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Full Length Research Paper

Evaluation and Characterization of Natural Radioactivity Levels in River Nile (Damietta Branch)

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Abstract
As a part of the national survey to evaluate the level of natural radioactivity in river Nile, soil, shore sediments, plant and surface water samples were collected along the river Nile (Damietta branch). The objective of this study is to evaluate the radionuclides contents in the collected samples to evaluate any radiological hazards to the surrounding area due to the non nuclear industries activities. The specific activity concentrations of ^{226}Ra (^{238}U) series, ^{232}Th series and ^{40}K were measured by a gamma ray spectrometers based on hyper-pure germanium detectors. To assess the radiological hazards, the absorbed dose rate, annual effective dose equivalent, hazard indices, activity utilization index and excess life time cancer risk are calculated. The data obtained in this study enables one to assess any possible radiological hazard to mankind due to the non nuclear industries which held around the river Nile. The results of this current study have been compared with the previous study and the world wide specified by the UNSCEAR (2000).

Keywords: *Natural radioactivity, Radiological hazards, river Nile.*

Introduction

The River Nile is the longest river in the world and is the creator of the fertile land of Egypt. The Nile water is the main source of water, providing nearly 95% of water requirement. The river split into two branches, Rosetta and Damietta (our concern in this study). As a result of the growth of industrial activities it has subjected to the continuous discharge of different types of waste water without adequate treatment. So an increase in pollution has been recorded in the environment of the Nile (M.R.Abd El-Bary, 1992). Measurements and studies of natural radioactivity in environmental samples are very important to determine the amount of change of natural background activity with time as a result of any radioactive release. Monitoring of any release of radioactivity to environment is important for environmental protection. Also natural radioactivity measurements are necessary not only due to its radiological impacts, but also because it acts as excellent biochemical and geochemical tracers in the environment (Sharqawy, 2000). Therefore, the assessment of radiation doses from natural radioactive sources is of particular importance as it is the largest contributor to the external dose of the world population.

Measurements of naturally occurring radionuclide's in the environment can be used not only as a reference when routine releases from nuclear installations or accidental radiation exposures but also as a baseline to evaluate the impact caused by non-nuclear activities such as assessment of the radiological impact of phosphate fertilizer used in agriculture.

Materials and Methods

Study area

The Damietta branch of the River Nile lies between 31°-32° Long. and 30°-32° Latt. with a total length of 200 km, starting from El-Kanater Delta Barrage and discharges into the Mediterranean sea at Ras El-Barr. This branch of the river passes through many governorates, i.e. Kalubyia (El-Kanater, Kafr Shokr and Banha),

Dakahlyia (Meet Ghamr, Talkha, El-Mansoura, Sherbeen), also Damietta and Ras El-Barr. With a total area of about 17000 km^2, most of the 20.2 million people of the Nile north delta use the Nile waters for life and livelihood.

Sample collection and preparation
Different environmental samples were collected from different locations- defined by using Global Positioning System (GPS) along the Damietta branch (Figure1). (IAEA-TECDOC-1415, 2004).

Soil samples: 8 soil samples have been taken at depths 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 radiation counting by drying in an oven at 105°C to ensure that moisture is completely removed then the samples are crushed, homogenized and sieved through 200 mesh sizes. Then weighted and transferred to 100 ml Marinelli beakers.

Shore Sediments Samples: 6 Shore Sediments samples have been taken at the shore of the Nile 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 radiation counting by drying in an oven at 105 °C to ensure that moisture is completely removed then the samples are crushed, homogenized and sieved through 200 mesh sizes. Then weighted and transferred to 100 ml Marinelli beakers.

***Surface Water Samples*:** 10 surface water samples were collected from the surface and transferred 100 ml to Marinelli.

Plant samples: 8 plant samples were collected from the Damietta branch of the River Nile then placed into plastic bags, cleaned from soil particles, dried, weighted, then dried at 100°c, reweighted, ground by a laboratory mill, packed in Marinelli-type beakers for analysis. Then all samples sealed and stored for one month to insure that secular equilibrium between nuclear chain members is obtained then measured on the (HPGe).

