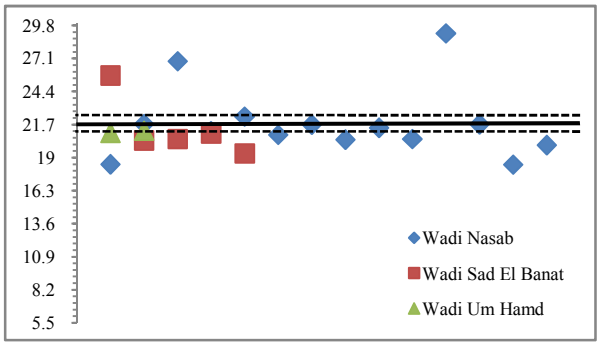


**Fig.7** Variations of the $^{234}U/^{235}U$ activity ratio in studied samples. The certified value of $^{234}U/^{235}U$ activity ratio is 21.7.

with the leaching out/in of uranium. While for Wadi Sad El Banat samples $^{234}U/^{235}U$ ratio range between 19.34 to 25.72, all the samples show normal distribution except one sample K15. The activity ratio $^{234}U/^{235}U$ in the two samples of Wadi Um Hamd location show normal distribution.

***Radiological hazard indices***

***Radium equivalent activity (Ra $_{eq}$)***

Since the distribution of the natural radionuclides are not uniform in the samples under analysis ,a radiological index called radium equivalent ($Ra_{eq}$) activity has been defined to estimate the radiation risk associated with these radionuclides. This index is calculated by the following equation:

$$Ra_{qe} = \left(\frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}\right) \times 370$$

Where $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity concentrations of $^{226}$Ra, $^{232}$Th and $^{40}$K in Bq/kg, respectively[El-Arabi *et al*., 2006]. This common index is convenient for comparing the specific activities of materials containing different concentrations of these radionuclides.

***External hazard index ($H_{ex}$)***

The external hazard index due to the emitted $\gamma$-rays of the samples is calculated according to the following criterion:

$$H_{ex} = \left(\frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}\right) \leq 1$$

Where $C_{Ra}$, $C_{Th}$ and $C_K$ are the activity concentration of $^{226}$Ra, $^{232}$Th, $^{40}$K in Bq/kg, respectively [Bassioni *et al*., 2012].

***Radiation Level Index ($I_\gamma$)***

This index can be used to estimate the level of $\gamma$-radiation hazard associated with the natural radionuclides in the samples which is given by the following equation

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500}$$

Where $C_{Ra}$, $C_{Th}$ and $C_K$ were the activity concentration of $^{226}$Ra, $^{232}$Th, $^{40}$K in Bq/kg, respectively [Bassioni *et al*., 2012].

**Table 3** The values of Radium equivalent activity, Radioactivity level index, External hazard index and Internal hazard index for three localities

| *Locality* | Rock Type | Sample | $Ra_{eq}$ | $I\gamma$ | $H_{ex}$ |
|---|---|---|---|---|---|
| *Wadi Nasab* | Shale | K1 | 7696.42 | 51.36 | 20.8 |
| | | K2 | 5687.74 | 37.98 | 15.37 |
| | | K3 | 12107.7 | 80.78 | 32.72 |
| | | K4 | 6855.06 | 45.75 | 18.53 |
| | | K5 | 1380.55 | 9.318 | 3.731 |
| | | K6 | 1271.44 | 8.595 | 3.436 |
| | | K7 | 1255.71 | 8.517 | 3.393 |
| | Sandy Dolomite | K8 | 2474.42 | 16.53 | 6.688 |
| | | K9 | 15182.5 | 101.2 | 41.03 |
| | Siltstone | K10 | 510.217 | 3.453 | 1.379 |
| | | K11 | 6155.32 | 41.06 | 16.64 |
| | | K12 | 1400.52 | 9.453 | 3.785 |
| | Claystone | K13 | 6806.55 | 45.43 | 18.4 |
| | | K14 | 2100.05 | 14.1 | 5.676 |
| | Siltstone | K15 | 1381.31 | 9.286 | 3.733 |
| | | K16 | 1522.77 | 10.28 | 4.115 |
| *Wadi Sad El Banat* | | K17 | 602.091 | 4.061 | 1.627 |
| | Sandstone | K18 | 680.229 | 4.659 | 1.838 |
| | Variegated shale | K19 | 690.459 | 4.754 | 1.866 |
| *Wadi Um Hamd* | Siltstone | K20 | 9060.18 | 60.59 | 24.49 |
| | | K21 | 10172.4 | 67.97 | 27.49 |

