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Assessment of Radionuclides and some Heavy Metals in Environmental Samples along AbuZenima, AbuRedis Coastline in Egypt

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ABSTRACT

The purpose of this study is to analyze the radioactivity levels of ^{238}U (^{226}Ra), ^{232}Th(^{228}Ra), and ^{40}K and the related radiological hazard indices, as well as the existing situation and concentrations of heavy metals along the AbuZenima- AbuRedis area, to identify potential contamination sources and establish a radioactive baseline for this area, 27 samples (18 sediments and 9 saltwater) were taken. A high-purity germanium (HPGe) detector was used, the measured activity concentrations of the collected materials were ^{238}U (^{226}Ra), ^{232}Th (^{228}Ra), and ^{40}K in Bq/kg, the active concentration of radionuclides were found in the range from 4.6 to 57.8 (14.46), 1.9 to 88.3 (13.13), and 13.2 to 357.7 (63.58) Bq/kg, results show that the average radioactive concentration of the average radionuclides was less than suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) ranges. Radium equivalent activity (Raeq) in Bq, the absorbed dose rate in nGy/h (D), the yearly effective dose rate in mSv/y, the external and internal hazard indices (Hex, Hin), and the cancer risk factor were calculated. ICP-OES was used to measure the amounts of heavy metals along the shoreline of the research area to determine the causes of contamination. Levels of heavy metals, Fe, Cu, Zn, Pb, Ni, and Cd in water, and the coastal sediments within the investigation region, vary. Temperature, TDS, pH, DO, and Eh of the Suez Gulf's water quality indicators were also measured. A comprehensive environmental assessment of the study area was completed by assessing the radioactivity and amounts of heavy metal pollution in sediments and saltwater. The mean annual effective doses calculated from the absorbed dose rates in the air are lower than the recommended for the general public.

INTRODUCTIO

Terrestrial radionuclides (in marine environments) are carried by seawater, where these radionuclides are largely leached from the top 30 cm of the soil, according to [1]. The amount and variety of pollutants in the marine environment have dramatically expanded over the past few decades. Worldwide, the majority of near-shore marine habitats are coming under more and more stress [2]. Because of its toxicity, environmental durability, non-biodegradability, and absorption into food chains, heavy metal pollution is one of the major environmental issues facing the world today [3], therefore, the availability, toxicity, and ecological harm they provide to marine creatures are extensively investigated [4].

Heavy metals are naturally present in coastal environments as a result of weathering processes, in addition, they are a result of anthropogenic activity like mining, shipping, tourism, and the burning of fuel for a vehicle [5]. The poor sediment's health was caused by heavy metal contamination, surface and groundwater, and food contamination which is a hazard to human health [6-9]. Therefore, knowledge about the heavy metal pollution of sediments is required to determine how governments and the scientific community should work together.

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The use of marine sediments as indication for monitoring heavy metal pollution is far superior to that of seawater or marine shells [10]; However, several studies have been carried out all over the world using sediments and/or seashells to evaluate pollution in coastal areas [11,12].

STUDY AREA

The study region lies in Sinai's southwest, between latitude 28°55'28" and 29°9'36", and longitude 33°4'23" and 33°29'36". It is connected to Abu Zenima and Abu Rudies by an international highway that crosses the Suez Canal and provides access from the Ahmed Hamdy Tunnel.

Abu Zenima and Abu Rudies have lovely asphalt roads and an extensive network of vehicle tracks. Numerous wadis traverse it; these wadis are inhabited with a sizable population in various locations known as villages; (14 villages). With an area of roughly 5000 square kilometers, Abu Zenima is one of the cities in South Sinai. It once had a pharaonic harbor where a ship could dock turquoise and copper across Egypt.

There are many reasons for contaminations as, factories for gypsum and manganese and most of its residents work at such companies, mines, and quarries, while another part the work in agriculture, and tourism is one of the city's industries, also Abu Redis is a city in Egypt's South Sinai Governorate, it covers an area of 2400 square kilometers. In the Wadi Feran area, there are numerous Christian churches.

The study region has been recognized as an important target for numerous possible ores such as copper, manganese, iron, kaolin, glass sands, and, more recently, uranium, and thorium [13]. Some trace elements such as B, V, Co, Ni, Pb, Zr, Zn, Sr, W, Y, and Au are also detected, [14]. All of these mineralizations are found in Palaeozoic rocks. Some sandstone strata are associated with the formation of kaolin, coal, glass sand, Mn-Fe, copper, uranium, and thorium ores. Furthermore, gibbsite-bearing sediments extend for kilometers.

Recently, Because of numerous rocks bearing radioactive mineralization, such as the younger granite rocks of the Um Bogma Formation, the study region has become one of the most important areas for radioactive prospecting a large number of inquiries into the field of radioactive mineral research. and several investigations that were conducted afterward revealed radioactivity up to 55 times that of the background [15].

The radioactive redistribution in various rocks linked with dolomitization, creation of dedolomitization, and karstification of calcrete is dependent on hydrothermal alteration processes, according to uranium deposits in Palaeozoic rocks in Sinai. The research area's inherent radioactivity is increased by the presence of these rocks, which impacts the people, employees, and their surroundings, therefore, it was crucial to recognize the possible risk to individuals, employees, and the environment from background gamma radiation.

Sources of radiation, both man-made and natural are regularly exposing people around the world, with the latter accounting for a large portion of the total absorbed dose that can be obtained in a year. Natural radiation includes gamma rays, cosmogenic radionuclides, and terrestrial radiation for both internal and exterior exposures. Although internal exposures are induced through radionuclide absorption by food or inhalation, such as the usual Primitive terrestrial radionuclides, particularly gamma emitters, are exposed externally when there is ^{40}K in the human body. The presence of radioactive quantities in soil and construction materials, particularly from the ^{238}U and ^{232}Th decay series, determines these exposures [16,17].

