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Dose Assessment Due to Natural Radioactivity in Sand, Soil and Water of Some Egyptian Beaches

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Abstract: About 90 soil and water samples were collected from six different beaches in red and Mediterranean Sea. Naturally occurring radionuclides ^{238}U, ^{232}Th series and ^{40}K were measured using a high resolution gamma rays spectrometry. Gamma exposure (μR/h) and absorbed dose rate (nGy/h), due to the natural radioactivity distribution for all sites, were calculated. Activity concentration levels of the naturally occurring radionuclides were found to be ranged over 3.54-42.8, 2-44.63 and 3.59-361.7 Bq/kg for ^{238}U, ^{232}Th series and ^{40}K respectively for the different beaches. While exposure rate was found to be ranged over 0.19 to 2.26, 0.14 to 3.15 and 0.02 to 1.74 (μR/h) for U-238, Th-232 and k-40 respectively. Absorbed dose was found to be ranged over 1.63 to 19.67, 1.23 to 27.42 and 0.15 to 15.1 nGy/h for U-238, Th-232 series and K-40 respectively. The annual effective dose (mSv/y) to man due to ^{238}U series, ^{232}Th series and ^{40}K was estimated and found to be ranged from 1.53E-11 to 3.35E-10, 4.13E-11 to 2.23E-09 and 2.0E-07 to 3.27E-05 mSv/y for different locations. Equivalent doses to all organs due to the three natural radioactive series were calculated. These calculations showed that the highest equivalent dose would be received by the skin and the lowest received by oesophagus due to ^{238}U series and ^{40}K. ^{232}Th series lead to bone surface highest equivalent dose and lowest to pancreas. Total effective dose to all organs, due to the three natural radionuclides for Taba beach, which has the highest activity concentration, was calculated and it was 1.75E-05 mSv/y and the total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, for the same beach was calculated as 2.882E-06 mSv/y. Water samples for all beaches show activity concentration below minimum significant activity. Finally we can conclude that, none of the studied beaches would be considered as a radiological risk.

Key words: radiological impact · External dose · Equivalent dose

INTRODUCTION

It is well known that natural radioactivity is present in rocks, soils, sediments, water and fish. Rocks and soil contain small quantities of the radioactive elements of ^{238}U and ^{232}Th and ^{40}K with their daughter products which is the major sources of external radiation [1]. The concentration of these elements varies considerably depending on the rock formation. The contribution from these components varies with location and altitude. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region in the World [2]. In most places on the earth, the natural radioactivity varies only within narrow limit, whereas there are few regions in the world which are known for high background radiation areas (HBRAs). These are due to the local geological controls and geochemical effects and cause increased levels of terrestrial radiation [3]. Natural sources of radiation constitute almost 80% of the collective radiation exposure of the World's population [4]. Estimation of the radiation dose distribution is vital in assessing the health risk to population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities [5,6]. The main objectives of the present study therefore, are to measure the natural radioactivity levels and to estimate the hazard indices; external and internal hazard index, absorbed dose rate and effective dose rate due to sand, sediment and water samples from Red Sea's beaches (Taba, Hurguda, Al-Ain Al-Sokhna and Ras Sedr) and Mediterranean Sea's beaches (Mersa Matrouh and Gamasa) in Egypt. These measurements completed to study the radiation hazard indicators of these areas. Also comparisons between them have been investigated.

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Sampling Techniques and Experimental Methods: Soil samples were collected from six different Egyptian beaches of Mediterranean and red sea. Mersa Matrouh and Gamasa represent Mediterranean sea beaches, while Taba, Ain Sokhna, Ras sedr and Hurguda represent red sea beaches. Soil samples were collected to a depth of 5 cm and well mixed after removing extraneous materials such as roots, mat portions, pieces of stones and gravel. After weighted, complete dryness obtained by drying samples in an oven at 105 °C for about 24 hours until mass remain constant. From 300-500g of dried soil was mixed thoroughly and filled in a polyethylene jar with a screw cover and perfectly sealed. After that it was left for more than one month to allow U-238 to come into equilibrium with its decay products.

Soil samples were directly measured by efficiency and energy calibrated HPGe detector. The main characteristics required for such detection systems are high efficiency, high-energy resolution and very low background. Especially the background features of the system are of considerable importance, as they must be known in order to get an estimate of the detection limits and the minimum detectable activity [5-6]. HPGe detector is a P-type coaxial detector with active volume of 138 cm^3, relative efficiency to NaI (Tl) detector is 30% measured at 1332 keV with source to detector distance of 25 cm. Resolution is 1.9 keV at 1332 keV.

The background was measured by using the same type of plastic jar containing pure silica with approximately the same weight of samples (about 500g). The counting time was between 6 and 16 hours.

The detector efficiency calibration was performed by using the IAEA quality assurance reference materials; (RGU-238), with 400 ppm concentration, 1.78 density and activity 4.9 Bq/gm and (RGTh-232), with 800 ppm, 1.71 density and activity 3.26 Bq/gm. The standard materials and samples were taken in containers of same size and type so that detection geometry remained the same.

To make a decision whether the sample contains activity, A, is then compared with a critical level L_c or minimum significant activity (MSA) which is the activity in a sample which produces a counting rate that may be reliably distinguished from background with 95% confidence intervals [7,8]. MSA is 0.6 Bq/kg, 0.7 Bq/kg and 1.1 Bq/kg for U-238, Th-232 series and K-40 respectively.

Dose Calculation

Dose Calculation from Soil: The most significant sources of Terrestrial radiation results from the primordial radionuclides are uranium, thorium and K-40 and their decay products. In geosciences, natural sources of radiation are studied through their ability to cause ionization in matter [9].

Table 1: Exposure and dose rate per unit radioelement.

