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Radiation Dose and Risk Assessment of Natural Radionuclides in Black Sand Collected From Rosetta Beach, Egypt

M. Abdel Geleel [1*], *Marwa Abdel Razik Abdou* [2], *M. Youssef* [3]

[1]Egyptian Atomic Energy Authority, Egypt.
[2]National Cancer Institute, Cairo University, Egypt.
[3]Faulty of medicine, Alexandria university, Egypt.

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Abstract: Concentration of natural radionuclides materials on seashores vary from time to time as a result of climate changes. Black sand are spread along the northern coast of Egypt, from Rosetta city to Rafah city, with a length of 400 Km. Egypt owns 1.3 billion cubic meters distributed on 4 main areas one of these area is Rosetta beach. Rosetta beach is one of the public beaches that most of the resident of Rashid city uses as a resort. 25 black sand samples were collected from about 3 km along Rosetta beach. The natural radionuclides activity concentrations were measured by gamma-ray spectrometry system with hyperpure germanium (HPGe) detector.

The Radium Equivalent Activity, the external hazard index, the absorbed dose rate and the annual effective dose were assessed and compared with internationally published values for external dose and activity concentrations. The activity concentration of Ra^{226}, U^{238}, Th^{232} and K^{40} in Rosetta black sand ranged from 7.44 ± 1.62 to 6.34 ± 1.27, 17.57 ± 3.6 to 6.97 ± 1.31, 16.11 ± 4.21 to 6.66 ± 1.30, 381.01 ± 43.33 to 141 ± 20.11 Bq kg-1, with a mean value of 11.93, 12.32, 11.78 and 259.11 Bq Kg^{-1} respectively. The results indicate that the absorbed dose rates range from 70.13 to 176.99 $nGyh^{-1}$ with mean value of 121.08 $nGy.h^{-1}$. The average absorbed dose rate for all samples are greater than the estimate of average global primordial radiation of 59 nGy/h and than the world range (10-200 nGy/h). The annual effective dose for outdoor and indoor varied between 0.086 and 0.217 mSv/y, with a mean average of 0.148 mSv/y and 0.344 and 0.868 mSv/y with a mean average of 0.591 mSv/y, respectively. Values of all studied samples are higher than the worldwide average for outdoor annual effective dose, which is 0.07 mSv/y.

Keywords: Annual effective dose, gamma ray spectrometry, natural radioactivity, radiation hazard indexes.

1 Introduction

Peoples are exposed to ionizing radiation originated mainly from naturally occurring radionuclides and the exposure to theses natural radiation are internally and externally [1,2]. The control of these levels of radiation is very important not only to evaluate the dose given at the place where you live, but also setting up baseline levels of the environmental radiation in order to detect any abnormal changes [3]. The measurement of the natural radioactivity concentrations in black sand depending upon the local geology of each region in the world, has been carried out many parts of the world mostly for the assessment of the dose and risk resulting from them. Additionally, it is also important to assess the concentrations and the distribution of natural radionuclides in the coastal zone in order to evaluate those provided by the ebb and flow tides of the sea [4].

The city of Rosetta is located at the head of the Rosetta branch, which is one of the two branches of the River Nile, and is 263 Km away from Cairo. In Rosetta region, Egypt requires periodic radiological assessments of the natural radionuclides due to their geographical location, high density of traffic by sea and owing to being one of the most important local population and resorts people destinations in a world. The total population of Rosetta is approximately 71,500 persons with approximately nine million tourists per year. The main objective of this study is to determine the levels of the naturally occurring Ra-226, Th-232 and K-40 in the most common seashores of Egypt and to estimate the radiological hazards due to the natural radionuclides contents of the beach sands in these resorts to assess any health risks.

The aim of this study is to reinvestigate the radioactivity concentrations in black sand collected from Rosetta beaches in Demiat region, Egypt. And to be exact,

*Corresponding author e-mail: mageleel2000@gmail.com

parameters of a health hazard are thoroughly discussed. It can be concluded that there is still a need for the implementation of environmental management practices in Rosetta to protect these ecosystems from the most pollutants that can affect human health and the environment.

2 Experimental Techniques

2.1 Sample analysis and preparation

Twenty one black sand samples were collected from Rosetta seashores. They were weighted dried at 100 0C for 24 h, re-weighted to determine the water content, grinned, and homogenized to pass through 1 mm meshes sieve. 100 ml of each sample was weighed, and transferred to Marinelli-beakers and sealed for 4 weeks (to obtain radioactive secular equilibrium) to be analyzed using gamma spectrometers. The samples were analyzed in the geometries used during the procedure of efficiency determination.

