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Risk Assessment of Natural Radioactivity and Heavy Metals Pollution at Ras-Gharib Al-Zafarana Area, Red Sea Coast, Egypt

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ABSTRACT

There is a lot of information that must be known before implementing economic development projects in a study area. So, twenty-two different environmental samples were collected from soil, sediment, and coastal water samples to examine the concentrations of natural radioactive elements of ^{226}Ra, ^{232}Th, and ^{40}K Bq/kg by a Hyper Pure Germanium Detector Gamma-Ray Spectrometry and the concentrations of selected heavy elements in the coastal environment samples, also measured using the inductively coupled plasma-optical emissions spectroscopy technique. Besides that, hourly metrological data for this site for the year 2020 were taken, into account. The maximum activity values recorded for soil were 447.65 Bq/kg, 19.5 Bq/kg, and 17.88 Bq/kg for ^{40}K, ^{232}Th, and ^{226}Ra, respectively; maximum values for sediment were 357.4 Bq/kg, 16.32 Bq/kg, and 4.3 Bq/kg for ^{40}K, ^{232}Th, and ^{226}Ra, respectively; also, maximum activity concentrations of ^{40}K, ^{232}Th, and ^{226}Ra for water were 23.54 Bq/l, 2.03 Bq/l, and 2.0 Bq/l, respectively. Our results were compared with those reported in the literature from other sites worldwide. Radiation hazard parameters were also calculated, and compared with recommended levels in UNSCEAR reports. Levels of heavy elements, Fe, Cu, Zn, Pb, Ni, and Cd in water and sediment samples were compared with the Canadian Environmental Quality Guidelines, and there is some variation within the study area. Water quality parameters (temperature, total dissolved solids, hydrogen ion concentration, dissolved oxygen, and oxidation/reduction potential) show that the high intensity of human activity influences the concentration.

INTRODUCTION

The importance of our study was recognized given the various uses of the study area and its surroundings, including recreation, crude oil extraction, tourism, fishing, and industrial water supply. In recent decades, more hazardous waste has been discharged into a variety of natural environments rapidly urbanizing and globalizing economic and industrial activities [1]. Major environmental problems and threats to the Red Sea coast and water bodies include oil pollution, water pollution, solid waste disposal, navigation activities, and phosphate pollution from ships and also, fisheries [2]. Heavy metal and radionuclide contamination of aquatic habitats is a major environmental concern of the modern world due to its enduring toxicity, sluggish natural breakdown, and rapid buildup [3]. Both natural geological processes and human activity release heavy metals into the environment, which then find their way into ecosystems through soil, sediment, and wastewater discharge [4-5].

The most important natural radionuclides in sediments are unevenly distributed; Information about their distribution in sediments plays an important role in radiation protection and measurements [6]. The isotope ^{226}Ra was chosen because external influences on the population were mainly via gamma rays emitted by its primary daughters ^{214}Pb and ^{21}4Bi. This gamma-ray contribution to the external dose includes about 98% of all gamma rays from all nuclides in the ^{238}U nuclides [7].

Heavy elements, in particular, receive great attention due to their toxicity and subsequent impact on the surrounding environment and human health [8]. Since heavy elements are natural components of the Earth's

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crust, they usually enter the aquatic system through weathering, soil, and volcanic activity, but the predominant pathway of heavy metals to the aquatic environment is anthropogenic pollution, including mining, marine activities, and industrial, municipal and agricultural emissions [9-10]**.** Shallow ecosystems play a key ecological role in providing fisheries and nursery grounds for many fish and invertebrates; So, the main objective of the ongoing work is to measure the background contamination by natural radioactive elements, and heavy elements, and their effects on people and the environment, as well as ways of protecting them from hazardous effects. Baseline data on natural and anthropogenic background radiation will be provided; This data can be used to evaluate any changes in pollution levels resulting from various activities related to radioactive materials and heavy metals or any radioactive fallout shortly. Since there are no existing databases for natural radioactivity in sediment samples from that area, our results are the beginning of establishing a database for the environment of the study area.

STUDY AREA

The study area, (Al-Zafarana - Ras-Gharib) is located in the eastern part of the Egyptian eastern desert on the Suez Gulf, between latitudes 28°16'14" N and 29°07'03"N, longitudes 33°09'25E and 32°39'34"E; it is the northernmost of the municipality in the Red Sea Governorate, it is located on the western side of the Suez Gulf and has an area of 1046 square kilometer.

The area of study has the distinguished presence of a large number of tourist villages directly along the Red Sea coast, which makes it one of the most important tourist areas after Hurghada what also distinguishes it is the presence of a wind turbine station that produces approximately 230 megawatts and a giant farm has been established to generate electricity from winds with a capacity of 120 thousand kilowatts.

The study area is characterized by the presence of many important raw materials for the development of local industry in Egypt, such as phosphates and manganese, which appear clearly in the rock structures of the beach on the Red Sea. The study area is under severe pressure due to overexploitation and has become highly vulnerable to human activities. Also, it is one of the important areas as it contains 90% of the oil and exploration wells in Egypt, which represents one of the main sources of contamination with natural radioactive materials, and a large number of ships pass through it and some of these ships traveling with nuclear energy, which may be one of the possibilities that cause nuclear accidents, If successive concentrations of these pollutants are present in the bottom sediments, the latter will act as a reservoir for the pollutants. So, we must be attentive to the Red Sea shoreline area to assess the radiological and environmental impact of irrational human activities. As a result of human activities, pollution extends along the shore and is discharged into nearshore waters. Some of these pollutants may be captured directly or indirectly by bottom sediments to maintain and defend the coastal environment of the Red Sea, it is crucial to develop radiological baseline data that currently does not exist and investigate the current radiological environmental impact of the non-nuclear industry [11].

