Measurement of natural radioactivity in the sediments of the beaches of the north east coast of Libya

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Abstract: In this study, we measured radiological hazards associated with beach sediments in the coastal area near the city of Al-Bayda, Libya. Radiation risk was assessed by estimating radium equivalent activity (Req), absorbed dose rate (D_R), and annual effective dose rate (AED_R). As well as the external health risks(H_{ex}) of the sediment samples collected. We Studies of naturally emitted gamma rays from the three radionuclides ^{226}Ra, ^{232}Th and ^{40} K. It was found that the average values of radioactivity were 8.26 Bq/Kg, 5.95 Bq/Kg and 66.1 Bq/Kg, respectively.

Gamma ray measurement was performed using the NaI (Tl) crystal detector technology. results indicates that the concentration of radioactivity corresponds to other countries of different regions the world. furthermore, radium equivalent activity (Req), absorbed dose rates (D_R), and annual effective dose rate (AED_R), as well as external health risks (Hex) below average global values..

Keywords: Radiological hazards; Beach sediments; Gamma ray.

1. Introduction:

Natural radiation comprises cosmic radiation and the radiation arising from the decay of naturally occurring radionuclides. The natural radionuclides include the primordial radioactive elements in the earth's crust such as ^{235}U, ^{238}U and their radioactive decay products as well as ^{40}K [1]. Human beings and other organisms are exposed to these natural radiations. Human beings should be cautious and alert to the dangers of their natural environment with regard to the radiation health effects [2].

Natural radioactivity is wide spread in the earth's environment and it exists in various geological formation such as sediments. Sediment is a naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind and/or water [3].

Beach sediment is mineral deposits formed through weathering and erosion of either igneous or metamorphic rocks [4]. Among the rock constituent minerals are some natural radionuclides that contribute to ionizing radiation exposure on Earth. Natural radioactivity in soils comes from ^{235}U and ^{238}U series and natural ^{40}K. The study of the distribution of primordial radionuclides allows the understanding of the radiological implication of these elements due to the gamma ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters [5].

Moreover, human nuclear activities such as enrichment, nuclear fuel fabrication, and radioactive isotope cause release of additional amounts of natural radionuclides into the environment. This accumulation of such substances have become source of contamination in coastal area and therefore raises many problems concerning safety of human beings [6]. Thus, studying the radioactivity concentration is extremely important.

Human exposure to ionizing radiation is one of the scientific subjects that nowadays attracts public attention due to the fact that radiation of natural origin is responsible for most of the total radiation exposure of the human population [7].

In this paper, we studies the radiological hazards that is associated with beach sediments in the coastal area near the city of Al-Bayda, Libya. We evaluate the radiological hazards by calculating the radium equivalent activity (Req), the absorbed dose rates (DR), the annual effective dose rate (AEDR), as well as the external hazard index (Hex).

2. MATERIAL AND METHODS

The sediment samples of the present study were collected from different locations along the north east coast of Libya as shown in Fig. 1. The collected samples were carried out during the low tide to avoid see water from covering the samples during the high tide [8]. A total of forty-eight sediment samples were randomly collected from the four following suburbs (Al-hanea, Al-hamama, Susa, and Ras El-helal) near Al-Bayda city. Twenty-four samples of which were collected at a depth of 5-10 cm, whereas the other twenty-four samples were collected at a depth of 50-70 cm. From each designated location, we collected twelve samples located 10-15 m away from the high tide that cover a distance of 3 km. Each six of which were collected at depth of 5-10 cm and 50-70 cm. The two different depths study is considered in order to estimate the dependence of the radioactivity on the depth [9].

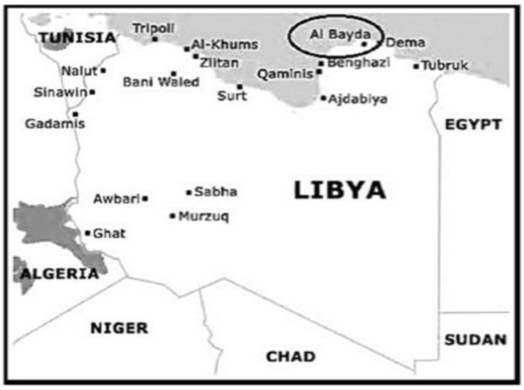

FIG. 1: The map of the study area.

