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Natural Radioactivity Measurements and Radiation Hazard levela for Some Sedimentary Rock Samples in Port Said,Egypt

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Abstract*: The natural radioactivity existed since creation of the universe due to the long life time of some radionuclides. This natural radioactivity is caused by γ-radiation originating fromthe radium and thoriumseries and ^{40}K. In this study, the gamma radiation has been measured to determine natural radioactivity of ^{226}Ra, ^{232}Th, and ^{40}K in collected sedimentary rock samples in Port Said, Egypt.The measurements have been performed using γ-ray spectrometer containing Hyper Pure Germanium detector and multichannel analyser (MCA). Absorbed dose rate (D), annual effective dose (AED), radium equivalent activities (Raeq), external hazard index (Hex), and internal hazard index (Hin) associated with the natural radionuclide were calculated to assess the radiation hazard of the natural radioactivity in the sedimentary rock samples. The average values of absorbed dose rate in air (D), annual effective dose (AED), radium equivalent activity (Raeq), external hazard index (Hex), and internal hazard index (Hin) were calculated and thesewere 36.92 nGy/h, 0.045mSv/y, 79.245Bq/kg, 0.213, and 0.36, respectively.*

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I. 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. Natural background radiation is of terrestrial and extraterrestrial origin. 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 [1-2].

In this study, the natural radioactivity concentrations of ^{40}K, ^{238}U (^{226}Ra), and ^{232}Th in some sedimentary rock samples collected in different regions of Turkey have been investigated. The results were used to assess the radiological hazard associated with the absorbed gamma dose rate in air (D), the annual effective dose rate, radium equivalent activities (Raeq), external hazard index (Hex), and internal hazard index (Hin) from gamma radiation.

Sample collection

Port Said city lies in the north-eastern part of Egypt, between latitudes 32°12'59" and 32°19'15" E and longitudes 31°12'4" and 31°17'6" N. It has a triangular shape, surrounded by the Suez navigation Canal to the east, the Mediterranean Sea to the north and the eastern part ofLake Manzala to the west (Figure 1).

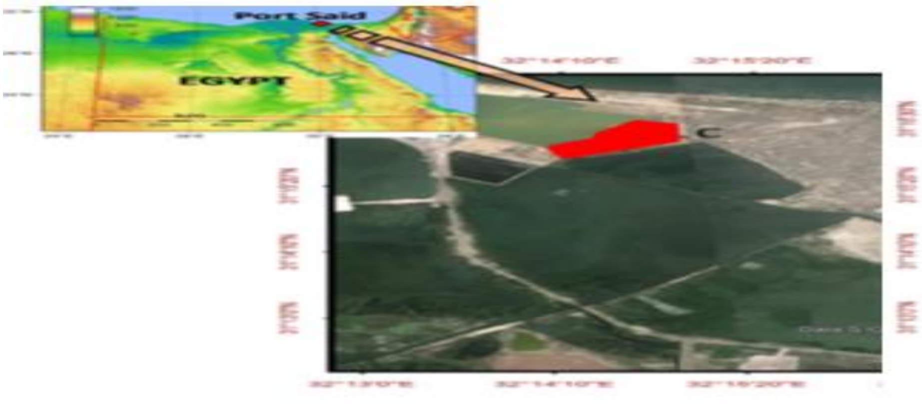

Figure 1: Location map of the studied in Port Said area city.

Preparation of the samples

These samples were prepared for 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. This step was necessary to ensure that radon gas is confined within the volume and the daughters still also remain in the sample**.**

Detection technique

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) of 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 10 cm thickness with inside dimension 28 cm diameter ×40.5cm 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 [3-4] 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 . The uranium standard (RGU-1) is U-ore diluted with silica with 4940 Bq kg^{-1} of ^{238}U, 228 Bq kg^{-1} of ^{235}U, a negligible amount of ^{40}K (less than 0.63 Bq kg^{-1}) and some traces of ^{232}Th (less than 4 Bq kg^{-1}). The thorium standard (RGTh-1) is Th-ore diluted with silica having 3250 Bq kg^{-1} of ^{232}Th, but containing some^{238}U (78 Bq kg^{-1}) and ^{40}K (6.3 Bq kg^{-1}). The potassium calibration standard (RGK-1) is produced from high purity (99.8%) potassium sulphate with 14000 Bq kg^{-1} of potassium with uranium and thorium contents lower than 0.001 and 0.01 ppm (parts per million), respectively .