METEROLOGICAL DATA ANALYSIS

Hourly metrological data for this site for the year 2020 [12]. The data were wind speed, wind direction, temperature, and relative humidity. Because they influence soil formation processes, climatic parameters such as temperature and precipitation affect the heavy metal content in soil [13]. Relative air humidity influenced the levels of heavy element concentration in soil samples which are likely to be lower in wet regions than in dry areas. From September to December, an increase in wind speed contributes to a significant decrease in heavy metals and natural radionuclides levels, which means that pollution is associated with changes in weather data in the study area.

Windrose

The annual Windrose was plotted to determine the preailing wind direction and the highly polluted study area. The wind rose Fig. 1. in the study area, shows the number of hours per year, that the wind blows in the specified direction. The winds from the Northwest and West accounted for more than 90 % of the wind directions. Analysis of the metrological data shows that the wind blows most frequently from the NW (Northwest direction) with the maximum wind speed reaching 30 km/h and the average annual wind speed being 20 km/h. The wind or surface water flow from precipitation can carry heavy metals. Metals can accumulate in the surface soil layer because of physicochemical processes or physical mechanisms such as the deposition and filtering of suspended materials [14-15].

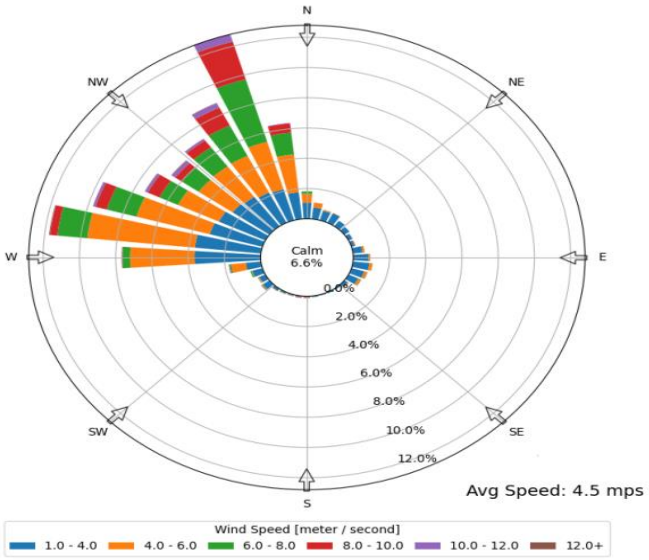

Fig. (1): The 2020 wind rose for the study area.

Temperature Analysis

The hottest month (with the highest average temperature) is July (43°C), while January has the lowest average temperature (24°C). The month with the lowest average temperature is July 21.4°C. The coldest month (with the lowest average temperature is January (8°C). In the study area, Fig. 2. Shows that the temperature is relatively high in the months of summer (June, July, and August). Raising temperatures have an impact on the renewal of soil dust particles, as they reduce soil water and increase evapotranspiration [16].

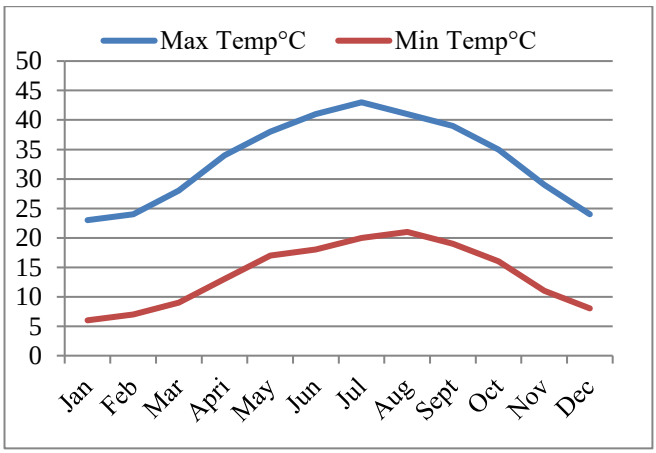

Fig. (2): Temperature analysis for the area of study

Relative Humidity

Fig. 3. Show that the relative humidity in the study area is generally moderate, varying between 40 % and 53% for most of the year (2020). October has the highest relative humidity (53%). June has the lowest relative humidity (41%).

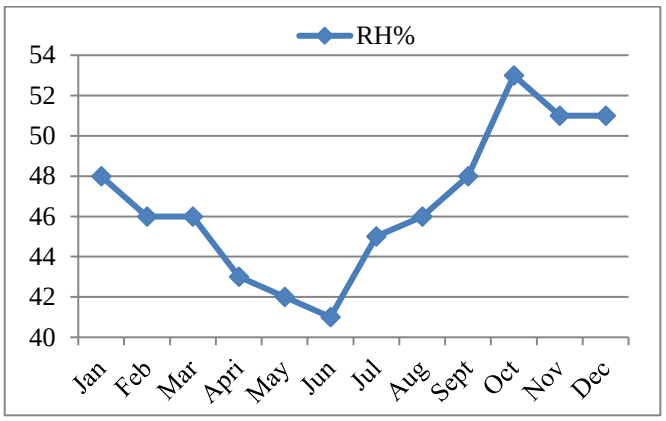

Fig. (3): Relative humidity analysis for the area of study

EXPERIMENTAL METHODS

Collection and Preparation of Samples

Twenty-two samples (16 soil, coastal sediment, and 6 water) were collected from the study area as shown in Fig. 4. Mechanical analyses for soil and shore sediment were performed in the laboratory using an Analytical Sieve Shaker.

