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Full Length Research Paper

Determination of Radioactivity Levels of both Natural and Anthropogenic Radionuclides in Suez Canal

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Abstract

This study has been carried out to assess the baseline of radioactivity in Suez Canal, to provide background information on the levels and distribution of radiation doses in the land around the canal, to develop maps of the distribution of natural radioactivity which can be used as a reference maps for the distribution of natural radioactivity levels in any future studies or any other purposes. Physical and chemical characteristics were carried on the water and shore sediment samples which collected from Suez Canal. For water samples the concentration of some trace elements Cu, Ni, Pb , Co and Mn have been measured by ICP/MS. In the collected samples the most trace metals concentration under this investigation recorded their highest mean value at North of canal while Pb and Mn gave their highest level at South locations of canal this attributed to the high polluted areas by industrial effluents, sewage, agriculture drainage, and brackish water from lack Manzala as well as ships passing through the canal. The specific activities of ^{238}U series, ^{232}Th series and ^{40}K (Bq/l) were measured using gamma ray spectrometer based on HPGe detector. The specific activities of water samples ranged from 0.92±0.24 to 4.21±0.4 Bq/l, 0.13±0.01 to 2.59±0.89 and 2.5±0.30 to 7.97±0.88 for $^{226}Ra(^{238}U)$ series, ^{232}Th series and ^{40}K respectively. The activity concentrations (Bq/kg) for sediment samples ranged from 3.04 ±1.10 to 14.7 ± 1.24 for ^{238}U, The activity ranged from 1.12 ± 0.66 to 16.1± 1.30 for ^{232}Th and ranged from 77.0± 4.9 to 350.5 ± 8.9 for ^{40}K. The obtained results of the present work have been compared with the previous studies and the worldwide average specified by the UNSCEAR 2000. The dose assessment and the radiological hazard indices were measured for water and shore sediment samples from the locations under this investigation and compared with the international level.

Keywords: *Water, Sediment, Elemental analysis, Natural Radioactivity, Suez Canal, Egypt.*

Introduction

Suez Canal the main route joining east with west world, was opened for international navigation since 17 November 1869. It extends between 29° 55\ N at Suez on the Gulf of Suez and 31° 15\ N at Port Said on the Mediterranean Sea, and stretches between 32° 17\ E and 32° 35\ E, with an average length along the major axis of 164 km. (Fig. 1). The cross sectional area of the canal however varies between 3900 and 4200 m^2. The canal depth ranges from 20.5 to 25.5 m (UNEP1997).

Fig. 1. Map of the Suze Canal.

Transportation of radioactive materials is directly associated with the progress in every activity involving the use of nuclear energy, including education, medicine, industry, research, nuclear fuel cycle, and power generation. Increasing number and quantities of radioactive material in many different forms are being transported throughout the world which result in an increased public concern about radiation safety in transport. There is a considerable amount of international trade transported in Egypt through the Suez Canal, this trade also involves the transportation of radioactive materials (Sabek 1987). The canal, passes through an area of considerable agricultural, industrial and touristic activities. The considerable amounts of international trade transported through the Suez Canal, include among others radioactive materials resulting in increasing public concern about radiation safety during transport (Abril and Abdel-Aal 2000). El-Tahawy et al.,(1994) measured the radioactivity levels of both natural and artificial radionuclide's in the stream water of Suez Canal and related bottom sediments and found that the fate of released radionuclide's will strongly dependent on the chemical affinity to particulate matter in suspended loads and bottom sediments.

In recent years, there has been a remarkable population growth, accompanied by intense urbanization, an increase of industrial activities and a higher exploitation of cultivable land. These transformations have brought about a huge increase in the quantity of discharges and a wide diversification in the types of pollutants, including heavy metals that reach Suez Canal water and have undesirable effects on its environment (Foneselius 1967).

The Suez Bay ecosystem is suffering of adverse effects of sewage discharge as well as industrial wastes from various activities based in Suez City (as oil refineries, fertilizer and chemical industry, power stations and harbors). Additional environmental threats might arise from envisaged development plants. Four hundred fifty new projects, e.g. steel factory, power station, pipelines, marinas, touristic village, vegetable oil industries,. . . etc. are planned for the northern part of the Gulf of Suez (FAO 1992).