Radioelement concentration	Exposure rate (μ R/h)	Dose rate (nGy/h)
1ppmU	0.653	5.675
1ppmTh	0.287	2.494
1% K in rock	1.505	13.078

Where, 1 ppm of U in soil = 12.35 Bq/kg, 1ppm of Th in soil = 4.06 and 1% of K =313 Bq/kg[10]

- According to IAEA recommendations[10] theoretical gamma exposure rates and gamma dose rates at 1 m above a plane and infinite homogenous soil medium per unit radioelement concentration assuming radioactive equilibrium in the ^{238}U and ^{232}Th decay series can be calculated as follow (Table 1):
- If naturally occurring radionuclides are uniformly distributed, dose rates, D, at 1 m above the ground surface in units of $nGyh^{-1}$ can be calculated by the following formula:

$$D = A_{Ei} * C_F \quad (1)$$

Where A_{Ei} is the specific activity measured in Bq /kg and C_F is the dose conversion factor in units of nGy kg / h Bq (absorbed dose rate in air per unit of activity concentration). In the present study, the mean dose conversion factors utilized are those given by UNSCEAR (1993)[11], These factors are 0.461, 0.623 and 0.0414 nGy kg / h Bq (with a precision of three decimal digits) for the Ra-226 sub series and Th-232 series respectively and by assuming secular equilibrium between U-238 and Ra-226. It may be noted that about 98% of the external dose from U-238 series is delivered by Ra-226 sub series. Therefore, the disequilibrium, if any, between Ra-226 and U-238 does not affect the dose estimation from the measurement of Ra-226 [12].

To estimate the annual effective doses, a value of 0.7 Sv / Gy was used for the conversion coefficient from absorbed dose in air to effective dose received by workers. Thus the effective dose rate, H_E, in unit m Sv / y, is calculated by the following formula:

$$H_E = D_a * T * F \quad (2)$$

Where, D_a is the calculated dose rate (nGy/h), T is the time of exposure (exposure time) (hr/y) and F is the absorbed-to-effective dose conversion factor ($0.7*10^{-6}$ m Sv/n Gy).

Organ doses due to naturally occurring Radionuclides distributed within soil: The principal dosimetric quantities in radiological protection are the mean absorbed dose in a tissue or organ, D_T, (Gy); the equivalent dose in a tissue or organ, H_T, (Sv) formed by weighting the absorbed dose by the radiation weighting factor (W_R), $H_T = D_T W_R$; and the effective dose, E, (Sv) formed by weighting the equivalent dose by the tissue weighting factor (W_T) and summing over the tissues $E = \Sigma H_T W_R$. Calculations of organ doses from external irradiation fields were undertaken by Eckerman and Ryman (DFEXT code)[13]. External dose coefficients were computed at Oak Ridge National Laboratory during the preparation of Federal Guidance Report No. 12. In this software the coefficients represent the dose per unit integrated exposure or the dose rate per unit concentration.

- h_t is the equivalent dose in tissue T per unit integrated exposure.
- e is the effective dose per unit integrated exposure = $\Sigma W_T h_t$, using W_T from ICRP-60[14].

Where the summation extends over the organs/tissues with explicit W_T, W_{rem} is the weighting factors for the remainder (0.3) and h_{rem} is the committed dose equivalent per unit integrated exposure for the remainder tissues. h_{rem} is given as: $h_{rem} = 1/5 \Sigma h_t$.

From these coefficients, equivalent dose (H_T) to any organ from soil can be calculated as follow:

$$H_T = A * T * 3600 \text{ (sec/hr)},* h_t \text{ (Sv)} \quad (3)$$

Where: A is the activity concentration in soil (Bq/m^3),
T is the exposure time (hr.)
h_t is the equivalent dose in tissue T per unit integrated exposure (Sv m^3/sec Bq),

While the effective dose (E) from soil can be calculated as follow:

$$E = A * T * 3600 * e \text{ (Sv)} \quad (4)$$

Where: e (Sv m^3/sec Bq) is the effective dose per unit integrated exposure computed as the $\Sigma W_T h_t$, using W_T from ICRP-60 [14].

RESULTS AND DISCUSSION

Specific Activity in Soil Samples: Sand and soil samples were collected from six different beaches of Mediterranean and Red sea. Tables (2-7) show activity concentration (Bq/kg), the range (min-max), mean values, median and standard deviation of activity concentration (Bq/kg) of U-238, Th-232 series and K-40 in different soil samples for different beaches. The activity concentration of natural radionuclides in the surface soil (0-5cm) had a wide range of variation from site to site. Taba beach (at red sea) shows the highest activity concentration for U-238 and Th-232 with average of 42.80 and 44.63Bq/kg respectively (Table 2), while Hurguda beach shows the highest K-40 concentration with average of 361.70 Bq/kg (Table 3). Fig. 1 and Table 8 show the average activity concentration for the three natural radionuclides for different locations.

Table 2: Activity concentration (Bq/kg) in Taba beach due to U-238, Th-232 series and K-40

Taba soil activity concentration (Bq/kg)			
Sample No.	U-238	Th-232	K-40
1	43.39	47.42	232.6
2	40.91	49.89	166.2
3	40.76	37.20	191.1
4	46.10	47.10	232.0
5	42.75	43.47	213.5
6	43.10	51.96	138.1
7	46.00	48.78	125.9
8	40.23	37.00	190.5
9	41.94	38.83	196.9
Range	40.23-46.1	37-51.96	125.9-232.6
Average ± St. dev.	42.80	44.63	187.4
St. dev.	2.14	5.71	37.9
Median	42.75	47.10	191.1

Table 3: Activity concentration (Bq/kg) in Hurguda beach due to U-238, Th-232 series and K-40

Ras Sedr soil activity concentration (Bq/kg)			
Sample No.	U-238	Th-232	K-40
1	6.67	1.88	89
2	10.85	4.72	101
3	11.7	4.95	103
4	9.14	1.94	84
5	8.55	5.47	78
6	5.09	1.12	75
7	7.98	4.3	90
8	12.9	3.4	76
9	5.6	2.5	89
10	8.9	3.1	83
11	6.6	2.8	93
12	7.8	4.7	77
Range	5.09-12.9	1.12-5.47	75-103
Average± St. dev.	8.48 ± 2.4	3.41± 1.41	86.50 ± 9.41
Median	8.27	3.25	86.5

External Exposure from Soil: Table 9 and Fig. 2 shows the calculated dose rate (nGy/h) and Exposure rate (μ R/h) from different locations due to U-238, Th-232 series and