For water samples: the parameters pH, EC, and TDS, were measured using a portable Manta 2, Water-Quality Multiprobe device (Model Sub 3, USA). The dissolved major ions included Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-, Na^+, K^+, Ca^{2+}, and Mg^{2+}. Heavy metals including Cadmium, iron, copper, manganese, nickel, lead, and zinc were determined using the ICP-OES technique at the Soil and Water Laboratory Unit, Desert Research Center, Cairo, Egypt, following the methods of the American Society for Testing and Materials [17].

For Soil and shore sediment samples Microwave acid digestion with a Milestone Digester was used for dissolving Soil and shore sediment samples (Ethose-D) using the method developed by [18]. The dried sample weighed 0.3 g and was transferred to an appropriate container with a controlled pressure relief system. A special program for digesting sediment samples includes the addition of (8 ml of 65% concentration) of nitric acid, (4 ml of 40% concentration) of Hydrofluoric acid, and (2 ml of 30% concentration of hydrogen peroxide. Digested samples were used to determine the concentrations of trace metals using a Thermo Scientific Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Heavy elements including cadmium, iron, copper, manganese, nickel, lead, and zinc concentrations of soil and shore sediment samples were measured with a measurement of the uncertainty ranges from (1–10 %). The calculation of these metal concentrations in mg/kg by using the following equation:

$$\text{Concentration (mg/Kg)} = \frac{\text{Conc. (mg/l)} * \text{V}}{\text{M}} \quad (1)$$

where V =final digestion volume (50 ml) and M = initial Weight (0.3g) of measured samples

For radiological investigations, ^{226}Ra, ^{232}Th, and ^{40}K, part of the soil and shore sediment samples were separately weighed, dried at 100 ^{0}C, and powdered. The powdered soil, shore sediment samples, and water samples were transmitted to a 100 ml polyethylene vessel for gamma-ray measurements and locked for 4 weeks to safeguard the secular equilibrium between radium and its radioactive daughters. Three high-decision gamma-ray spectrometers established on a hyper-pure germanium detector (HpGe) were used for the gamma-ray analysis. Confirmation was given to determine the activity of ^{226}Ra, ^{232}Th, and ^{40}K.

For the ^{226}Ra were determined by summing gamma-ray peaks in the series of 295.1 keV (19.2%), 325.0 keV (37.1%) ^{214}Pb, 609 keV (46.1%), 768.4 keV (5%), 934.0 keV (3.4%) and 1120 keV (15%) ^{214}Bi. ^{232}Th activity concentrations were determined by summing the peaks of ^{228}Ra peaks with gamma-ray energies 338.42 keV (11.26), 911.2 keV (29%) ^{228}Ac, and 583.0 keV (30.9%) ^{208}Tl in the series. ^{40}K activity was determined at gamma-ray peak 1460.8 keV (10.7%).

Sources of Soil and Shore Sediment Samples

Soil and shore sediment samples were gathered from the shoreline of the area of study, as in Fig. 4. The field characterization can give a conception of soil and shore sediment resources and chemical composition besides the prime geological operations (weathering, baring, sedimentation, and digenesis) accountable for their forming [19].

All soil and shore sediment samples consist of sand-sized particles mixed, in some locations, gravel with various amounts, and small pieces of rock and clay. Most of the samples consist of poorly arranged grains of sand, indicating differences in density grain and the influence of rising transfer energy (floods and/or wind). The characteristic angular to sub-angular grains of some specimens indicate the short time and distance required to transport weathered materials from the rocks from the high surrounding mountains to the sedimentation site (valleys and plains). Also, the high mountains are the main sources of soil cover and coastal deposits, such as metamorphic and igneous rocks, and sedimentary rocks such as shale, limestone, and sandstone in the study area.

Radiological Characterization

Radiological hazard indices for soil and coastal sediment samples were evaluated, depending on measuring the activity concentrations, as in Table (1).

Table (1): The calculation of some radiation hazard indices for soil and coastal samples

No.	The calculated radiation hazard indices of samples	Ref.
1	Radium Equivalent Activity (Ra_{eq}) = A_{Ra} + 1.43 A_{Th} + 0.077A_k	[19]
2	Absorbed gamma dose rate (D) $= 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K$	[20]
3	External hazard index (H_{ex}) $= \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1$	[21]
4	Annual equivalent dose (AED) = D x 8760 x 0.7 x 10^{-6} x 0.8 (mSv/y)	[22]
5	Representative level index (Iγr,) = (A_{Ra}/150 + A_{Th}/100 + A_K/1500)	[21]
6	Excess cancer risk of a lifetime (ELCR) = AED × DL × RF	[22]
7	Annual gonadal dose equivalent (AGED)=3.09A_{Ra}+4.18A_{Th}+0.314 $_K$(μSv/y)	[23]

A_{Ra}, $A_{Th,}$ and A_K are activities of ^{226}Ra (^{238}U- series, ^{232}Th (^{232}Th- series), and ^{40}K respectively in Bq/kg, D is the dose rate factor of absorption in (nGy/h), 0.7 Sv/Gy conversion factor, 0.8 part of the time of spending indoors, AED is equivalent to an effective dose annually, DL means an average lifetime of duration (70 years), and RF is a factor of risk (Sv^{-1}) for stochastic effects for the population, ICRP 60 uses 0.05 values.

