Radiation Science and Technology
2022; 8(1): 5-21
http://www.sciencepublishinggroup.com/j/rst
doi: 10.11648/j.rst.20220801.12
ISSN: 2575-5935 (Print); ISSN: 2575-5943 (Online)

Investigation of Radioactivity Levels and Lead in Soil and Shore Sediment from Port Said, Egypt

Raghda Ahmed Eissa[1], Ashraf Ali Arafat[2, *], Abd Elnaser Ahmed Mansour[1], Mossad EL-Metwally[3]

[1]Physics and Mathematics Engineering Department, Faculty of Engineering, University of Port Said, Port Said, Egypt

[2]Nuclear and Radiological Safety Research Centre, Egyptian Atomic Energy Authority, Cairo, Egypt

[3]Physics Department, Faculty of Science, University of Port Said, Port Said, Egypt

Email address:

ashraf.arafat@eaea.org.eg (A. A. Arafat), ashrafaly2001@yahoo.com (A. A. Arafat)

[*]Corresponding author

To cite this article:

Raghda Ahmed Eissa, Ashraf Ali Arafat, Abd Elnaser Ahmed Mansour, Mossad EL-Metwally. Investigation of Radioactivity Levels and Lead in Soil and Shore Sediment from Port Said, Egypt. *Radiation Science and Technology*. Vol. 8, No. 1, 2022, pp. 5-21. doi: 10.11648/j.rst.20220801.12

Received: March 22, 2022; **Accepted**: April 14, 2022; **Published**: April 22, 2022

Abstract: Soil is one of the foremost vital foundations of life for humans, animals, and plants, so the soil contamination by radionuclides is a dangerous threat of human health. This study investigated the ^{226}Ra, ^{228}Ra, ^{40}K, ^{137}Cs and pb to assess their risks in soil cover of Port Said governorate. So, 41 samples (29 soil samples and 12 shore sediment samples) were collected to cover the districts area, beaches and industrial areas in Port Said governorate. Activity concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs were determined by Hyper-Pure Germanium detector, and their Pearson's coefficient correlations were calculated and to assess the effects of radiation produced from these radionuclides, their hazards indices were estimated. Pb was determined using Ionized coupled plasma optical emission spectroscopy (ICP-OES), Geo-accumulation index (I-geo) and Contamination Factor (CF) were calculated. The activity concentration of soil for ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs ranged from 2.78 to 26.88, BDL to 19.69, BDL to 382.34 and BDL to 1.14 Bq/Kg with average values 11.59, 7.53, 218.77 and 0.25 Bq/Kg respectively. The activity concentrations of shore sediment for ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs ranged from 5.48 to 15.17, BDL to 11.75, BDL to 448.48 and BDL to 1.14 Bq/Kg with average values 10.16, 6.91, 364.23 and 0.38 Bq/Kg respectively. The highest activity concentrations and values of hazard indices are around the industrial facilities in both cases of soil and shore sediment samples as a result of contamination from factories. But the average activity concentration of ^{226}Ra, ^{228}Ra, and ^{40}K in the soil and shore sediment samples are still lower than the worldwide activity concentrations average values and the Egyptian activity concentrations mean values. Also, all values of hazard indices and their average values are below recommended values by UNSCEAR 2000. Geo-accumulation Index (I-geo) and Contamination Factor (CF) for Pb indicated that more than 2 thirds of soil and 80% of shore sediment samples are moderately polluted or considerably contaminated by Pb. Pearson's Correlation indicated that pb from side and ^{226}Ra, ^{228}Ra and ^{40}K from other side may be from different sources.

Keywords: Natural Radioactivity, Hazard Indices, Lead, Geo-accumulation Index, Contamination Factor

1. Introduction

Soil is one of the foremost vital foundations of life for humans, animals, and plants, so the soil contamination is a dangerous threat of human health. Soil contamination is an alarming issue. It has been identified as the third most important threat to soil functions in Europe and Eurasia, fourth in North Africa, fifth in Asia, seventh in the Northwest Pacific, eighth in North America, and ninth in sub-Saharan Africa and Latin America [1]. Soil contamination can be natural or due to human activities [2]. Contamination natural sources are such as volcanic eruptions, earthquakes, and geographical changes [3]. And human activities sources of the soil contamination are Pesticide [2], fertilizers [4], Deforestation [5] and the most important one is the industrial activity [6].

Among the possible sources of industrial pollution are: aluminum production, the manufacturing of paints, fertilizers production, plastics industry, petro-chemicals, detergents, other types of consumable chemicals and burning of fossil fuels [6]. Highly poisonous organic, inorganic, toxic metals and radioactive elements are among the contaminants produced by these industries [7].

The long-lived parents ^{238}U and ^{232}Th identify two decay series that contribute significantly to human exposure to natural radiation. Another series, represented by ^{235}U, has quite little impact. Many of these radioisotopes decay by releasing alpha particles, gamma rays as well as beta particles [8]. However, as a result of nuclear weapon testing, radioactive contamination from nuclear technology or the wastes from the different industries, humans may be exposed to radiation coming from artificially radionuclides such as ^{137}Cs [9].

In terms of public health, the radioactive gases ^{220}Rn (Thoron) and ^{222}Rn (Radon) are members of ^{232}Th and ^{238}U series respectively. They escape from soil and rock into the atmosphere, as well as into the airspace of buildings. Some of their daughter products, which release alpha particles, may be breathed, posing a threat of radiation damage to cells in the lungs, which might cause lung cancer. ^{222}Rn and its daughters are usually more toxic than ^{220}Rn and its daughters, owing to ^{220}Rn's much shorter half-life, which makes decay more possible before emission into the atmosphere [8].

Radionuclides can reach to living organism through the soil, so it is significant to determine the concentrations of radionuclides within it. Radioactivity in the soil is generally essential for creating basic data for future radiation impact assessments, radiation protection, and research [10]. The characterization of radionuclides or radiation sources is the first stage in the environmental dose assessment process.

Lead is used in various applications such as gasoline use, lead battery, cables production, sports equipment, crystalline glass and making TV and computer screen glass to protect watcher from the resulting radiation. Lead is rare in nature and is found in the environment in different concentrations as a result of industrial activities [11]. Lead accumulates in the bodies of aquatic organisms and soil organisms as a result of its entry into the environment through various human activities such as burning solid waste, burning fuel, and industrial processes [12]. When high levels of lead are present in the soil; it may block fundamental soil functions, especially near highways and factories [13].

Lead pollution is the most dangerous form of pollution [14]. Lead is considered one of the four most harmful elements to human health. In the human body lead does not perform important functions but causes significant health damages such a high blood pressure, anemia, brain damage and learning difficulties with children [15].

Port Said government (in northeastern Egypt) at the northern entrance of the Suez Canal, it is bounded by the Mediterranean Sea in the north and by Port Fouad city in the east. Port Said has remarkable industrial activities in different locations in the government. The industrial area in the south of Port Said, there are Spegeco factory for cement and building materials industry, Schlumberger company for petroleum services, port said factory for iron and steel industry, TCI sanmar factory for chemicals and petrochemicals industry, KAPCI 1 and KAPCI 2 factories for coating painting industries, Royal factory for chemicals industry. Other industrial activities are found on the side of the international coastal road, where, Egyptian Propylene & Polypropylene company, Zohr gas field, IPIC company for Piping Industry, mining and welding activities, and Balaeim Petroleum Company. So, monitoring the impact of anthropogenic activities and assessment the pollution levels on the environment of Port Said government is very important.

Many previous studies discussed the radioactivity content in Port Said governorate. For example, ^{226}Ra, ^{228}Ra, ^{40}K, and ^{137}Cs levels and its radiation hazards indices and their relation to heavy metals in the industrial area of Port Said were discussed by Attaia et al 2015 [16]. The radiological impact of two block factories and a chemical factory in the industrial area of Port Said was studied by abozeed et al 2017 [17]. Along the beach of Part Said, environmental monitoring of gamma radiations and its radiological impact were studded by Aziz et al 2020 [18].

In all previous studies, Port Said areas not covered in a good way or not enough samples were collected. So, our study covered all Port Said areas; industrial, beaches, and residential. Comprehensive assessment of soil contamination in Port Said government were achieved by using Hyper-Pure Germanium (HPGe) detector to determine the activity concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs within 41 samples (soil and shore sediments) and inductively coupled plasma-optical emission spectroscopy (ICP-OES) was used for lead analysis. The radiation hazard indices were determined for ^{226}Ra, ^{228}Ra and ^{40}K and Geo-accumulation index (I-geo) and Contamination Factor (CF) were used to investigate the contamination by Pb. The obtained data are recent base line to the radioactivity and Pb in Port Said governorate in addition to the calculated pollution indices are useful in monitoring the contamination in the Port Said governorate from place to place and from time to time.

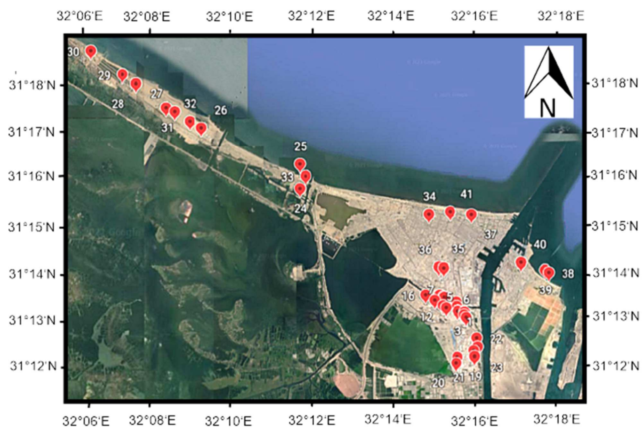

Figure 1. *The map locations of soil and shore sediment samples.*

2. Methodology

2.1. Sampling and Laboratory Preparation

The present study covered all various regions in Port Said government in Egypt by collecting 41 samples (12 shore sediments samples and 29 soil samples) from; Industrial area in south of port Said (Thirteen samples), Manzala Lake (Nine samples), Port Said - Ismailia Road (Two samples), Port Said and Port Fouad Beaches (Four samples), Factories located on the international coastal road (Seven samples), and different residential district (Six samples).

The coordinates of samples locations were carefully identified with its longitude and latitude axes by the Global Positioning System device (GPS, e Trex, Personal Navigator, Garmin Ltd). The description locations of samples of the studied area and its coordinates are presented in table 1. And the locations map of the studied area is presented in figure 1.

Soil and shore sediments samples are collected according to a random and Judgmental sampling design using the template method, 25 × 25 cm^2 area sample and 15 cm depth was cut out. Samples were placed in polyethylene bags and was transported to the lab. At the temperature of 100°C, samples were oven dried even have constant weight (nearly 48 hours). The dried samples were sieved by a sieve of 1mm mesh size.