Radionuclides of various types naturally occur All people are exposed to the external radiation environment that these radionuclides produce in rocks, terrestrial soils, and the building materials that are the outcome of them. Considering the dosage, ^{40}K,^{232}Th, and ^{238}U are the major primordial radionuclides. The number of radionuclides in the soil, the amount of time spent outside, and the shielding of structures are the main factors that determine a person's exposure rate. However, because radionuclides are frequently included in the materials used to create many buildings, the shielding of the external radiation environment by structures is often more than countered by the addition of extra radionuclides to the building materials [18,19]. Numerous studies have demonstrated the importance of determining the amount of natural radiation absorbed in the air from terrestrial sources furthermore computing radiologic risk coefficients such as excess lifetime cancer [20].

This study aims to assess radionuclide distribution in the coastal environment Crucial radiological baseline mapping is provided, which is required for determining human radiation risk and exposure from natural sources, and establishment and the creation of radiation protective, as distribution of heavy metals along the

coastline of the study area using sediments and seawater, and its impact on the coastal environment and human health by identifying its contamination sources.

MATERIALAND METHODS

Twenty-seven samples (18 sediments and 9 seawater) were collected from the study area as shown in Fig. (1). The bulk of the study region was covered by the sampling locations, which is significant for future research. Although getting to the shoreline is challenging due to the tall mountains and cliffs on the Suez Gulf's eastern edge due to the presence of clearly identifiable sources of pollution, particularly the study area was sampled using a judgmental systematic sampling method. Samples of sediment were taken using a 25 x 25 cm^2 template at a depth of 5 cm; Gravels with a diameter of more than 2 cm were eliminated. [21].

GAMMA-RAY SPECTROMETRY

Shore sediment samples have been dried. In ovens, at 105 °C and 70 °C until completely dry [22]**.** These dry materials were minced, ground, and homogenized. To bring ^{226}Ra and ^{232}Th, as well as their offspring, into secular equilibrium, sediment and acidified water samples were packaged in 100 cc polyethylene containers, before gamma-ray spectrometric analysis, the samples were maintained with other samples in a sealed container for a month.

Activity concentrations of ^{238}U (^{226}Ra), ^{232}Th (^{228}Ra), and^{40}K in Bq/kg dry weight were assessed using a gamma-ray spectrometer by high-purity germanium (HPGe) detector with a relative efficiency of 40% and a resolution of 1.92 keV for the 1332 keV gamma-ray line of ^{60}Co. The detector was linked to a multi-channel analyzer with 16k channels. Activity concentrations of ^{226}Ra, ^{228}Ra, and ^{40}K. Were measured utilizing their strongest gamma transitions, likewise /or their progeny. For ^{226}Ra (^{238}U series), transitions in gamma-ray energy were (295.2 and 351.9keV) of the ^{214}Pb; (609.3 ,1120.3, and 1764.5 keV) of the^{214}Bi. Other gamma-ray energy transitions (238.6keV) of 212Pb, (583 keV) of ^{208}Tl, and (911.2 and 969 keV) of ^{228}Ac were used for ^{228}Ra (^{232}Th series). For ^{40}K, a gamma transition at 1460.7 keV was chosen.

CALCULATING THE EFFECTS OF RADIATION

Radiation hazard indices [annual effective dose (AED), absorbed dose rate (D), and radium equivalent activity (Raeq)], external (Hex), Excess cancer risk of a lifetime (ELCR) and representative gamma index (Iγ)] were calculated as shown in Table (1).

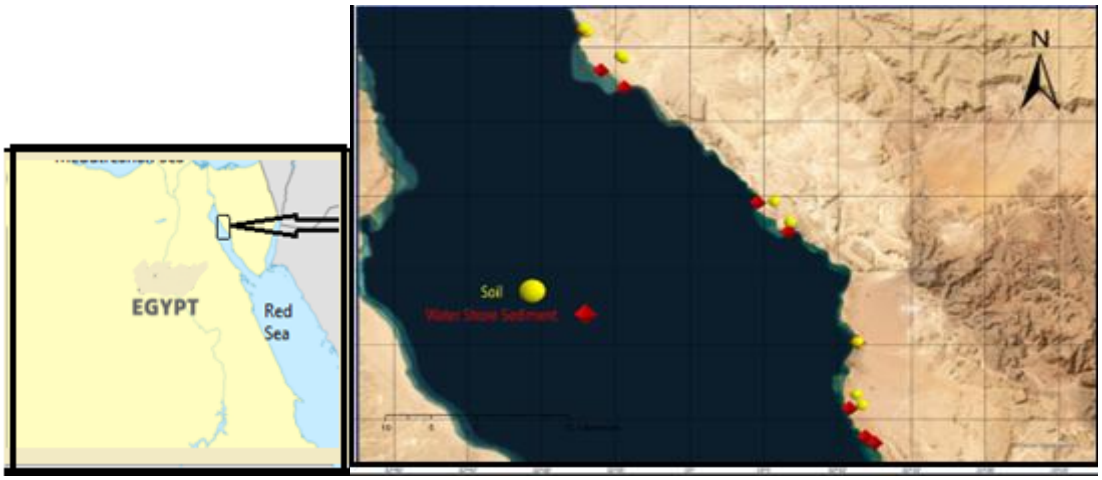


Fig (1): Location map of the sampling site (Study Area)

Table (1): The calculation of some radiation hazard indices for sediments samples

No.	The calculated radiation hazard indices of samples	References
1	Radium Equivalent Activity (Ra_{eq}) = A_{Ra} + 1.43 A_{Th} + 0.077A_k	[23]
2	Absorbed gamma dose rate (D) $= 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K$	[17]
3	External hazard index (H_{ex}) $= \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1$	[23]
4	Annual equivalent dose (AED) = D x 8760 x 0.7 x 10^{-6} x 0.8 (mSv/y)	[17]
5	Representative level index (Iγr,) = (A_{Ra}/150 + A_{Th}/100 + A_K/1500)	[17]
6	Excess cancer risk of a lifetime (ELCR) = AED × DL × RF	[24]