Table (3) gives the radium equivalent ($Ra_{eq}$) in Bq/Kg, external hazard index ($H_{ex}$) and radioactivity level index (I γ) in the three studied locations. The ranges of $Ra_{eq}$, I γ and $H_{ex}$ are (510.217 -15182.5) Bq/Kg, (3.453- 101.2) and (1.379-41.03), respectively for Wadi Nasab location. For Wadi Sad El Banat are (602.09 -1522.77) Bq/Kg, (4.06- 10.28) and (1.63-4.12), respectively. while for Wadi Um Hamd $Ra_{eq}$, I γ and $H_{ex}$ appear higher than the internationally recommended values, and the highest values present in the sample K21, which are 10172.4 Bq/Kg, 67.97, 27.49 and 63.83, respectively. The results of the three studied locations points to dangerous effect in that region for human health, and are higher than the recommended limit of $Ra_{eq}$ 370 Bq/Kg ant higher than unity for I γ and $H_{ex}$ given as UNSCEAR (2010).

***Absorbed dose rate (D)***

The absorbed dose rate D in outdoor air at 1m above the ground level was assessed from the natural activities of $^{226}$Ra, $^{232}$Th and $^{40}$K supposed to be equally distributed in ground. For the conversion of $\gamma$ -radiation originating from $^{226}$Ra, $^{232}$Th and $^{40}$K, the factors of 0.436 nGy h$^{-1}$ Bq$^{-1}$ kg$^{-1}$ for $^{226}$Ra, 0.599 nGy h$^{-1}$ Bq$^{-1}$ kg$^{-1}$ for $^{232}$Th and 0.0417 nGy h$^{-1}$ Bq$^{-1}$ kg$^{-1}$ for $^{40}$K were used for calculating the (D) by the following equation [Ajayi and Kuforiji, 2001; El-Arabi *et al*., 2006].

$$D_{out} = 0.436\ C_{Ra} + 0.599\ C_{Th} + 0.0417\ C_K\ (nGyh^{-1})$$

This factor is very important to evaluate the annual effective dose in an outdoor environment, AED can be given by the following relation:

$$AED = D_{out}\ (nGyh^{-1}) \times 20\%\ of\ 8760\ h \times 0.7\ (Sv\ Gy^{-1})$$

$$AED = D_{out} \times 1.226\ \mu Sv$$

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

Based upon calculated values of annual effective dose, the excess lifetime cancer risk (ELCR) was calculated using the following equation;

$$ELCR = AED \times 66 \times 0.05$$

Where the 66 is the life expectancy (66years) and 0.05 is the fatal risk factor per Sievert, [Qureshi *et al*., 2014].

**Table 4** The values of absorbed doses rate D, the annual effective doses AED and excess lifetime cancer risk ELCR for the samples of the studied localities