The sediment samples were collected by using a template of 25×25 cm^2. The samples were sieved through a 2 mm mesh-size and dried in vacuum dryer at 110^{o}C for two days [10]. The homogenize sediments were later weighed and transferred to 350 cm^3 marinelli beakers and stored for about four weeks to ensure that the equilibrium between the chain members are attained. .

Radioactivity concentration level of ^{226}Ra, ^{232}Th, and ^{40}K in the collected sediment samples was investigated by using gamma ray spectrometer in the Laboratory of Nuclear Physics at the University of Ain Shams, Egypt. A NaI(Tl) crystal detector based on HPGE of size 3 ×3, active volume 62.3 cm^3, and resolution 1.8 % 30 keV at 1.33 MeV γ-line was used to record gamma spectra [11]. Due to the sensitivity of the HPGE, an appropriate lead shielding with thickness of 5 cm was utilized to reduce the background. The energy calibration of the spectrometer was performed with standard of 350 cm^3 marinelli that contains well known standard sources of (^{22}Na, ^{60}Co, ^{57}Co, and ^{241}Am) [12]. The concentrations of various radionuclides were directly determined by using the count spectra of gamma ray photo peaks corresponding to 1460.75 KeV for ^{40}K and 46.50 KeV for ^{210}Pb. On the other hand, the indirect determination was conducted to estimate gamma-ray peaks that corresponding to the following energies (351.90 KeV ^{210}Pb) and (609.32, 1120.28, and 1764.49 KeV ^{214}Bi) for ^{226}Ra, whereas for ^{232}Th we used the corresponding energies of (338.40 KeV 228Ac), (538.14KeV ^{208}TI) and (911.07, 964.60 and 968.90 KeV ^{228}Ac) [13].

Finally, performed the calculation and the systematic errors study by a ROOT software which was written based on C++. ROOT is an object-oriented program and library developed by CERN [14]. There are several sources of systematic errors study in a measurement. A typical way to estimate their magnitude is by varying the measurement of the signal and extracting its uncertainty. In this study, we evaluate the signal of each element at specific depth several times. The mean values of the resulting signals are the typical final values that we obtained. The width of the resulting variation in the final result is quoted as the systematic error. It is found to be smaller than 5%.

3. CALCULATIONS AND DISCUSSION:

3.1. Activity concentration:

The activity concentration (Bq.kg^{-1}) measurements[15] of the ^{226}Ra ^{232}Th and ^{40}K on the collected sediment samples are listed in table(1). The mean values for the depth of 5-10 cm are (8.26 for ^{226}Ra , 5.95 for ^{232}Th and 66.1 for ^{40}K), whereas for the depth of 50-70 cm are found to be (7.5 for ^{226}Ra , 5.10 for ^{232}Th and 68.6 for ^{40}K). The activities distribution for both depths of 5-10 cm and 50-70 cm for the ^{226}Ra, ^{232}Th and ^{40}K are shown Fig. 2, Fig. 3 and Fig.4 respectively. The wide variations of the activity concentration values are due to their different depths as well as their physical, chemical and geo-chemical properties. The maximum activity concentration of ^{226}Ra and ^{40}K were observed in Ras El-helal, whereas the maximum value of ^{232}Th was observed in Susa. Fig. 5 shows that the mean activity value of ^{226}Ra, ^{232}Th and ^{40}K in our study is lower when compared with worldwide average (35 for ^{226}Ra, 30 for ^{232}Th and 400 for ^{40}K). The figure also indicates that our results are lower than most countries and comparable to those of few randomly selected countries which are listed in table(2).