Table 1. *The description locations of samples of the studied area and its coordinates.*

Samples				Location	Longitude/Latitude
Site		Type	No		
Industrial Area In The South Of Port Said	Around Different Factories	Soil	1	Spegeco Factory for Cement and building materials industry. at 200 m from Raswa exit.	31°13'51.6"N, 32°17'23.0"E
			2		31°13'45.1"N, 32°17'23.7"E
			3	Schlumberger Company for Petroleum Services, 650 m east of the Industrial area.	31°13'37.2"N, 32°17'25.4"E
			4		31°13'38.2"N, 32°17'25.9"E
			5	Port Said factory for Iron and Steel Industry, 700 m from north-east of the Industrial area.	31°13'31.9"N, 32°17'37.0"E
			6		31°13'27.8"N, 32°17'40.6"E
			7	TCI Sanmar for Petrochemical Industries (C9 zone).	31°13'42.6"N, 32°17'04.2"E
			8		31°13'45.9"N, 32°16'58.6"E
	Manzala Lake In Industrial Area In South Of Port Said	Shore Sediments	9	Around TCI Sanmar factory south-east of Manzala Lake.	31°13'58.9"N, 32°17'03.7"E
			10		31°13'58.7"N, 32°17'03.7"E
			11		31°13'59.2"N, 32°17'03.1"E
			12		31°13'58.6"N, 32°17'00.7"E
			13		31°13'59.5"N, 32°16'59.5"E
			14		31°14'01.8"N, 32°16'52.5"E
			15		31°13'54.1"N, 32°16'44.0"E
	Manzala Lake In Industrial Area In South Of Port Said	Shore sediments	16	Around TCI Sanmar factory south-east of Manzala Lake.	31°14'02.1"N, 32°16'27.7"E
	Around Different Factories	Soil	17	KAPCI for coating paints industry, 220 m from starting point of the Industrial area.	31°13'36.2"N, 32°17'37.7"E
			18	Royal for chemicals industries, 2.7 km from east of the Industrial area.	31°12'36.8"N, 32°17'54.1"E
			19		31°12'28.3"N, 32°17'55.5"E
			20	KAPCI 2, factory located at 3.5 km from the Industrial area.	31°12'18.6"N, 32°17'22.7"E
			21		31°12'26.8"N, 32°17'24.6"E
	Ismailia -Port Said Road.	Soil	22	Ismailia -Port Said Road at 5 km and 2 km.	31°12'56.1"N, 32°17'59.2"E
			23		31°12'42.5"N, 32°18'01.0"E
The International Coastal Road	Port Said Beach	Shore Sediment	24	Port Said Beach at 1 km and 5.5 km from Gameil exit.	31°16'44.6"N, 32°12'39.9"E
			25		31°17'21.4"N, 32°12'39.9"E
	Around Different Factories	Soil	26	Egyptian Propylene & Polypropylene Company 7 km of the International Coastal Road.	31°18'17.2"N, 32°09'42.0"E
			27	Zohr Gas Field at 9 km and 10 km of the road.	31°18'42.2"N, 32°08'54.0"E
			28		31°19'24.5"N, 32°07'43.7"E
			29	International Piping Industry Company IPIC, 12 km of the road.	31°19'38.1"N, 32°07'19.1"E
			30	Automatic Welding & Fabrication Pipe spools Workshops, at 16 km of the International Coastal Road And Parallel Pharonic Petrol Company.	31°20'14.2"N, 32°06'22.3"E
			31	The International Coastal Road at 9.5 km.	31°18'48.0"N, 32°08'38.5"E
			32	Balaeim Petroleum Company at 8 km of the road.	31°18'27.1"N, 32°09'21.1"E
	Manzala Lake Along The International Costal Road	Shore Sediment	33	East of Manzala Lake	31°17'03.4"N, 32°12'50.5"E
The Residential Districts	El-Zohor District	Soil	34	EL-Zohor district from Abd Elhady Elhadidy street.	31°16'05.5"N, 32°16'33.7"E
	El-Dawahy District		35	EL-Dawahy District around Henkel Company for Detergents Industry.	31°14'45.2"N, 32°16'51.3"E
			36		31°14'43.9"N, 32°16'59.9"E
	EL-Arab District		37	Al-Arab District in front of Saad Zaghloul Park.	31°16'05.2"N, 32°17'50.2"E
	Port Fouad Beach	Shore Sediment	38	Port Fouad Beach	31°14'37.1"N, 32°20'09.9"E
			39		31°14'40.7"N, 32°20'03.1"E
	Port Fouad District	Soil	40	Port Fouad District (street 25)	31°14'52.2"N, 32°19'19.4"E
			41	El-Manakh District from the center of the district.	31°16'09.3"N, 32°17'11.6"E

NB: Samples from 1 to 23, from 24 to 33 and from 34 to 41 represent the industrial area, the international coastal road and the districts area respectively.

2.2. Sample Preparation for HPGe Detector and Specific Activity Calculation

From the dried, mixed and sieved samples; constant volume of the samples was transported into Marnilli beaker and weighed. The sample's identifying parameters, such as sample location, sample number, net weight, and preparation date, were written on the Marnilli beaker. The Marnilli beakers were sealed tightly with insulating tape for 30 days before measurement. During this period, secular equilibrium will occur between ^{222}Rn and its decay products (^{214}Pb and ^{214}Bi). In the ^{232}Th decay series the radon isotope (^{220}Rn) poses no serious problem because of its short half-life of 55 seconds, ^{40}K and ^{137}Cs are measured directly from their gamma lines [19].

P type HPGe detector was supplied by ORTEC is used to analyze samples with 32% relative efficiency and 1.9 keV energy resolution at 1332 keV photons from ^{60}Co. The spectra of all samples were perfectly analyzed using Gamma vision 5.3 spectra analysis software.

The ^{228}Ra was determined from the average concentrations of ^{228}Ac (338.32, 911, 968.97 keV) and ^{208}Tl (583.19 keV). ^{226}Ra was determined from the average concentration of the ^{214}Pb (351.9 keV) and ^{214}Bi (609.3, 1120, and 1764.5 keV) decay products. ^{137}Cs and ^{40}K were determined from 661.6.8 and 1460 keV, respectively. Marnilli beaker (empty) was counted to determine background spectrum of the germanium detector, and the background was eliminated from the peak areas of the samples.

Checking the accuracy and precision of the measurements by measuring the reference materials IAEA 313, IAEA-326, IAEA-154 and Soil 6. Activity concentrations are presented as Bq/kg for soil and shore sediments samples.

2.3. Soil Preparation for ICP-OES

21 samples (16 soil and 5 shore sediment) were digested according to method 3050B [20]. And the volumes of the digested samples were adjusted to 100 ml with deionized H_2O, filtrated into polyethylene bottles and introduced for lead analysis using ICP-OES.

2.4. Radiation Hazard Indices Calculations

Many publications discussed the radiation hazard indices [21-26]. For shore sediment and soil samples, the following radiation hazard indices are determined:

$$\text{Radium Equivalent Activity } (Ra_{eq});\ Ra_{eq}\ (Bq/Kg) = A_{226Ra} + 1.43\ A_{228Ra} + 0.077\ A_{40K} \quad (1)$$

$$H_{ex}\ (Bq/Kg) = A_{226Ra}/370 + A_{228Ra}/259 + A_{40k}/4810 \quad (2)$$

$$\text{Internal hazard index } (H_{in});\ H_{in}\ (Bq/Kg) = A_{226Ra}/185 + A_{228Ra}/259 + A_{40k}/4810 \quad (3)$$

$$\text{Representative level Index } (I_{\gamma r});\ I_{\gamma}\ (Bq/Kg) = A_{226Ra}/150 + A_{228Ra}/100 + A_{40K}/1500 \quad (4)$$

$$\text{Absorbed gamma dose rate (D); D (nGy/h)} = 0.462\ A_{226Ra} + 0.604\ A_{228Ra} + 0.0417\ A_{40k} \quad (5)$$

$$\text{Annual Effective Dose Equivalent (AEDE) outdoor; AEDE } (\mu Sv/y) = D\ (nGy/h) \times 0.7\ (Sv/Gy) \times 8760\ (h/y) \times 0.2 \times 10^{-3} \quad (6)$$

$$\text{Annual Gonadal Equivalent Dose (AGED); AGED (mSv/y)} = 3.09\ A_{226Ra} + 4.18\ A_{228Ra} + 0.314\ A_{40K} \quad (7)$$

$$\text{Excess Lifetime Cancer Risk (ELCR); ELCER} = AEDE \times DL \times RF \quad (8)$$

Where, A_{226Ra}, A_{228Ra} and A_{40K}, are the activities concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in Bq/kg. DL is the average duration of life (70 years) and RF is the risk factor (Sv), for stochastic effects, for the public RF is 0.05 [27].

2.5. Geo-accumulation Index (I-geo) and Contamination Factor (CF) Calculations

The degree of contamination and state of pollution are described by many terminologies. In this study, Contamination Factor (CF) and Geo-accumulation index (I-geo) are used for assessing the contamination degree of the studied area for lead.

The I-geo was calculated according to the equation [28].

$$I_{geo} = \log_2 (C_n/1.5\ B_n) \quad (9)$$

Where, C_n (ppm) is the concentration of metal, and B_n (ppm) is the geochemical background. We applied modification based on the equation given by Loska, et al., (2004) [29], where B_n is the average concentration of the determined element in earth's crust [30]. The factor 1.5 is used for lithologic variations of trace elements.

Müller (1981) [31] has distinguished six classes of the geo-accumulation index: Unpolluted (Class 0, I-geo < 0); unpolluted to moderated polluted (Class 1, 0 < I-geo < 1); moderately polluted (Class 2, 1 < I-geo < 2), moderately to strongly polluted (Class 3, 2 < I-geo < 3); strongly polluted (Class 4, 3< I-geo<4); strongly to extremely polluted (Class 5, 4 < I-geo < 5); and extremely polluted (Class 6, I-geo > 5).

The contamination factor was calculated according to equation [32].

$$C_f^i = \frac{C_{0-1}^i}{C_n^i} \quad (10)$$

Where C_{0-1}^i is the concentration of the metal i, C_n^i is the background value of the metal. We applied a modification of the factor as applied by Loska, et al., (2004) [29] where C_n^i is the average concentration of elements in the earth's crust [30].

Four contamination categories are documented on the basis of the contamination factor [33]. C_f^i <1 low contamination; $1 \le C_f^i < 3$ moderate contamination; $3 \le C_f^i < 6$ considerable contamination; $C_f^i \ge 6$ very high contamination.

3. Results and Discussions

3.1. Activity Concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs

3.1.1. Activity Concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in Soil

The results for the activity concentrations (dry weight) of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in soil and shore sediment samples of the three studied area were reported in Table 2, and reported as Bq/Kg dry weight.

Soil samples at the Industrial Area in the South of Port Said showed activity concentrations ranged from 8.63 to 14.59 Bq/Kg (11.99 Bq/Kg, in average) for ^{226}Ra, ranged from 5.22 to 10.11 Bq/Kg (8.03 Bq/Kg, in average) for ^{228}Ra, ranged from 93.01 to 382.34 Bq/Kg (260.09 Bq/Kg, in average) for ^{40}K, and ranged from 0.08 to 0.49 Bq/Kg (0.2 Bq/Kg, in average) for ^{137}Cs. Sample number 1 (Spegeco factory for cement and building materials industry) has the highest activity concentration value of ^{226}Ra (14.59 Bq/Kg), Sample number 19 (Royal factory for chemical industry) has the highest activity concentration of ^{228}Ra (10.11Bq/Kg) and sample number 8 (beside TCI Sanmar for Petrochemicals industry) has the highest activities concentrations of ^{40}K (382.34 Bq/Kg) and ^{137}Cs (0.49 Bq/Kg).

Table 2. *Results for the activity concentrations (dry weight) for ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in soil and shore sediment samples.*

Sample No.	Sample site	Sample type	226Ra (Bq/Kg)	228Ra (Bq/Kg)	40K (Bq/Kg)	137Cs (Bq/Kg)	226Ra/228Ra
1	The Industrial Area in South of Port Said.	Soil	14.50±0.30	8.75±0.27	282.81±2.8	0.21±0.07	1.65
2			8.64±0.20	5.20±0.27	93.01±1.7	0.23±0.06	1.66
3			11.87±0.20	8.04±0.39	292.36±2.86	0.17±0.06	1.47
4			12.43±0.20	8.10±0.33	224.03±2.7	0.08±0.1	1.53
5			11.98±0.20	8.14±0.40	315.22±2.0	0.11±0.06	1.47
6			14.05±0.40	9.29±0.43	352.65±3.1	0.31±0.08	1.51
7			13.09±0.20	6.98±0.35	206.48±2.51	0.19±0.07	1.87
8			14.26±0.20	9.33±0.40	382.34±3.5	0.49±0.11	1.52
9		Shore Sediments	9.41±0.03	7.53±0.03	327±0.01	0.43±0.186	1.24
10			10.15±0.20	7.89±0.46	289.68±2.7	0.40±0.20	1.28
11			9.00±0.20	6.75±0.44	299.1±2.9	0.60±0.14	1.33
12			10.86±0.20	11.7±0.40	317.83±3.1	1.14±0.08	0.93
13			10.23±0.03	8.5±0.03	265.3±0.01	0.78±0.11	1.20
14			13.54±0.04	BDL	BDL	BDL	------
15			10.51±0.20	9.28±0.29	310.46±3.1	0.32±0.12	1.13
16			12.45±0.47	8.81±0.86	312.5±5.91	BDL	1.41
17			9.74±0.2	8.68±0.40	340.62±3.0	0.15±0.06	1.12
18		Soil	12.05±0.2	9.40±0.38	287.49±2.72	0.28±0.07	1.28
19			12.06±0.28	10.10±0.30	318.68±3.10	0.23±0.13	1.19
20			10.00±0.03	5.61±0.03	158.2±0.01	0.08±0.76	1.78
21			11.20±0.03	6.78±0.03	188.2±0.01	0.16±0.34	1.65
22			11.70±0.30	9.50±0.32	284.38±3.08	0.35±0.07	1.23
23	The International Coastal Road	Shore Sediments	12.16±0.20	6.62±0.43	174.79±2.1	0.09±0.06	1.83
24			15.10±0.24	11.1±0.44	409.71±3.41	0.35±0.07	1.36
25			9.23±0.19	6.32±0.36	448.48±3.50	0.23±0.07	1.46
26		Soil	9.88±0.23	5.93±0.62	207.61±2.31	0.42±0.10	1.66
27			6.61±0.28	5.921±0.36	128.97±1.97	0.22±0.07	1.11
28			11.98±0.19	8.08±0.30	250.65±2.52	0.09±0.06	1.48
29			26.88±0.28	19.6±1.21	192.60±2.25	1.14±0.09	1.37
30			13.22±0.26	7.93±0.80	231.70±2.67	0.30±0.09	1.66
31			14.53±0.29	11.30±0.34	280.80±2.68	1.06±0.11	1.28
32		Shore Sediments	12.15±0.24	8.03±0.35	206.85±2.30	0.18±0.07	1.51
33			8.51±0.19	6.84±0.32	333.44±3.10	0.66±0.10	1.24
34			8.96±0.22	5.50±0.96	208.99±3.30	0.18±0.08	1.63
35	The Residential Districts	Soil	2.79±0.04	2.10±0.08	43.66±0.02	BDL	1.32
36			8.43±0.26	BDL	BDL	BDL	------
37		Shore Sediments	8.85±0.19	4.80±0.31	123.94±2.13	0.07±0.05	1.84
38			5.40±0.21	BDL	BDL	BDL	------
39			7.67±0.24	5.00±0.27	130.35±2.04	0.09±0.06	1.53
40		Soil	9.66±0.03	6.07±0.05	193.95±0.01	BDL	1.59
41			11.06±0.22	5.26±0.41	154.82±2.34	0.34±0.06	2.10

BDL: below detection limit.