INDUCTIVELY COUPLED PLASMA-OPTICAL EMISSION SPECTROMETER (ICP-OES)

Coastal sediment samples, according to [25] were digested using the designed Milestone Digester (Ethose-D) microwave digestion technique. A 0.3-gram dry sample was weighed and then moved to a suitable vessel with a regulated pressure release system. Following that, 8 mL of 65% concentrated nitric acid, 4 mL of HF (40%), and 2 mL of H_2O_2 (20%) were added as part of a specialized protocol for soil sample digestion, [26]. The content of heavy metals in digestion solutions was measured using an Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) I CAP 6000 Duo, Thermo Scientific, England, 1000mg/L multi-element certified standard solution, Merck, Germany. The concentrations of these metals in mg/kg were calculated using the following formula:

$$\text{Concentration (mg/kg)} = \frac{\text{Concentration (mg/l)} \times V}{M} \quad (1)$$

Where *V* = Final volume (50 ml), except Fe final volume (50*250 ml) of the solution, and *M* = Initial weight (0.3g) of the measured sample. Seawater samples were collected in polyethylene bottles, water quality parameters as hydrogen ion concentration (pH), total dissolved solids (TDS mg/L), temperature (˚C), dissolved oxygen (DO mg/L), and Eh) were measured using Manta 2, Water-Quality Multiprobe device, Model Sub 3, USA, another portion of the samples were acidified and evaluated for the presence of heavy metals (Fe, Zn, Cu, Pb, Ni, and Cd) using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

EVALUATION OF POSSIBLE ENVIRONMENTAL RISK

Heavy metals in sediments endure in the ecosystem and can harm benthic organisms, as well as aquatic organisms, they are also problematic because they can discharge metals into the surrounding water. Numerous minerals and fundamental biological elements exist, but if their concentrations rise over predetermined levels, they can negatively impact living things. Minerals from the sludge can build up in the tissues of marine creatures, which might potentially harm all links in the food chain.

The contamination factor illustrates the relationship between a metal's concentration and the amount corresponding to its background level (CF) [27,28], the contamination factors were found to represent metal ion concentrations in a sample or substance concerning a natural reference (shale), using the equation below. The Potential Ecological Risk Index (Ei) was first developed by [27] to evaluate the level of metal pollution in sediments in light of metal toxicity and the environment's reaction as in equation: $Ei = Ti\ CFi$

where CFi is the contamination factor, Ei is the monomial ecological risk factor (Ti) is the standard for poisonous and sensitivity, and it is the toxic response factor for a specific drug, [29]; The values for Fe, Cd, Cu, Pb, Ni, and Zn are 50, 30, 5, 5, 5, and 1 correspondingly; [30]

POTENTIAL ECOLOGICAL RISK INDEX (RI):

[27] established a system for assessing ecological risks in the control of water pollution, this technique assumes that an aquatic system's sensitivity and productivity are inversely correlated. Based on heavy metal toxicity and environmental response, the potential ecological risk index (RI) was developed to gauge the level of heavy metal pollution in sediments, and (nRIE) is the sum of all risk factors for heavy elements in sediments used to calculate total (RI).

RESULTS AND DISCUSSION

NATURAL RADIOACTIVITY

The distribution of activity concentrations of ^{238}U (^{226}Ra), ^{232}Th (^{228}Ra), and ^{40}K (Bq/kg) for shore sediment and (Bq/l) for water samples was given in Table (2). The activity concentrations in sediment and water samples in the study area were compared with those in the nearby area and on coasts worldwide Table (2,3), to determine the similarities or differences of the environmental circumstances affecting them.

The activity concentrations of ^{238}U (^{226}Ra) were 14.46 (0.58) Bq/kg on average, with values ranging from (4.6 (0.2) to 57.8 (1.30)) Bq/kg. While the activity concentrations of ^{232}Th (^{228}Ra) ranged from (1.9 ±0.2 to88.3 ± 2.1) Bq/kg with an average value of 13.13 ± 0.46Bq/kg. The ^{40}K activity concentrations were between (13.2 ± 1.1 to 357.7 ± 8.4) Bq/kg, with an average 63.58 ± 2.69Bq/kg. The highest activity concentrations of ^{238}U(^{226}Ra) and ^{232}Th (^{228}Ra) were recorded at sample number (2) 57.8 1.30 and 88.3 ± 2.1Bq/kg respectively, and this is explained by the presence of an intertidal zone that is covered with a layer of heavy oil that came from activities such as drilling for crude oil, extracting, and flooding some oil wells. The

concentrations of activity of ^{226}Ra (^{238}U series), ^{228}Ra (^{232}Th series), and ^{40}K in every sample studied were below the global limits determined by [17] (35, 30, and 400 Bq/kg, respectively) except for sample number (2) which this site was covered with a layer of heavy oil as a result of activities related to the exploration and extraction of crude oil as well as the flooding of some oil wells.

[31] found that the average activity of ^{238}U (^{226}Ra), ^{232}Th (^{228}Ra), and ^{40}K were similar to those values, which were 9.9 ± 0.8 (2.25–30.58), 6.6 ± 0.9 (1.18–24.37), and 172.15 ± 5.4 (5.4–587.3) Bq/ kg, respectively. In maritime environments, the activity concentration of natural radionuclides is determined by their physical, chemical, and geochemical characteristics as the surrounding environment.