| Locality | Rock Type | Sample | D (nGyh$^{-1}$) | AED (mSvy$^{-1}$) | ELCR × 10$^{-3}$ |
|---|---|---|---|---|---|
| Wadi Nasab | Shale | K1 | 3356.6 | 4.12 | 13.6 |
| | | K2 | 2481.1 | 3.04 | 10 |
| | | K3 | 5281 | 6.47 | 21.4 |
| | | K4 | 2988.8 | 3.66 | 12.1 |
| | | K5 | 604.64 | 0.74 | 2.45 |
| | | K6 | 557.57 | 0.68 | 2.26 |
| | | K7 | 550.25 | 0.67 | 2.23 |
| | Sandy Dolomite | K8 | 1079.9 | 1.32 | 4.37 |
| | | K9 | 6620.6 | 8.12 | 26.8 |
| | Siltstone | K10 | 223.65 | 0.27 | 0.9 |
| | | K11 | 2684.4 | 3.29 | 10.9 |
| | | K12 | 613.49 | 0.75 | 2.48 |
| | Claystone | K13 | 2968.7 | 3.64 | 12 |
| | | K14 | 918.17 | 1.13 | 3.71 |
| | Siltstone | K15 | 601.14 | 0.74 | 2.43 |
| | | K16 | 666.45 | 0.82 | 2.7 |
| Wadi Sad El Banat | | K17 | 264.08 | 0.32 | 1.07 |
| | Sandstone | K18 | 300.11 | 0.37 | 1.21 |
| | Variegated shale | K19 | 305.7 | 0.37 | 1.24 |
| Wadi Um Hamd | Siltstone | K20 | 3956.3 | 4.85 | 16 |
| | | K21 | 4440.3 | 5.44 | 18 |

For Wadi Nasab location the values of D, AED and ELCR (Table 4) ranged from (223.65 to 6620.6) nGyh$^{-1}$, (0.27 to 8.12) mSvy$^{-1}$ and (0.9 × 10$^{-3}$ to 26.8 × 10$^{-3}$.), respectively. While for Wadi Sad El Banat the values ranged from (264.08 to 666.45) nGyh$^{-1}$ , (0.32 to 0.82) mSvy$^{-1}$ and (1.07 × 10$^{-3}$ to 2.7 × 10$^{-3}$), respectively. Finally for Wadi Um Hamd the highest values

present in the sample K21, which are 4440.3 $nGyh^{-1}$, 5.44 $mSvy^{-1}$ and 18 respectively. The results of the three studied locations are higher than the world average of absorbed dose rate D in an outdoor air , Annual effective dose AED in outdoor air and excess lifetime cancer risk ELCR which are 59 $nGyh^{-1}$, 0.07 $mSvy^{-1}$ and $0.29 \times 10^{-3}$, respectively as [UNSCEAR, 2010 and Qureshi *et al*., 2014] as shown in table(4).

## CONCLUSIONS

This study appears the sedimentary rocks of the three locations contain high activity concentrations of $^{238}U$ and its progenies, while $^{232}Th$ and $^{40}K$ occur in small activities and their contributions to natural radioactivity are relatively low. The activity concentrations of $^{238}U$, $^{226}Ra$, $^{232}Th$ and $^{40}K$ in the three locations are higher than the world's average.

The activity ratios in different rock types are guide for what happened in these rock varieties. The different physico-chemical conditions affecting $^{238}U$ and $^{234}U$ resulted in their fractionation and, thus, the respective activity ratios will therefore be greater or less than unity. The activity ratios $^{234}U/^{238}U$, $^{230}Th/^{238}U$, $^{230}Th/^{234}U$ and $^{226}Ra/^{238}U$ for all studied samples are around the secular equilibrium. The activity ratio $^{238}U/^{235}U$ for all the samples of the three locations were varied from 20.33 to 22.07 which reflect little deviation from the natural ratio 21.7 within the error and the $^{234}U/^{235}U$ ratios is ranging between 18.43 and 29.16.

$Ra_{eq}$, $I\gamma$ and $H_{ex}$, have been calculated where found higher than the recommended limit which points to dangerous effect in that region for human health. The absorbed dose rate in outdoor air, the annual effective dose in outdoor environment and the excess lifetime cancer risk were higher than the world's average which represent radiological risk for people who work in these locations to protect against high radioactivity.

Finally, this study can be used as a baseline for future investigations and the data obtained in this study may be useful for natural radioactivity mapping.

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