Soil samples of both sides of The International Coastal Road showed activity concentrations ranged from 6.61 to 26.88 Bq/Kg (13.60 Bq/Kg, in average) for ^{226}Ra, ranged from 5.92 to 19.69 Bq/Kg (9.55 Bq/Kg, in average) for ^{228}Ra, ranged from 128.97 to 280.8 Bq/Kg (214.16 Bq/Kg, in average) for ^{40}K, and ranged from 0.085 to 1.14 Bq/Kg (0.48 Bq/Kg, in average) for ^{137}Cs. Sample number 29 (IPIC Company for Piping Industry) has the highest activity concentration value of Ra^{226} (26.88 Bq/Kg), ^{228}Ra (19.69 Bq/Kg), and ^{137}Cs (1.14 Bq/Kg). Sample number 31 (located at kilo 9.5) has the highest activity concentration of ^{40}K (280.8 Bq/Kg).

Soil samples of Residential Districts area showed activity concentrations ranged from 2.78 to 11.06 Bq/Kg (8.29 Bq/Kg, in average) for ^{226}Ra, ranged from BDL to 6.07 Bq/Kg (3.95 Bq/Kg, in average) for ^{228}Ra, ranged from BDL to 208.69 Bq/Kg (120.89 Bq/Kg, in average) for ^{40}K, and ranged from BDL to 0.34 Bq/Kg (0.098 Bq/Kg, in average) for ^{137}Cs. Sample number 41 (El Manakh District) has the highest activity concentration value of ^{226}Ra (11.06 Bq/Kg) and ^{137}Cs (0.34 Bq/Kg). Sample number 40 (located in Port Fouad District) has the highest activity concentration value of ^{228}Ra (6.07 Bq/Kg), and Sample number 34 (located Alzohour district) has the highest activity concentration of ^{40}K (208.69 Bq/Kg).

In the soil samples, the activity concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs for all the three studied areas ranged from 2.78 to 26.88 with an average value 11.59 Bq/Kg, ranged from BDL to 19.69 Bq/Kg with an average value 7.53 Bq/Kg, ranged from BDL to 382.34 Bq/Kg with an average value 218.77 Bq/Kg and ranged from BDL to 1.14 Bq/Kg with an average value 0.25 Bq/Kg respectively. In the soil samples the sample number 29 (IPIC Company for Piping Industry) has the highest activity concentrations (26.88, 19.69 and 1.14Bq/Kg) for ^{226}Ra, ^{228}Ra and Cs^{137} respectively. While, the sample number 8 (beside TCI Sanmar for Petrochemicals Industry) has the highest concentration (382.34 Bq/Kg) for ^{40}K. Our average values are lower than the worldwide activity concentrations average values (35, 30 and 400 Bq/Kg) and the Egyptian activity concentrations mean values (17, 18 and 370 Bq/Kg) for ^{226}Ra, ^{228}Ra, ^{40}K respectively [24]. Previous study on Port Said area introduced by Mona Abozeed et al 2017 [17] showed higher average values (13.74 and 228.23 Bq/Kg) for ^{228}Ra and ^{40}K respectively and lower average value (9.64 Bq/Kg) for ^{226}Ra by comparison with our results.

The soil average specific activity of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs for Port Said area previous studies and various countries are indicated in table 3 for comparison.

Table 3. *Comparison of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs average specific activity of soil samples for various countries.*

Country	Average Activity Concentration (Bq/Kg)				References
	^{226}Ra	^{228}Ra	^{40}K	^{137}Cs	
Port Said (Egypt)	11.59	7.53	218.77	0.25	Current work
Port said	9.64	13.74	228.23	-----	[17]
Gabal El Khashab and from Sinai (Egypt)	94.93	80.21	700.79	-----	[34]
Iron and Steel factoriesin different locations in Egypt	16.8	10.62	154.35	BDL	[35]
Rashid area Egypt	111.24	140.38	474.68	-----	[36]
Alexandria Egypt	16.43	18.31	268.16	7.24	[37]
MarsaAlam-Shalateen area, Red Sea (Egypt)	18.45	16.78	334.35	-----	[38]
Abu Zaabal (Egypt)	7.7	10.1	9.18	1.26	[39]
Shebeen (Egypt)	10.1	11.7	136	1.63	[39]
Qattamia region (Egypt)	23.66	13.95	146.33	4.37	[40]
Abha city (Saudi Arabia)	38.67	23.49	217.87	----	[41]
Bethlehem Province (Palestine)	41.4	19.5	113.3	2.8	[42]
Kurdistan Region (Iraq)	0.100	0.076	0.429	0.30	[43]
Panipat city (India)	30.24	29.89	291.06	-----	[44]
Rize Province (Turkey)	24.5	51.8	344.9	26.3	[45]
Richards Bay (South Africa)	28.28	31.5	0.013	-----	[46]
Fraser's Hill (Malaysia)	106.36	211.47	709.23	-----	[47]
Southern Serbia	45	50	651	10	[48]
Istanbul (Turkey)	21	37	342	------	[49]
Fars Province (Iran)	26.3	14.9	271	6.37	[50]
Worldwide an average values	33	45	412		[51]

3.1.2. Activity Concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in Shore Sediment Samples

All shore sediment samples of the industrial area in the south of Port Said located around TCI sanmar for petrochemicals factory and showed activity concentrations ranged from 9 to 13.54 Bq/Kg (10.76 Bq/Kg, in average) for ^{226}Ra, ranged from BDL to 11.75 Bq/Kg (7.56 Bq/Kg, in average) for ^{228}Ra, ranged from BDL to 327.16 Bq/Kg (265.25 Bq/Kg, in average) for ^{40}K, and ranged from BDL to 1.14 Bq/Kg (0.46 Bq/Kg, in average) for ^{137}Cs. Sample no 12 has the highest values (11.75 and 1.14 Bq/Kg) for ^{228}Ra and ^{137}Cs respectively. Sample no 14 has the highest value (13.54 Bq/Kg) of ^{226}Ra and sample number 9 has the highest activity concentration of ^{40}K (327.16 Bq/Kg).

Shore sediment samples of the International Coastal Road showed activity concentrations ranged from 8.51 to 15.17 Bq/Kg (10.97 Bq/Kg, in average) for ^{226}Ra, ranged from 6.32 to 11.17 Bq/Kg (8.11 Bq/Kg, in average) for ^{228}Ra, ranged from 333.44 to 448.48 Bq/Kg (397.21 Bq/Kg, in average) for ^{40}K, and ranged from 0.23 to 0.66 Bq/Kg (0.41 Bq/Kg, in average) for ^{137}Cs. At Port Said Beach; sample 24 has the highest values (15.17 and 11.17 Bq/Kg) for ^{226}Ra and ^{228}Ra respectively and sample no 25 has the highest value (448.48 Bq/Kg) for ^{40}K. While, sample no 33 (East part of Manzala Lake) has the highest value (0.66 Bq/Kg) of ^{137}Cs.

Shore sediment samples of The Residential Districts (2 samples), the activity concentrations of ^{226}Ra ranged from 5.48 to 7.67 Bq/Kg with an average value 6.57. Only, sample number 39 (along Port Fouad Beach) has a detectable activity concentration of ^{228}Ra (5 Bq/Kg), ^{40}K (130.35 Bq/Kg), and ^{137}Cs (0.09 Bq/Kg).

The activity concentrations of shore sediment for ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in the studied areas ranged from 5.48 to

15.17 with an average value 10.16 Bq/Kg, ranged from BDL to 11.75 Bq/Kg with an average value 6.91Bq/Kg, ranged from BDL to 448.48 Bq/Kg with an average value 264.23Bq/Kg and ranged from BDL to 1.14 Bq/Kg with an average value 0.38 Bq/Kg respectively. Sample number 12 (where TCI sanmar for petrochemicals dumping its wastes) has the highest activity concentrations (11.75, and 1.14 Bq/Kg) ^{228}Ra, and ^{137}Cs respectively. And Port Said Beach has the highest values for ^{226}Ra (15.17 Bq/Kg) and ^{40}K (448 Bq/Kg) for samples numbers 24 and 25 respectively.

Our average values are lower than the worldwide activity concentrations average values (35, 30 and 400 Bq/Kg) and the Egyptian activity concentrations mean values (17, 18 and 370 Bq/Kg) for ^{226}Ra, ^{228}Ra and ^{40}K respectively [24]. Previous studies on port Said area showed higher average values (25, 20.56 and 389.32 Bq/Kg) for ^{226}Ra, ^{228}Ra and ^{40}K respectively for study introduced by Attia et al 2015 [16] and the study introduced by Azziz et al 2020 [18] showed lower average values (6.16 and 223.30 Bq/Kg) for ^{228}Ra and ^{40}K and showed higher average value for ^{226}Ra (12.37 Bq/Kg) by comparison with our results.

The shore sediment average specific activity of ^{226}Ra, ^{228}Ra, ^{40}K, and ^{137}Cs for Port Said area previous studies and various countries are indicated in table 4 for comparison.

Table 4. *Comparison of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs average specific activity of shore sediment samples for various countries.*

Country	Average Activity Concentration				References
	^{226}Ra	^{228}Ra	^{40}K	^{137}Cs	
Port Said (Egypt)	10.16	6.91	264.23	0.38	Current work
Manzala Egypt	25	20.56	389.32	------	[16]
Port said beach	12.37	6.16	223.30	------	[18]
The Egyptian Red Sea coast	27.38	38.45	419.4	------	[52]
El Dabaa (Egypt)	5.47	0.92	11.43	------	[53]
Rosetta beach (Egypt)	107.6	201.6	116.2	------	[54]
Brulus Lake (Egypt)	17.26	10.03	299.7	3.33	[55]
Mariout Lake (Egypt)	12.65	7.24	518.75	3.68	[55]
Idku beach sediments (Egypt)	13.08	13.97	345.97	0.48	[56]
Calabria (Southern Italy)	21.3	30.3	849	-----	[57]
Ponnaiyar river (India)	7.31	46.85	384.03	-----	[9]
Tamilnadu (India)	BDL	14.29	360.23	-----	[58]
Henties Bay (Namibia)	175.59	40.17	349.66	-----	[59]
Coast of Greater Accra (Ghana)	22.04	108.60	29.78	-----	[60]

3.1.3. Comparison Between Activity Concentrations of ^{226}Ra, ^{228}Ra, ^{40}K and ^{137}Cs in Soil and Shore Sediment

From comparison of the soil samples and shore sediment we can conclude that; the highest activity concentrations samples are around the industrial facilities. In case of soil, sample number 29 (IPIC Company for Piping Industry) has the highest concentrations of ^{226}Ra, ^{228}Ra and ^{137}Cs and sample number 8 (TCI Sanmar for Petrochemicals Factory) has the highest value of ^{40}K. In case of shore sediment sample number 12 (TCI Sanmar for Petrochemicals Factory) has the highest concentrations of ^{228}Ra and ^{137}Cs. And samples number 24 and 25 (beside Propylene and Polypropylene Factory Oil Fields at these regions) have the highest values of ^{226}Ra and ^{40}K respectively and that also may be related to the geological nature (black sand) of beach area [18].