Table (2): Activity concentrations of shore sediment and water samples in the study area

1	28°55'11.3"N	33°11'19.2"E	Shore sediment	27.5±0.9	28.7±0.9	357.7±8.4
			Water	<DL	<DL	44.1 ±2.2
2	28°55'11.3"N	33°11'20.4"E	Shore sediment	57.8±1.3	88.3±2.1	253.9±5.7
3	28°51'40.0"N	33°11'13.9"E		5.06±0.4	8.2±0.5	58.2±2.3
				20.4±0.8	27.1±0.4	39.3±4.8
4	28°50'44.5"N	33°10'47.9"E	Water	<DL	<DL	50.7 ±2.6
5	28°50'56.9"N	33°11'37.8"E	Shore sediment	6.8±0.2	6.5±0.4	44.5±3.6
6	28°48'49.8"N	33°11'52.8"E		10.3±0.5	6.2±0.2	24.5±1.5
			Water	<DL	<DL	29.6 ±2
7	28°48'25.4"N	33°12'30.9"E	Shore sediment	7.2±0.3	2.5±0.2	17.6±1.1
			Water	<DL	<DL	45.4 ±2.2
8	29°03'15.7"N	33°06'45.6"E	Shore sediment	4.6±0.5	1.9±0.2	19.8±1.9
				20.8±0.2	8.7±0.2	29.9±1.4
9	29°02'37.0"N	33°06'40.0"E	Water	<DL	<DL	27.9 ±1.9
10	29°04'39.5"N	33°05'41.3"E	Shore sediment	17±1.1	7.8±0.3	21.8±1.9
				30.2±0.8	16.4±0.4	19.3±1.8
11	29°04'35.4"N	33°04'36.6"E	Water	<DL	<DL	67.2 ±3.3
12	29°14'15.0"N	32°55'33.1"E	Shore sediment	5.7±1.1	3.7±0.7	18.4±1.3
				6.4±0.4	4.1±0.2	23.6±4.4
13	29°14'15.0"N	32°55'35.3"E	Water	<DL	<DL	77.4 ±3.3
14	29°14'25.0"N	32°55'18.6"E	Shore sediment	11.7±0.4	5.2±0.3	13.2±1.2
				5.9±0.6	4.4±0.3	17.4±2.1
15	29°13'27.6"N	32°54'00.6"E	Water	<DL	<DL	74.8 ±3.2
16	29°16'01.8"N	32°53'03.8"E	Shore sediment	6.3±0.4	5.6±0.4	55.9±1.3
17	29°16'17.8"N	32°52'48.5"E		6.2±0.3	4.9±0.4	26.7±1.4
				10.4±0.3	6.2±0.2	102.8±2.3
18	29°16'09.7"N	2°52'49.5"E	Water	<DL	<DL	48.6 ±2.9

Table (3): Comparison of natural activity concentrations for shore sediments in this study with other studies worldwide

Study Area	Natural Activity Concentration (Bq/kg)			References
	^{226}Ra	^{232}Th	^{40}K	
Abu Zenima AbuRedis Coastline	4.6-57.8	1.9-88.3	13.2-357.7	Present study
Upper Egypt	10–19	1–5	94–107	[32]
Kosovo	8–30	7–31	105–515	[33]
Serbia	20–55	30–73	167–559	[34]
Saudi Arabia	9–41	8–49	203–993	[35]
Iraq	10–16	9–11	242–342	[36]
Jordan	6–1134	MDA-168	19–1362	[37]
Korea	9–108	15–282	203–1560	[7]
Libya	-	5–17	242–424	[38]
Lithuania	2–37	0–21	155–710	[39]
Tunisia	5–50	5–30	93–319	[40]
Macedonia	24–42	38–52	502–707	[41]
Turkey	16–62	24–63	316–878	[42]
Italy	11–29	–	336–1401	[43]

The minimum detectable activity (MDA) of HPGe gamma-ray spectrometer's, was 0.7 and 0.6 Bq/l, respectively, for the distribution of ^{238}U (^{226}Ra) and ^{232}Th (^{228}Ra) radionuclides, the results of these nuclides in water samples, was smaller than these values of the minimum detectable limits as indicated in Table 2, the same radioactive elements were compared with the worldwide coastal areas as indicated in Table 4 to assess the quality of this water sampling.

The average oceanic concentrations as reference values in Table (3), the activity concentrations of ^{40}K ranged from 27.9 ±1.9 to 77.4 ±3.3 Bq/l, with an average value of 51.74±2.8 Bq/l. At sample number 5, the activity concentration was 27.9±1.9 Bq/l with the lowest activity concentration of ^{40}K. While sample number 7 had the highest activity concentration at 77.4±3.3 Bq/l, the relatively high increase in the concentration of ^{40}K at this sample site was due to the relative fasting of evaporation; According to [44]**.** Also, the Petroleum Companies can be affected by oil production, as a significant volume of household and drainage effluents may be the main causes of the comparatively high.

Table (4): Comparison of natural activity concentrations for water samples in this study with other studies worldwide

Study Area	Natural Activity Concentration (Bq/l)			References
	^{226}Ra	^{228}Th	^{40}K	
Abu Zenima AbuRedis coastline	MDA	MDA	51.7	Present study
Nigeria	2.9–13.7	0.34–3.9	48.4–109.4	[45]
Egypt	4.9	2.3	31.9	[46]

RADIOLOGICAL DOSES AND ASSOCIATED RISKS FOR WORKERS

The radiological hazards indices radium equivalent activity (Ra_{eq}), absorbed dose rates (D), annual effective dose (AED), external hazard (H_{ex}), an appropriate gamma index (Iγ), along with elevated lifelong cancer risk (ELCR), as shown in fig (2 – a, b) and table (5) lists the results of the calculations.

The results showed that Raeq values varied from 8.84 to 203.62Bq/kg, with an average of, 38.14Bq/ kg. According to (17), the average gamma dosage absorbed in

the air was 17.16 nGy/h, which is lower than the global average of 57 nGy/h. The lowest dose rates were discovered in sample number 8, which was the surface layer of a public beach; the highest dose rates were found in an area where petroleum activity was present.