The work presented in this paper includes; chemical and radiological analysis of several surface water and sediments samples from different selected locations along the Suez Canal coasts to investigate the radioactivity levels of both natural and artificial radionuclides. The obtained data will used as a records to trace any potential radioactive contamination may be result from passing the ships through Canal in the convoy system or through increasing the non-nuclear industries.

Materials and methods

Sample collection and preparation

Eighteen sediment and water samples were collected from different locations on the long line of the Suez Canal starting from the beginning of the Canal at Gabal Mariam and then samples from Athmason coast, El-ismailia port, El-Qantara, El-Firdan, El-temsah Lake, Al-salam bridge, port-said and por-foad as in Figure 2. Sampling locations and general characterization of samples were performed using the standard methods.

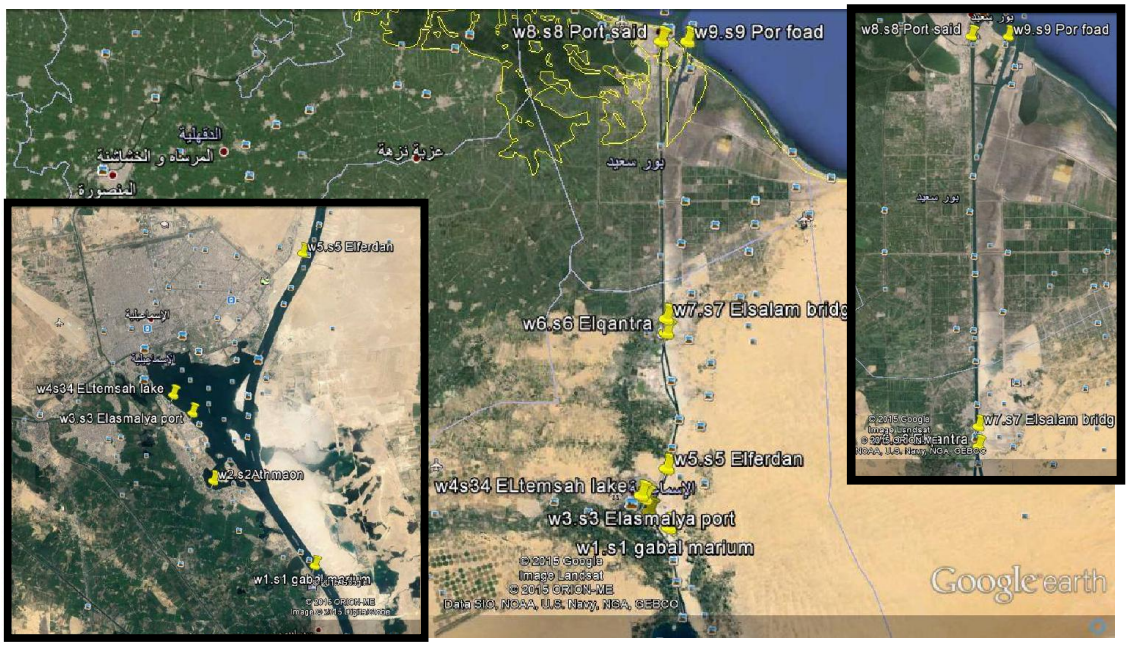

Fig. 2. Sampling locations within Suez Canal.

Sediment Samples: Nine samples were collected from different locations at the shore of the canal of about 5 to 10 cm from the surface, each sample of about 1 Kg was placed in plastic bags and transported to the laboratory. The collected samples were prepared for counting by drying at 105 °C, crushed, homogenized and sieved through 200 mesh sieve shaker. Then weighted and transferred to 100 ml Marinelli beakers.