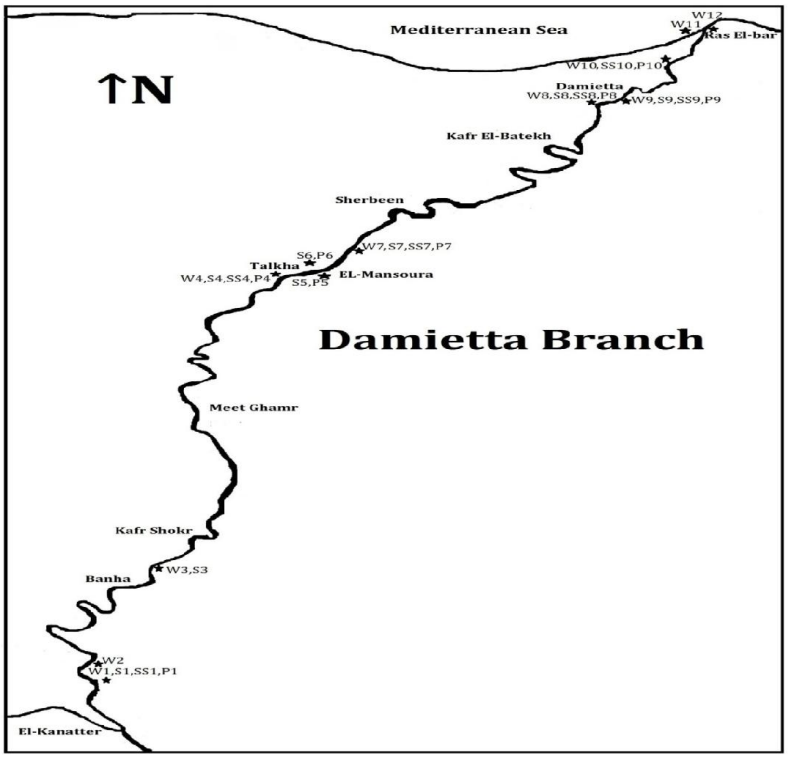

Figure 1: Samples on Damietta Branch

Gamma spectrometric analysis

Activity measurements have been performed by gamma ray spectrometer at the 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 is provided by the IAEA. The specific activity calculations of ^{226}Ra, ^{232}Th, and ^{238}U were obtained indirectly from the gamma rays emitted by their progenies which are in secular equilibrium with them while K activity was determined from the 1460.7 KeV gamma line.

Results and Discussion

The specific activity concentrations of the radionuclide's ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in the collected soil samples considered in the present study are calculated and illustrated in Table (1). From the data obtained, it can be seen that the ^{226}Ra series concentrations vary between (10.2 ± 0.7 - 23.6 ± 1.2) while ^{232}Th (10.4 ± 1.0 - 29.2 ± 1.7) and ^{40}K (191 ± 4.2 - 424 ± 7.5) Bq/Kg.

Table 1: Specific activity (BqKg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in soil samples (dry weight) using ɤ-Spectroscopy

Sample name	Ra-226	Th-232	K-40
S1	23.6±1.2	21.5±0.2	366±6.6
S3	17.7±1.2	18.1±1.4	335±6.1
S4	17.2±1.1	21.6±1.5	301±6.1
S5	20±1.12	22.2±1.5	314±6.2
S6	17.3±0.9	10.4±1.0	191±4.2
S7	20.2±1.2	21.3±1.5	370±7.2
S8	10.2±0.7	11.3±1.0	243±4.9
S9	22.1±1.2	29.2±1.7	424±7.5

The specific activity concentrations of the radionuclide's ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in the collected sediment samples considered in the present study are calculated and illustrated in Table (2). From the data obtained, it can be seen that the ^{226}Ra series concentrations vary between (8.2 ± 0.7 - 20.2 ± 1.3) while ^{232}Th (9.2 ± 1.2 - 27.3 ± 2.0) and ^{40}K (216 ± 4.4 - 463 ± 8.6) Bq/Kg.

Table 2: Specific activity (BqKg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in Shore sediment (dry weight) using ɤ-Spectroscopy

Sample name	Ra-226	Th-232	K-40
SS1	19.5±0.9	18.4±1.2	216±4.4
SS4	19.4±1.2	19.8±1.5	297±6.4
SS7	18.2±1.0	17.3±1.3	320±5.9
SS8	16.1±1.0	20.1±1.5	325±6.4
SS9	20.2±1.3	27.3±2.0	463±8.6
SS10	8.24±0.7	9.2±1.2	398±7.1

The specific activity concentrations of the radionuclides ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in the collected plant samples considered in the present study are calculated and illustrated in Table (3). From the data obtained, it can be seen that the ^{226}Ra series concentrations vary between (2.7 ± 0.4 - 5.9 ± 0.8) while ^{232}Th (2.9 ± 2.6 - 8.4 ± 2.5) and ^{40}K (303 ± 6.8 - 1423 ± 11.3) Bq/Kg.