Fig. (4): Location map of samples in the study area.

Table (2): Physical, Chemical Characteristics and Major Cations and Anions of Water Samples

Site	PH	EC (m/s)	TDS	TC%	°C	Na+ mg/L	K+ mg/L	Ca++ mg/L	Mg++ mg/L	Cl- mg/L	SO_4^{--} mg/L	HCO_3- mg/L
1	8.21	58.4	37376	0.119	19.3	14950	280	401	1751	27896	5741	332
2	8.21	58.3	37312	0.144	19.2	14950	280	441	1678	26628	5352	332
4	8.19	58.8	37632	0.91	19.1	15176	280	441	1702	28530	6100	332
5	8.14	59.2	37888	0.096	19.2	15410	262	401	1775	30115	4694	345
7	8.11	58.6	37569	0.049	19.3	15413	272	440	1750	30114	4483	334
8	8.13	58.9	37634	0.078	19.2	15415	281	441	1700	28848	4654	332
Average	8.17	58.70	37568	0.23	19.22	15219	276	427.50	1726	28688	5170.67	335
Max	8.21	59.20	37888	0.91	19.30	15415	281	441.00	1775	30115	6100.00	345
Min	8.11	58.30	37312	0.05	19.10	14950	262	401.00	1678	26628	4483.00	332

RESULTS&DISSECUTIONS

Water samples

Hydro-chemical Characteristics

The hydro-chemical characteristics of water may change, due to physical activities and/or anthropogenic. Field measurements including pH, EC, TC (Total Carbon) and (TDS), major ion concentrations, and some heavy elements in water samples as shown in Table (2). The water sample of the Red Sea shows brief alkaline variations ranging from 8.11 to 8.21 under reaction conditions, with electrical conductivity ranging from 58.3 to 59.2 with an average estimate of 58.7. The total dissolved solid average value was 37569 and ranged from 37888 to 37312, and the total percentage of carbon ranged from 0.049 to 0.91. The concentrations of major cations in mg/l (Na^+, Mg^{++}, Ca^{++}, and K^+) and major anions (Cl^-, SO_4^{--}, and HCO_3^-) in water samples, were measured. Cation concentrations ranged from 14950 to 15415 mg/l for Na^+, from 401 to 441 mg/l for Ca^+, from 262 to 281 mg/l for K^+, and from 1678 to 1775 mg/L for Mg++. Anion concentrations of Cl-, SO_4-and HCO_3- ranged from 26628 to 30115 mg/l for Cl^-, from 2283 to 46100 mg/l for SO_4^- and from 332 to 345 mg/l for HCO_3^-. The ion sequence shows the order: Na^+, Mg^{++}, Ca^{++}, and K^+ for cations and Cl^-, SO_4^{--}, and $HCO_3^-$for anions. The ionic progression to the chemical type of high salinity NaCl water reflected the marine nature of the water

Activities Distribution for Water Samples

Fig. 6. describes the distribution of activity concentration of water samples containing ^{226}Ra, ^{232}Th, and ^{40}K. Where the ^{226} Ra activities ranged from 1.22 ± 0.01 to 3.64 ± 0.22 Bq/l, on average 2.04 Bq/l. ^{232}Th activity in the samples ranged from under detection limits to 3.83 ±0.67Bq/l with an average of 2.03Bq/l. In contrast, 40K activity was recorded for most samples ranging from 15.3± 0.49 to 27.55 ±1.92 Bq/l with an average value of 23.5 ± 0.29 Bq/l. The activity concentrations of ^{226}Ra, ^{232}Th, and ^{40} K radionuclides of water samples in the studied area were below the MDA of the HPGe detector with values of (0.7, 1.1, and 6.9 Bq/L) of each element respectively.

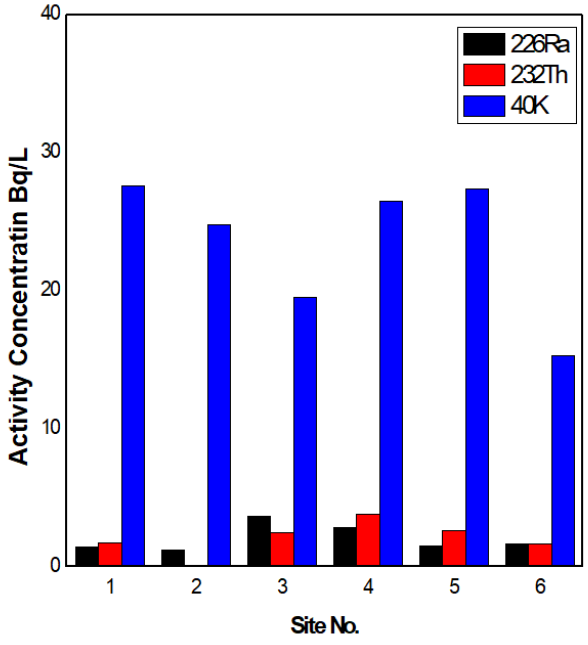

Fig. (6): Concentration activities of ^{226}Ra, ^{232}Th and ^{40}K (Bq/l) for samples water

Table (3): Heavy metal concentrations (µg/L) for water samples under investigation comparison with those in other studies [27].