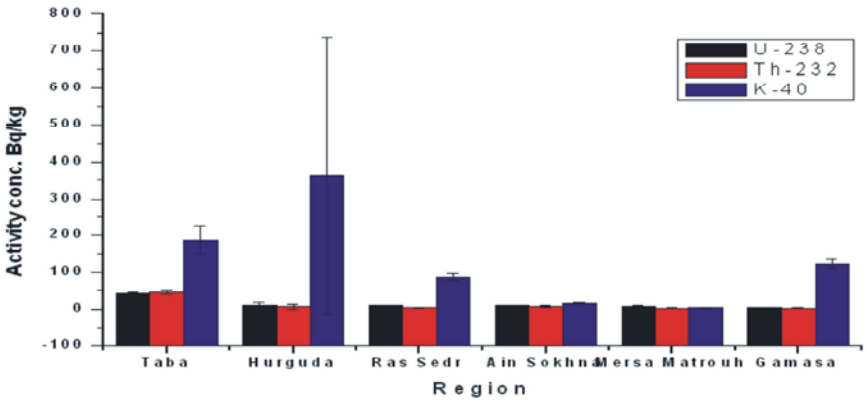

Fig. 1: Average soil concentration (Bq/kg) for U-238, Th-232 and K-40

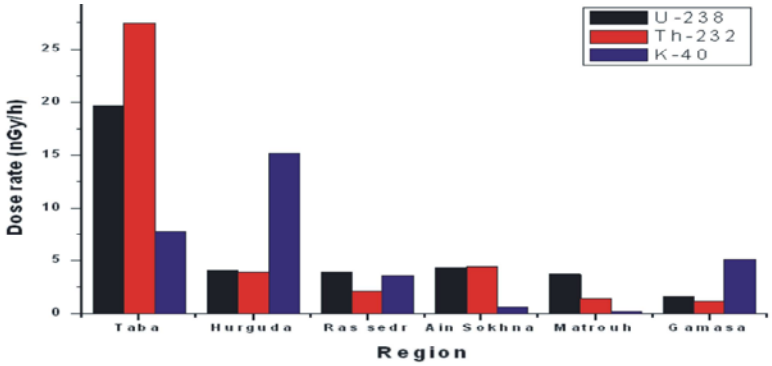

Fig. 2: Dose Rate (nGy/h) for all locations due to to U-238, Th-232 series.

Table 4: Activity concentration (Bq/kg) in Ras Sedr beach due to U-238, Th-232 series and K-40

Hurguda soil activity concentration (Bq/kg)			
Sample no.	U-238	Th-232	K-40
1	7.70	2.90	258.8
2	11.00	7.86	258.3
3	7.70	5.51	413.0
4	8.23	5.45	415.0
5	7.43	6.70	380.1
6	8.35	3.60	380.0
7	9.20	2.46	377.3
8	7.84	5.03	343.4
9	9.19	8.96	346.6
10	11.89	8.36	436.4
11	14.15	4.50	373.5
12	7.37	8.12	404.6
13	7.53	7.40	380.6
14	7.62	9.66	326.2
15	9.18	9.91	332.4
Range	7.37-14.15	2.46-9.91	258.3-436.4
Average± St dev.	8.96±1.96	6.43±2.42	361.7±52.3
Median	8.23	6.70	377.3

Table 5: Activity concentration (Bq/kg) in Ain Sokhna beach due to U-238, Th-232 and K-40

Ain Sokhna soil activity concentration (Bq/kg)			
Sample no.	U-238	Th-232	K-40
1	8.26	6.45	15.16
2	10.23	7.65	15.56
3	9.97	7.64	14.61
4	10.32	7.60	13.80
5	9.97	5.00	7.87
6	8.49	4.10	14.34
7	9.82	10.42	14.60
8	9.93	6.68	11.00
9	8.18	9.56	21.40
Range	8.18-10.32	4.1-10.42	7.87-15.56
Average± St dev.	9.46 ±0.88	7.23 ± 1.99	14.26 ± 3.63
Median	9.93	7.6	14.6

K-40. Exposure rate was found to be ranged over 0.19 to 2.26, 0.14 to 3.15 and 0.02 to 1.74 (µR/h) for u-238, Th-232 and K-40 respectively. Absorbed dose rate was found to be ranged over 1.63 to 19.67, 1.23 to 27.42 and 0.15 to 15.1 nGy/h for U-238, Th-232 series and K-40 respectively.

A total exposure time of 1800 hr/y (12hr/d * 30 d/m *5 m/y) was considered and the total effective dose due to these naturally occurring radionuclides was ranged between 0.1045 and 1.316 m Sv/y. We can conclude that,

Table 6: Activity concentration (Bq/kg) in Gamasa beach due to U-238, Th-232 series and K-40

Gamasa soil activity concentration (Bq/kg)			
Sample No.	U-238	Th-232	K-40
1	5.20	3.8	128.60
2	4.13	2.5	130.00
3	4.10	3.60	132.0
4	3.52	1.00	104.7
5	2.10	1.00	127.0
6	2.30	1.00	103.1
7	3.45	1.10	133.0
Range	2.1-5.2	1-3.8	103.1-133
Average± St dev.	3.54+1.08	2.00+1.28	122.6+13.0
Median	3.52	1.1	128.6

Table 7: Activity concentration (Bq/kg) in Mersa Matrouh beach due to U-238, Th-232 series and K-40

Matrouh soil activity concentration (Bq/kg)			
Sample No.	U-238	Th-232	K-40
1	7.60	3.41	3.46
2	7.29	2.23	2.96
3	7.10	2.30	2.66
4	9.55	2.40	2.66
5	8.86	2.50	2.72
6	8.95	2.16	3.45
7	7.54	2.10	5.97
8	7.93	1.93	2.67
9	8.77	2.10	2.68
10	7.19	1.34	2.67
11	7.40	5.69	5.89
12	9.77	5.16	2.80
13	7.72	2.20	6.00
14	8.52	2.63	4.40
15	7.43	1.89	2.90
Range	7.10-9.77	1.34-5.69	2.66-6.00
Average± St dev.	8.11±0.89	2.67±1.21	3.59±1.31
Median	7.72	2.23	2.9

Table 8: Activity concentration (Bq/kg) for different beaches due to U-238, Th-232 and K-40