The soil and shore sediment ^{226}Ra/^{228}Ra ratios are indicated in table 2. In the soil sample, the ^{226}Ra/^{228}Ra ratios ranged from 1.12 to 1.87 (1.52, in average), ranged from 1.11 to 1.66 (1.44, in average) and ranged from 1.32 to 2.10 (1.41, in average) for industrial area in the south of Port Said, International Road and The Residential Districts respectively. In the shore sediment samples, the ^{226}Ra/^{228}Ra ratios ranged from 0.93 to 1.41 (1.06, in average) for industrial area in the south of Port Said, ranged from 1.24 to 1.46 (1.35, in average) for The International Road and only sample number 39 (Port Fouad Beach) has ^{226}Ra/^{228}Ra ratio (1.53) for The Residential Districts.

The ratios of ^{226}Ra/^{228}Ra in all samples (soil and shore sediment) are above unity with clear variation and elevation. So, that normal pattern of the soil and shore sediment in Port Said area may be affected by pollution of industry and human activities. And the Port Fouad region has ^{226}Ra/^{228}Ra maximum ratios (2.10 and 1.53) for soil sample number 41 (in the Port Fouad District) and shore sediment sample 39 (Port Fouad Beach) respectively.

Table 5. *Comparison of ^{226}Ra, ^{228}Ra and ^{40}K standard deviation of soil and shore sediment samples for the studied area.*

	Industrial area		International road		Residential area	
	Soil	Shore sediment	Soil	Shore sediment	Soil	Shore sediment
^{226}Ra	1.65	1.520	6.39	3.61	2.85	1.60
^{228}Ra	1.49	1.59	4.79	2.62	1.32	------
^{40}K	82.7	20.60	48.13	58.53	65.76	------

The standard deviation results for activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K are presented in table 5. The results indicated that The International Road has the highest standard deviation values for ^{226}Ra (6.39 and 3.61) and ^{228}Ra (4.79 and 2.62) in case of soil and shore sediment respectively. And that is attributed to samples no 29 (IPIC Company for Piping

Industry) and sample 24 (Port Said Beach beside Propylene And Polypropylene Factory And Oil Fields) have elevated activity concentration values for ^{226}Ra (26.88 and 15.1 Bq/Kg) and ^{228}Ra (19.6 and 11.1 Bq/Kg) respectively and when the standard deviation is recalculated without their values decreased from 6.39 to 2.8 and from 3.61 to 0.5 in case for ^{226}Ra and decreased from 4.79 to 1.96 and from 2.62 to 0.37 for soil and shore sediment respectively. The soil of residential area has higher standard deviation (2.85) for ^{226}Ra and that is related to the sample no 35 (El Dwahy Distract) has lower activity concentration value (2.79 Bq/Kg) with great difference with the other samples and when the standard deviation is recalculated without this value decreased from 2.85 to 1.03. Also, ^{40}k has standard deviation elevated values in cases of soil of The Industrial Area and Residential Area and that is attributed to some samples have lower activity concentration values with a wide range when compared with the other activity concentration values.

3.1.4. Lateral Distribution of ^{226}Ra, ^{228}Ra and ^{40}K in Port Said Area

Figures 2, 3 and 4 indicate the activity concentration levels in all samples (soil and shore sediment) for ^{226}Ra, ^{228}Ra and ^{40}K respectively, collected from Port Said area.

The activity contour maps showed that the trends of the increase and decrease of ^{226}Ra and ^{228}Ra contents are similar (the direction of increment from east to west all over the studied area) and that may be related to transportation of radioactive black sands deposition originally deposited along the Nile delta shoreline towards port said beach via long shore drift process [18]. In the other side, the activity content of ^{40}K in samples has a different behavior compared with ^{226}Ra and ^{228}Ra. It has the maximum value near center of the studied area and decreases to N, W, S and E directions.

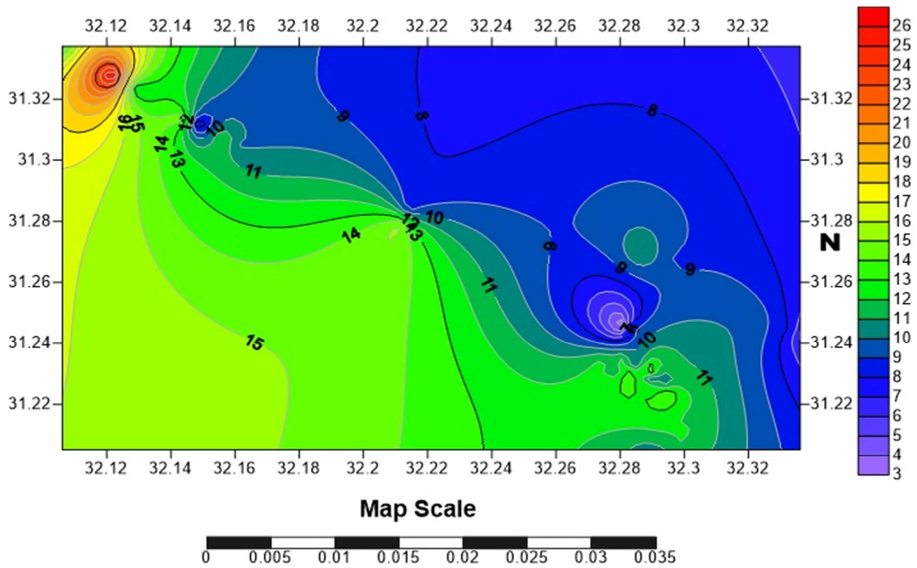

***Figure 2.** Lateral distribution of ^{226}Ra for soil cover of Port Said.*

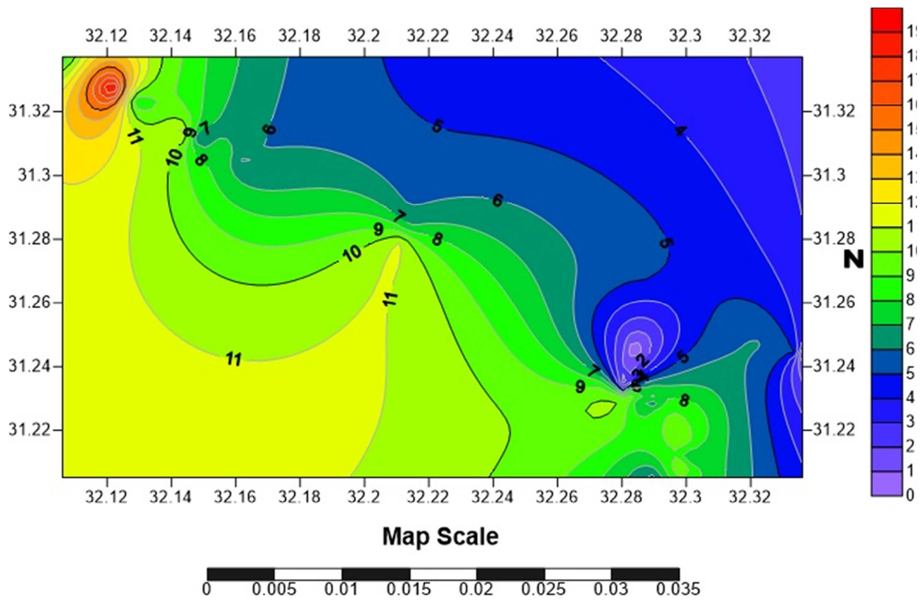

***Figure 3.** Lateral distribution of ^{228}Ra for soil cover of Port Said.*

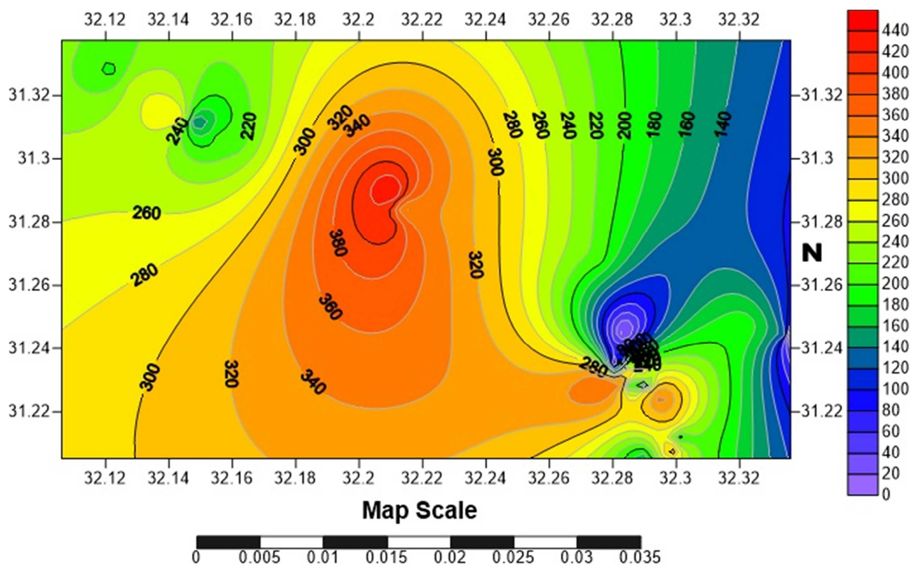

Figure 4. *Lateral distribution of ^{40}K for soil cover of Port Said.*

3.2. Radiation Hazard Parameters

3.2.1. Radiation Hazard Parameters for Soil

The results for the radiological hazard parameters of soil samples of the studied area were reported in Table 6.

Table 6. *The results for the radiological hazard parameters of soil samples.*

Sample No.	Location	$Ra_{eq\ Bq/Kg}$	H_{ex}	H_{in}	Iɣ Bq/Kg	D nGy/h	AEDE µSv/y	AGED mSv/y	ELCR × 10^{-3}
1		48.91	0.132	0.171	0.373	23.69	29.05	170.57	0.102
2		23.26	0.062	0.086	0.171	10.84	13.29	77.72	0.047
3		45.88	0.123	0.156	0.354	22.49	27.59	162.09	0.097
4		41.27	0.111	0.145	0.313	19.83	24.32	142.63	0.085
5		47.91	0.129	0.161	0.371	23.59	28.93	170.07	0.101
6		54.50	0.147	0.185	0.421	26.78	32.84	193.02	0.115
7	The Industrial Area In The South Of Port Said	38.98	0.105	0.140	0.294	18.68	22.92	134.49	0.080
8		57.05	0.154	0.192	0.443	28.16	34.54	203.14	0.121
17		48.38	0.130	0.157	0.378	24.05	29.49	173.36	0.103
18		47.63	0.128	0.161	0.366	23.18	28.43	166.82	0.100
19		51.06	0.137	0.170	0.394	24.96	30.61	179.62	0.107
20		30.22	0.081	0.108	0.228	14.46	17.74	104.08	0.062
21		35.42	0.095	0.126	0.268	16.98	20.83	122.15	0.073
22		47.28	0.127	0.159	0.363	23.00	28.21	165.47	0.099
23		35.08	0.094	0.127	0.263	16.70	20.49	120.13	0.072
26		34.35	0.092	0.119	0.263	16.73	20.52	120.54	0.072
27		25.01	0.067	0.085	0.189	11.94	14.65	85.68	0.051
28	The International Coastal Road	42.82	0.115	0.148	0.327	20.77	25.47	149.47	0.089
29		69.87	0.188	0.261	0.504	31.65	38.82	225.86	0.136
30		42.40	0.114	0.150	0.321	20.39	25.01	146.76	0.088
31		52.36	0.141	0.180	0.397	25.12	30.81	180.45	0.108
32		39.57	0.106	0.139	0.299	18.93	23.22	136.10	0.081
34		32.91	0.088	0.113	0.254	16.13	19.78	116.29	0.069
35		9.16	0.024	0.032	0.068	4.34	5.32	31.15	0.019
36	The Resident Districts	8.45	0.022	0.045	0.056	3.60	4.42	26.11	0.015
37		25.26	0.068	0.092	0.189	12.01	14.73	86.35	0.052
40		33.28	0.089	0.116	0.254	16.13	19.78	116.14	0.069
41		30.50	0.082	0.112	0.229	14.55	17.85	104.79	0.062

The hazard indices of The Industrial area in the south of port said, ranged from 23.26 to 57.05 Bq/Kg, 0.06 to 0.15, 0.08 to 0.19, 0.17 to 0.44 Bq/Kg, 10.84 to 28.16 nGy/h, 13.29 to 34.54 µSv/y, 77.72 to 203.14µSv/y and 0.04 × 10^{-3} to 0.12 × 10^{-3} with averages values 43.52 Bq/Kg, 0.11, 0.14, 0.33 Bq/Kg, 21.16 nGy/h, 25.95 µSv/y, 152.4 µSv/y and 0.09 × 10^{-3} for Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D, AEDE, AGED and ELCER respectively. Sample number 8 (TCI Sanmar for Petrochemicals Factory), has the highest values (57 Bq/Kg, 0.15, 0.19, 0.44 Bq/Kg, 28.16 nGy/h, 34.55 µSv/y, 203.14 µSv/y and 0.12 × 10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D, AEDE, AGED and ELCER. While, sample number 2 (Spegco factory for cement and building materials industry) has the lowest values (23.30 Bq/Kg, 0.06, 0.08, 0.172 Bq/Kg, 10.84 nGy/h, 13.29 μSv/y, 77.72 μSv/y and 0.047×10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively.