		Zn	Fe	Mn	Cu	
Egypt	Red Sea	0.54±0.11	18.66 ± 7.40	0.72 ± 0.34	0.88 ± 0.24	[25]
Egypt	Red Sea	1.7-11.4	12.7-25.3	0.16-0.3	0.16-3.8	[26]
Canadian Council of Ministers of the Environment	World	5	300	50	4	[27]
Egypt	Study area	0.07	0.38	0.07	0.07	Present work

Heavy Metals for Water Samples

The mean values of Zn, Fe, Mn, and Cu ions were 0.07, 0.38, 0.07and 0.07 µg/kg dry weight, respectively. The minimum concentrations for these ions were 0.04, 0.32, 0.04, and 0.05µg/kg respectively as shown in Fig.7. The maximum values were 0.09, 0.59, 0.09, and 0.08 µg/kg, respectively. Still, Ni, Pb, and Cd ions concentrations in water samples were under the limits established according to the analytical processes used [24].

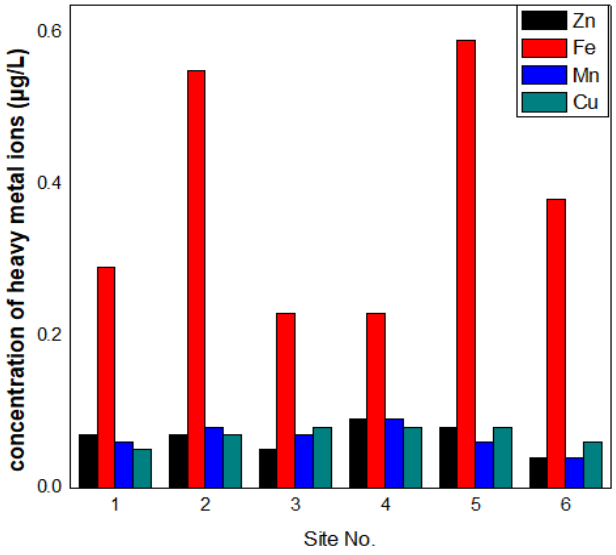

Fig. (7): Heavy metals concentrations of water samples

Comparing current data to Previous studies showed that the average values for metals were less than those reported in other studies [25-26]. The levels were compared to the acceptable standards of [27], and it was established that all the metal ions in water were less than standard limits as presented in Table (3).

SOIL SAMPLES

Activities Distributions

The radionuclide activity values of soil samples are shown in Fig. 8. It has an average value of 17.88 Bq/kg, ranges between 12.18 to 27.98 Bq/kg for ^{226}Ra, 11.46 to 24.86 Bq/kg (average value of 19.50Bq/kg) for ^{232}Th and 270.04 to 649.59 Bq/kg (average value 447.86 Bq/kg) for ^{40}K; in order of ^{40}K> ^{226}Ra> ^{232}Th. This indicates that the condensation of radionuclides in the soil is partly determined due to the chemical makeup and grain size. The increase of ^{40}K compared to other radionuclides for soil samples can be explained by its increase in basement rocks in the environment. It is a series to remind us that the ^{40}K content is significantly more than ^{226}Ra and ^{232}Th radionuclide content in open underground rocks [29-29]. The highest levels of 40K activity were found in the study area at site number (2), with a lot of granite and quartz mines, and construction materials such as sand and gravel mines, which commonly result in a great release of potassium into the environment.

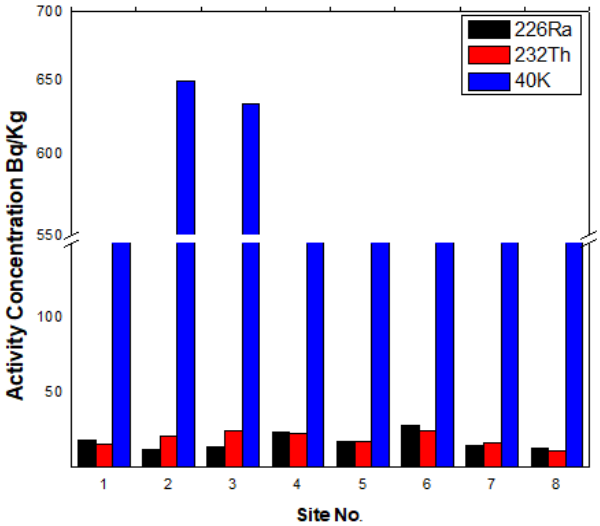

Fig. (8): Activities value (Bq/kg) of natural radionuclides, soil samples

Table (4): Activity concentration of natural radionuclides, soil samples

Location			^{226}Ra	^{232}Th	
	N	E			
1	29°07'03"	32°39'34"	1.12±18.5	1.01±16.29	317.44±7.62
2	29°06'22"	32°39'46"	0.80±12.18	1.48±20.86	649.59±16.24
3	29°10'27"	32°38'56"	0.90±14.22	1.51±24.86	633.57±14.19
4	28°30'05"	32°58'17"	1.10±24.29	1.27±22.66	435.93±9.59
5	28°30'55"	32°57'53"	1.31±17.88	1.19±17.99	528.15±11.62
6	28°20'16"	33°06'40	1.81±27.98	1.32±24.75	462.23±12.53
7	28°16'01"	33°08'59"	1.24±15.16	1.08±17.16	284.24±7.01
8	27°49'59"	33°27'08"	1.00±12.8	0.89±11.46	270.04± 6.97
Average			1.16±17.88	1.22±19.50	447.65± 10.72
Max			1.81±27.98	24.86±1.51	649.59± 16.24
Min			0.80±12.18	0.89±11.46	270.04± 6.97