The γ-ray transitions used to measure the concentration of the assigned nuclides in the series are follows:^{238}U was determined from the gamma rays emitted by its daughterproducts. ^{234}Th and ^{234m}Pa activities determined from the 63.3 and 1001 keV photo peaks, respectively, ^{214}Bi(609.3, 1120.3, 1238.1, 1377.7, and 1764.5 keV), ^{214}Pb (295.1 and 352.0 keV), The specific activity of ^{226}Ra was measured using the 186.1 keV from its own gamma-ray (after the subtraction of the 185.7 keV of ^{235}U), The specific activity of ^{232}Th was measured using the 338.4, 911.2 and 968.9 keV from ^{228}Ac and 583 keV from ^{208}Tl and ^{40}K was measured using 1460.8 keV for potassium.

II. Results and Discussion

The activity concentrations of natural radionuclides (^{226}Ra,^{232}Th and ^{40}K) in the sedimentary rocks collected in Port Said, Egypt are presented in Table 1, the activity concentrations of sedimentary rock samples have ranged from 25.07to 53.93Bq/kg for ^{226}Ra, from 8.34 to 11.67 Bq/kg for ^{232}Th, and from 395.3 to 244 Bq/kg for ^{40}K. The obtained results have been displayed in Figure 2.The highest concentrations for all natural radionuclides were detected in the sample 2 (S2)

Table 1: The activity concentration of ^{40}K, ^{226}Ra, and ^{232}Th(in Bq/kg) of sedimentary rock samples.

Sample	Ra-226	Th-232	K-40
S1	31.5	8.34	244
S2	53.93	11.4	395.3
S3	25.07	9.3	328.49
S4	37.65	11.67	285.2
S5	50.42	10.73	376
S6	40.69	9.48	307.6
UNSCEAR 2000	50	50	500

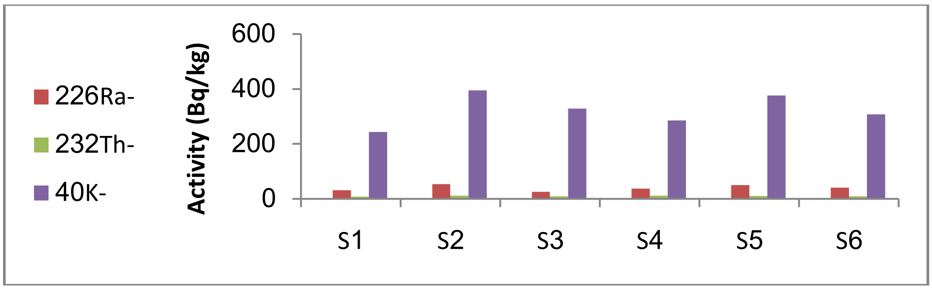

Figure 2: The activity concentration of ^{226}Ra, ^{232}Th and ^{40} K, for all samples.

Radiation Exposure Hazard Indices

Radium Equivalent Activity

Radium equivalent activity is an index that has been introduced to represent the specific activities of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them. This index can be calculated according to **[5]**as:

$$\mathbf{Ra_{eq}=A_{Ra}+1.43A_{Th}+0.077A_{K}}$$

Where: ARa, ATh and AK are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively. The lowest limit of 370 Bq kg^{-1} adopted by the Organization for Economic Cooperation and Development **[6].**

Absorbed Dose Rate

Absorbed dose rate conversion factors to transform specific activities ARa, ATh and AK of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively, in absorbed dose rate at 1.0 meter above the ground (in nGy h^{-1} by Bq kg−1) are calculated by the Monte Carlo method and the values in **[7].**

$$\mathbf{D\ (nSv/h) = 0.49CRa + 0.67CTh + 0.048Ck}$$

Where D is the absorbed dose rate in nGy h−1 and ARa, ATh and AK are the specific activities of 226Ra, 232Th and 40K in Bq kg−1, respectively. The average and range of absorbed dose rate in air due to natural radionuclides in the Egyptian soil is 51 nGy h−1 and 20–400 nGy h−1 in areas of high natural radiation background (Monazite sands) **[8]**.

Internal Hazard Index

The internal hazard index (Hin) can be examined according the following criterion **[5].**

$$\mathbf{H_{in} = C_{Ra}/185 + C_{Th} / 259 + C_{k} /4810} \le 1$$

Where, A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}, respectively.

External Hazard Index

The external hazard index is obtained from Raeq expression through the assumption that its maximum allowed value (equal to unity) corresponds to the upper limit of Raeq (370 Bq kg^{-1}). This index value must be less than unity in order to keep the radiation hazard insignificant; i.e. the radiation exposure due to the radioactivity from construction materials is limited to 1.0 mSvy^{-1}. Then, the external hazard index can be defined as:

$$\mathbf{H_{ex} = C_{Ra}/370+ C_{Th}/259+ C_{k}/4810} \le 1$$

Where, A_{Ra}, A_{Th} and A_K are the specific activities of^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1},, respectively. (H_{ex} must be less than unity) showing little risk of external hazard to workers handling the sediments.