The hazard indices of the International Coastal Road ranged from 25.01 to 69.87 Bq/Kg, 0.06 to 0.18, 0.08 to 0.216, 0.18 to 0.50 Bq/Kg, 11.94 to 31.65 nGy/h, 14.65 to 38.82 μSv/y, 85.68 to 225.86 μSv/y, 0.05×10^{-3} to 0.13×10^{-3} with averages values 43.77 Bq/Kg, 0.11, 0.15, 0.32 Bq/Kg, 20.79 nGy/h, 25.50 μSv/y, 149.27 μSv/y and 0.08×10^{-3} for Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D, AEDE, AGED and ELCER respectively. Sample number 29 (IPIC company for piping industry), has the highest values (69.87 Bq/Kg, 0.18, 0.26, 0.50, 31.65, 38.82, 225.86 and 0.13×10^{-3}). While sample number 27 (Zohr Gas Field) has the lowest values (25.01 Bq/Kg, 0.068, 0.085, 0.18 Bq/Kg, 11.94 nGy/h, 14.65 μSv/y, 85.68 μSv/y and 0.05×10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively.

The hazard indices of The Residential Districts ranged from 8.45 to 33.28 Bq/Kg, 0.023 to 0.09, 0.03 to 0.11, 0.056 to 0.254 Bq/Kg 3.60 to 16.134 nGy/h, 4.42 to 19.78 μSv/y, 26.11 to 116.29 μSv/y and 0.01×10^{-3} to 0.0692×10^{-3} with averages values 23.26 Bq/Kg, 0.06, 0.08, 0.14 Bq/Kg, 11.13 nGy/h, 13.65 μSv/y, 80.14 μSv/y and 0.04×10^{-3} for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. Sample number 40 (Port Fouad District) has the highest values (33.28 Bq/Kg, 0.089, 0.116, 16.134 nGy/h, 19.787 μSv/y and 0.692×10^{-3}) of Ra_{eq}, H_{ex}, H_{in}, D, AEDE and ELCER respectively, and sample 34 (EL-Zohor District) has the highest value (116.293 μSv/y) for AGED, and both of the 2 samples (34 and 40) have the same maximum value for I_{γ} (0.245 Bq/Kg). While sample number 36 (EL-Dawahy District) has the lowest values (8.45 Bq/Kg, 0.022, 0.056 Bq/Kg, 3.6 nGy/h, 4.42 μSv/y, 26.11 μSv/y and 0.015×10^{-3}) for Ra_{eq}, H_{ex}, Iγ, D, AEDE, AGED and ELCER respectively and sample number 35 (EL - Dawahy district) has the lowest value (0.032) for H_{in}.

In all the soil samples in the studied areas of Ra_{eq}, H_{ex}, H_{in}, I_{γ}, D, AEDE, AGED and ELCER ranged from 8.45 to 69.87 Bq/Kg, 0.02 to 0.189, 0.03 to 0.261, 0.05 to 0.50 Bq/Kg, 3.60 to 31.65 nGy/h, 4.42 to 38.82 μSv/y, 26.11 to 225.86 μSv/y and from 0.01×10^{-3} to 0.13×10^{-3} with averages values 39.24 Bq/Kg, 0.1, 0.13, 0.29 Bq/Kg, 18.92 nGy/h, 23.20 μSv/y, 136.11 μSv/y and 0.08×10^{-3} respectively. All values of Ra_{eq}, H_{ex}, H_{in}, and I_{γ} and its average values are below the maximum allowed limits recommended by UNSCEAR 2000 [24], 370 Bq/Kg, 1, 1 and 1 Bq/Kg respectively. And all D, AEDE, AGED, and ELCER and its average values are below average worldwide values (60 nGy/h, 70 μSv/y, 300μSv/y and 0.29×10^{-3} respectively) recommended by UNSCEAR 2000 [24]. Sample number 29 (IPIC Company for piping industry) has the highest values for Ra_{eq} (69.87 Bq/Kg), H_{ex} (0.189), H_{in} (0.261), I_{γ} (0.50 Bq/Kg), D (31.65 nGy/h), AEDE (38.82 μSv/y), AGED (255.86 μSv/y), and ELCER (0.136×10^{-3}). Sample number 36 that is located in EL-Dawahy District has the lowest values of Ra_{eq} (8.45.16 Bq/Kg), H_{ex} (0.23), Iγ (0.056 Bq/Kg), D (3.60 nGy/h), AEDE (4.42 μSv/y), AGED (26.11 μSv/y), and ELCER (0.015×10^{-3}). And sample number 35 located in EL-Dawahy District has the lowest values of H_{in} (0.032).

The results for the radiological hazard parameters of soil samples of various countries are indicated in table 7 for comparison.

Table 7. *Comparison of hazard indices of soil samples for various countries.*

Region	H_{ex}	H_{in}	Ra_{eq} Bq/Kg	Iγ Bq/Kg	D nGy/h	AEDE μSv/y	AGED mSv/y	ELCR × 10^3	References
Port said	0.105	0.137	39.24	0.29	18.92	23.20	136.11	0.08	This study
Port said	-------	-------	------	-------	------	802	-------	-----	[16]
Port said	0.103	0.140	39.54	0.150	19.22	92	-------	-----	[17]
Abo Zaabal, Egypt	0.094	0.127	33.88	-------	14.2	17.4	127.8	-----	[61]
Iron and Steel factories in different locations in Egypt	0.12	0.17	44.47	7.45	20.98	25.74	146	0.09	[35]
Quseir Safaga	5.8	11.4	2160	14.5	855	105	------	-----	[62]
Delta State, Nigeria	0.3	0.4	98.5	0.8	54.6	70	------	-----	[63]
Dammam, Saudi Arabia	------	-------	------	0.62	40.28	43	0.63	-----	[64]
Rize Province, Turkey	0.34	--------	125	-------	56.9	69.8	------	-----	[45]

3.2.2. Radiation Hazard Parameters for Shore Sediment

The results for the radiological hazard parameters of shore sediment samples of the studied area were reported in Table 8.

The hazard indices of the Industrial Area in the south of port said, ranged from 13.54 to 52.13 Bq/Kg, 0.03 to 0.14, 0.07 to 0.17, 0.09 to 0.40 Bq/Kg, 5.78 to 25.39 nGy/h, 7.09 to 31.14 μSv/y, 41.85 to 182.45 μSv/y and 0.02×10^{-3} to 0.10×10^{-3} with averages values 42.01 Bq/Kg 0.11, 0.14, 0.32 Bq/Kg, 20.57 nGy/h, 25.23 μSv/y, 124.80 μSv/y and 0.08×10^{-3} for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. In the industrial area, the sample number 12 (TCI Sanmar factory for petrochemicals), has the highest values (52.13 Bq/Kg, 0.141, 0.17, 0.4 Bq/Kg, 25.399 nGy/h, 31.15 μSv/y, 182.5 μSv/y and 0.109×10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. while sample number 14 (Spegco factory for pipes industry) has the lowest values (13.5 Bq/Kg, 0.037, 0.073, 0.09 Bq/Kg, 5.78 nGy/h, 7.1 μSv/y, 41.8 μSv/y and 0.025×10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively.

The hazard indices of The International Coastal Road ranged from 43.98 to 62.70 Bq/Kg, 0.11 to 0.16, 0.148 to 0.210, 0.34 to 0.48 Bq/Kg, 22.10 to 30.84 nGy/h, 27.11 to 37.82 μSv/y, 159.63 to 222.24 μSv/y and 0.09×10^{-3} to 0.13×10^{-3} with averages values 53.16 Bq/Kg, 0.14, 0.15, 0.41 Bq/Kg, 26.66 nGy/h, 32.70 μSv/y, 192.55 μSv/y and 0.11×10^{-3} for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. Sample number 24 (Port Said Beach beside

Propylene and Polypropylene Factory and Oil Fields) has the highest values (62.701 Bq/Kg, 0.169, 0.210, 0.4Bq/Kg, 30.84 nGy/h, 37.8 µSv/y, 222.24 µSv/y and 0.13 × 10^{-3}) of Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. While sample number 33 (Manzala Lake) has the lowest values (43.98 Bq/Kg, 0.116, 0.148, 0.348 Bq/Kg, 22.11 nGy/h, 27.11 µSv/y, 159.63 µSv/y and 0.095× 10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively.

Table 8. *The radiological hazard parameters in the studied shore sediments samples.*

Sample No.	Location	H_{ex}	H_{in}	Ra_{eq} Bq/Kg	$I_γ$ Bq/Kg	D nGy/h	AEDE µSv/y	AGED mSv/y	ELCR × 10^3
9		0.123	0.148	45.375	0.356	22.636	27.761	163.296	0.097
10		0.118	0.146	43.743	0.340	21.558	26.439	155.318	0.093
11	The Industrial	0.113	0.137	41.686	0.327	20.782	25.488	149.951	0.089
12	Area in The	0.141	0.170	52.131	0.402	25.399	31.150	182.458	0.109
13	South Of Port	0.116	0.143	42.857	0.330	20.929	25.667	150.574	0.090
14	Said	0.037	0.073	13.546	0.090	5.784	7.094	41.857	0.025
15		0.129	0.157	47.698	0.370	23.448	28.756	168.787	0.101
16		0.133	0.166	49.110	0.379	24.075	29.525	173.419	0.103
24	The	0.169	0.210	62.701	0.486	30.846	37.830	222.245	0.132
25	International	0.143	0.168	52.805	0.424	27.045	33.168	195.775	0.116
33	Coastal Road	0.116	0.148	43.981	0.348	22.109	27.115	159.632	0.095
38	The Residential	0.015	0.030	5.488	0.037	2.343	2.874	16.957	0.010
39	Districts	0.067	0.088	24.864	0.188	11.903	14.598	85.551	0.051

The hazard indices of The Residential Districts ranged from Ra_{eq} 5.48 to 24.86 Bq/Kg, 0.01 to 0.06, 0.03 to 0.11, 0.03 to 0.18 Bq/Kg, 2.34 to 11.90, 2.87 to 14.59 µSv/y, 16.95 to 85.55 µSv/y and 0.01× 10^{-3} to 0.05×10^{-3} with averages values 15.17 Bq/Kg, 0.04, 0.08, 0.11 Bq/Kg, 7.12 nGy/h, 8.73 µSv/y, 51.25 µSv/y and 0.03×10^{-3} for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. In shore sediment samples on The Residential Districts, the sample number 39 (Port Fouad beach) has the highest values (24.864 Bq/Kg, 0.067, 0.088, 0.188 Bq/Kg, 11.903 nGy/h, 14.598 µSv/y, 85.551 µSv/y and 0.051×10^{-3}) of Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively. While sample number 38 (Port Fouad Beach) has the lowest values (5.488 Bq/Kg, 0.015, 0.030, 0.037 Bq/Kg, 2.343 nGy/h, 2.874 µSv/y, 16.957 µSv/y and 0.010×10^{-3}) for Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER respectively.