Table (4) contains the computed and reported annual effective dose (AED) of shore sediment samples for outdoor exposure to the natural radionuclides ^{238}U (^{226}Ra), ^{232}Th(^{228}Ra), and ^{40}K. The yearly outdoor effective dosage, of shore sediment samples ranged from 0.03 to 0.4 mSv. According to the AED distribution patterns, the south-eastern edge of the study (abu znema area) where they are relatively more elevated, which may be because there are intertidal zones there that have seen large spillage of oil as a result of drilling and exploratory activities as well as flood damage to a few oil wells. Additionally, a significantly high AED was detected in samples (1) and (2), which may be related to activities for extracting petroleum from the Gulf of Suez. External hazard indices computed average values were below unity.

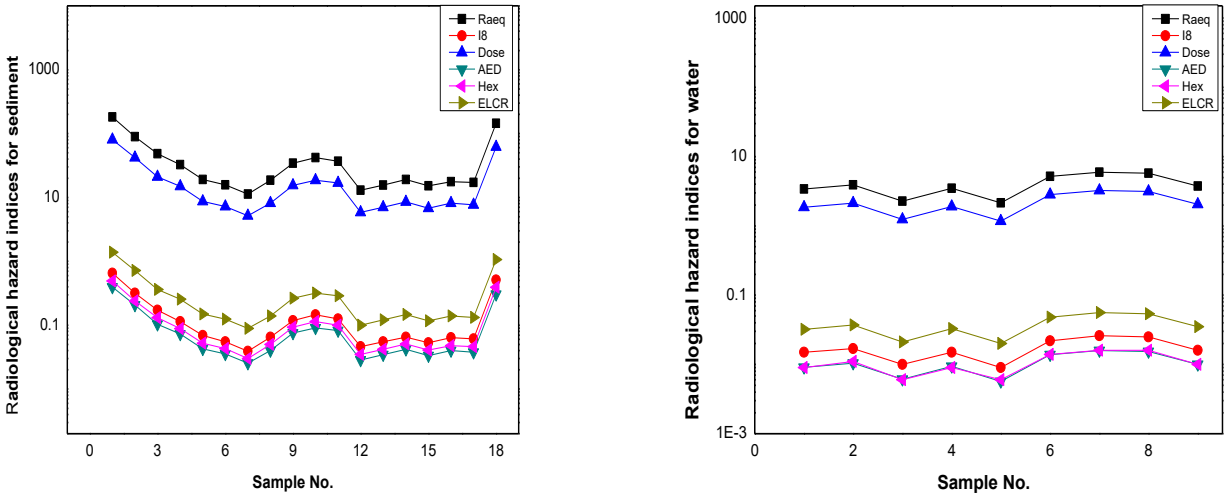
As a result, we can conclude that the radiation threat in coastal sediment samples taken from the Suez Gulf's eastern coast is negligible. The hazard from gamma rays associated with natural radioactivity was calculated using the Representative Level Index ($I\gamma$) in Table (4). Cancer risk results from a rise in the representative gamma index that is less than the unit value and can cause harm to humans.

According to the findings, the representative gamma index had an average value of 0.15 and varied from 0.04 to 0.65. Because the average value of ($I\gamma$) is less than unity, exposure to silt in the study area poses no health hazards.

According to [47], excess lifetime cancer risk (ELCR) is the increased likelihood of acquiring cancer throughout one's lifetime as a result of radiation exposure. The method for calculating the excess lifetime cancer risk (ELCR) is as follows: ELCR = AED × DL (70 years) × Rf (0.05 Sv^{-1}), where AED, DL, and RF stand for annual effective dose equivalent, life expectancy (70 years), and cancer risk factor (Sv^{-1}). For coastal sediment collected from the study area, ELCR values ranged from 0.09 10^{-06} to 1.38 10^{-06} with an average of 0.33 10^{-06}

Table (5): Summary statistics values of radiological hazard indices for some natural radionuclides in sediment and water samples

sample type		Ra eq Bq/kg	$I_{\gamma r}$	Dose nGy/ h	AED mSv/y	Hex nGy/h	ELCR10^{-6}
Shore sediment	Average	42.87	0.15	19.14	0.09	0.12	0.33
	Max	181.31	0.65	80.57	0.40	0.49	1.38
	Min	11.27	0.04	5.17	0.03	0.03	0.09
	Stdev	47.93	0.17	21.12	0.10	0.13	0.36
	Skewness	2.17	2.19	2.15	2.15	2.17	2.15
	Kurtosis	4.08	4.22	4.01	4.01	4.09	4.01
Water	Average	3.98	0.02	2.17	0.01	0.01	0.04
	Max	5.96	0.03	3.25	0.02	0.02	0.06
	Min	2.15	0.01	1.17	0.01	0.01	0.02
	Stdev	1.39	0.01	0.76	0.00	0.00	0.01
	Skewness	0.21	0.21	0.21	0.21	0.21	0.21
	Kurtosis	-1.16	-1.16	-1.16	-1.16	-1.16	-1.16



(a) **(b)**

Fig (2): Radiological hazard indices for shore sediment (a) and water (b) samples

MECHANICAL ANALYSIS AND HEAVY METALS IN COASTLINE SEDIMENT SAMPLES

The total concentrations of the examined heavy metals and mechanical analysis of shore sediments from the study area ((Fe, Cu, Zn, Pb, Ni, and Cd,) are presented in Table (6) and Fig (3 - a, b), The heavy metals concentration in sediment samples in the study area were compared with those on coasts worldwide Table (7), to determine the similarities or differences of the environmental circumstances affecting them. The results illustrate that mechanical analysis of the coastal sediments consists of mud (31.43%), sand (64.52%), and gravel (4.04%) fractions. Marine skeletal fragments made up the majority of the sand and gravel fractions.