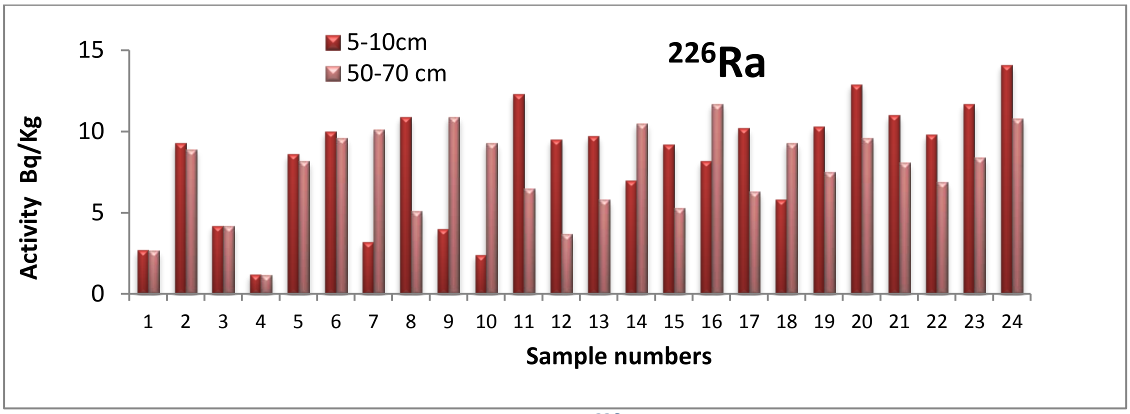

FIG. 2: Activity concentration of ^{226}Ra in sediment samples.

TABLE (1) : Geographical location and activity concentration ($Bq.kg^{-1}$) for ^{226}Ra ^{232}Th and ^{40}K in the collected beach sediment samples of Northeast Coast of Libya at depth 5-10 cm and 50-70cm.

	S.NO	Depth 5-10 cm			Depth 50-70 cm		
		^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
Al-hanea	1	2.70	2.30	22.6	2.67	2.31	15.0
Al-hanea	2	9.30	4.90	73.6	8.90	7.40	72.1
Al-hanea	3	4.20	3.75	24.1	4.17	3.80	16.5
Al-hanea	4	1.20	5.30	21.1	1.17	0.80	13.5
Al-hanea	5	8.60	4.20	72.9	8.20	6.70	71.4
Al-hanea	6	10.0	5.60	74.3	9.60	8.10	72.8
Susa	7	3.20	3.16	23.3	10.1	7.70	69.9
Susa	8	10.9	8.37	75.8	5.10	9.80	62.4
Susa	9	4.00	3.96	24.1	10.9	8.50	70.7
Susa	10	2.40	2.36	22.5	9.30	6.90	69.1
Susa	11	12.3	9.77	77.2	6.50	11.0	63.8
Susa	12	9.50	6.97	75.8	3.70	8.20	61.0
Al-hamama	13	9.70	6.40	68.8	5.80	7.80	66.3
Al-hamama	14	6.99	5.30	85.2	10.5	5.22	72.6
Al-hamama	15	9.20	5.90	68.3	5.30	7.30	65.8
Al-hamama	16	8.20	6.45	86.4	11.7	6.40	73.8
Al-hamama	17	10.2	6.90	69.3	6.30	8.30	66.8
Al-hamama	18	5.80	6.90	84.0	9.30	4.00	71.4
Ras El-helal	19	10.3	7.85	80.5	7.50	4.95	99.4
Ras El-helal	20	12.9	9.40	99.2	9.60	6.20	90.9
Ras El-helal	21	11.0	8.45	81.1	8.10	5.55	100
Ras El-helal	22	9.80	7.25	79.9	6.90	4.35	98.8
Ras El-helal	23	11.7	8.20	98.0	8.40	5.00	89.7
Ras El-helal	24	14.1	10.6	100.4	10.8	7.40	92.1
Average		8.26	5.95	66.1	7.50	5.10	68.6

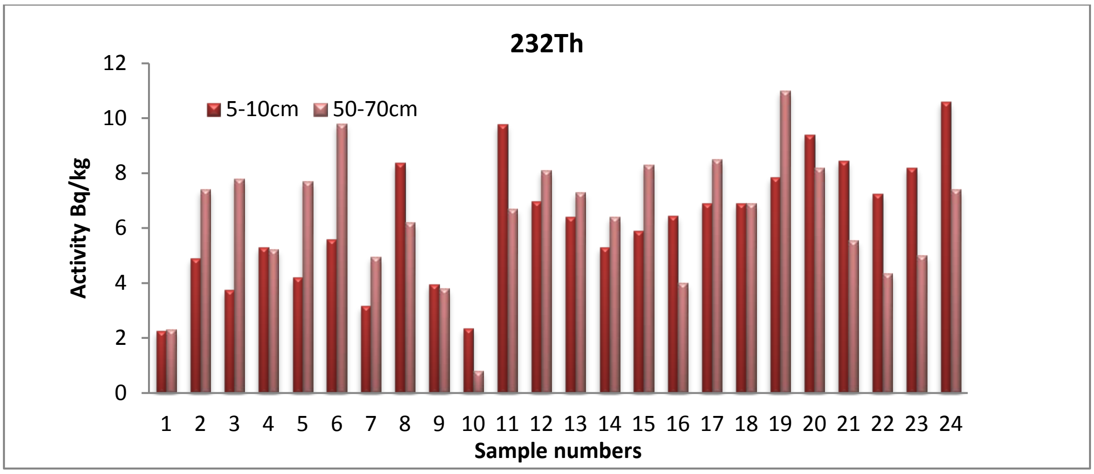

FIG. 3: Activity concentration of ^{232}Th in sediment samples.