In all the shore sediment samples in the studied area of Ra_{eq}, H_{ex}, H_{in}, Iγ, D, AEDE, AGED and ELCER range from 5.48.26 to 62.70 Bq/Kg, 0.015 to 0.169, 0.030 to 0.210, 0.03 to 0.48 Bq/Kg, 2.34 to 30.48 nGy/h, 2.87 to 37.82 µSv/y, 16.95 to 222.24 µSv/y and from 0.01 × 10^{-3} to 0.08×10^{-3} with averages values 40.46 Bq/Kg, 0.10, 0.13, 0.31 Bq/Kg, 19.91 nGy/h, 24.42 µSv/y, 147.25 µSv/y and 0.08 × 10^{-3} respectively. In all the shore sediment samples, all values of Ra_{eq} H_{ex}, H_{in} and $I_γ$ values and its averages values are below the maximum allowed limits of recommended by UNSCEAR (2000) [24], 370 Bq/Kg, 1, 1, and 1 Bq/Kg respectively. Also, all values of D, AEDE, AGDE and ELCER values and its averages values are below average worldwide values (60 nGy/h, 70 µSv/y, 300µSv/y and 0.29× 10^{-3} respectively) recommended by UNSCEAR (2000) [24]. Sample number 24 (located along Port Said Beach beside Propylene and Polypropylene Factory and oil fields) has the highest values of Ra_{eq} (62.70Bq/Kg), H_{ex} (0.169), H_{in} (0.210), $I_γ$ (0.48 Bq/Kg), D (30.84 nGy/h), AEDE (37.83 µSv/y), AGED (222.24 µSv/y), and ELCER (0.132× 10^{-3}). While Sample number 38 (that is located in along Port Fouad Beach.) has the lowest value of D (2.34 nGy/h), H_{ex} (0.015), H_{in} (0.030), $I_γ$ (0.037 Bq/Kg), of AEDE (2.874 µSv/y), AGED (16.95 µSv/y), and ELCER (0.010× 10^{-3}).

The results for the radiological hazard parameters of shore sediment samples of the studied area and various countries are indicated in table 9 for comparison.

Table 9. *Comparison of hazard indices of shore sediment samples for various countries.*

Region	H_{ex} msv/y	H_{in} msv/y	Ra_{eq} Bq/Kg	$I_γ$ Bq/Kg	D nGy/h	AEDE µSv/y	AGED mSv/y	ELCR × 10^3	References
Port said	0.109	0.136	40.46	0.31	19.91	24.42	147.25	0.08	This study
Port said	-------	-------	-------	------	18.75	120	------	0.46	[18]
Rosetta beach Egypt	1.1	-------	404.8	1.4	186	--------	------	0.8	[53]
Greater Accra, Ghana	0.48	-------	9	------	77.02	90	------	-----	[60]
Hurghada City, Northern Red Sea, Egypt	-------	-------	60	------	28.7	35.2	------	-----	[65].
North Dune beach, Henties Bay, Namibia	0.70	1.18	-------	255.8	105.43	129.30	-------	0.45	[59]

From comparison the hazard indices samples of the soil and shore sediment samples we can conclude that; the highest hazard indices samples are around the industrial facilities. In case of soil, Sample number 29 that is located around IPIC Company for Piping Industry has the highest values for Ra_{eq} (69.87Bq/Kg), H_{ex} (0.189), H_{in} (0..261), $I_γ$ (0.50Bq/Kg), D (31.65 nGy/h), AEDE (38.82 µSv/y), AGED (255.86 µSv/y), and ELCER (0.136 × 10^{-3}). In case of shore sediment Sample number 24 (beside Propylene and Polypropylene Factory and Oil Fields) has the highest values of Ra_{eq} (62.70 Bq/Kg), H_{ex} (0.169), H_{in} (0.210), $I_γ$ (0.48 Bq/Kg), D (30.84 nGy/h), AEDE (37.83 µSv/y), AGED (222.24 µSv/y) and ELCER (0.132 × 10^{-3}).

3.3. Pearson's Correlation

3.3.1. Pearson's Correlation Between Radionuclides in the Soil and Shore Sediment Samples

Pearson's correlation coefficient analysis can be used to evaluate the relationships and degree of correlations that may exist between the detected radionuclides in the samples and between the radionuclide and hazard parameters.

As shown in Table 10, in soil samples ^{226}Ra has strong positive correlation with ^{228}Ra (r =0.88). ^{226}Ra has weak positive correlation with ^{40}K (r =0.43) and positive strong correlation with ^{137}Cs (r = 0.72). ^{228}Ra has moderate positive correlation with ^{40}K (r =0.59) and strong positive correlation with ^{137}Cs (r =0.75). While ^{40}K has positive weak correlation with ^{137}Cs (r =0.28).

Table 10. *The Pearson's correlation coefficient of radionuclides of soil samples in the studied areas.*

	^{226}Ra	*^{228}Ra*	*^{40}K*	*^{137}Cs*
^{226}Ra	1			
^{228}Ra	0.889876	1		
^{40}K	0.430421	0.598503	1	
^{137}Cs	0.728165	0.759647	0.280127	1

As shown in Table 11, in shore sediment samples, ^{226}Ra has weak positive correlation with *^{228}Ra* (r =0.40), and negligible correlations with ^{40}K (r =0.28) and ^{137}Cs (r =0.01). ^{228}Ra has strong positive correlation with ^{40}K (r =0.82) and moderate positive correlation with ^{137}Cs (r =0.62). While ^{40}K has weak positive correlation with ^{137}Cs (r =0.43).

Table 11. *The Pearson's correlation coefficient of radionuclides of all shore sediment samples.*

	^{226}Ra	***^{228}Ra***	**^{40}K**	**^{137}Cs**
^{226}Ra	1			
^{228}Ra	0.407271	1		
^{40}K	0.285884	0.827281	1	
^{137}Cs	0.01052	0.624544	0.453174	1

The highest Pearson's correlation coefficients (r = 0.88) and (r = 0.82) were existed between ^{226}Ra and ^{228}Ra in case of soil and were excited between ^{228}Ra and ^{40}K in case of shore sediment respectively. these coefficients values can't explain the amount of variation in ^{228}Ra activity concentrations due to the variation in ^{226}Ra activity concentrations in soil and the amount of variation in ^{228}Ra activity concentrations due to the variation in ^{40}K activity concentrations variation in shore sediment samples, so we used determination coefficient (R^2) for more explanation.

As illustrated in figures 5 and 6, determination coefficients (R^2 = 0.79) and (R^2 = 0.68), explained that 79% of variation in the ^{228}Ra activity concentrations is due to the variation in ^{226}Ra activity concentrations in soil samples and 68% of variation in the ^{40}K activity concentrations is due to the variation in ^{228}Ra activity concentrations in shore sediment samples. These high determination coefficients interpret the strong Pearson's correlation.

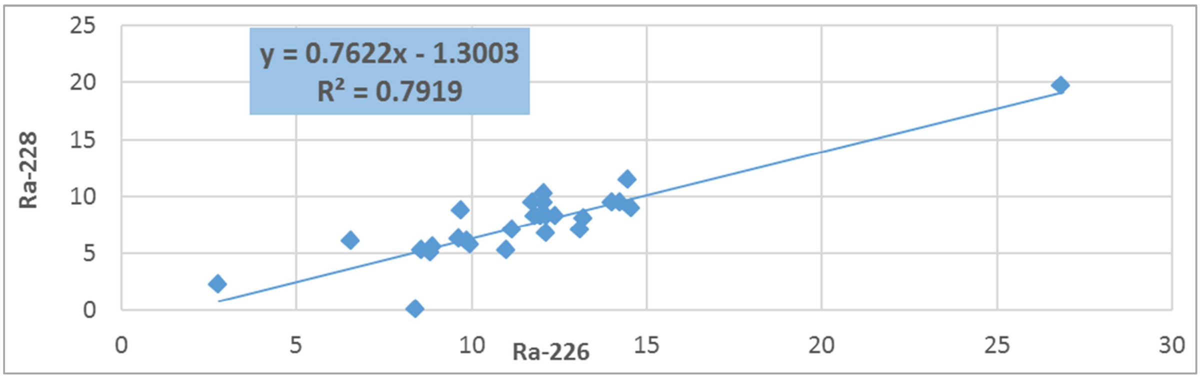

Figure 5. *Strong positive correlation between Ra^{226} and ^{228}Ra in soil samples.*

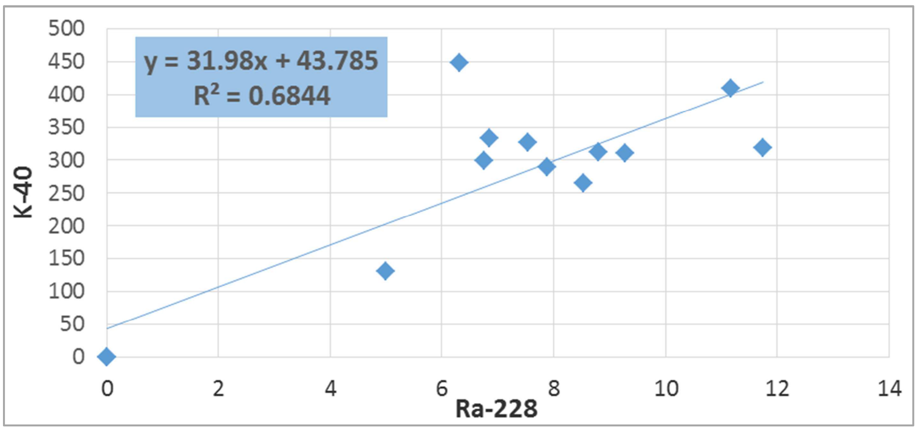

Figure 6. *Strong positive correlation between ^{228}Ra and ^{40}k in shore sediments samples.*

3.3.2. Pearson's Correlation Between Radiation Hazard Parameters and Radionuclides in the Soil and Shore Sediment Samples

Results of the Pearson correlation coefficients between radionuclides and radiological parameters in soil and shore sediment samples are shown in tables 12 and 13 respectively.

Table 12. *The Pearson correlation coefficients among the radiological parameters and between radionuclides and radiological parameters in all studied soil samples.*

	^{226}Ra	^{228}Ra	^{40}K	^{137}Cs	H_{ex}	H_{in}	Ra_{eq}	I_γ	D	ADED	AGDE	ELCR
Hex	0.824	0.918	0.851	0.622	1.000							
Hin	0.891	0.941	0.781	0.667	0.991	1.000						
Raeq	0.824	0.918	0.851	0.623	1.000	0.991	1.000					
Iɣ	0.788	0.894	0.883	0.591	0.998	0.981	0.998	1.000				
D	0.784	0.889	0.887	0.585	0.997	0.980	0.997	1.000	1.000			
ADED	0.784	0.889	0.887	0.585	0.997	0.980	0.997	1.000	1.000	1.000		
AGDE	0.780	0.886	0.891	0.581	0.997	0.978	0.997	1.000	1.000	1.000	1.000	
ELCR	0.784	0.890	0.887	0.587	0.997	0.980	0.997	1.000	1.000	1.000	1.000	1.000

Table 13. *The Pearson correlation coefficients among the radiological parameters and between radionuclides and radiological parameters in all studied shore sediments samples.*

	^{226}Ra	^{228}Ra	^{40}K	^{137}Cs	H_{ex}	H_{in}	Ra_{eq}	I_γ	D	ADED	AGDE	ELCR
Hex	0.47227	0.92390	0.96412	0.49736	1.00000							
Hin	0.58005	0.91229	0.93203	0.46114	0.99196	1.0000						
Raeq	0.47215	0.92390	0.96414	0.49739	1.00000	0.9919	1.00000					
Iɣ	0.44376	0.91467	0.97403	0.49480	0.99918	0.9871	0.99918	1.0000				
D	0.44299	0.91174	0.97527	0.49192	0.99895	0.9868	0.99895	1.0000	1.0000			
ADED	0.44299	0.91174	0.97527	0.49192	0.99895	0.9868	0.99895	1.0000	1.0000	1.0000		
AGDE	0.44198	0.90937	0.97629	0.48971	0.99871	0.9864	0.99872	0.9999	1.0000	1.0000	1.0000	
ELCR	0.44299	0.91174	0.97527	0.49192	0.99895	0.9868	0.99895	1.0000	1.0000	1.0000	1.0000	1.0000

In soil samples, ^{226}Ra, ^{228}Ra and ^{40}K have strong positive correlations with all radiological parameters that is attributed to the three radionuclides contribute to the release of gamma radiation. In shore sediment samples, ^{228}Ra and ^{40}K have strong positive correlations with all radiological parameters while, ^{226}Ra has moderate positive correlations with all radiological parameters. ^{137}Cs has moderate positive correlations with all radiological parameters in both cases of soil and shore sediment samples.

Perfect positive correlations were existed among all studied radiological parameters in case of soil and in case of shore sediment.

3.4. Lead Concentration in the Soil and Shore Sediment Samples by ICP-OES and Calculated Pollution Indices

Table 14. Shows the concentration, Geo-accumulation Index (I-geo) and Contamination Factor (CF) of the lead in the soil and shore sediment.