Surface Water Samples: nine surface water samples were collected using PVC water sampler. The water samples were then drained into polyethylene bottles that had been previously soaked in nitric acid (0.2 M) and rinsed with bi-distilled water. The precautions recommended by (Kremling 1983) to minimize risk of sampling contamination were followed during collection, treatment and filtration of samples. The water samples were filtered in a dust free clean lab. the filtration was passed through acid washed 0.45 μm filter paper. Then a part of samples send for ICP/MS for analysis Cu, Ni, Pb , Co and Mn in water and 100 ml of water samples transferred to Marinelli. Finally, all samples sealed and stored for one month to insure the secular equilibrium between nuclear chain members is obtained when measured by the (HPGe).

Inductively Coupled Plasma Mass Spectrometry (ICP/MS)

ICP was used for the measurement of Cu, Ni, Pb , Co and Mnin collected water samples. All measurements were performed by ICP-MS Agilent 7500CE/CX inductively coupled plasma mass spectrometry with ChemStation Software controlled by a personal computer in combination with the WinNt utility. The plasma is generated through inductive coupling of free electrons with rapidly oscillating magnetic field (27 MHz) and transient signals such as those from a laser ablation pulse or chromatography can be measured over a wide dynamic range.

Gamma spectrometric analysis

Activity measurements have been performed by gamma ray spectrometer at Nuclear and Radiological Regulatory Authority, Central Laboratory for Radioactivity Measurements (CLERMIT) using vertical HPGe detector of relative efficiency 40% and full width at half maximum (FWHM) of 1.95 KeV for ^{60}Co gamma energy line at 1.33 MeV. The detector was operated with Canberra Genie 2000 software for gamma acquisition and analysis. The HPGe detector was contained in a 5 cm thickness free standing lead castle providing a low background environment, to shield the detector from lead fluorescent X-rays and bremsstrahlung, the lead is lined with 1.5 mm iron and 1.0 mm Cu metals, before performing the spectroscopic measurements, the spectrometer has been calibrated using multi-nuclides standard sources distributed in a reference materials soil which have certified concentration of natural radioactivity which provided by the IAEA. The specific activity calculations of ^{238}U series, and ^{232}Th series were obtained indirectly from the gamma rays emitted by their progenies which are in secular equilibrium with them while ^{40}K and ^{137}Cs activities were determined from the 1460.7 KeV and 661 Kev gamma lines respectively. The gamma ray radiation hazards due to the specified radionuclides will be assessed by three different ways such as radium equivalent (Ra_{eq}), the absorbed dose rate (D) and the annual effective dose rate (AED).

Radiological Effects

Radium equivalent (Ra_{eq})

Radium equivalent (Ra_{eq}) in Bq/kg is a convenient index to compare the specific activities of samples containing different concentrations of ^{226}Ra, ^{232}Th (^{228}Ra) and ^{40}K. It is defined based on the assumption that 10 Bq/kg of ^{226}Ra, 7 Bq/kg of ^{232}Th and 130 Bq/kg of ^{40}K produce the same gamma dose rate. The index is given as in equation 1 (Al Zahraniet al. 2011).

$$Ra_{eq}=C_{Ra}+1.43C_{Th}+0.077C_{K} \text{.....(1)}$$

Where: C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively.

Estimation of dose rate (D):

Conversion factors to transform specific activities A_{K-40}, A_{Ra-226} and A_{Th-232} of K, Ra and Th, respectively, in absorbed dose rate at 1m above the ground (in nGy h^{-1} and activity concentration by Bq kg^{-1}) are calculated by Monte Carlo method and the values are in natural environmental radioactivity situations, the effective dose is calculated from the absorbed dose by applying the factor 0.7 Sv/Gy equation 2 (UNSCARE 1993& 2000).

$$D(nGyh^{-1}) = 0.0414A_{K-40} + 0.461A_{Ra-226} + 0.623A_{Th-232} \text{.....(2)}$$

Effective dose rate

To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7 Sv Gy^{-1}) and outdoor occupancy factor (0.2). The effective dose rate in units of μSvyr^{-1} was calculated by equation 3.

$$\text{Effective dose rate } (\mu Sv\ yr^{-1}) = \text{dose rate } (nGyh^{-1}) \times 8760\ h \times 0.2 \times 0.7\ Sv\ Gy^{-1} \times 10^{-3}) \text{ …….. (3)}$$

The external hazard index (H_{ex}) can be defined according the following equation 4.