2.2 Gamma Ray Spectrometry

The samples from area of the study were analyzed using a high-resolution; low background gamma-ray spectrometry system based on a coaxial high purity germanium detector (HPGe). The gamma-ray spectra which were analyzed were created through converting the event energy into a pulse height spectrum. The signal processing was done by connecting the detector to a preamplifier and a standard spectroscopy shaping amplifier. The resultant spectra were analyzed using Canberra Genie software "Genie-2000". The activity concentration of K-40 was measured directly via its 1461 keV peak of the gamma ray spectra. To determine the activity concentration of Ra-226, the average value of gamma ray lines 295.1 and 351.9 keV from Pb-214, the average value of gamma ray lines 609.3 and 1764.5 keV gamma rays from Bi-214 are used. Activity concentration of Th-232 is determined using the average value of gamma ray lines 238.6 and 338.4 keV from Pb-212, the average value of gamma ray lines [5] 727.65 and 1620.56 keV from Bi-212., the average value of gamma ray lines , 911.1 and 968.9 keV from Ac-228 the average value of gamma ray lines 583.1 and 2614 keV from Tl-208 are used. The detector was calibrated for the efficiency using Ra-226 point source to first produce a relative efficiency curve followed by standardization using KCl as a standard solution [6,7, 8]. Quality control and quality assurance of the measurements using International Atomic Energy Agency (IAEA) reference materials (Soil 6, IAEA-326). In addition, duplicate samples were added to insure the analysis consistency of the measurements. Blank samples were added to eliminate the cross-contamination occurrence in the samples.

2.3 Estimation of Radium Equivalent Activity

The distribution of U-238, Th-232 and K-40 in black sand is not uniform and to assess the real activity level of Ra-226, Th-232 and K-40 in samples, a common radiological index has been defined in terms of radium equivalent activity (Raeq) can be used, provides a very useful guideline in regulating the safety standards in radiation protection for a human population based on Beretka and Matthew [9] study that says 10 Bq/kg of Ra-226, 7 Bq/kg of Th-232 and 130 Bq/kg of K-40 produce the same gamma ray dose rate. The radium equivalent activity uniforms the radiation exposure as follows:

$$Raeq = CRa + 1.43CTh + 0.077CK$$

Where CRa, CTh and CK are the concentrations in Bq/kg of Ra-226, Th-232 and K-40 respectively.

2.4 Estimation of absorbed dose and effective dose

The measured activity of Ra-226, Th-232 and K-40 were converted into doses by applying the factors 0.462, 0.604 and 0.0417 for radium, thorium and potassium, respectively (UNSCEAR, 2000) [10]. These factors were used to calculate the total absorbed gamma dose rate in air at 1 m above the ground level using the following equation:

$$\text{Absorbed Dose (nGy / h)} = 0.462CRa + 0.604CTh + 0.0417CK$$

Where CRa, CTh and CK are the concentrations in Bq/kg of Ra-226, Th-232 and K-40 respectively.

According to (UNSCEAR, 2000) "to estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor". The conversion coefficient used in this report is 0.7 Sv/Gy for adults and the indoor occupancy factor, i.e. the fraction of time spent indoors and outdoors is 0.8 and0.2, respectively. The annual effective doses are determined as follows:

$$\text{Effective Dose (mSv)} = \text{Absorbed Dose(nGy/h)} \times 8760h \times \text{occupancy factor} \times 0.7\ (Sv/Gy) \times 10^{-6}$$

2.5 Radium equivalent activity (Raeq), external and internal hazard index (Hex, Hin)

Radium equivalent activity is a widely hazard index used when comparing the specific activity of the samples containing different amounts of Ra-226, Th-232 and K-40. It is supposed that 370 Bq/kg of Ra-226, 259 Bq/kg of

Th-232 and 4810 Bq/kg of K-40 produce the same dose rate of gamma rays. The maximum value allowed for public dose is 370 Bq/kg [9].

Raeq = ARa + 1.43ATh + 0.077AK

where: ARa , ATh and AK are the activity concentrations of Ra-226, Th-232 and K-40 in Bq/kg, respectively.