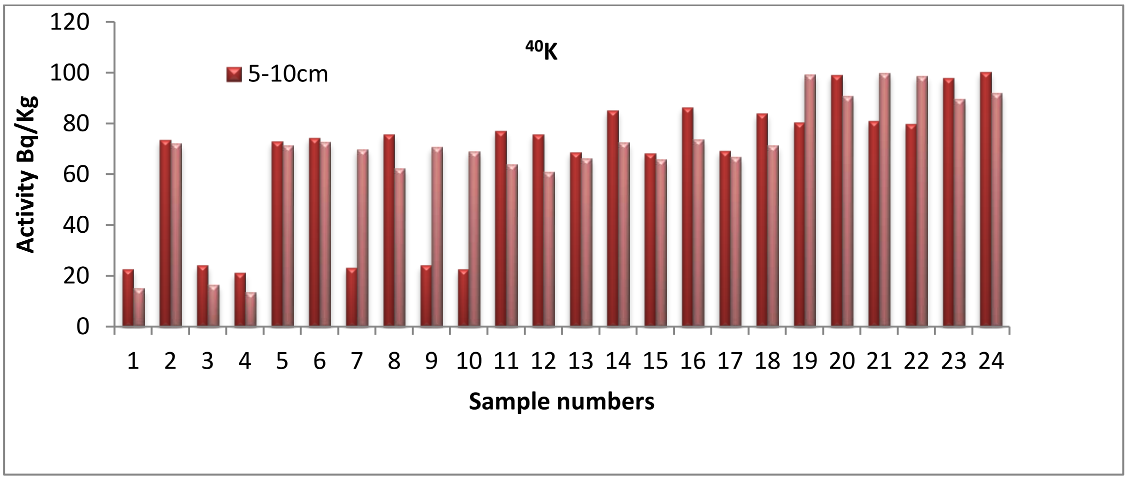

FIG. 4: Activity concentration of ^{40}K in sediment samples.

TABLE (2) : Comparison of average activity concentrations values in (Bq.kg^{-1}) for ^{226}Ra ^{232}Th and ^{40}K in beach sediment samples for different countries.

Country	^{226}Ra	^{232}Th	^{40}K	Reference
Northeast Libya	8.26	5.95	66.1	Present study
Spain	32.0	33.0	470	[17]
World	35.0	30.0	400	[17]
Japan	33.0	28.0	310	[17]
Cost Rica	46.0	`11.0	140	[17]
Algeria	50.0	25.0	370	[17]

3.2 The (^{210}Pb/^{226}Ra) activity ratio:

The activity ratio of (^{210}Pb/^{226}Ra) [16] was calculated at both depths of 5-10 cm and 50-70 cm in order to evaluate the geochemical behavior (Ref12). We randomly selected eight sediment samples at each depth to perform and estimate the activity ratio. The results which are listed in table(3) show that the average activity ratio (^{210}Pb/^{226}Ra) is 1.48 and 1.28 at the depths of 5-10 cm and 50-70 cm respectively. Fig. 6 shows that the beach sediment samples near the surface have higher activity ratio than the bottom collected sediment samples. This variation in the ratios could be due to the presence of varying degrees of disequilibrium between the members of ^{238}U decay series in the coastal marine sediments or some amounts of different pollutants in the sea water.

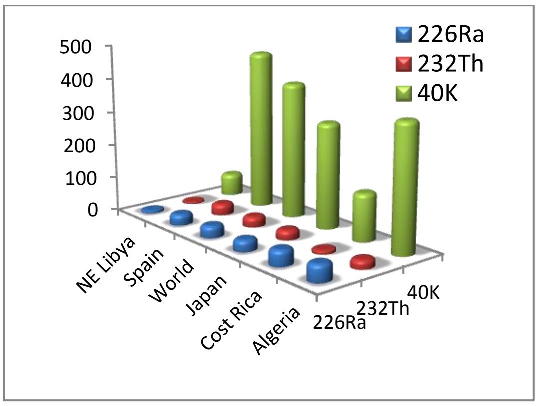

FIG. 5: Comparison of average activity concentrations values in (Bq.kg^{-1}) for ^{226}Ra ^{232}Th and ^{40}K in beach sediment samples for different countries.