Table 3: Specific activity (BqKg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in Plant (dry weight) using ɤ-Spectroscopy

Sample name	Ra-226	Th-232	K-40
P1	5.2±0.8	5.3±2.2	538±13.8
P4	3.2±0.5	7.8±2.3	1423±11.3
P5	5.3±1.2	2.9±2.6	411±15.7
P6	3.1±0.4	4.9±1.1	303±6.8
P7	3.3±0. 6	5.4±2.1	303±9.1
P8	5.9±0.8	8.4±2.5	1051±20.1
P9	5.7±0.7	7.6±1.6	556±14.1
P10	2.7±0.4	5.0±1.7	681±12.6

The specific activity concentrations of the radionuclides ^{226}Ra (^{238}U series), ^{232}Th series and ^{40}K in the collected water samples considered in the present study are calculated and illustrated in Table (4). From the data obtained, it can be seen that the ^{226}Ra series concentrations vary between (0.2 ± 0.1 - 4.5 ± 0.4) while ^{232}Th (0.7 ± 0.2 - 3.2 ± 1.1) and ^{40}K (0.5 ± 0.0 - 26.0 ± 1.1) Bq/Kg.

Table 4: Specific activity (BqKg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K in water using ɤ-Spectroscopy

Sample name	Ra-226	Th-232	K-40
W1	1.6±0.3	0.8±0.2	16.9±0.8
W2	4.5±0.4	3.2±1.1	17.5±0.9
W3	0.3±0.1	2.1±0.9	6.6±0.3
W4	2.5±0.3	0.7±0.2	7.3±0.4
W7	0.8±0.1	2±0.7	1.9±0.1
W8	0.7±0.1	0.7±0.8	9.1±0.5
W9	0.3±0.1	2.6±0.8	0.6±0.0
W10	2.0±0.3	1±0.2	20.6±1.0
W11	0.2±0.1	1.6±0.9	13.4±0.7
W12	0.2±0.1	1.9±0.5	25.9±1.1

The obtained results for ^{226}Ra, 232Th and ^{40}K are lower than the average international radioactivity levels which are 35, 50 and 500 Bq/Kg respectively. (UNSCEAR,2000).

Radiation Hazard Parameters

The natural specific activity of rocks is usually determined from ^{226}Ra, ^{232}Th and ^{40}K contents. The reason of considering ^{226}Ra rather than ^{238}U is that 98.5% of the radiological effects of U series are produced by Ra and its daughter products (Huy et al.,2006). The gamma ray radiation hazards due to the specified radionuclides will be assessed by three different ways: radium equivalent (Ra_{eq}), the absorbed dose rate (D) and the annual effective dose rate (AED).

Radium equivalent activity is a widely used hazard index. It is calculated using the following equation (Huy et al.,2006): $Ra_{eq} = A_{Ra} + 1.43\ A_{Th} + 0.077A_k$

Where: A_{Ra}, A_{Th} and A_K are activities of ^{226}Ra, ^{232}Th and ^{40}K respectively in Bq/kg.

The maximum value of Ra_{eq} must be < 370 Bqkg^{-1} in order to keep the external dose <1.5 mGy/y **(**OECD, 1979). As shown in Table 5, the Ra_{eq} values are lower than the internationally value (370 Bq/kg).

The absorbed dose rates due to γ-radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) are also calculated. The conversion factors used to compute absorbed γ-dose rate *(D)* in air per unit activity concentration in Bq per kg (dry weight) corresponds to 0.462 nGy h^{-1} for ^{226}Ra, 0.621 nGy h^{-1} for ^{232}Th and 0.0417 nGy h^{-1} for ^{40}K. Therefore, *D* can be calculated according to the following formula:

$$D = 0.462A_{Ra} + 0.621A_{Th} + 0.0417A_K$$

Where: A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively. As shown in Table (5), the absorbed dose rates are lower than the world average value (55 $nGyh^{-1}$) (UNSCEAR, 2000).

The annual effective dose is a useful concept that enables the radiation doses from different radionuclides and from different types and sources of radioactivity to be added. It is calculated based on the risks of radiation induced health affects which the annual effective dose rate AED (mSv/y) can be calculated using the following formula:

$AED = D \times 8760 \times 0.7 \times 10^{-6} \times 0.8$ (mSv/y)

Where D is the absorbed dose rate in (nGy/h), 0.7 $SvGy^{-1}$ is the conversion coefficient from absorbed dose to effective dose and 0.8 the fraction of time spent indoors.