Table 14. *The concentration, Geo-accumulation Index (I-geo) and Contamination Factor (CF) of the lead in the soil and shore sediment.*

Areas	Sample code	Pb (mg/g)	(I_{geo})	Classes of (I_{geo})	(C_f^i)	Contamination categories
The Industrial Area In The South Of Port Said	Soil 1	71.91	1.94	moderately polluted	5.76	considerable contamination
	Soil 4	39.01	1.05	moderately polluted	3.12	considerable contamination
	Soil 5	33.84	0.85	Unpolluted to moderated polluted	2.70	Low contamination
	Soil 8	43.59	1.22	moderately polluted	3.49	considerable contamination
	Shore sediment 12	88.68	2.24	moderately to strongly polluted	7.10	Very high contamination
	Soil 19	47.89	1.35	moderately polluted	3.83	considerable contamination
	Soil 21	31.60	0.75	Unpolluted to moderated polluted	2.53	Low contamination
The International Coastal Road	Soil 23	45.91	1.29	moderately polluted	3.67	considerable contamination
	Shore sediment 24	38.80	1.05	moderately polluted	3.10	considerable contamination
	Shore sediment 26	48.38	1.37	moderately polluted	3.87	considerable contamination
	Soil 28	27.09	0.53	Unpolluted to moderated polluted	2.17	Low contamination
	Soil 29	26.29	0.49	Unpolluted to moderated polluted	2.10	Low contamination
	Soil 30	44.91	1.26	moderately polluted	3.60	considerable contamination
	Soil 32	43.67	1.22	moderately polluted	3.50	considerable contamination
The Residential Districts	Shore sediment 33	41.09	1.13	moderately polluted	3.30	considerable contamination
	Soil 34	76.20	2.02	moderately to strongly polluted	6.10	Very high contamination
	Soil 35	50.38	1.43	moderately polluted	4.03	considerable contamination
	Soil 37	38.65	1.04	moderately polluted	3.10	considerable contamination
	Shore sediment 39	66.22	1.82	moderately polluted	5.30	considerable contamination
	Soil 40	56.82	1.56	moderately polluted	4.55	considerable contamination
	Soil 41	69.71	1.90	moderately polluted	5.58	considerable contamination

In the soil, Pb concentrations ranged from 31.6 to 71.91 ppm (44.82 ppm, in average) for the industrial area, ranged from 44.91 to 44.91 ppm (35.49 ppm, in average) for The International Coastal Road and ranged from 38.65 to 76.20 ppm (58.35 ppm, in average) for Residential Districts area. Geo-accumulation Index (I-geo) ranged from 0.75 to 1.94 (1.21, in average) for the Industrial Area of Port Said, ranged from 0.49 to 1.26 (0.87, in average) for The International Coastal Road and ranged from 1.04 to 2.02 (1.60, in average) for Residential Districts area. Contamination Factor (CF) ranged from 2.53 to 5.75 (3.60, in average) for the industrial area, ranged from 2.10 to 3.60 (2.83, in average) for the international coastal road and ranged from 3.10 to 6.10 (4.70, in average) for residential districts area.

For the soil samples, in The Industrial Area, soil number 1 (Spegeco Factory for cement and building materials industry) has the highest values (71.91 ppm, 1.94 and 5.75), in The International Coastal Road, soil number 30 (Automatic Welding and Fabrication Pipe spools Workshops) has the highest values (44.91 ppm, 1.26 and 3.60) and in the Residential Area soil number 34 (El-Zohor District) has the highest values (76.20 ppm, 2.02 and 6.10) for pb, Geo-accumulation Index (I-geo) and Contamination Factor (CF) respectively.

In the shore sediment, Pb concentration is 88.68 ppm for sample number 12 (TCI Sanmar for petrochemical industries) in The Industrial Area of Port Said, ranged from 38.8 to 48.38 ppm (42.75 ppm, in average) for The International Coastal Road and 66.22 ppm for sample number 39 (Port Fouad Beach) in The Residential Districts area, Geo-accumulation Index (I-geo) is 2.24 for sample number 12 (TCI Sanmar for petrochemical industries) in The Industrial Area of Port Said, ranged from 1.05 to 1.37 (1.18, in average) for the International Coastal Road and 1.82 for sample number 39 (Port Fouad beach) in The Residential Districts area. Contamination Factor (CF) is 7.10 for sample number 12 (TCI Sanmar for petrochemical industries) in The Industrial Area, ranged from 3.10 to 3.90 (3.42, in average) for the International Coastal Road and 5.30 for sample number 39 (Port Fouad beach) in The Residential Districts area.

In all the soil samples, the sample number 34 (El-Zohor District) in The Residential Area has the highest values (76.20 ppm, 2.02 and 6.10) and in all the shore sediment sample number 12 (TCI Sanmar for petrochemical industries) in The Industrial Area has the highest values (88.68 ppm, 2.24 and 7.10) for pb, Geo-accumulation Index (I-geo) and Contamination Factor (CF) respectively.

Pearson's Correlation between Pb, ^{226}Ra, ^{228}Ra and ^{40}K were estimated (results not presented here). The correlations showed that, in soil samples, Pb has a negative weak correlation with ^{226}Ra (-0.35) and ^{228}Ra (-0.42) and a negligible correlation with ^{40}K (-0.08). In shore sediment samples Pb has a negative weak correlation with ^{226}Ra (- 0.23) and ^{40}K (- 0.46) and a positive weak correlation with ^{228}Ra (0.26). So, we can conclude that pb from side and ^{226}Ra, ^{228}Ra and ^{40}K from other side from different origins or sources.

4. Conclusion

In the port said governorate,

1) The highest activity concentrations are around the industrial facilities in both cases of soil and shore sediment samples. because the soil and shore sediment were affected by contamination from factories in cases of soil and shore sediment in addition to geological nature (black sand) in case of shore sediment. That is confirmed by the elevated ratios of 226Ra/228Ra from side and from another side by a wide range of variation of standard deviations of the determined radionuclides. But the average activity concentration of 226Ra, 228Ra and 40K in the soil and shore sediment samples are still lower than the worldwide activity concentrations average values and the Egyptian activity concentrations mean values. The contour maps indicted that 226Ra and 228Ra take the same behavior while 40K has a different behavior.
2) The values of Raeq, Hex, Hin, Iγ, D, AEDE, AGED and ELCER ranged from 8.45 to 69.87 Bq/Kg, 0.02 to 0.189, 0.03 to 0.261, 0.05 to 0.50 Bq/Kg, 3.60 to 31.65 nGy/h, 4.42 to 38.82 µSv/y, 26.11 to 225.86 µSv/y and from 0.01 × 10-3 to 0.13 × 10-3 with averages values 39.24 Bq/Kg, 0.1, 0.13, 0.29 Bq/Kg, 18.92 nGy/h, 23.20 µSv/y, 136.11 µSv/y and 0.08 × 10-3 respectively for soil. Raeq, Hex, Hin, Iγ, D, AEDE, AGED and ELCER range from 5.48.26 to 62.70 Bq/Kg, 0.015 to 0.169, 0.030 to 0.210, 0.03 to 0.48 Bq/Kg, 2.34 to 30.48 nGy/h, 2.87 to 37.82 µSv/y, 16.95 to 222.24 µSv/y and from 0.01 × 10-3 to 0.08×10-3 with averages values 40.46 Bq/Kg, 0.10, 0.13, 0.31 Bq/Kg, 19.91 nGy/h, 24.42 µSv/y, 147.25 µSv/y and 0.08 × 10-3 respectively for shore sediment. All values of hazard indices and their average values are below recommended values by UNSCEAR 2000.
3) Geo-accumulation Index (I-geo) and Contamination Factor (CF) for Pb indicated that, in soil samples more than 2 thirds are moderately polluted or considerably contaminated, 25% are unpolluted to moderately polluted or low contamination and only one sample is moderately to strongly unpolluted or very high contamination according to Classes of Geo-accumulation Index and Contamination categories of contamination factor respectively. in shore sediment samples, 80% of samples are moderately polluted or considerably contaminated and only 20% (one sample) moderately to strongly unpolluted or very high contamination according to Classes of Geo-accumulation Index and Contamination categories of contamination factor respectively. Pearson's Correlation between Pb, 226Ra, 228Ra and 40K indicated that pb from side and 226Ra, 228Ra and 40K from other side may be from different origins.

References

[1] FAO and ITPS. 2015. Status of the World's Soil Resources (SWSR) – Main Report. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.

[2] Aqeel, M., Jamil, M., & Yusoff, I. (2014). Soil Contamination, risk assessment and remediation. In Environmental Risk Assessment of Soil Contamination. In Tech https://doi.org/10.5772/57287.

[3] Masindi, V., & Muedi, K. L. (2018). Environmental contamination by heavy metals. *Heavy Metals*. https://doi.org/10.5772/intechopen.76082.

[4] Al Attar, L., Al-Oudat, M., Shamali, K., Abdul Ghany, B., & Kanakri, S. (2012). Case study: heavy metals and fluoride contents in the materials of Syrian phosphate industry and in the vicinity of phosphogypsum piles. Environmental technology, 33 (1-3), 143–152. https://doi.org/10.1080/09593330.2011.552531.

[5] Mainville, N., Webb, J., Lucotte, M., Davidson, R., Betancourt, O., Cueva, E., & Mergler, D. (2006). Decrease of soil fertility and release of mercury following deforestation in the Andean Amazon, Napo River Valley, Ecuador. The Science of the total environment, 368 (1), 88–98. https://doi.org/10.1016/j.scitotenv.2005.09.064.

[6] Akpabio F. M. (2000), The Impacts of the Location of Aluminum Smelter Company of Nigeria (ALSCON) on Environment in IkotAbasiUrbar, AkwaIbom State., Unpublished MURP Thesis, Department of Urban and Regional Planning, University of Uyo, Uyo. pp. 42-51.

[7] Harald, A. N. (2000), Heavy Metal Contents in Agricultural Soils, In: Remediation of soils Contaminated With Metals, Li G. C. (Ed.). Special issue of Journal on Environmental Geochemistry and Health, vol. 16, pp. 161-170.

[8] Shultis, J. K., & Faw, R. E. (2005). Radiation shielding technology. *Health Physics*, *88* (4), 297-322.

[9] Ramasamy V, Suresh G, Meenakshisundaram V, Gajendran V (2009). Evaluation of natural radionuclide content in river sediments and excess lifetime cancer risk due to gamma radioactivity. Res J Env Earth Sci; 1: 6–10.

[10] Ramli, A. T., Hussein, A. W., & Wood, A. K. (2005). Environmental 238U and 232Th concentration measurements in an area of high level natural background radiation at Palong, Johor, Malaysia. Journal of environmental radioactivity, 80 (3), 287–304. https://doi.org/10.1016/j.jenvrad.2004.06.008

[11] Scoullos, M. J., Vonkeman, G. H., Thornton, I., &Makuch, Z. (2001). Mercury—cadmium—lead handbook for sustainable heavy metals policy and regulation (Vol. 31). Springer Science & Business Media.

[12] Boldyrev, M. (2018). Lead: Properties, history, and applications. WikiJournal of Science, 1 (2), 7. https://doi.org/10.15347/wjs/2018.007.

[13] Sharma, P., & Dubey, R. S. (2005). Lead toxicity in plants. *Brazilian journal of plant physiology*, *17*, 35-52.

[14] Tong, S., von Schirnding, Y. E., & Prapamontol, T. (2000). Environmental lead exposure: a public health problem of global dimensions. Bulletin of the World Health Organization, 78 (9), 1068–1077.

[15] Assi MA, Hezmee M. N. M, Haron A. W., Sabri M. Y., Rajion, M. A (2016). The detrimental effects of lead on human and animal health, Veterinary World, 9 (6): 660-671.

[16] Attia, T. E., Shendi, E. H., & Shehata, M. A. (2015). Assessment of natural and artificial radioactivity levels and radiation hazards and their relation to heavy metals in the industrial area of Port Said city, Egypt. Environmental Science and Pollution Research, 22 (4), 3082-3097.

[17] Abozeed, M., Allam, K. A., Metwali, M. A., & EL Herizy, A. (2017). Evaluation of radiological impact of some nonnuclear industries in north Suez Canal Region. *Journal of Nuclear and Radiation Physics*, *12*, 1-12.

[18] Aziz, A., Attia, T., & Hanafi, M. (2020). Radiological Impact and Environmental Monitoring of Gamma Radiations along the Public Beach of Port Said, Egypt. Pure and Applied Geophysics, 177 (6), 2871-2876.

[19] Van Cleef D. J. (1994). Determination of ^{226}Ra in soil using ^{214}Pb and ^{214}Bi immediately after sampling. Health physics, 67 (3), 288–289. https://doi.org/10.1097/00004032-199409000-00012.