TABLE (3): Activity concentration of ^{210}Pb and the activity ratio of ($^{210}Pb/^{226}Ra$) in sediment samples.

S.No	Depth 5-10 cm		Depth 50-70 cm	
	^{210}Pb	$^{210}Pb/^{226}Ra$	^{210}Pb	$^{210}Pb/^{226}Ra$
1	3.80	1.40	3.10	1.16
2	13.9	1.49	11.6	1.30
3	15.5	1.59	8.10	1.39
4	9.80	1.40	12.6	1.20
5	4.80	1.50	13.1	1.29
6	17.4	1.59	7.10	1.39
7	14.5	1.39	9.00	1.20
8	19.4	1.50	12.5	1.30
Average	12.39	1.48	9.64	1.28

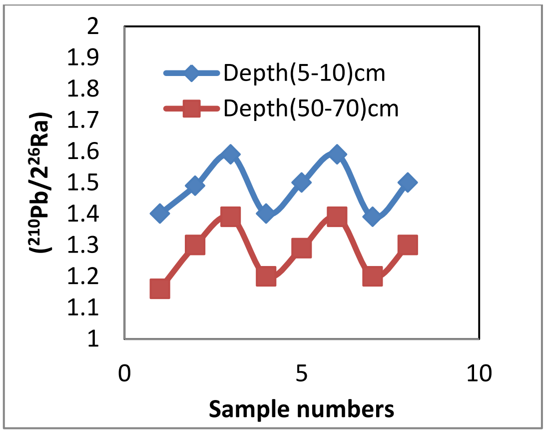

FIG. 6: Comparison of activity ratio of ($^{210}Pb/^{226}Ra$) in sediment samples at depths of 5-10 cm and 50-70 cm

3.3 Radium equivalent activity (Req):

The radium equivalent activity (Req) Bq.kg^{-1} is used as a relative measure of the gamma ray exposure rates and therefore external exposure risk associated with ^{226}Ra, ^{232}Th, and ^{40}K. The radium equivalent activity was calculated according to Eq 1 [17].

$$R_{eq} = A_{Ra} + 1:43A_{Th} + 0:077A_K \qquad (1)$$

Where, A_{Ra}, A_{Th} and A_k are the activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K respectively. As it can be seen from table (4), the radium equivalent values R_{eq} in sediment samples are ranged from 3.912 to 36.99 with mean value of 21.85 at the depth of 5-10 cm, whereas it ranges from 3.354 to 28.474 with mean value of 20.07 at depth the depth 50-70 cm. The R_{eq} mean values in our study (21.85 and 20.07) Bq.kg^{-1} are found to be less than the maximum admissible value of 370 Bq.kg^{-1} [17].

3.4 The absorbed dose rates (D_R):

The absorbed dose rate (D_R) nGh^{-1} describes the amount of radiation absorbed by an object or person which is the amount of energy that radioactive sources such as ^{226}Ra, ^{232}Th, and ^{40}K deposit in materials through which they pass. The DR was calculated according to Eq 2 [17].

$$D=0:462A_{Ra}+0:621A_{Th}+0:0417A_K \qquad (2)$$

Table (4) shows the measured D_R which was calculated from the concentrations of the three radionuclides, ^{226}Ra, ^{232}Th, and ^{40}K. The results are ranged from 1.906 to 17.28 with average of 10.27 at the depth of 5-10 cm, whereas at the depth 50-70 cm are ranged from 1.6 to 13.43 with average of 9.492. The estimated mean values in our study are lower than the world average absorbed dose rate of 84 nG.h^{-1} [17].

3.5 Annual effective dose rates (AED_R):

The annual effective dose rates (AED_R) mSv .y^{-1} takes into account the object being irradiated and the type of radiation. The AED_R was calculated by the following Eq 3 [17].

$$AED_R = D \times 8760h \times 0:2 \times 0:7SvGy^{-1} \times 10^{-6} \quad (3)$$

As it can be seen in table(4), the corresponding AED_R measurements are ranged from 0.002 to 0.021 and from 0.002 to 0.016 at the depth of 5-10 cm and 50-70 cm respectively. Therefore, the mean values in our study are found to be (0.013 and 0.012) mSv y^{-1} which is less than the estimated world average value of 0.07 mSv y^{-1} [17].