3 Results and discussion

3.1 Activity concentrations A (Bq/kg)

Activity concentrations were determined by measuring its decay daughters [11]. The activity concentrations evaluate the intensity of each line taking into account the mass of the sample, branching ratios of g decay, counting time and efficiency of the detector were found. The net count of the sample was brought about by subtracting a linear background distribution of the corresponding peak energy area [12]. The activity concentrations account of the study sample consisted of following equation:

A=(CPS)net/((IεM))

where A is the activity concentration in Bq/kg, (CPS) net is (count per second). (I) is the intensity of the g -line in a radionuclide, ε is the efficiency detector for each g -line and M is the mass of the sample in kilograms.

The activity concentrations of radionuclides measured in beach sand samples from Rosetta are shown in Table12. The activity concentration of Ra226, U238, Th232 and K40 in Rosetta black sand ranged from 7.44 ± 1.62 to 6.34 ± 1.27, 17.57 ± 3.6 to 6.97 ± 1.31, 16.11 ± 4.21 to 6.66 ± 1.30, 381.01 ± 43.33 to 141 ± 20.11 Bq kg-1, with a mean value of 11.93 12.32, 11.78 and 259.11 Bq Kg-1 respectively.

Table 1. Activity concentration for Ra^{226}, U^{238}, Th^{232} and K^{40} (Bq/Kg) in Rosetta beach sand.

Sample No.	Activity (Bq/Kg)			
	Ra^{226}	U^{238}	Th^{232}	K^{40}
1	12.03 ± 2.41	9.65 ± 1.41	12.08 ± 2.23	347.21 ± 67.03
2	15.1 ± 3.01	14.03 ± 3.21	14.79 ± 3.27	368.33 ± 41.21
3	16.9 ± 3.9	17.57 ± 3.62	16.11 ± 4.21	381.01 ± 43.33
4	13.21 ± 1.9	16.11 ± 2.43	13.01 ± 2.51	348.36 ± 68.12
5	14.83 ± 2.2	16.9 ± 2.61	14.23 ± 2.6	371.33 ± 39.02
6	9.62 ± 1.09	10.99 ± 1.38	10.32 ± 1.81	183.62 ± 28.3
7	11.03 ± 1.21	11.98 ± 1.54	11.13 ± 1.71	294 ± 31.09
8	10.71 ± 1.60	10.79 ± 1.1	10.51 ± 1.82	198 ± 26.32
9	8.43 ± 1.53	9.09 ± 1.23	8.52 ± 1.41	191 ± 21.22
10	8.99 ± 1.72	9.59 ± 1.62	9.01 ± 1.61	181 ± 25.11
11	10.33 ± 1.61	10.99 ± 1.91	10.12 ± 1.60	281 ±29.32
12	11.47 ± 1.91	12.01 ± 1.94	11.72 ± 1.87	317 ± 33.31
13	11.63 ± 2.01	12.42 ± 1.99	11.56 ± 1.91	291 ± 35.01
14	8.71 ± 1.63	9.32 ± 1.50	9.01 ± 1.21	184 ± 23.61
15	17.41 ± 3.71	15.92 ± 2.99	14.33 ± 6.01	288 ± 34.52
16	16.35 ± 3.70	14.81 ± 2.72	14.12 ± 5.32	287 ± 31.41
17	17.16 ± 3.02	15.82 ± 3.01	15.21 ± 5.62	291 ± 33.03
18	7.44 ± 1.62	8.03 ± 1.20	7.19 ± 1.21	189 ± 22.32
19	6.34 ± 1.27	6.97 ± 1.31	6.66 ± 1.30	151 ± 20.21
20	11.06 ± 3.81	12.71 ± 2.53	13.79 ± 6.21	141 ± 20.11
21	11.80 ± 3.83	13.01 ± 2.64	13.99 ± 6.6	158 ± 21.21
average	11.39	12.32	11.8	159.11

3.2 Absorbed dose and effective dose

The absorbed dose rate (D) indoor air calculated from the measured activities in Rosetta black sand samples are given in table 2. The absorbed dose rate D were found to vary from 70.13 to 176.99 nGy/h with a mean average value 121.08 $nGy.h^{-1}$. The average absorbed dose rate for all samples are greater than the estimate of average global primordial radiation of 59 nGy/h and than the world range (10-200 nGy/h) [10,11]. The highest value of gamma absorbed dose rate may be due to the highest back ground radiation level in this area.