[20] Environmental Protection Agency, EPA (1996), Method 3050B, Acid Digestion of Sediments, Sludges, and Soils, Revision 2.

[21] Beretka, J. and Mathew, P. J (1995), Natural radioactivity of Australian building materials, industrial waters and by-products, Health Phys, vol. 48, pp. 87-95.

[22] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (1988). Sources, effects and risks of ionizing radiation. New York: United Nations. Report to the General Assembly with Annexes.

[23] NEA-OECD (1979) Exposure to Radiation from Natural Radioactivity in Building Materials. Report by NEA Group of Experts of the Nuclear Energy Agency, OECD, Paris, France.

[24] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2000). Sources and effects of ionizing radiation. New York: United Nations. Report to the General Assembly with Annexes.

[25] Avwiri, G. O., Osimobi, J. C and Agbalagba, E. O. (2012) Evaluation of Radiation Hazard Indices and Excess Lifetime Cancer Risk Due to Natural Radioactivity in soil profile of Udi and Ezeagu Local Government Areas of Enugu State, Nigeria. Comprehensive Journal of Environmental and Earth Sciences Vol. 1 (1), pp. 1 - 10, Nov. 2012.

[26] Taskin, H., Karavus, M., Ay, P., Topuzoglu, A., Hidiroglu, S., & Karahan, G. (2009). Radionuclide concentrations in soil and lifetime cancer risk due to gamma radioactivity in Kirklareli, Turkey. Journal of environmental radioactivity, 100 (1), 49–53. https://doi.org/10.1016/j.jenvrad.2008.10.012

[27] ICRP (International Commission on Radiological Protection). (1990). Recommendationsof the international Commission on radiological protection. ICRP Publication, 60 Ann.

[28] Müller, G. (1969), Index of geo-accumulation in sediments of the Rhine River, Geo. J., (2), pp. 108-118.

[29] Loska, K., Wiechuła, D., & Korus, I. (2004). Metal contamination of farming soils affected by industry. Environment international, 30 (2), 159–165. https://doi.org/10.1016/S0160-4120(03)00157-0

[30] Taylor, S. R (1964), Abundance of chemical elements in the continental crust, a new table, Geochimica et Cosmochimica Acta, vol. 28, Issue 8 pp. 1273-1285.

[31] Müller, G. (1981), The heavy metal pollution of the sediments of Neckars and its tributary: a stocktaking. Chemical Zeitung, vol. 105, pp. 157–164.

[32] Tippie, V. K. (1984), An environmental characterization of Chesapeake Bay and a frame work for action. In: Kennedy V (ed) The estuary as a filter. Academic Press, New York.

[33] Hakanson, L. (1980). An ecological risk index for aquatic pollution control. A sedimentological approach. Water research, 14 (8), 975-1001. https://doi.org/10.1016/0043-1354(80)90143-8.

[34] Abel-Ghany, H. A., El-Zakla, T. and Hassan, A. M. (2009). Environmental radioactivity measurements of some Egyptian sand samples. Romanian journal of Physics, 54 (1-2), 213-223.

[35] Mohamed, R. S., Bakr, W. F., Arafat, A. A., El Hemamy, S. T., & Abo-Aly, M. M. (2019). Evaluation of environmental impact of iron and steel industry in Egypt; radiological and heavy metals contribution. Journal of Nuclear Technology in Applied Science, 7 (1), 79–100. https://doi.org/10.21608/jntas.2019.54555.

[36] Abdel-Rahman, M. A. E., & El-Mongy, S. A. (2017). Analysis of radioactivity levels and hazard assessment of black sand samples from Rashid area, Egypt. Nuclear Engineering and Technology, 49 (8), 1752–1757. https://doi.org/10.1016/j.net.2017.07.020.

[37] Saleh, I. H., Hafez, A. F., Elanany, N. H., Motaweh, H. A., & Naim, M. A. (2007). Radiological study on soils, foodstuff and fertilizers in the Alexandria Region, Egypt. Turkish Journal of Engineering and Environmental Sciences, 31 (1), 9–17. https://doi.org/10.3906/tar-1201-1.

[38] Arafat, A. A., Salama, M. H. M., El-Sayed, S. A., & Elfeel, A. A. (2017). Distribution of natural radionuclides and assessment of the associated hazards in the environment of Marsa Alam-Shalateen area, Red Sea coast, Egypt. Journal of radiation research and applied sciences, 10 (3), 219-232.

[39] Abu – Khadra, S. A., & Eissa, H. S. (2008). Natural Radionuclides in Different plants, Together with Their Corresponding Soils in Egypt at Inshas Region and the Area Nearby. IX Radiation Physics and Protection Conference 15-19 November, Cairo, Egypt.

[40] Nada, A., Abd-El Maksoud, T. M., Abu-Zeid Hosnia, M., El-Nagar, T., & Awad, S. (2009). Distribution of radionuclides in soil samples from a petrified wood forest in El-Qattamia, Cairo, Egypt. Applied Radiation and Isotopes, 67 (4), 643–649. https://doi.org/10.1016/j.apradiso.2008.11.016.

[41] Ibraheem, A. A., El-Taher, A., & Alruwaili, M. H. M. (2018). Assessment of natural radioactivity levels and radiation hazard indices for soil samples from Abha, Saudi Arabia. Results in Physics, 11, 325–330. https://doi.org/10.1016/j.rinp.2018.09.013.

[42] Abu Samerh, M. M., Thabayneh, K. M., & Khrais, F. W. (2014). Measurement of activity concentration levels of radionuclides in soil samples collected from Bethlehem Province, West Bank, Palestine. Turkish journal of Engineering and Environmental Sciences, 38, 113–125. https://doi.org/10.3906/muh-1303-8.

[43] Ahmed, A. H., & Gafur, A. A. (2014). Natural radioactivity measurements of soil samples from soran district in kurdistan region-iraq. Solid State Science and Technology, 22 (1-2), 26–39.

[44] Amanjeet, Kumar, A., Kumar, S., Singh, J., Singh, P., & Bajwa, B. S. (2017). Assessment of natural radioactivity levels and associated dose rates in soil samples from historical city Panipat, India. Journal of Radiation Research and Applied Sciences, 10 (3), 283–288. https://doi.org/10.1016/j.jrras.2017.05.006.

[45] Durusoy, A., & Yildirim, M. (2017). Determination of radioactivity concentrations in soil samples and dose assessment for Rize Province, Turkey. Journal of Radiation Research and Applied Sciences, 10 (4), 348-352.

[46] Masok, F. B., Masiteng, P. L., Mavunda, R. D., Maleka, P. P., & Winkler, H. (2018). Measurement of radioactivity concentration in soil samples around phosphate rock storage facility in Richards Bay, South Africa. Journal of radiation research and applied sciences, 11 (1), 29-36.

[47] Abu Bakar, A. S. A., Hamzah, Z., & Saat, A. (2017, January). Measurements of natural radioactivity in soil of Fraser’s Hill, Pahang, Malaysia. In AIP Conference Proceedings (Vol. 1799, No. 1, p. 030009). AIP Publishing LLC.

[48] Sarap, N. B., Janković, M. M., Todorović, D. J., Nikolić, J. D., & Kovačević, M. S. (2014). Environmental radioactivity in southern Serbia at locations where depleted uranium was used. Archives of Industrial Hygiene and Toxicology, 65 (2), 189–197. https://doi.org/10.2478/10004-1254-65-2014-2427

[49] Karahan, G., & Bayulken, A. (2000). Assessment of gamma dose rates around Istanbul (Turkey). Journal of Environmental Radioactivity, 47 (2), 213–221. https://doi.org/10.1016/s0265-931x (99)00034-x.

[50] Faghihi, R., Mehdizadeh, S., & Sina, S. (2011). Natural and artificial radioactivity distribution in soil of Fars Province, Iran. Radiation Protection Dosimetry, 145 (1), 66–74. https://doi.org/10.1093/rpd/ncq367.

[51] UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2008). Sources and effects of ionizing radiation. New York: United Nations. Report to the General Assembly with Annexes.

[52] El-Taher, A., & Madkour, H. A. (2011). Distribution and environmental impacts of metals and natural radionuclides in marine sediments in-front of different wadies mouth along the Egyptian Red Sea Coast. Applied Radiation and Isotopes, 69 (2), 550-558.

[53] El-Daly, A., & Hussein, A. S. (2008). Natural radioactivity levels in environmental samples in north western desert of Egypt. Proceedings of the 3rd Environmental Physics Conference, 19-23 Feb. 2008, Aswan, Egypt.

[54] Mubarak, F., Hassan, M. F, Mansour, N. A., Ahmed, T. S., & Ali, A. (2017). Radiological investigation of high background radiation areas. Scientific reports, 7 (1), 1-12. https://doi.org/10.1038/s41598-017-15201-2

[55] Dar, M. A., & El Saharty, A. A. (2013). Activity levels of some radionuclides in Mariout and Brullus Lakes, Egypt. Radiation Protection Dosimetry, 157 (1), 85–94. https://doi.org/10.1093/rpd/nct106

[56] Fahmi, N. M., El-Khatib, A., Abd El-Salam, Y. M., Shalaby, M. H., El-Gally, M. M. & Naim, M. A., (2011). Study of the environmental impacts of the natural radioactivity presents in beach sand and Lake Sediment samples Idku, Behara, Egypt. 10th Radiation Physics & Protection Conference, 27-30 November 2010, Nasr City - Cairo, Egypt.

[57] Caridi, F., Di Bella, M., Sabatino, G., Belmusto, G., Fede, M. R., Romano, D., Italiano, F., & Mottese, A. F. (2021). Assessment of natural radioactivity and radiological risks in river sediments from Calabria (southern Italy). Applied Sciences, 11 (4), 1729. https://doi.org/10.3390/app11041729.

[58] Ravisankar, R., Chandramohan, J., Chandrasekaran, A., Jebakumar, J. P. P., Vijayalakshmi, I., Vijayagopal, P., & Venkatraman, B. (2015). Assessments of radioactivity concentration of natural radionuclides and radiological hazard indices in sediment samples from the East coast of Tamilnadu, India with statistical approach. Marine pollution bulletin, 97 (1-2), 419-430. https://doi.org/10.1016/j.marpolbul.2015.05.058

[59] Onjefu, S. A., Taole, S. H., Kgabi, N. A., Grant, C., & Antoine, J. (2017). Assessment of natural radionuclide distribution in shore sediment samples collected from the North Dune beach, Henties Bay, Namibia. Journal of radiation research and applied sciences, 10 (4), 301-306. https://doi.org/10.1016/j.jrras.2017.07.003.

[60] Amekudzie, A., Emi-Reynolds, G., Faanu, A., Darko, E. O., Awudu, A. R., Adukpo, O., Quaye L. A. N., Kpordzro R., Agyemang B., & Ibrahim, A. (2011). Natural radioactivity concentrations and dose assessment in shore sediments along the coast of Greater Accra, Ghana. World Applied Sciences Journal, 13 (11), 2338-2343.

[61] Morsy, Z., Abd El-Wahab, M., & El-Faramawy, N. (2012). Determination of natural radioactive elements in Abo Zaabal, Egypt by means of gamma spectroscopy. Annals of Nuclear Energy, 44, 8-11.

[62] Gaafar, I., El-Shershaby, A., Zeidan, I., & El-Ahll, L. S. (2016). Natural radioactivity and radiation hazard assessment of phosphate mining, Quseir-Safaga area, Central Eastern Desert, Egypt. *NRIAG Journal of Astronomy and Geophysics*, *5* (1), 160-172.

[63] Agbalagba, E. O., Avwiri, G. O., & Chad-Umoreh, Y. E. (2012). γ-Spectroscopy measurement of natural radioactivity and assessment of radiation hazard indices in soil samples from oil fields environment of Delta State, Nigeria. *Journal of environmental radioactivity*, *109*, 64-70.

[64] Abd El-Azeem, S. A., & Mansour, H. (2021). Determination of natural radionuclides and mineral contents in environmental soil samples. Arabian Journal for Science and Engineering, 46 (1), 697-704. https://doi.org/10.1007/s13369-020-04738-6

[65] Zakaly, H. M., Uosif, M. A., Madkour, H., Tammam, M., Issa, S., Elsaman, R., & El-Taher, A. (2019). Assessment of natural radionuclides and heavy metal concentrations in marine sediments in view of tourism activities in Hurghada City, Northern Red Sea, Egypt. Journal of Physical Science, 30 (3), 21–47. https://doi.org/10.21315/jps2019.30.3.3.