$$H_{ex} = \frac{A_{^{226}Ra}}{370} + \frac{A_{^{232}Th}}{259} + \frac{A_{^{40}K}}{4810} \leq 1 \quad \text{…..(4)}$$

Where:

A_{Ra-226}, A_{Th-232} and A_{K-40} are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in Bqkg^{-1}, respectively. This index value must be less than unity in order to keep the radiation hazard insignificant (Alias et al., 2008). Another radiation hazard index called the representative level index, $I_{\gamma r}$; is defined as in NEA-OECD (1979) and Alam et al., (1999), This index can be used to estimate the level of gamma radiation hazard associated with the natural radionuclide's in the materials, equation 5.

$$I_{Yr} = \left(\frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500}\right) \ldots\ldots (5)$$

Where:

A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in Bq/kg.

Results and Discussion

Heavy metals in water samples

The assessment of trace metal levels in water can play a key role in detecting sources of pollution in environment. Table (1) showed that the water samples of the studied locations had different concentrations of the measured elements Cu, Ni, Pb , Co and Mn. The average concentrations of Cu varied from 0.49 to 2.33µg/l. The lowest concentration for Cu was found at samples collected from Port Said location, while the highest Cu concentration was found at sample collected from Marium Mountain location. For Ni, the concentration ranged from 0.97 to 5.3 µg/l. The lowest Ni concentration was found at sample collected from Blagat road location, while the highest Ni concentration was found at sample collected from El-Kantra west. For Pb, the concentration ranged from 0.15 to 0.98µg/l while the concentration of Co ranged from 0.20 to 0.60µg/l. finally the concentrations of Mn varied from 0.33 to 1.13µg/l. Comparison between the obtained results for metals in water in µg/l with the other published data illustrated in Table (2).

Table 1. Concentration of Cu, Ni, Pb, Co and Mn in water collected from different coastal location along the Suze canal.

Location	Concentration (µg/l)				
Metal	Copper	Lead	Nickel	Cobalt	Manganese
Marium mountain	0.82	0.77	1.01	0.22	1.13
Blagat road	0.77	0.49	0.97	0.20	0.54
Suze canal port	2.33	0.98	2.33	0.27	0.84
Kantra west	0.84	0.57	5.31	0.40	0.79
Before port said (30k)	0.49	0.34	4.33	0.31	0.84
Port said	2.14	0.41	1.83	0.60	0.33
Por foad	1.40	0.15	3.26	0.61	0.58
Average concentration	1.255	0.53	2.72	0.372	0.721

Table 2. Comparison the present levels of total heavy metals in water (µg/l) with other studies on Suze canal.

Location	Concentration (µg/l)					References
Metal	Copper	Lead	Nickel	Cobalt	Manganese	
Suez canal	1.26	0.53	2.72	0.37	0.72	Present study
Suez canal	1.71	3.52	1.46	0.33	2.89	El- Moselhy et al., (2005)
Suez canal	5.12	0.45	2.90	0.69	3.10	Hamed, (1996)
Port said Mediterranean	1.91	1.75	--	--	--	Abdelmeniem and Fattouh , (1994)
Gulf of Suez	2.68	0.39	2.96	0.7	2.50	Hamed, (1996)
Suez Bay	8.20	2.07	6.73	0.78	7.26	Hamed and el., Moselhy, (2000)

The most trace metals concentration under this investigation recorded their highest mean value at North of canal while Pb and Mn gave their highest level at South locations of canal. This may be attributed to Port Said sector are the most industrialized area in the Suez Canal and the results agree with other investigator (El-Moselhy et al. 1998). Suez Canal suffered from considerable sources of land based activities; waste discharging from tankers passing across the canal, domestic wastes, industrial effluents and fish processing activities, most of these sources are concentrated in the northern part of the canal. The middle of the canal are affected mainly by agriculture effluents, shipyard of the Suez Canal and sewage discharge from Ismailia city and other small villages. The southern part (Port Tawfik) is affected by invaded water coming from the Suez Bay which is loaded by oil and industrial effluents and this illustrate the present of some Pb concentration in the samples collected from the southern locations. In Suez Canal, the principal process dominating the ecosystem are the mean sea level, the velocity and direction of current which are responsible for the distribution of pollutants along Suez Canal (El Samra et al., 1983).