Heavy Elements for Soil Samples

The average estimated values of metal ions as Zn, Fe, Mn, Ni, Cu, and Pb were 151.5, 1634.50, 61.25, 24.38, 25.38, and 60.54 µg/kg dry weights respectively. The minimum concentrations for these elements were 132, 949, 34, 21, 16, and 12 µg/kg respectively. The maximum concentrations were 190, 1900, 74, 27, 39, and 195.8 µg/kg, respectively. The mean concentration of Cd ions was under detection limits. Maximum and minimum concentrations for Zn were at samples numbers (6 and 1); Fe was found at samples numbers 2 and 8. Mn was found in sample number 6 and 2. Ni was found in samples number 3 and 2. Cu was found in sample number 8 and 4. Pb was found in sample number 2 and 8. The Cd was not detected in all samples as shown in Fig. 9.

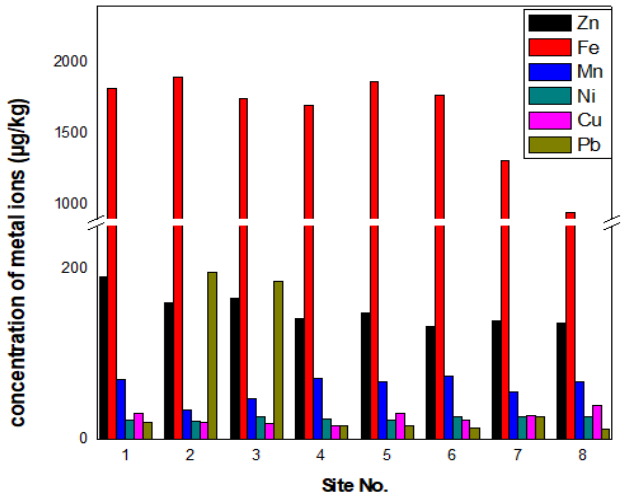

Fig. (9): The concentration of heavy metal ions (µg/kg) for soil samples.

Sediment Samples

Activity Distribution

Activity values of coastal sediment samples of radionuclides are shown in Fig. 10. The average concentration values of the activity were 14.30 Bq/ kg (2.29 to 38.18 Bq/ kg) for ^{226}Ra, 16.32Bq/ kg (3.39 to 43.21Bq/ kg) for 232Th, and 357.40Bq/kg (21.63 to 781.66Bq/ kg) for 40K. Although they have the same dominant order of radionuclide, as in soil samples ^{40}K> ^{232}Th >^{226}Ra, the activity values of shore sediment samples are in general low, this, is high probably, because of the tidal wave effects of seawater, which such sediments continuously result in leaching.

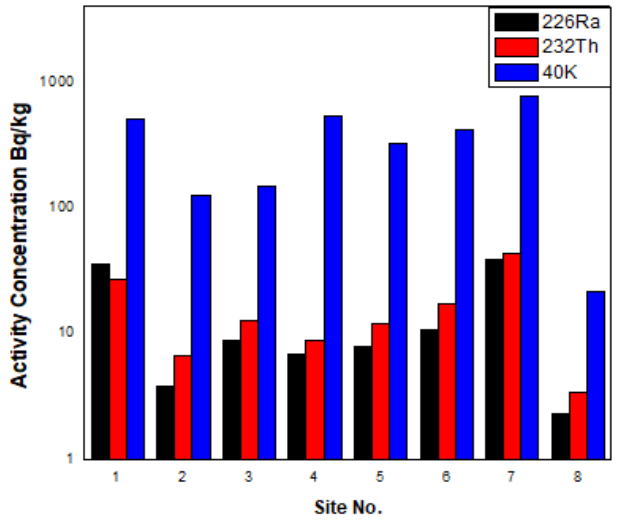

Fig. (10): Activity concentration (Bq/kg) of natural radionuclides for sediment samples

Table (5): Average concentration values of natural radionuclides under investigation with those in other studies for sediment samples

		^{226}Ra	^{232}Th	^{40}K	
Egypt	Study area	14.30	16.3	357.40	Present study
Egypt	Red Sea Marine sediment	27.4(18-48)	38.5(34-110)	419.4(214-641)	[30]
Egypt	Red sea shore sediment	24.6(52-105)	31.4(2.3-22.19)	428(98-101)	[31]
U K	Irish sea	7-58	8-59	277-1611	[32]
Italy	Tyrrhenian Sea	28.2+4.4	91.7+-13.4	604+–30	[33]
Worldwide Soil	Soil	32	45	420	[34]

Table (6): The average concentrations of heavy metals in sediment samples (µg/kg) under investigation compared with those in other countries.