The outdoor annual effective dose was determined as recommended by UNSCEAR, 2000 [10]. In studied samples locations, the annual effective dose for outdoor and indoor varied between 0.086 and 0.217 mSv/y, with a mean average of 0.148 mSv/y and 0.344 and 0.868 mSv/y with a mean average of 0.591 mSv/y, respectively. Values of all studied samples are higher than the worldwide average for outdoor annual effective dose, which is 0.07 mSv/y, as reported by UNSCEAR, 2000 [10]. It indicates the presence of significant amounts of monazite and zirconite sands, and may be the reason of the black colorations of the sand of Rosetta and for high concentration of radionuclides [13-14].

Table 2 .Absorbed dose (nGy/h) and annual effective dose rate (outdoor – indoor) (mSv/y) for natural radioisotopes [Ra^{226}, U^{238}, Th^{232} and K^{40} activity concentration (Bq/Kg)] in Rosetta beach sand samples.

Sample No.	**Absorbed Dose Rate D (nGy / h)**	**Annual Effective Dose (mSv/y)**	
		Outdoor (0.2)	**Indoor (0.80)**
1	158.05	0.194	0.775
2	170.02	0.209	0.834
3	176.99	0.217	0.868
4	159.68	0.196	0.783
5	170.8	0.209	0.838
6	87.32	0.107	0.428
7	134.79	0.163	0.661
8	94.23	0.116	0.462
9	88.97	0.109	0.436
10	85.38	0.105	0.419
11	128.41	0.157	0.630
12	144.96	0.178	0.711
13	134.1	0.164	0.658
14	86.49	0.106	0.424
15	137.39	0.168	0.674
16	136.32	0.167	0.669
17	139.05	0.171	0.682
18	86.85	0.107	0.426
19	70.13	0.086	0.344
20	72.16	0.089	0.356
21	80.19	0.098	0.393
average	121.08	0.148	0.591

3.3. Radium equivalent activity (Raeq), external and internal hazard index (Hex, Hin)

Table 3 show radium equivalent activity (Raeq), the external and internal hazard index (Hex, Hin), and gamma index (Iγ). The mean value of Raeq was 50.869 Bq/kg which is below the recommended value of 370 Bq/kg (UNSCEAR 2000)[10] .

The value of Hex must be lower than unity in order to keep the radiation hazard insignificant. From table 2, it's clear that the obtained values of internal hazard index (Hex, Hin) were found to vary from 0.074 to 0.187 and from 0.091 to 0.233 with mean value 0.119 and 0.151 respectively. The representative gamma index (Iγ) are varied from 0.210 to 0.528 with mean values of 0.370 which are lower than the recommended value ≤1 that corresponds to 0.3 mSv/y [15-17].

Table 3. Radiation hazard indexes of natural radioisotopes in Rosetta beach sand samples.

Sample No.	Hazard index (H)			
	Raeq (Bq/kg)	Iγ	Hex	Hin
1	56.04	0.432	0.151	0.184
2	64.61	0.494	0.174	0.215
3	69.28	0.528	0.187	0.233
4	58.64	0.450	0.158	0.194
5	63.77	0.489	0.172	0.212
6	38.47	0.289	0.104	0.130
7	49.58	0.381	0.134	0.164
8	40.99	0.309	0.111	0.140
9	35.32	0.269	0.095	0.118
10	35.81	0.271	0.097	0.121
11	46.44	0.357	0.125	0.153
12	52.64	0.405	0.142	0.173
13	50.57	0.387	0.137	0.168
14	35.76	0.271	0.097	0.120
15	60.08	0.451	0.162	0.209
16	58.64	0.442	0.158	0.203
17	61.32	0.461	0.166	0.212
18	32.27	0.248	0.087	0.107
19	27.49	0.210	0.074	0.091
20	41.64	0.306	0.112	0.142
21	43.90	0.324	0.119	0.151
average	50.869	0.370	0.124	0.163

4 Conclusions

The conclusion of our study can be summarized in the following points:

- The specific activity concentration of natural radionuclide 226Ra,232Th and 40K at Rosetta beach sand were measured using HPGe gamma ray spectrometer.
- The mean average activity concentration of Ra^{226}, U^{238}, Th^{232} and K^{40} in Rosetta black sand were 11.93 12.32, 11.78 and 259.11 Bq Kg^{-1} respectively.
- The absorbed dose rate D were found to vary from 70.13 to 176.99 nGy/h with a mean average value 121.08 nGy/h.
- The average absorbed dose rate for all samples are greater than the estimate of average global primordial radiation of 59 nGy/h and than the world range (10-200 nGy/h).
- The annual effective dose for outdoor and indoor varied between 0.086 and 0.217 mSv/y, with a mean average of 0.148 mSv/y and 0.344 and

0.868 mSv/y with a mean average of 0.591 mSv/y, respectively.