Natural Radioactivity Measurements

The specific activity concentrations for the collected water samples for the radionuclide's, ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in this study are determined and illustrated in Table (3). The results showed that ^{40}K activity concentrations ranged from 2.9 ± 0.28 to 7.97± 0.88Bq/l while ^{232}Th 0.13 ± 0.01 to 2.59 ± 0.89) and ^{226}Ra (^{238}U series) (0.92 ± 0.24 to 4.21 ± 0.40) Bq/l. The activity for ^{137}Cs are below the detection limits by gamma spectrometry of 0.1 Bq/l. The high content of uranium in Suez Canal surface water in some locations may be attributed release of uranium through waste water in the recovery and production of

petroleum oil and petrol, high content of carbonate (if presented) can increase the leaching of uranium with formation of soluble carbonate complex and also the geological nature of the Suez canal itself may contain a lot of uranium sources and that be easily leached to the water content (Lasheen et al., 2008). Comparison between the activity of naturally occurring radionuclide's in Suez canal surface water and other related seas water have been reported by several authors as illustrated in Table (4).

Table 3. Specific activity (Bq.l^{-1}) of ^{226}Ra (^{238}U), ^{232}Th and ^{40}K in water using ɤ-Spectroscopy

Sample locations	^{226}Ra(^{238}U) (Bq/l)	^{232}Th (Bq/l)	^{40}K (Bq/l)
Gabal Marium	4.21 ± 0.40	2.59 ± 0.89	7.97 ± 0.88
Athmanon coast	2.64 ± 0.28	0.74 ± 0.22	3.00 ± 0.37
El-ismailia port	2.00 ± 0.31	2.00 ± 0.67	2.50 ± 0.30
EL-temsah lake	1.57 ± 0.30	1.0 ± 0.24	3.00 ± 0.40
El-ferdan	0.95 ± 0.24	1.50 ± 0.89	3.20 ± 0.29
El-qantra	0.92 ± 0.24	0.13 ± 0.01	3.40 ± 0.25
El-salam bridg	1.51 ± 0.29	0.77 ± 0.25	2.90 ± 0.28
Port said	1.10 ± 0.24	1.6 ± 0.89	4.50 ± 0.49
Por foad	1.88 ± 0.30	2.01 ± 0.86	3.30 ± 0.37

For sediment samples, The results showed that ^{40}K activity concentrations ranged from (350.5 ± 8.9 to 77± 4.9)Bq/kg while ^{232}Th (16.1 ± 1.3 to 1.12± 0.66) and ^{226}Ra (^{238}U series) (14.7± 1.24 to 3.04± 1.1) Bq/kg as illustrated in Table (5).The obtained results for^{226}Ra ,^{232}Th and ^{40}K are lower than the average international radioactivity levels which are 35, 50 and 500 Bq/Kg respectively (UNSCEAR2000).

Table 4. Comparison between the water average activity levels in Suez Canal and other seas of the related areas

Sample Location	Radioactivity level Bq/l			References
	^{226}Ra(^{238}U) (Bq/l)	^{232}Th (Bq/l)	^{40}K (Bq/l)	^{137}Cs (Bq/l)	
Suez canal	1.86 ± 0.24	1.37 ± 0.55	3.75 ± 0.40	<D.L	Present study
Suez canal	1.27 ± 0.02	0.129 ± 0.004	3.210 ± 0.092	-	Lashen, Y.F. et al., (2008)
Suez canal	0.6	-	18	-	El-Tahawy et al., (1994)
Arabian Gulf	0.192	-	-	-	Kraemer, (2003)
Sea water	0.08	-	11.1	-	IEER, (1996)
Sea water	0.037	0.002	--		Choppin and Rydberg, (1980)
Italian Mediterranean Sea	-	-	-	3× 10^{-3}	Delfanti et al., (2002)

D.L: Detection limit

Table 5. Specific activity (Bq.kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in sediment samples using ɤ-Spectroscopy