		Zn	Fe	Mn	Ni	Cu	Pb	
Egypt	Study area	140.75	743.88	68.75	18.00	24.13	11.63	Present work
Italy	Adriatic Sea	95.80	0.88	-	-	16.98	4.43	[35]
Egypt	Suez Golf	23.68	-	-	-	10.25	28.34	[36]
Jordan	Aqaba Gulf	195.0	1.46	263.0	62.1	24.00	182.0	[37]

The comparison of natural nuclides in sediments of the studied areas and other coastal and aquatic environments shows that current concentrations of ^{226}Ra were less active than at all sites such as those measured in the Irish Sea in the UK and the Tyrrhenian Sea in Italy [32-33]**,** as listed in Table (5) So, for the sediments, we can conclude that all sample measurements of our study agree with those reported [34]**.**

Heavy Metals

From study areas, Sediments were analyzed to determine and distribute heavy metal concentrations such as Zn, Cu, Pb, Ni, Cd, Fe, and Mn. The average concentration values of Zn, Fe, Mn, Ni, Cu, Pb, and Cd are 140.75, 743.88, 68.75, 18, 24.13, and 11.63 µg/kg dry weight, respectively. The minimum concentrations for these elements are 123, 238, 48, 13, 13, and 3.0µg/kg respectively, and the maximum concentrations are 166, 1245, 116, 30, 30, and 19 µg/kg, respectively. For the Zn element, the maximum and minimum concentrations were in samples number 1 and 2, Fe was found in samples number 2 and 6, Mn was found in samples number 1 and 8, Ni was found in samples number 4 and 8, and Cu is found in samples number 2 and 7. Pb is found in sample number 3 and 5. Cd is not detected in all samples as shown in Fig (11). The difference in sample distribution indicates that the transport of weathered material from the rocks of mountains to the sediment in the environmental wadis and plains takes a short time and distance. Consequently, the main sources of sediments covering the study area were base complexes of igneous and metamorphic rocks and also, sedimentary rocks such as limestone, sandstone, and shale from the high mountains.

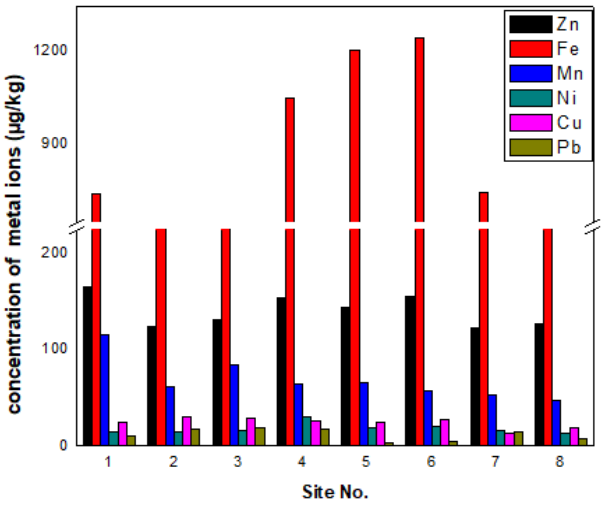

Fig. (11): The concentration of heavy metals (µg/kg) for shore sediment samples.

Hazard Indices

The calculated hazard indices and their radiological effects on the population were assessed and illustrated in Tables (7) and (8).

Radium Equivalent (Ra_{eq})

The Ra_{eq} index in Bq/kg is the most used for measuring the radiological hazard indices, it is suitable for comparing the activity concentration of samples, including the concentrations of natural radionuclides, ^{226}Ra, ^{232}Th, and ^{40}K. It can be determined by the assumption that 10 Bq/ kg of ^{226}Ra, 7 Bq/kg of ^{232}Th, and 130 Bq/ kg of ^{40}K. According to [18]) they have the same output of gamma dose rate, Ra_{eq} the calculated values for soil and sediment samples were shown in Tables (3) & (4), it ranges from 49.98 to 98.96 Bq/kg with an average 80.60 Bq/kg for soil, and ranges from 8.80 to 160.16 Bq/kg with an average 64.20 Bq/kg for sediment, were below the permissible limit (370 Bq/kg). [23][16]

Representative Gamma Index (Iγr)

Completely as (Iγr) is used to evaluate the scale of γ-radiation hazard connected with the naturally occurring radionuclides in a definite sample. The Iγ indicator is used to get together the annual dose because of the further external gamma radiation brought by exterior materials [38]. The estimated values of gamma Index (Iγr) range from 0.190 to 0.383 Bq/kg with an average of 0.307 Bq/kg for soil samples and from 0.032 to 0.604 Bq/kg with averages of 0.246 Bq/g but, for coastal sediment samples as showmen in Tables (3) and (4); the obtained values were underworld permissible limits [39].

Absorbed Dose Rate (DR)

Natural radionuclides in air donate to the absorbed dose rate (DR), depending on the concentration of natural radioactivity of ^{226}Ra, ^{232}Th, and ^{40}K. It is possible to calculate the radiation dose in the air at 1 m above ground level, by knowing the specific activity [36-38]. Transformation factors 0.0417 nGy/h for 40K, 0.604 nGy/h for 232Th, and 0.462 nGy/h for ^{226}Ra were used to estimate the absorbed gamma dose rate (DR) in the air per unit of activity concentration in Bq/kg (dry weight). For soil the amounts of absorbed gamma dose rate range from 24.07 to 48.02 (with an average of 38.74 nGy/h, but from 3.99 to 76.20 (with an average of 31.00 nGy/h for coastal sediment samples as shown in Tables (3) & (4). All values were under the international values for terrestrial exposition 57 nGy/h, except the coastal sediment sample number (7) where the activity of 40K is more than the global common of natural radionuclides in sediment [40]

Annual Gonadal Equivalent Dose (AGED)