Annual Effective Dose

The annual out door effective dose (E_{out}) is estimated from the outdoor external dose rate (D_{out}), time of stay in the outdoor or occupancy factor (OF =20% of 8760 h in a year) and the conversion factor (CF = 0.7Sv Gy^{-1}) to convert the absorbed dose in air to effective dose. During the present study, the (E^{out}) was calculated using the following equations from (7)

$$E_{out} = D_{out}\,(nGyh^{-1}) \times 0.2 \times 8760\ h \times 0.7\ (SvGy^{-1})$$

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

Table 2. The radium equivalent,absorbed dose rate , the external and internal hazard index andThe annual out door effective dose for the sediment samples. P.L. is permissible level

Sample	Raeq(Bq/kg)	D(out)(nGy/h)	Hex	H_{in}	E(out)(mSv/y)
1S	62.21	28.9	0.168	0.28	0.035
2S	100.67	46.82	0.27	0.46	0.057
3S	63.66	30.19	0.17	0.26	0.037
4S	76.29	35.29	0.21	0.34	0.043
5S	94.71	44.08	0.25	0.43	0.054
6S	77.93	36.24	0.21	0.35	0.044
p.l	370	55	1	1	0.07

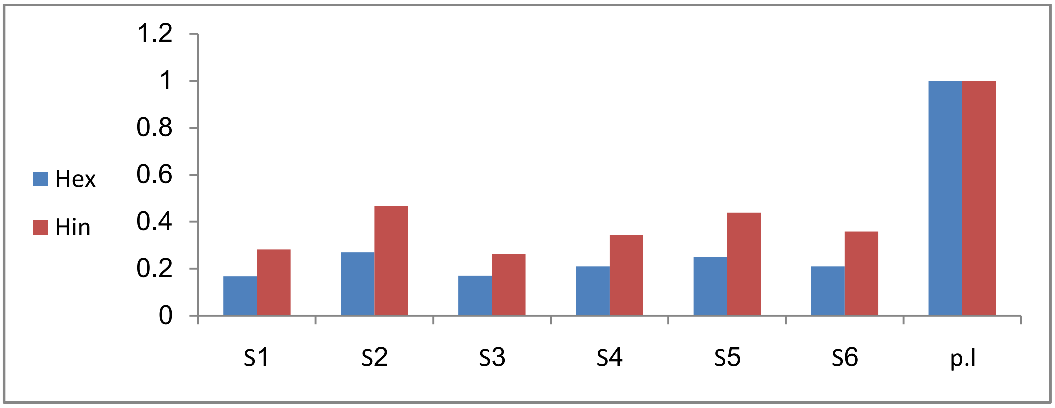

Figure 3: External and internal hazard index for all samples

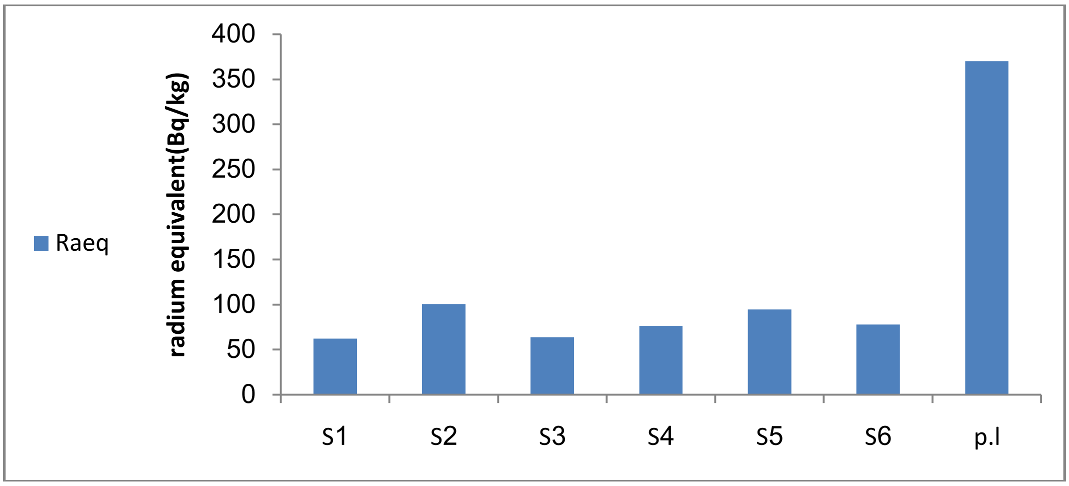

Figure 4: Radium equivalent activity for all samples.

For internal and external radiation hazard index, it can be seen that all measured results are lower than the upper limit of unity as at fig.(3). The estimated values of Ra_{eq} in the present work are lower than the recommended maximum value of 370 Bq/kg as at fig.(4).