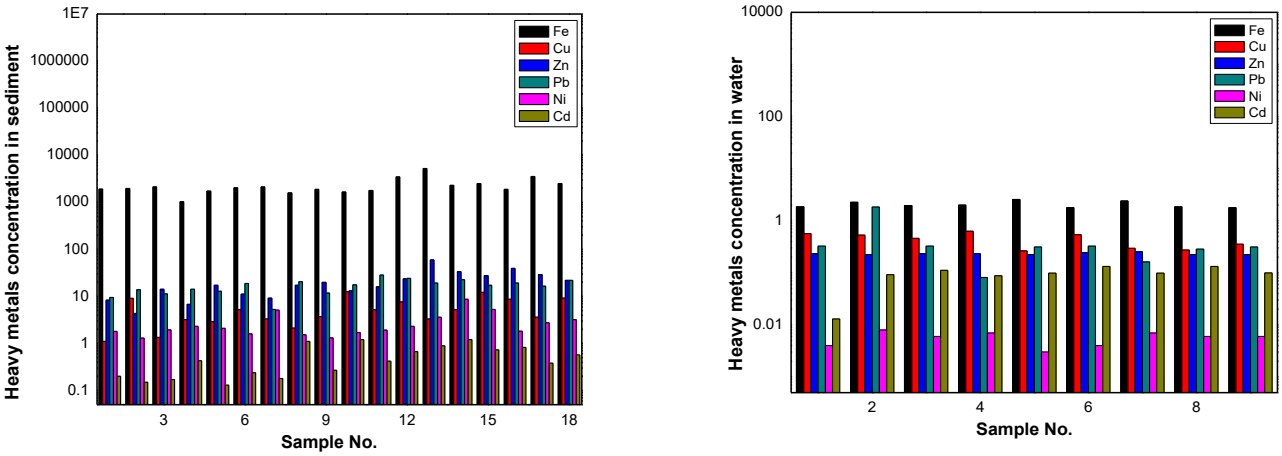
The heavy metals test findings within the study area revealed some differences between the chosen samples. The most prevalent heavy metal in the sediments along the shore of average values for Fe (2289.9 µg /g), which was followed by Zn (20.64 µg /g), Pb (16.94 µg /g), Cu (5.41 µg /g), Ni (2.79 µg /g), and Cd (0.4 µg /g). Generally, the study area's heavy metal concentrations show that the Abu-Rdes has higher concentrations of these metals than the Abu Znema, indicating that the north area has been more impacted by human activity.

To evaluate the environmental quality of the sediments of the study area, ecological indicators of heavy metal deposits were measured and obtained as shown in Table (8). (I_{geo}) contamination factor results are less than one (≤1), which indicates that the severity of heavy metal contamination in sediments ranges from unpolluted to moderately polluted according to the (EF) enrichment factor as estimated by [48] and (49) classifications. The results indicated that nickel (EF = 0.83), copper showed (EF = 2.2), Zinc showed moderate enrichment (EF = 6.02), lead showed severe enrichment (EF = 25.7) and cadmium showed very severe enrichment (EF >50) (50). The (CF) contamination factor results indicated that all the studied metals in the sediment samples had low contamination (CF < 1), except for Cd and Pb which showed moderate contamination (CF = 1–3), according to [26].

In this case, the pollution factor (CF) and geographical accumulation index (I_{geo}) of Cd, Pb, and Zn cause high pollution in the study area due to industrial effluents, boats, ships, and fertilizers generated from agricultural activities. Therefore, it is highly recommended that marine pollution from the area near the Suez region and the chemical and fertilizer industries must be reduced. Industrial discharges, especially those from the chemical and fertilizer sectors, should be monitored to ensure they meet regional standards and requirements for effluents released into marine environments.

Table (6): Summary statistics of heavy metal content in (µg/g) and mechanical analysis for shore sediment samples

	Mud	Sand	Gravel	Cd (µg/g)	Zn (µg/g)	Pb (µg/g)	Cu (µg/g)	Ni (µg/g)	Fe (µg/g)
Average	31.43	64.52	4.04	0.40	20.64	16.94	5.41	2.79	2289.89
Max	34.90	70.30	8.80	0.88	59.40	28.30	13.20	8.70	5127.00
Min	24.90	56.40	1.40	0.12	4.33	5.30	1.21	1.30	1098.00
Stdev	2.73	3.42	2.20	0.22	13.52	5.68	3.42	1.90	906.37
Skewness	-0.90	-0.51	0.72	0.73	1.49	-0.07	0.97	2.15	1.99
Kurtosis	0.50	0.43	-0.07	-0.17	2.84	-0.01	0.26	4.91	5.08



(a) **(b)**

Fig (3): Heavy metal contents for shore sediment (a) and water (b) samples

Table (7): summary of heavy metal concentrations (µg/g) in the sediment's samples and other sites worldwide

Site	Fe	Cu	Zn	Pb	Ni	Cd	References
Abu Zenima AbuRedis Coastline	2284.9	5.54	20.64	16.94	2.80	0.54	present study
Sharm El-Sheikh coast, Egypt	2629	30.0	41.4	32.4	45	2.53	[51]
Hurghada coast, Egypt	345.7	1.23	7.47	41.9	1.73	0.14	[52]
Shalateen coast, Egypt	8451	9.43	44.2	11.4	17.5	0.53	[53]
Arabian Gulf, Saudi Arabia	7552	183	52.7	5.36	75.1	0.23	[6]
Mediterranean coast, Libya	2084	17.3	26.6	11.7	22.7	0.83	[54]
Kazakhstan coast	6730	6.4	11.1	5.75	10.4	0.05	[55]
Sediment quality guidelines (ERL)	–	34	150	47	21	1.2	[56]
Interim sediment quality guideline	-	18.7	124	30.2	15.9	0.7	[57]
Continental crust	56,300	55	70	12.5	75	0.2	[58]
WHO	20000	33	95	19	57	0.1	[59]

PHYSICOCHICAL PROPERTIES OF SURFACE WATER

The findings of field measurements of the parameters relating to water quality (temperature, TDS, Eh, pH, and DO) are presented in Table (8). According to [60], One of the most important environmental factors influencing chemical and biological activities in water is the water's temperature, during the current investigation, there were no discernible regional variations in water temperature. On the other hand, TDS readings varied slightly along the study area's coast, ranging from 39.71 mg/l at sample number (1) to 41.22 mg/l at sample number (8). The highest TDS levels could be attributable to the release of massive volumes of wastewater. The highest seawater temperature recording of 26.73 °C for sample number (4) but sample number (5) had the lowest value of 25.59 °C. The distribution of TDS and salinity exhibit the same pattern. Surface seawater's normal Eh levels ranged from 264 to 272 mV.