Sample locations	^{226}Ra(^{238}U) (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)
Gabal Marium	9.20 ± 1.20	6.20 ± 1.01	150.01 ± 9.20	< D.L
Athmanon coast	5.15 ± 1.40	2.41 ± 0.71	83.77 ± 5.10	< D.L
El-ismailia port	6.65 ± 1.80	2.52 ± 0.90	280.43 ± 8.10	< D.L
EL-temsah lake	8.05 ± 2.01	1.12 ± 0.66	140.15 ± 8.90	< D.L
El-ferdan	3.04 ± 1.10	2.36 ± 0.90	240.73 ± 7.40	< D.L
El-qantra	5.1 ± 3.80	4.10 ± 0.66	77.00 ± 4.90	< D.L
El-salam bridg	5.55 ± 1.22	5.68 ± 0.79	83.77 ± 5.50	< D.L
Port said	11.10 ± 1.33	10.50 ± 1.20	330.50 ± 9.10	< D.L
	14.50 ± 0.99	14.00 ± 1.66	250.70 ± 14.10	
Por foad	14.70 ± 1.24	16.10 ± 1.30	350.50 ± 8.90	< D.L

Radiological Effects

Table (6) shows the external hazard index (Ra_{eq}), dose rate, effective dose rate and external hazard index (H_{ex}) for collected sediment and water samples. The highest Ra_{eq} activity value reached 64.712±3.784Bq/kg in Por-foad bottom sediments; while the lower value amounted 15.047±2.808 Bq/kg in Athmanon location collected sediment as illustrated in Table (6). All the sediment samples have radium equivalent activities lower than the limit set in the OECD (The Organization for Economic Cooperation and Development) report (370Bq.Kg^{-1}). The overall mean outdoor terrestrial gamma dose rate was 28.98nGy.h^{-1} and the corresponding outdoor annual effective dose was 0.04mSv.y^{-1} (El-Aydarous 2007).

It is clear that Ra_{eq} values lower the maximum permissible radium activity (Ref. value is 370 Bq/kg) as reported by UNSCEAR 1994. The higher the radioactivity level in the sample, the higher radiological impacts, especially when considering the potential of operators to be exposed via internal contamination, the $I_{\gamma r}$ values are within the internationally accepted value (IAEA 1996).

The values of gamma absorbed dose rates in air resulted from the locations under this investigation are between 32.077 ± 1.775 and 7.413±1.288 nGy/h as shown in Table (6). Therefore, the total absorbed dose rates increases with the activity concentration, and consequently enhances the radiological impact on the workers surrounded by the industrial activities. The recommended acceptable total absorbed dose rate by the workers in areas containing γ-radiations from ^{238}U and ^{232}Th series and their respective decay progenies, as well as ^{40}K, must not exceed 0.055 mGy/h (UNSCARE 1994).

The external hazard index H_{ex} values for sediment samples are calculated according to equation (4) and the resulted illustrated in Table (6). The H_{ex} ranged from 0.175±0.01 to 0.041±0.008 the values of H_{ex} of all samples studied in this work are lower than unity. $I_{\gamma r}$ was calculated and listed in Table (6) to indicate different levels of external gamma radiation due to different combinations of specific natural activities in specific other materials. $I_{\gamma r}$ was ranged from 0.493±0.027 Bq/kg to 0.114±0.02 Bq/kg, the results show that the average $I_{\gamma r}$ values are lower than the internationally accepted value of 1 Bq/kg as in (UNSCEAR 1988). This index can be used to estimate the level of gamma radiation hazard associated with the natural radionuclide's in the materials. The Radiation Hazard calculations used to estimate the contamination from the activities nuclear and non-nuclear industries and the resulting doses received by the worker.

The obtained results for sediment sites under this investigation show the highest observed annual effective dose was 39.34μSv and the lowest value 9.09 μSv with a mean average value 20.16μSv. This value is lower than the worldwide average annual effective dose which is approximately 70 μSv (Kotb El-Sayed 2014) and the values of the external hazard indexes are less than unity in all samples**.**

According to the safety series publication No. 115 (IAEA 1996& 2014)and International Commission on Radiological Protection (ICRP) as the maximum annual dose to members of the public (ICRP 1991) the currently accepted dose limit recommended is 1.0 mSv/yr which is the main aim to achieve (ALARA) optimization for general public to decrease radiological hazard.