In most of samples under investigation, the annual effective dose is higher than the world average (0.07 mSv/y) for annual effective dose.

Hazard Indices (H_{ex} and H_{in}): The two indices are that represent the external and internal radiation hazards. These indices are calculated as shown in Table 5 using the following relation [(Orgun et al., 2007)]:

$H_{ex} = (C_u/370+C_{Th}/259+C_K/4810) \leq 1$

$H_{in} = (C_u/185+C_{Th}/259+C_K/4810) < 1$

where: C_u, C_{Th} and C_K are the mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq/Kg respectively.

Table 5: Radium equivalent activity (Bq/Kg), absorbed dose rate (nGy/h) and the annual effective dose (mSv/y).

Sample Name	Ra_{eq}	D_R	AED	H_{in}	H_{ex}	HELC
S1	80±3.6	39.3±1.6	0.19±0	0.29±0.01	0.22±0.01	0.67±0.01
SS1	60.9±2.9	29.2±1.3	0.14±0	0.22±0.01	0.17±0.01	0.5±0.01
S3	67.1±3.7	33.2±1.7	0.16±0	0.24±0.01	0.19±0.01	0.57±0.01
S4	69.1±3.6	33.6±1.6	0.16±0	0.24±0.01	0.19±0.01	0.58±0.01
SS4	68.5±3.8	33.4±1.7	0.16±0	0.24±0.01	0.19±0.01	0.57±0.01
S5	73.7±3.7	35.8±1.7	0.18±0	0.26±0.01	0.21±0.01	0.62±0.01
S6	45.4±2.7	22.3±1.2	0.11±0	0.17±0.01	0.13±0.01	0.38±0.01
S7	76.6±3.9	37.8±1.8	0.19±0	0.27±0.01	0.21±0.01	0.65±0.01
SS7	65.3±3.4	32.3±1.5	0.16±0	0.23±0.01	0.18±0.01	0.55±0.01
S8	43.3±2.6	21.7±1.2	0.11±0	0.15±0.01	0.12±0.01	0.37±0.01
SS8	67.6±3.6	33.2±1.6	0.16±0	0.23±0.01	0.19±0.01	0.57±0.01
S9	93.4±4.1	45.6±1.9	0.22±0	0.32±0.01	0.26±0.01	0.78±0.01
SS9	91.7±4.7	45.3±2.1	0.22±0	0.31±0.02	0.26±0.01	0.78±0.01
SS10	49.3±2.9	26.1±1.4	0.13±0	0.16±0.01	0.14±0.01	0.45±0.01

From the data obtained, the internal and external hazard indices are ranged from [(0.15±0.01),(0.12±0.01)] to [(0.32±0.01),(0.26±0.01)] with an average [(0.24±0.01),(0.19±0.01)] which is lower than unity and corresponds to an annual effective dose < 0.3 mSv/y (El-Gamal et al.,2007).

Excess lifetime Cancer risk (ELCR): Excess Lifetime Cancer Risk (ELCR) is also calculated using the following equation:

$ELCR = AED \times DL \times RF$

Where: AED, DL and RF is the annual effective dose equivalent, duration of life (70 years) and risk factor (Sv^{-1}), for stochastic effects, ICRP 60 uses values of 0.05 for the public (Taskin et al., 2009).

The radiological fatality cancer risks for the population and severe hereditary effects based on ICRP publication 60, ICRP publication 103, risk assessment methods are carried out and the results are shown in Table (5). The range of ELCR is (0.37±0.01) to (0.78±0.01) with an average of (0.6±0.01).

Conclusion

This work aimed to assess the effect of some non-nuclear industries around the river Nile (Damietta branch) by collecting some samples of water, soil, shore sediments and plant which measured by (HPGe). The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the collected samples are (9.1 ±0.7), (10.1 ± 1.3) and (310.5 ± 6. 2) Bq kg^{-1} dry weight respectively. The obtained results for ^{226}Ra (^{238}U) and ^{232}Th are lower than the international levels. The absorbed dose rate due to the radionuclide's in the samples is calculated to be in the range of (21.7±1.2) to (45.6±1.9) nGy/h. The corresponding annual effective dose average is calculated to be (0.16±0 mSv/year). The internal and external hazard indices in all the samples are less than the unity with average values of (0.24±0.01),(0.19±0.01), respectively. The present data are compared with the previous studies and from the data obtained it can be concluded that due to the human activities around the river Nile (Damietta branch), the background levels does not changed.

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