In the narrow range of 8.15 to 8.25 for (pH) there are no discernible changes across the sampling sites according to the hydrogen ion concentration in saltwater. The surface water in the study area has dissolved oxygen (DO) values that range from 6.82 to 8.10 mg/l at sample number (1) and sample number (4), respectively, the saturation values of oxygen depend on other parameters like temperature and salinity demonstrate that the entire tested area had a well-oxygenated condition (7.29 mg/l) due to enhanced photosynthetic activity. It is evident from redox indicators that oxidizing conditions predominate in the surrounding Suez Gulf.

Most elements become more mobile under these oxidizing circumstances, which may explain why some samples have lower levels of specific metals than others. The seawater of the study area was subjected to various elements that were undoubtedly influenced by the physicochemical features of water as human influences, as evidenced by the minor changes in the examined variables (Temperature °C, TDS, Eh, pH, and DO).

Table (8): Pollution indices for sediment samples

S. No.	Fe		Cd			Zn			Pb			Cu			Ni			RI
	CF	Er	CF	EF	Er	CF	EF	Er	CF	Ef	Er	CF	EF	Er	CF	Ef	Er	
1	0.04	0.20	2.20	54.20	66.00	0.12	2.92	0.12	0.63	15.60	3.17	0.02	0.54	0.11	0.03	0.63	0.13	69.73
2	0.04	0.21	1.60	38.27	48.00	0.06	1.48	0.06	0.92	22.00	4.60	0.15	3.52	0.74	0.02	0.44	0.09	53.70
3	0.05	0.23	1.90	42.00	57.00	0.20	4.48	0.20	0.75	16.65	3.77	0.03	0.58	0.13	0.03	0.59	0.13	61.46
4	0.02	0.12	3.40	147.09	102.00	0.10	4.21	0.10	0.95	40.95	4.73	0.06	2.52	0.29	0.03	1.38	0.16	107.40
5	0.04	0.18	1.20	32.80	36.00	0.25	6.75	0.25	0.85	23.32	4.27	0.05	1.45	0.26	0.03	0.84	0.15	41.11
6	0.04	0.22	2.10	48.47	63.00	0.16	3.69	0.16	1.26	29.08	6.30	0.10	2.19	0.48	0.02	0.52	0.11	70.26
7	0.05	0.23	1.60	34.25	48.00	0.13	2.82	0.13	0.35	7.56	1.77	0.06	1.25	0.29	0.07	1.55	0.36	50.79
8	0.03	0.16	3.30	102.72	99.00	0.25	7.69	0.25	1.37	42.75	6.87	0.04	1.20	0.19	0.02	0.65	0.10	106.57
9	0.04	0.20	2.90	72.54	87.00	0.28	7.08	0.28	0.79	19.68	3.93	0.07	1.73	0.35	0.02	0.45	0.09	91.85
10	0.04	0.18	4.20	113.68	126.00	0.19	5.10	0.19	1.17	31.76	5.87	0.21	5.71	1.05	0.02	0.64	0.12	133.41
11	0.04	0.19	4.30	113.60	129.00	0.23	6.00	0.23	1.89	49.84	9.43	0.09	2.50	0.47	0.02	0.62	0.12	139.44
12	0.07	0.35	6.90	97.98	207.00	0.34	4.79	0.34	1.61	22.91	8.07	0.14	1.97	0.69	0.03	0.45	0.16	216.61
13	0.11	0.54	8.80	81.53	264.00	0.85	7.86	0.85	1.28	11.86	6.40	0.06	0.56	0.30	0.05	0.46	0.25	272.34
14	0.05	0.25	5.40	107.41	162.00	0.48	9.49	0.48	1.51	29.97	7.53	0.09	1.85	0.46	0.12	2.40	0.60	171.33
15	0.05	0.27	7.10	130.26	213.00	0.39	7.21	0.39	1.15	21.16	5.77	0.24	4.40	1.20	0.07	1.35	0.37	221.00
16	0.04	0.19	5.00	133.20	150.00	0.56	14.92	0.56	1.28	34.10	6.40	0.12	3.25	0.61	0.03	0.67	0.13	157.88
17	0.07	0.35	3.60	51.09	108.00	0.41	5.86	0.41	1.10	15.61	5.50	0.07	1.01	0.36	0.04	0.53	0.19	114.81
18	0.05	0.26	5.60	107.04	168.00	0.31	5.98	0.31	1.45	27.78	7.27	0.17	3.27	0.86	0.04	0.85	0.22	176.92
Min	0.02	0.12	1.20	32.80	36.00	0.06	1.48	0.06	0.35	7.56	1.77	0.02	0.54	0.11	0.02	0.44	0.09	38.14
Max	0.11	0.54	8.80	147.09	264.00	0.85	14.92	0.85	1.89	49.84	9.43	0.24	5.71	1.20	0.12	2.40	0.60	276.63
Average	0.05	0.24	3.95	83.78	118.50	0.29	6.02	0.29	1.13	25.70	5.65	0.10	2.20	0.49	0.04	0.83	0.19	125.37
STDEV	0.02	0.10	2.16	37.76	64.88	0.19	3.01	0.19	0.38	11.21	1.89	0.06	1.41	0.31	0.03	0.52	0.13	67.50

THE INVESTIGATION OF SAMPLES OF HEAVY METALS IN WATER

The number of heavy metals analyzed (Fe, Cu, Zn, Pb, Ni, and Cd) in seawater samples is displayed in Table (9) and fig (4 - a, b). To assess the quality of this water sampling, the same heavy metals were compared with the worldwide coastal areas, concentrations as reference values in Table (10). The results revealed that concentrations of heavy metals in seawater vary depending on the element examined. However, the amounts of the constituents under investigation were comparable to those found in previously published investigations [61,62].