Region	U-238	Th-232	K-40
Taba:			
Range	20.23-46.1	37-51.96	125.9-232.6
Average	42.80	44.63	187.4
Median	42.75	47.10	191.1
St. Dev.	2.14	5.71	37.9
Hurguda:			
Range	7.37-14.15	2.46-9.91	258.3-436.4
Average	8.96	6.43	361.7
Median	8.23	6.70	377.3
St. Dev.	1.96	2.42	52.3
Ras Sedr:			
Range	5.09-12.9	1.12-5.47	75-103
Average	8.48	3.41	86.50
Median	8.27	3.25	86.5
St. Dev.	2.4	1.41	9.41
Ain Sokhna:			
Range	8.18-10.32	4.1-10.42	7.87-15.56
Average	9.46	7.23	14.26
Median	9.93	7.6	14.6
St. Dev.	0.88	1.99	3.63
Mersa Matrouh:			
Range	7.10-9.77	1.34-5.69	2.66-6.00
Average	8.11	2.67	3.59
Median	7.72	2.23	2.9
St. Dev.	0.89	1.21	1.31
Gamasa:			
Range	2.1-5.2	1-3.8	103.1-133
Average	3.54	2.00	122.6
Median	3.52	1.1	128.6
St. Dev	1.08	1.28	13.0
Average Range	3.54-42.80	2.00-44.63	3.59-361.7

Table 9: Calculated exposure rate (μ R/h) and dose rate nGy/h due to U-238, Th-232 series for different sites

	U-238			Th-232			K-40		
Region	ppm	Exposure rate(μ R/h)	dose rate nGy/h	ppm	Exposure rate (μ R/h)	dose rate nGy/h	1% K	Exposure rate (μ R/h)	dose rate n Gy/h
Taba	3.47	2.26	19.67	10.99	3.15	27.42	0.6	0.9	7.8
Hurguda	0.73	0.47	4.12	1.58	0.45	3.95	1.16	1.74	15.1
Ras sedr	0.69	0.45	3.9	0.84	0.24	2.1	0.28	0.42	3.6
Ain Sokhna	0.77	0.5	4.35	1.78	0.51	4.44	0.05	0.07	0.6
Matrouh	0.66	0.43	3.73	0.66	0.19	1.46	0.01	0.02	0.15
Gamasa	0.29	0.19	1.63	0.49	0.14	1.23	0.39	0.59	5.1

Table 10: Minimum and maximum equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Taba Beach

Taba	U-238		Th-232		K-40	
Organ	Min	Max	Min	Max	Min	Max
R Marrow	7.52E-11	1.71E-10	1.28E-09	1.80E-09	8.93E-06	1.65E-05
Adrenals	5.21E-11	1.19E-10	1.12E-09	1.57E-09	1.02E-05	1.88E-05
B Surface	4.55E-10	1.04E-09	5.34E-09	7.50E-09	9.10E-06	1.68E-05
Brain	5.90E-11	1.34E-10	1.30E-09	1.83E-09	8.97E-06	1.66E-05
Breast	3.66E-10	8.33E-10	2.12E-09	2.98E-09	8.74E-06	1.61E-05
G Bladder	5.00E-11	1.14E-10	1.10E-09	1.55E-09	8.22E-06	1.52E-05
Esophagus	3.62E-11	8.25E-11	9.78E-10	1.37E-09	9.62E-06	1.78E-05
ST Wall	6.76E-11	1.54E-10	1.29E-09	1.82E-09	9.55E-06	1.77E-05
SI Wall	4.59E-11	1.05E-10	1.08E-09	1.52E-09	9.45E-06	1.75E-05
ULI Wall	5.17E-11	1.18E-10	1.15E-09	1.61E-09	8.48E-06	1.57E-05
LLI Wall	4.90E-11	1.12E-10	1.12E-09	1.58E-09	8.52E-06	1.57E-05
Heart	6.18E-11	1.41E-10	1.24E-09	1.75E-09	8.67E-06	1.60E-05
Kidneys	8.00E-11	1.82E-10	1.34E-09	1.88E-09	8.91E-06	1.65E-05
Liver	6.80E-11	1.55E-10	1.32E-09	1.85E-09	8.85E-06	1.63E-05
Lungs	8.07E-11	1.84E-10	1.48E-09	2.08E-09	9.51E-06	1.76E-05
Ovaries	4.48E-11	1.02E-10	1.04E-09	1.46E-09	8.44E-06	1.56E-05
Pancreas	4.21E-11	9.59E-11	1.05E-09	1.48E-09	8.16E-06	1.51E-05
Skin	1.22E-09	2.79E-09	3.50E-09	4.91E-09	1.75E-05	3.24E-05
Spleen	6.62E-11	1.51E-10	1.32E-09	1.85E-09	8.93E-06	1.65E-05
Testes	2.83E-10	6.44E-10	1.93E-09	2.71E-09	1.02E-05	1.88E-05
Thymus	8.18E-11	1.86E-10	1.41E-09	1.98E-09	9.10E-06	1.68E-05
Thyroid	1.00E-10	2.29E-10	1.42E-09	1.99E-09	8.97E-06	1.66E-05
U Bladder	6.55E-11	1.49E-10	1.25E-09	1.75E-09	8.74E-06	1.61E-05
Uterus	4.35E-11	9.91E-11	1.05E-09	1.48E-09	8.22E-06	1.52E-05
Muscle	1.95E-10	4.45E-10	1.63E-09	2.29E-09	9.62E-06	1.78E-05

Table 11: Average equivalent organs dose (H_T) mSv/y due to U-238, Th-232 and K-40 in Taba Beach

Organ	U-238	Th-232	K-40
R Marrow	1.59E-10	1.54E-09	2.69E-06
Adrenals	1.10E-10	1.35E-09	3.06E-06
B Surface	9.63E-10	6.45E-09	2.74E-06
Brain	1.25E-10	1.57E-09	2.70E-06
Breast	7.74E-10	2.56E-09	2.63E-06
G Bladder	1.06E-10	1.33E-09	2.48E-06
Esophagus	7.66E-11	1.18E-09	2.90E-06
ST Wall	1.43E-10	1.56E-09	2.88E-06
SI Wall	9.71E-11	1.30E-09	2.84E-06
ULI Wall	1.09E-10	1.39E-09	2.55E-06
LLI Wall	1.04E-10	1.35E-09	2.57E-06
Heart	1.31E-10	1.50E-09	2.61E-06
Kidneys	1.69E-10	1.61E-09	2.68E-06
Liver	1.44E-10	1.59E-09	2.66E-06
Lungs	1.71E-10	1.79E-09	2.86E-06
Ovaries	9.49E-11	1.26E-09	2.54E-06
Pancreas	8.90E-11	1.27E-09	2.46E-06
Skin	2.59E-09	4.22E-09	5.27E-06
Spleen	1.40E-10	1.59E-09	2.69E-06
Testes	5.98E-10	2.33E-09	3.06E-06
Thymus	1.73E-10	1.70E-09	2.74E-06
Thyroid	2.12E-10	1.71E-09	2.70E-06
U Bladder	1.39E-10	1.51E-09	2.63E-06
Uterus	9.20E-11	1.27E-09	2.48E-06
Muscle	4.13E-10	1.96E-09	2.90E-06