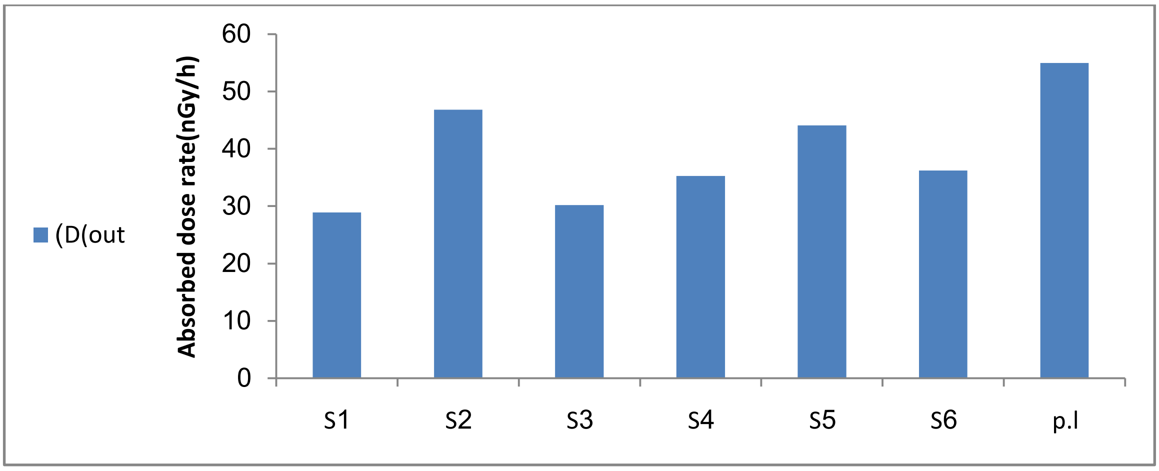

Figure 5: Gamma absorbed dose rate at 1m above ground for all samples.

The absorbed dose rate ranged from 28.9to 46.82 $nGy \cdot h^{-1}$. The absorbed dose rate is displayed in Figure 5.The global average value of absorbed dose rate is 55 $nGy \cdot h^{-1}$
The annual effective dose rate values varied from 0.035to 0.057$mSv \cdot y^{-1}$. The AED results have been displayed in Figure 6.The average AED from the terrestrial radionuclides is 0.07 $mSv \cdot y-1$ in areas with the normal background radiation

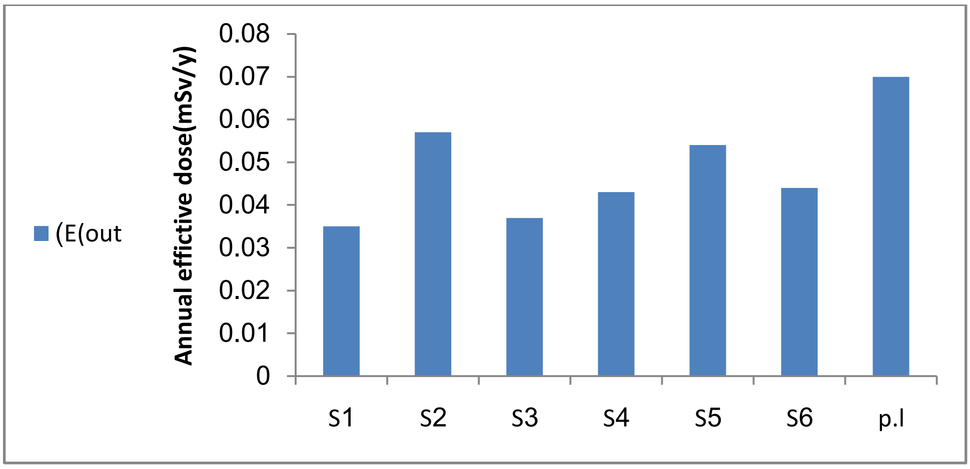

Figure 6: Effective dose rate for all samples

III. Conclusion

The mean activity concentrations of ^{226}Ra, ^{232}Th and^{40}K, were 39.87, 10.15 and 322.765 (Bq/kg). respectively. The mean activity concentrations are lower than the world mean values identified by UNSCEAR [8]. From the measured values, the average values of absorbed dose rate in air (D), annual effective dose (AED), radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), and internal hazard index (H_{in}) were calculated and these were 36.92nGy/h, 0.045 mSv/y, 79.245 Bq/kg, 0.21, and 0.36, respectively. All the calculated values are lower than the recommended maximum values in the UNSCEAR [8] reports. As a result of these, it can be concluded that for people who are using andmining sedimentary rock in these regions of Turkey are safe in terms of radiation hazards.

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