Any elevation in the annual gonadal equivalent dose (AGED) affects the bone marrow, destroying red blood cells, which are then replaced by white blood cells, this situation leads to a blood cancer called leukemia, which is fatal [22]. The annual gonadal dose equivalent is equal to a measure of the genetic values of the annual dose equivalent obtained by the reproductive organs of the population (gonads) [34-39]. In the same context, bone marrow cell and bone marrow surface activities are interesting [40-43]. The values obtained for (AGED) range from 172.30 to 346.92 μSv/y (with a mean value of 277.57 μSv/y) for soil samples and from 28.04 to 544.19 μSv/y (with a mean value of 222.85 μSv/y) for shore sediment samples, as shown in Tables (3) and (4). These results are below the maximum permissible value (3×10^{-5} mSv /y) recommended by [19].

Annual Effective Dose (AED)

From the obtained natural radionuclide elements, ^{226}Ra, ^{232}Th, and, ^{40}K in Bq/Kg outdoor the AED (mSv/y) can be obtained [19]. For coastal samples of soil and sediments, AED extended from 0.118 to 0.236 with an average of 0.190 mSv/y and from 0.020 to 0.374 mSv/y with an average of 0.152 mSv/y, as tabulated in Tables (7 and 8); the obtained data were below the allowable value for the population 1 mSv/y [44].

External Hazard Index (Hex)

The Hex values between 0.135 and 0.268 nGy/h with averages of 0.218 nGy/h for soil samples and 0.024 to 0.433 nGy/h with an average of 0.174 nGy/h for sediment samples as shown in Tables (7 and 8).

Excess Lifetime Cancer Risk (ELCR)

An increase in the probability of lifetime cancer development due to human radiation exposure is defined as ELCR [30,33]. The studied values of ELCR for soil samples ranged from 0.413 to 0.825 with an average of 0.665 mSv/y, and for sediment samples from 0.068 to 1.308 mSv/y with an average of 0.532 mSv/y. ELCR values for all samples were under the ordinary worldwide range of 0.29×10^{3} mSv/g [45].

Table (7): The calculated hazard indices for soil samples

Sample No.	Ra_{eq} Bq/kg	Iγr	Dose nGy/h	AGED μSv/y	AED mSv/y	Hex nGy/h	ELCR10^{-6}
1	66.24	0.249	31.56	225.00	0.1548	0.179	0.542
2	92.03	0.361	45.37	328.93	0.2225	0.249	0.779
3	98.55	0.383	48.02	346.92	0.2356	0.267	0.825
4	90.26	0.340	43.01	306.74	0.2110	0.244	0.738
5	84.27	0.326	41.15	296.39	0.2019	0.228	0.706
6	98.96	0.371	47.05	335.15	0.2308	0.268	0.808
7	61.59	0.231	29.16	207.88	0.1431	0.167	0.501
8	49.98	0.190	24.07	172.30	0.1181	0.135	0.413
Average	80.24	0.31	38.67	277.41	0.19	0.22	0.66
Max	98.96	0.38	48.02	346.92	0.24	0.27	0.83
Min	49.98	0.19	24.07	172.30	0.12	0.14	0.41

Table (8): The calculated hazard indices for coastal sediment samples

Sample No.	Ra_{eq}	Iγr	D	AGED	AED	Hex	ELCR
1	113.04	0.422	53.68	381.51	0.2633	0.306	0.9217
2	23.06	0.088	11.03	79.15	0.0541	0.062	0.1893
3	38.65	0.143	18.00	127.79	0.0883	0.105	0.3090
4	60.16	0.243	30.64	224.30	0.1503	0.163	0.5261
5	50.21	0.195	24.55	177.40	0.1204	0.136	0.4215
6	67.22	0.260	32.63	235.36	0.1601	0.182	0.5603
7	160.16	0.604	76.20	544.19	0.3738	0.433	1.3084
8	8.80	0.032	3.99	28.04	0.0196	0.024	0.0685
Average	65.16	0.25	31.34	224.72	0.15	0.18	0.54
Max	160.16	0.60	76.20	544.19	0.37	0.43	1.31
Min	8.80	0.03	3.99	28.04	0.02	0.02	0.07

CONCLUSION

This paper contains information regarding the concentration and distribution of radionuclides and heavy elements and besides that the associated hazards of radionuclides on the coast of Ras-Gharib Al-Zafarana Area. The obtained data display a variation content of heavy elements and radionuclides in all samples and agreement with the other studies carried out in another region of Egypt; (^{226}Ra and ^{232}Th) are below the world limits, while ^{40}K is higher than the international average of radionuclides in coastal sediment depending on the type of rock from which it is formed, the aerial sedimentation (dry and wet), and the physic-chemical properties of the coastal sediment [22], this also, can be explained by the effects of the climatic parameters, evapotranspiration, the wave-shore interaction, and the concentration of proper compound factors, which the solubility of heavy elements and radionuclides in the environmental samples can increase, they can adsorb to solids deposited on the sediment. The calculated hazard

indices for all samples including (Ra_{eq}), (I_γ), (D), (AGED), (AED), (Hex), and (ELCR) were lower than the worldwide limits therefore, the components of the environment can be used for all purposes of human needs is considered safe. In addition, the obtained results can be considered, as a reference for any studies in the future on heavy metal and radionuclide backgrounds and intended to support government authorities in natural resource management in the future to protect public health.

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