Table 12: Minimum and maximum equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Hurguda Beach

Hurguda	U-238		Th-232		K-40	
Organ	Min	Max	Min	Max	Min	Max
R Marrow	2.74E-11	5.26E-11	8.52E-11	3.43E-10	1.83E-05	3.10E-05
Adrenals	1.90E-11	3.64E-11	7.43E-11	2.99E-10	2.09E-05	3.53E-05
B Surface	1.66E-10	3.19E-10	3.55E-10	1.43E-09	1.87E-05	3.16E-05
Brain	2.15E-11	4.13E-11	8.64E-11	3.48E-10	1.84E-05	3.11E-05
Breast	1.33E-10	2.56E-10	1.41E-10	5.68E-10	1.79E-05	3.03E-05
G Bladder	1.82E-11	3.50E-11	7.34E-11	2.96E-10	1.69E-05	2.85E-05
Esophagus	1.32E-11	2.53E-11	6.50E-11	2.62E-10	1.97E-05	3.33E-05
ST Wall	2.46E-11	4.73E-11	8.60E-11	3.46E-10	1.96E-05	3.31E-05
SI Wall	1.67E-11	3.21E-11	7.17E-11	2.89E-10	1.94E-05	3.27E-05
ULI Wall	1.89E-11	3.62E-11	7.63E-11	3.08E-10	1.74E-05	2.94E-05
LLI Wall	1.78E-11	3.43E-11	7.47E-11	3.01E-10	1.75E-05	2.95E-05
Heart	2.25E-11	4.32E-11	8.26E-11	3.33E-10	1.78E-05	3.01E-05
Kidneys	2.92E-11	5.60E-11	8.89E-11	3.58E-10	1.83E-05	3.09E-05
Liver	2.48E-11	4.75E-11	8.77E-11	3.53E-10	1.81E-05	3.07E-05
Lungs	2.94E-11	5.65E-11	9.86E-11	3.97E-10	1.95E-05	3.30E-05
Ovaries	1.63E-11	3.14E-11	6.92E-11	2.79E-10	1.73E-05	2.92E-05
Pancreas	1.53E-11	2.94E-11	7.01E-11	2.82E-10	1.67E-05	2.83E-05
Skin	4.46E-10	8.57E-10	2.32E-10	9.36E-10	3.59E-05	6.07E-05
Spleen	2.41E-11	4.63E-11	8.77E-11	3.53E-10	1.83E-05	3.10E-05
Testes	1.03E-10	1.98E-10	1.28E-10	5.17E-10	2.09E-05	3.53E-05
Thymus	2.98E-11	5.72E-11	9.40E-11	3.79E-10	1.87E-05	3.16E-05
Thyroid	3.66E-11	7.02E-11	9.44E-11	3.80E-10	1.84E-05	3.11E-05
U Bladder	2.39E-11	4.58E-11	8.31E-11	3.35E-10	1.79E-05	3.03E-05
Uterus	1.58E-11	3.04E-11	7.01E-11	2.82E-10	1.69E-05	2.85E-05
Muscle	7.11E-11	1.37E-10	1.08E-10	4.36E-10	1.97E-05	3.33E-05

Table 13: Average equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Hurguda Beach

Organ	U-238	Th-232	K-40
R Marrow	3.33E-11	2.23E-10	2.57E-05
Adrenals	2.31E-11	1.94E-10	2.92E-05
B Surface	2.02E-10	9.29E-10	2.62E-05
Brain	2.61E-11	2.26E-10	2.58E-05
Breast	1.62E-10	3.68E-10	2.51E-05
G Bladder	2.22E-11	1.92E-10	2.36E-05
Esophagus	1.60E-11	1.70E-10	2.76E-05
ST Wall	2.99E-11	2.25E-10	2.74E-05
SI Wall	2.03E-11	1.87E-10	2.71E-05
ULI Wall	2.29E-11	2.00E-10	2.44E-05
LLI Wall	2.17E-11	1.95E-10	2.45E-05
Heart	2.73E-11	2.16E-10	2.49E-05
Kidneys	3.54E-11	2.32E-10	2.56E-05
Liver	3.01E-11	2.29E-10	2.54E-05
Lungs	3.58E-11	2.58E-10	2.73E-05
Ovaries	1.99E-11	1.81E-10	2.42E-05
Pancreas	1.86E-11	1.83E-10	2.34E-05
Skin	5.42E-10	6.07E-10	5.03E-05
Spleen	2.93E-11	2.29E-10	2.57E-05
Testes	1.25E-10	3.36E-10	2.92E-05
Thymus	3.62E-11	2.46E-10	2.62E-05
Thyroid	4.45E-11	2.47E-10	2.58E-05
U Bladder	2.90E-11	2.17E-10	2.51E-05
Uterus	1.93E-11	1.83E-10	2.36E-05
Muscle	8.65E-11	2.83E-10	2.76E-05

Table 14: Minimum and maximum equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Ain Sokhna Beach