Conclusion

The most trace metals concentration under this investigation recorded their highest mean value at North of canal while Pb and Mn gave their highest level at South locations of canal this may be attributed to the different types of pollution by industrial effluents, sewage and agriculture drainage and brackish water from different Lakes as well as ships passing through the canal. The results of the radioactivity are used to distinguish any future changes due to non-nuclear industries on the Egyptian coast. The calculated absorbed rate and annual effective dose lower than the worldwide average which is approximately 70 μSv and the values of the external hazard indexes are less than unity in all locations.

Table 6. The Ra_{eq}, dose rate, effective dose rate and the hazard indexes (H_{ex}& $I_{\gamma r}$) for collected samples.

Sample code	Locations	Ra_{eq} kBq/kg			H_{ex}			$I_{\gamma r}$			Abs. dose rate (nGy/h)			Eff. dose rate (µSv/y)		
Water																
W1	Gabal Marium	8.527	±	1.741	0.023	±	0.005	0.059	±	0.012	3.857	±	0.798	4.730	±	**0.979**
W2	Athmanon	3.929	±	0.623	0.011	±	0.002	0.027	±	0.004	1.747	±	0.281	2.142	±	**0.345**
W3	El-ismailia port	5.053	±	1.291	0.014	±	0.003	0.035	±	0.009	2.286	±	0.589	2.804	±	**0.722**
W4	El-temsah lake	3.231	±	0.674	0.009	±	0.002	0.023	±	0.005	1.462	±	0.304	1.793	±	**0.373**
W5	Elferdan	3.341	±	1.535	0.009	±	0.004	0.024	±	0.011	1.537	±	0.704	1.885	±	**0.864**
W6	El-qantra	1.368	±	0.274	0.004	±	0.001	0.010	±	0.002	0.626	±	0.120	0.767	±	**0.147**
W7	El-salam bridg	2.834	±	0.669	0.008	±	0.002	0.020	±	0.005	1.280	±	0.301	1.569	±	**0.370**
W8	Port said	3.735	±	1.550	0.010	±	0.004	0.026	±	0.011	1.723	±	0.713	2.113	±	**0.874**
W9	Por foad	5.008	±	1.558	0.014	±	0.004	0.035	±	0.011	2.276	±	0.713	2.791	±	**0.875**
Sediment																
S1	Gabal Marium	29.617	±	3.353	0.080	±	0.009	0.223	±	0.024	14.513	±	1.578	17.799	±	**1.936**
S2	Athmanon	15.047	±	2.808	0.041	±	0.008	0.114	±	0.020	7.413	±	1.288	9.092	±	**1.580**
S3	El-ismailia port	31.848	±	3.711	0.086	±	0.010	0.257	±	0.026	16.622	±	1.714	20.386	±	**2.102**
S4	El-temsah lake	20.443	±	3.639	0.055	±	0.010	0.158	±	0.026	10.233	±	1.680	12.550	±	**2.060**
S5	El-ferdan	24.951	±	2.957	0.067	±	0.008	0.204	±	0.021	13.260	±	1.385	16.262	±	**1.699**
S6	El-qantra	16.892	±	5.121	0.046	±	0.014	0.126	±	0.035	8.218	±	2.271	10.079	±	**2.785**
S7	El-salam bridg	20.123	±	1.644	0.054	±	0.004	0.150	±	0.012	9.749	±	0.759	11.956	±	**0.930**
$S8_a$	Port said	51.564	±	3.747	0.139	±	0.010	0.399	±	0.027	25.968	±	1.755	31.848	±	**2.153**
$S8_b$	Port said	53.824	±	4.450	0.145	±	0.012	0.404	±	0.033	26.290	±	2.131	32.242	±	**2.613**
S9	**Por foad**	**64.712**	**±**	**3.784**	**0.175**	**±**	**0.010**	**0.493**	**±**	**0.027**	**32.077**		**1.775**	**39.339**	**±**	**2.176**

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