3.6 External hazard index (Hex):

The natural radioactivity present in the environment is the main source of radiation exposure for humans. The primary contributors to external exposure from gamma rays are ^{226}Ra, ^{232}Th, and ^{40}K. The activity of these nuclides is converted into a single quantity named as external hazard index(H_{ex}). This H_{ex} index value must be less than unity in order to keep the radiation hazard to be insignificant. The H_{ex} was evaluated according to Eq 4 [17].

$$H_{ex} = \frac{A_{Th}}{259} + \frac{A_{Ra}}{370} + \frac{A_K}{4810} \qquad (4)$$

Our Hex results in this study, which can be found in table (4), are ranged from 0.011 to 0.099 with average value of 0.059 at depth of 5-10 cm, whereas, it ranges from 0.009 to 0.076 with average value of 0.054 at the bottom depth of 50-70 cm. The two estimated average values are found to be significantly less than unity which is the recommended limit according to Radiation Protection 112 and UNSCEAR, 2000 report [17]

TABLE (4) : Values of radium equivalent (R_{eq}), external hazard index (H_{ex}), absorbed dose rate (D_R), and the annual effective dose rate (AED_R) at depth of 5-10cm and 50-70cm.

Symbols	Depth 5-10 cm			Depth 50-70 cm		
	Min	Max	Average	Min	Max	Average
$\mathbf{R_{eq}}$	3.912	36.98	21.85	3.354	28.47	20.07
$\mathbf{D_R}$	1.906	17.28	10.27	1.600	13.43	9.492
$\mathbf{AED_R}$	0.002	0.021	0.013	0.002	0.016	0.012
$\mathbf{H_{ex}}$	0.011	0.099	0.059	0.009	0.076	0.054

CONCLUSION:

In summary, the results indicate that the natural radioactivity concentration of ^{226}Ra, ^{232}Th, and ^{40}K in north east coast of Libya is less than the worldwide average. The average values of the radium equivalent activity R_{eq}, absorbed dose rate D_R, and annual effective dose rate AED_R are found to be less than the recommended values. Furthermore, the external hazard index Hex is found to be significantly less than the unity which is the recommended worldwide average. The results therefore indicate that the radiological threat of sediments in north east coast of Libya is negligible and confirm that it is safe to carry out the activities for the human beings.

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قياس النشاط الإشعاعي الطبيعي في رواسب شواطئ الساحل الشمالي الشرقي لليبيا

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الملخص العربي:.

في هذه الدراسة قمنا بقياس الأخطار الإشعاعية المصاحبة لرواسب الشاطئ في المنطقة الساحلية بالقرب من مدينة البيضاء ، ليبيا. تم تقييم مخاطر الإشعاع من خلال تقدير نشاط مكافئ الراديوم (Req) ، ومعدل الجرعة الممتصة (D_R) ، ومعدل الجرعة الفعالة السنوية (AED_R). وكذلك المخاطر الصحية الخارجية (Hex) لعينات الرواسب التي تم جمعها. قمنا بدراسة أشعة جاما المنبعثة بشكل طبيعي من النويدات المشعة الثلاثة من Ra^{226} و Th^{232} و ^{40} K. ووجد أن متوسط قيم النشاط الإشعاعي كان 8.26 Bq / Kg و 5.95 Bq / Kg و 66.1 Bq / Kg على التوالي.

تم إجراء قياس أشعة جاما باستخدام تقنية كاشف الكريستال(NaI (Tl . تشير النتائج إلى أن تركيز النشاط الإشعاعي يتوافق مع بلدان أخرى من مناطق مختلفة للعالم. علاوة على ذلك ، فإن نشاط مكافئ الراديوم (Req) ، ومعدلات الجرعة الممتصة (D_R) ، ومعدل الجرعة الفعالة السنوي (AED_R) ، وكذلك المخاطر الصحية الخارجية (Hex) أقل من متوسط القيم العالمية.

الكلمات المفتاحية: الأخطار الإشعاعية , رواسب الشاطئ , أشعة جاما.