	U-238		Th-232		K-40	
Organ	Min	Max	Min	Max	Min	Max
R Marrow	3.04E-11	3.84E-11	1.42E-10	3.61E-10	5.58E-07	1.10E-06
Adrenals	2.11E-11	2.66E-11	1.24E-10	3.15E-10	6.36E-07	1.26E-06
B Surface	1.84E-10	2.32E-10	5.92E-10	1.51E-09	5.69E-07	1.13E-06
Brain	2.39E-11	3.01E-11	1.44E-10	3.66E-10	5.61E-07	1.11E-06
Breast	1.48E-10	1.87E-10	2.35E-10	5.97E-10	5.46E-07	1.08E-06
G Bladder	2.02E-11	2.55E-11	1.22E-10	3.11E-10	5.14E-07	1.02E-06
Esophagus	1.46E-11	1.85E-11	1.08E-10	2.75E-10	6.01E-07	1.19E-06
ST Wall	2.73E-11	3.45E-11	1.43E-10	3.64E-10	5.97E-07	1.18E-06
SI Wall	1.86E-11	2.34E-11	1.20E-10	3.04E-10	5.90E-07	1.17E-06
ULI Wall	2.09E-11	2.64E-11	1.27E-10	3.23E-10	5.30E-07	1.05E-06
LLI Wall	1.98E-11	2.50E-11	1.24E-10	3.16E-10	5.33E-07	1.05E-06
Heart	2.50E-11	3.15E-11	1.38E-10	3.50E-10	5.42E-07	1.07E-06
Kidneys	3.24E-11	4.08E-11	1.48E-10	3.77E-10	5.57E-07	1.10E-06
Liver	2.75E-11	3.47E-11	1.46E-10	3.71E-10	5.53E-07	1.09E-06
Lungs	3.26E-11	4.12E-11	1.64E-10	4.18E-10	5.95E-07	1.18E-06
Ovaries	1.81E-11	2.29E-11	1.15E-10	2.93E-10	5.27E-07	1.04E-06
Pancreas	1.70E-11	2.15E-11	1.17E-10	2.97E-10	5.10E-07	1.01E-06
Skin	4.95E-10	6.25E-10	3.87E-10	9.84E-10	1.10E-06	2.17E-06
Spleen	2.68E-11	3.38E-11	1.46E-10	3.71E-10	5.58E-07	1.10E-06
Testes	1.14E-10	1.44E-10	2.14E-10	5.44E-10	6.36E-07	1.26E-06
Thymus	3.31E-11	4.17E-11	1.57E-10	3.98E-10	5.69E-07	1.13E-06
Thyroid	4.06E-11	5.12E-11	1.57E-10	4.00E-10	5.61E-07	1.11E-06
U Bladder	2.65E-11	3.34E-11	1.38E-10	3.52E-10	5.46E-07	1.08E-06
Uterus	1.76E-11	2.22E-11	1.17E-10	2.97E-10	5.14E-07	1.02E-06
Muscle	7.90E-11	9.96E-11	1.80E-10	4.58E-10	6.01E-07	1.19E-06

Table 15: Average equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Ain Sokhna Beach

Organ Ain Sokhna	U-238	Th-232	K-40
R Marrow	3.52E-11	2.50E-10	1.01E-06
Adrenals	2.44E-11	2.18E-10	1.15E-06
B Surface	2.13E-10	1.04E-09	1.03E-06
Brain	2.76E-11	2.54E-10	1.02E-06
Breast	1.71E-10	4.14E-10	9.90E-07
G Bladder	2.34E-11	2.16E-10	9.31E-07
Esophagus	1.69E-11	1.91E-10	1.09E-06
ST Wall	3.16E-11	2.53E-10	1.08E-06
SI Wall	2.15E-11	2.11E-10	1.07E-06
ULI Wall	2.42E-11	2.24E-10	9.61E-07
LLI Wall	2.29E-11	2.19E-10	9.65E-07
Heart	2.89E-11	2.43E-10	9.82E-07
Kidneys	3.74E-11	2.61E-10	1.01E-06
Liver	3.18E-11	2.58E-10	1.00E-06
Lungs	3.77E-11	2.90E-10	1.08E-06
Ovaries	2.10E-11	2.03E-10	9.56E-07
Pancreas	1.97E-11	2.06E-10	9.24E-07
Skin	5.73E-10	6.83E-10	1.98E-06
Spleen	3.10E-11	2.58E-10	1.01E-06
Testes	1.32E-10	3.77E-10	1.15E-06
Thymus	3.82E-11	2.76E-10	1.03E-06
Thyroid	4.69E-11	2.77E-10	1.02E-06
U Bladder	3.07E-11	2.44E-10	9.90E-07
Uterus	2.03E-11	2.06E-10	9.31E-07
Muscle	9.13E-11	3.18E-10	1.09E-06

Table 16: Minimum and maximum equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Gamasa Beach

Gamasa	U-238		Th-232		K-40	
Organ	Min	Max	Min	Max	Min	Max
R Marrow	7.81E-12	1.93E-11	3.46E-11	1.32E-10	7.31E-06	9.43E-06
Adrenals	5.41E-12	1.34E-11	3.02E-11	1.15E-10	8.33E-06	1.08E-05
B Surface	4.73E-11	1.17E-10	1.44E-10	5.49E-10	7.45E-06	9.62E-06
Brain	6.12E-12	1.52E-11	3.51E-11	1.33E-10	7.34E-06	9.48E-06
Breast	3.80E-11	9.40E-11	5.73E-11	2.18E-10	7.15E-06	9.23E-06
G Bladder	5.19E-12	1.29E-11	2.98E-11	1.13E-10	6.73E-06	8.69E-06
Esophagus	3.76E-12	9.31E-12	2.64E-11	1.00E-10	7.87E-06	1.02E-05
ST Wall	7.02E-12	1.74E-11	3.50E-11	1.33E-10	7.82E-06	1.01E-05
SI Wall	4.76E-12	1.18E-11	2.92E-11	1.11E-10	7.73E-06	9.98E-06
ULI Wall	5.37E-12	1.33E-11	3.10E-11	1.18E-10	6.94E-06	8.96E-06
LLI Wall	5.09E-12	1.26E-11	3.04E-11	1.15E-10	6.97E-06	9.00E-06
Heart	6.41E-12	1.59E-11	3.36E-11	1.28E-10	7.10E-06	9.16E-06
Kidneys	8.31E-12	2.06E-11	3.62E-11	1.37E-10	7.29E-06	9.41E-06
Liver	7.05E-12	1.75E-11	3.56E-11	1.35E-10	7.24E-06	9.34E-06
Lungs	8.38E-12	2.07E-11	4.01E-11	1.52E-10	7.78E-06	1.00E-05
Ovaries	4.66E-12	1.15E-11	2.81E-11	1.07E-10	6.90E-06	8.91E-06
Pancreas	4.37E-12	1.08E-11	2.85E-11	1.08E-10	6.67E-06	8.62E-06
Skin	1.27E-10	3.15E-10	9.45E-11	3.59E-10	1.43E-05	1.85E-05
Spleen	6.88E-12	1.70E-11	3.56E-11	1.35E-10	7.31E-06	9.43E-06
Testes	2.93E-11	7.26E-11	5.22E-11	1.98E-10	8.33E-06	1.08E-05
Thymus	8.49E-12	2.10E-11	3.82E-11	1.45E-10	7.45E-06	9.62E-06
Thyroid	1.04E-11	2.58E-11	3.84E-11	1.46E-10	7.34E-06	9.48E-06
U Bladder	6.80E-12	1.68E-11	3.38E-11	1.28E-10	7.15E-06	9.23E-06
Uterus	4.51E-12	1.12E-11	2.85E-11	1.08E-10	6.73E-06	8.69E-06
Muscle	2.03E-11	5.02E-11	4.40E-11	1.67E-10	7.87E-06	1.02E-05