Surface seawater concentrations of Fe varied significantly over space, and from 1.77 to 2.56 µg/l, at samples number (9) and (5) respectively. Copper concentrations were varied from 0.26 µg/l at sample number (5) to 0.63 µg/l at sample number (4), The upsurge in human activity is due to the high level. The geographical distribution of Zn in surface seawater revealed a declining pattern. Sample number (7) had the highest Zn concentration of 0.25 g/l, while sample number (2) had the lowest concentration of 0.22 g/l. The higher Pb concentration values were 1.82µg/l at sample number (2) and the lower value 0.08 µg/l at sample number (4). The concentrations of Ni were varied from 0.003 to 0.008µg/l at samples number (5) and (2), respectively. Cadmium concentrations were varied from 0.13 µg/ 0.01 µg/l, at samples number (6,8) to sample number (1).

The concentration of heavy metals was high in the area near Suez City, where the bay is susceptible to run-off from sewage, fertilizer companies, and power stations, among other sources. According to [63], the Al-Kabanon drain, which is situated 6 kilometers south of Suez City, and the Al-Nasr fertilizer factory, both contribute significantly to the elevated levels of most metals found in some samples; These results revealed that all of these metals might have come from both natural and artificial sources.

In addition, sewage, irrigation, industrial waste, and factories for manganese and gypsum. Kaolin deposits may be responsible for these effects, which were manifest in the study area, [64]. Additionally, the majority of, heavy metals found in coastal seawater originate from terrestrial processes including continental weathering, building infrastructure, and urban runoff, and they have built up over time in the region's surface sediment; [65,66].

Table (9): Summary statistics of heavy metal content in (µg/l) and physicochemical parameters for water samples

Element concentration	Fe (µg/l)	Cu (µg/l)	Zn (µg/l)	Pb (µg/l)	Ni (µg/l)	Cd (µg/l)	DO (mg/L)	pH	Eh (mV)	TDS (mg/l)	Temp (˚C)
Average	2.05	0.43	0.23	0.44	0.01	0.10	7.38	8.32	271.15	40.87	26.49
Max	2.56	0.63	0.25	1.82	0.01	0.13	8.21	8.36	275.54	41.76	27.08
Min	1.77	0.26	0.22	0.08	0.00	0.01	6.91	8.26	267.43	40.23	25.92
Stdev	0.29	0.14	0.01	0.53	0.00	0.04	0.48	0.03	2.58	0.53	0.40
Skewness	0.90	-0.03	1.09	2.84	-0.38	-1.77	0.85	-0.71	0.25	0.85	0.21
Kurtosis	-0.68	-1.85	0.61	8.33	-0.96	4.47	-0.58	-0.03	-0.59	-0.42	-1.16

Table (10): Summary concentration of heavy metal concentrations (µg/g) in the water samples and other sites worldwide

Sites	Fe	Cu	Zn	Pb	Ni	Cd	References
Abu Zenima AbuRedis	2.05	0.43	0.23	0.44	0.01	0.1	present study
Gulf of Aqaba	2.8–42.1	1.10–12.70	1.10–6.00	0.02–0.45	-	0.005–0.069	[67]
Rosetta coast	0.22	-	0.013	0.006	0.006	-	[68]
Groundwater, Libya	–	0.17	0.97	0.093	0.09	0.044	[69]
Al-Khobar, Arabian Gulf	3.54	5.24	16.21	0.11	4.36	0.04	[70]
Jinzhou Bay	–	3.06	11.87	0.61	–	0.92	[30]
Luoyuan Bay	–	5.58	4.99	0.16	–	2.5	[71]
Oceanic average concentration	0.04	0.12	0.40	0.001	–	0.07	[72]

CONCLUSIONS

From a national and international standpoint, the study area represents an important water route because of the significant pollution sources, it is vulnerable to environmental changes. Therefore, it is important to constantly check on and research the levels and trends of various contaminants in the Gulf of Suez. Environmental samples from the Gulf of Suez were tested for heavy metal and radionuclide activity concentrations. Except for a few sites near sites of crude oil exploration and extraction, the average activity concentrations of ^{238}U (^{226}Ra), ^{232}Th(^{228}Ra), and $^{40}K$of shore sediment samples were examined and within the global median activity concentrations.

The chance of a health danger from exposure to sand from the Suez Gulf in areas close to oil exploration and production sites was suggested using radiological hazard indices. The order of the heavy metal concentrations in the coastal sediments of the study area was Fe, Zn, Pb, Cu, Ni, and Cd. These sediments are significantly enriched in Zn, very enriched in Pb, and exceptionally highly enriched in Cd. These metals come from human-made sources. The concentrations of sediments are still below several standard values, including (57). The order of the average metal concentrations in the seawater samples from the study area was Fe, Pb, Cu, Zn, Cd, and Ni. These metal concentrations are higher than the typical oceanic metal concentrations indicated by [73], particularly those of Fe, Pb, Cu, and Cd. The findings of this study region demonstrate that anthropogenic causes such as gypsum and manganese factories, kaolin deposits, sewage, industrial wastes, irrigation, and urban runoff are to blame for the presence of heavy metals.

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