- Values of all studied samples are higher than the worldwide average for outdoor annual effective dose, which is 0.07 mSv/y.

References

[1] A. F. Ibrahim., A. I. Mohammed , Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan, *J. Radiat. Meas.*, **44,** 102-110, 2009.

[2] B. Senthikumar, V. Dhavamani, S. Ramkumar, P. Philominathan, Measurement of gamma radiation levels in soil samples from Thanjavur using gamma-ray spectrometry and estimation of population exposure, J.Med.Phys., 35(1), 48-53, 2010.

[3] M. A. Hilal, E. H. Borai, Hazardous parameters associated with natural radioactivity exposure from black sand. Regulatory Toxicology and Pharmacology., 92, 245-250, 2018.

[4] M. A. Arnedo, A. Tejera, J. G. Rubiano, H. Alonso, J. M. Gil, R. Rodriguez, P. Martel, Natural radioactivity measurements of beach sands in Gran Canaria Islands (Spain), Journal of Radiat. Prot. Dosimetry. 156 (1), 5-86, 2013.

[5] M. A. M. Uosif and A. El-Taher, Comparison of Total Experimental and Theoretical Absolute gamma ray Detection Efficiencies of a Cylindrical NaI (Ti) Crystal. Arab Journal of Nuclear Science and Applications, 38, 357- 365, 2005.

[6] A. El-Taher, S. Makhluf, Radiological Significance of Egyptian Limestone and Alabaster used for Construction of Dwellings. Indian Journal of Pure and Applied Physics, 49, 157-161, 2011.

[7] A. El-Taher and M. A. M. Uosif, The Assessment of the Radiation Hazard Indices due to Uranium and Thorium in Some Egyptian Environmental Matrices. Journal of Physics D: Applied Physics, 39, 4516-4521, 2006.

[8] A. El-Taher, A. Nossair, A. H. Azzam, K. L. Kratz and A.S. Abdel-Halim, Determination of Traces of Uranium and Thorium in Some Egyptian Environmental Matrices by Instrumental Neutron Activation Analysis. Journal of Environmental Protection Engineering, 29, 19-30 (2004).

[9] J. Beretka and P. J. Mathew, Natural radioactivity of Australian building materials, industrial wastes and by products, Health Physics, 48, 87-95, 1985.

[10] United Nation Scientific Committee on the effect of atomic radiation (UNSCEAR) Source, effects and risks of ionizing radiation, United Nation, New York, 2000.

[11] A. Kurnaz, B. Küçük€omeroðlu, R. Keser, N. T. Okumusoglu, F. Korkmaz, G. Karahan, Determination of radioactivity levels and hazards of soil and sediment samples in firtina valley (Rize, Turkey). Applied Radiation and Isotopes, 65, 1281-1289, 2007.

[12] R. M. Keyser, Characterization and applicability of low- background germanium detectors. Oak Ridge, TN, USA: Technical Note, EG and G ORTEC, 1995.

[13] H. Taskin, M. Karavus, P. Ay, A. Topuzoglu, S. Hindiroglu, G. Karahan, Radionuclide concentrations in soil and lifetime cancer risk due to the gamma radioactivity in Karlareli, Turkey, Journal of environmental radioactivity, 100, 49-53, 2009.

[14] El-Taher, HA Madkour., Environmental and radio-ecological studies on shallow marine sediments from harbor areas along the Red Sea coast of Egypt for identification of anthropogenic impacts Isotopes in environmental and health studies 50 (1), 120-133.

[15] F Alshahri, A. El-Taher., Investigation of Natural Radioactivity Levels and Evaluation of Radiation Hazards in Residential-Area Soil Near a Ras Tanura refinery, Saudi Arabia. Polish Journal of Environmental Studies 28 (1). 2019.

[16] MAE Abdel-Rahman, M Sabry, MR Khattab, Atef El-Taher, SA El-Mongy., 2021 Radioactivity and risk assessment with uncertainty treatment for analysis of black sand minerals. Zeitschrift für anorganische und allgemeine Chemie 647 (4), 210-217.

[17] NEA-OECD, Nuclear Energy Agency, Exposure to radiation from natural radioactivity in building materials, Paris: OECD. Report by NEA group of experts, 1979.