Table 17: Average equivalent organs dose (H_T) mSv/y due to U-238, Th-232 series and K-40 in Gamasa Beach.

Organ Gamasa	U-238	Th-232	K-40
R Marrow	1.32E-11	6.92E-11	8.70E-06
Adrenals	9.12E-12	6.04E-11	9.91E-06
B Surface	7.97E-11	2.89E-10	8.86E-06
Brain	1.03E-11	7.03E-11	8.74E-06
Breast	6.40E-11	1.15E-10	8.51E-06
G Bladder	8.75E-12	5.97E-11	8.01E-06
Esophagus	6.34E-12	5.29E-11	9.37E-06
ST Wall	1.18E-11	6.99E-11	9.30E-06
SI Wall	8.03E-12	5.83E-11	9.20E-06
ULI Wall	9.05E-12	6.21E-11	8.26E-06
LLI Wall	8.57E-12	6.07E-11	8.30E-06
Heart	1.08E-11	6.72E-11	8.45E-06
Kidneys	1.40E-11	7.23E-11	8.68E-06
Liver	1.19E-11	7.13E-11	8.61E-06
Lungs	1.41E-11	8.01E-11	9.26E-06
Ovaries	7.85E-12	5.63E-11	8.22E-06
Pancreas	7.36E-12	5.70E-11	7.94E-06
Skin	2.14E-10	1.89E-10	1.71E-05
Spleen	1.16E-11	7.13E-11	8.70E-06
Testes	4.94E-11	1.04E-10	9.91E-06
Thymus	1.43E-11	7.64E-11	8.86E-06
Thyroid	1.76E-11	7.67E-11	8.74E-06
U Bladder	1.15E-11	6.75E-11	8.51E-06
Uterus	7.61E-12	5.70E-11	8.01E-06
Muscle	3.42E-11	8.80E-11	9.37E-06

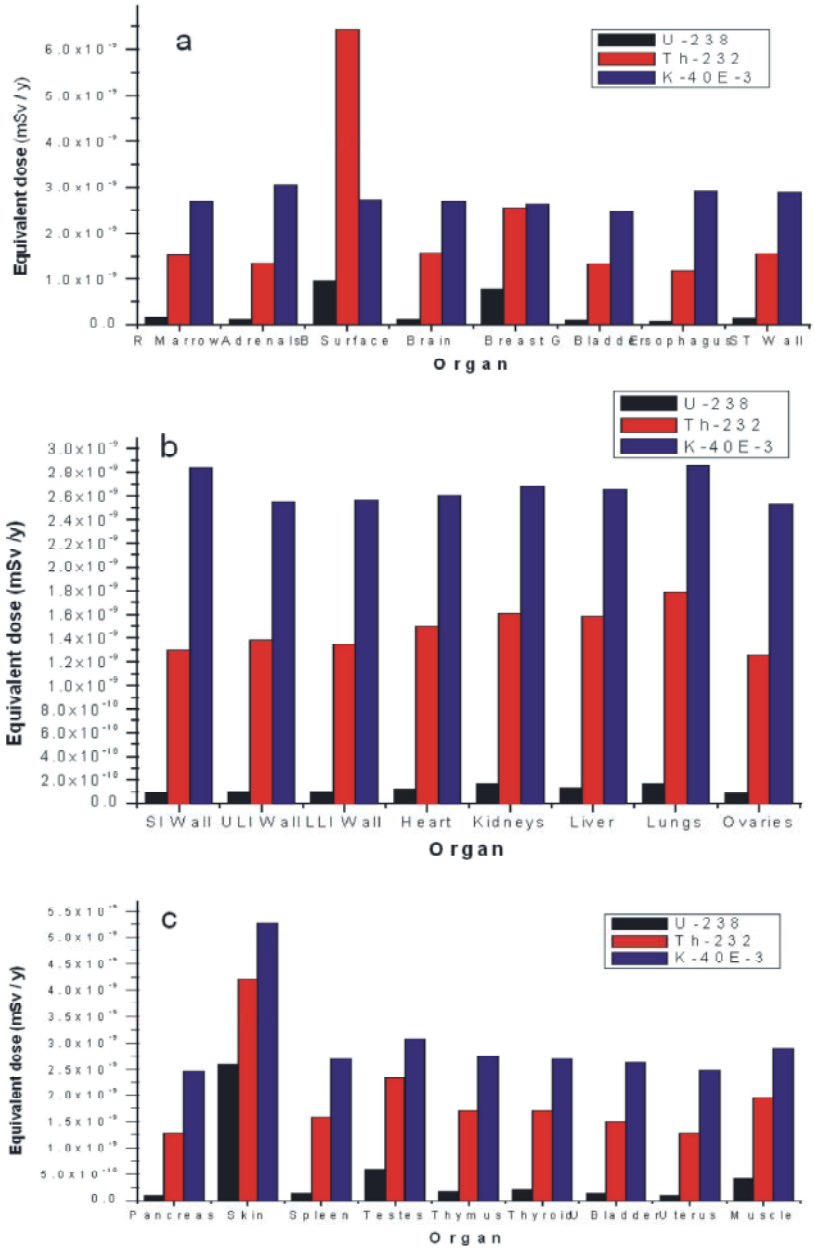

Fig. 3(a, b, c): Average equivalent organs dose (H_T) mSv/y due to U-238 and Th-232 series and K-40 (which multiplied by E-3) for Taba Beach.

none of the studied beaches were considered as a radiological risk. So the external exposure to workers in these sites is in permissible limits and hence the external exposure to public is very low.

Minimum and maximum equivalent organs dose (H_T) and average H_T due to U-238, Th-232 series and K-40 in some locations were presented in Tables 10 - 17. From these Tables we can conclude that, the highest equivalent dose would be received by the skin and the lowest received by oesophagus due to ^{238}U series, ^{232} Th series lead to bone surface highest equivalent dose and lowest to pancreas, while the highest equivalent dose would be received by the skin and the lowest received by oesophagus due to ^{40}K.

Figs. 3 (a, b, c) illustrate average equivalent organs dose (H_T) mSv/y for Taba beach due to U-238, Th-232 series and K-40. Table 18, shows the effective dose due to the three natural radio-activities in all locations.

Table 18: Effective dose due to natural radioactivity in different locations (mSv/y)

location	U-238	Th-232	K-40
Taba:			
Range	1.47E-10 - 3.35E-10	1.53E-09 – 2.23E-09	9.45E-06 - 1.75E-05
Average	3.11E-10	1.84E-09	2.84E-06
Hurguda:			
Range	5.35E-11 - 1.03E-10	1.02E-10 - 4.09E-10	1.94E-05 - 3.27E-05
Average	6.51E-11	2.65E-10	2.71E-05
Ras Sedr:			
Range	3.7E-11 – 9.37E-11	4.62E-11 – 2.26E-10	5.63E-06 – 7.73E-06
Average	6.16E-11	1.41E-10	6.49E-06
Ain Sokhna:			
Range	5.94E-11- 7.50E-11	1.69E-10 - 4.30E-10	5.90E-07 - 1.17E-06
Average	6.87E-11	2.98E-10	1.07E-06
Mersa Matrouh:			
Range	5.16E-11 - 1.73E-10	5.53E-11- 2.35E-10	2.00E-07- 4.50E-07
Average	5.89E-11	1.10E-10	2.69E-07
Gamasa:			
Range	1.53E-11 - 3.78E-11	4.13E-11 - 1.57E-10	7.73E-06 - 9.98E-06
Average	2.57E-11	8.25E-11	9.20E-06
Average Range	2.57E-11- 3.11E-10	8.25E-11 – 1.84E-09	2.69E-07– 2.71E-05

Table 19: Total Committed dose due to natural radioactivity in different locations (mSv/y)

location	U-238	Th-232	K-40
Taba:			
Range	1.82E-10 - 4.15E-10	1.59E-09 - 2.23E-09	9.55E-06 - 1.77E-05
Average	3.85E-10	1.92E-09	2.88E-06
Hurguda:			
Range	6.64E-11 - 1.27E-10	1.06E-10 - 4.26E-10	1.96E-05 - 3.31E-05
Average	8.07E-11	2.76E-10	2.74E-05
Ras Sedr:			
Range	4.58E-11-1.16E-10	4.81E-11-2.35E-10	5.09E-06-7.82E-06
Average	7.64E-11	1.47E-10	6.56E-06
Ain Sokhna:			
Range	7.37E-11- 9.29E-11	1.76E-10 - 4.48E-10	5.97E-07 - 1.18E-06
Average	8.52E-11	3.11E-10	1.08E-06
Mersa Matrouh:			
Range	6.39E-11 - 2.14E-10	5.76E-11 - 2.45E-10	2.00E-07 - 4.55E-07
Average	7.30E-11	1.15E-10	2.72E-07
Gamasa:			
Range	1.89E-11 - 4.68E-11	4.30E-11 - 1.63E-10	7.82E-06 - 1.01E-05
Average	3.19E-11	8.59E-11	9.30E-06
Average Range	3.19E-11-3.85E-10	8.59E-11-1.92E-09	2.72E-07-2.74E-05

The calculated values show that Taba beach which has the highest U-238 and Th-232 activity concentration was calculated and it was 1.75E-05 mSv/y. Hurguda beach shows the highest effective dose due to K-40. The total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, for different beaches was calculated as shown in Table 19.

CONCLUSIONS

Activity concentration levels of the naturally occurring radionuclides were found to be ranged over 3.54-42.8, 2-44.63 and 3.59-361.7 Bq/kg for ^{238}U, ^{232}Th series and ^{40}K respectively for the different beaches. Taba beach shows the highest activity concentration in ^{238}U and ^{232}Th series with average of 42.8 and 44.63 Bq/kg respectively. Hurguda beach shows the highest K-40 activity concentration with average of 361.7 Bq/kg. Gamasa beach has the lowest activity concentration for U-238 and Th-232 with average of 3.54 and 2 Bq/kg respectively, while the lowest K-40 activity concentration was represented by Mersa Matrouh beach with average of 3.59 Bq/kg.

Exposure rate was found to be ranged over 0.19 to 2.26, 0.14 to 3.15 and 0.02 to 1.74 (μR/h) for U-238, Th-232 and k-40 respectively. Absorbed dose was found to be ranged over 1.63 to 19.67, 1.23 to 27.42 and 0.15 to 15.1 nGy/h for U-238, Th-232 series and K-40 respectively. The annual effective dose (mSv/y) to man due to ^{238}U series, ^{232}Th series and ^{40}K was estimated and found to be ranged from 1.53E-11 to 3.35E-10, 4.13E-11 to 2.23E-09 and 2.0E-07 to 3.27E-05 mSv/y for different locations. Equivalent doses to all organs due to the three natural radioactive series were calculated. These calculations showed that the highest equivalent dose would be received by the skin and the lowest received by oesophagus due to ^{238}U series, ^{232}Th series lead to bone surface highest equivalent dose and lowest to pancreas, while the highest equivalent dose would be received by the skin and the lowest received by oesophagus due to ^{40}K. Total effective dose to all organs, due to the three natural radionuclides for Taba beach which has the highest activity concentration, was calculated and it was 1.75E-05 mSv/y and the total committed dose equivalent for the remainder tissues, H_{com} due to all radionuclides, for the same beach was calculated as 2.882E-06 mSv/y. Water samples for all beaches show activity concentration below minimum significant activity. Finally we can conclude that, none of the studied beaches were considered as a radiological risk.

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