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RADIONUCLIDE CONCENTRATIONS AND RADIOLOGICAL HEALTH RISKS IN VARIOUS BLACK SAND LOCATIONS: A PRELIMINARY ASSESSMENT

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Abstract: ***We collected 7 samples of Black sand from Rosetta beach (north of Nile Delta, Egypt), we measured the activity concentrations of 238U, 232Th and 40K using (HPGe) detector. Average values of 238U, 232Th and 40K were 102.7± 6.2, 173.7 ± 7.9 and 66.6 ± 3.6 Bq kg−1 for samples respectively, Concentrations ranged between 195 ± 11.5 to 14 ± 0.97 Bq kg−1 for 238U, 366 ± 16 to 15 ± 0.9 Bq kg−1 for 232Th, 83.7 ± 4.1 to 53.5 ± 2.7 Bq kg−1 for 40K***
The activity of some samples is more than the United Nations Scientific Committee on the Effects of Atomic Radiation UNSCEAR - and the International Atomic Energy Agency IAEA-recommended exemption threshold. Also, we calculated the radiological indices which have values more than recommended limits. So, radiation exposure to Black sand may present a radiological hazard which needs radiation regulations and regular monitoring of black sand sites.

Keywords: ***Radionuclides, HPGe, Radiological hazards, Black Sand, Egypt***

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I. INTRODUCTION

The aim of the work is to preliminary make assessment for the activity concentrations of radionuclides of 226Ra, 232Th and 40K in Black sand at the intersection of the North of Nile Delta with the Mediterranean Sea Cost using HPGe detector, The radionuclides concentration of Egyptian Black sand was compared to the International recommended limits. Moreover, we calculated and compared the radiological hazard indices of radium equivalent activity (Raeq), internal (Hin) and external (Hex), alpha and gamma, and annual effective dose to the UNSCEAR and IAEA international safety recommendations.

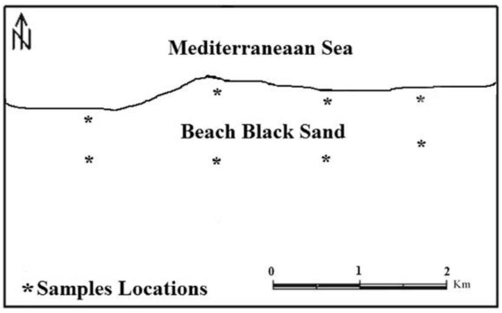
II.Material and Methods

Sample Preparation

7 Samples were taken in the vicinity of Rosetta Beach, which runs parallel to the Mediterranean coast, north of the Nile Delta. This space is open, level, and almost horizontal. To increase the samples homogeneity, they were sieved through a 1-mm mesh size. After that, they were dried for 24 hours at 105 °C to eliminate any last traces of moisture. homogenous. The samples were placed in desiccators to cool to ambient temperature for 24 hours. Then, we filled the samples in 100 mL polyethylene containers, then each dried sample was mixed thoroughly, weighed (About 200 g of each) and thoroughly sealed with adhesive tapes to create an airtight seal and stop any chance of radon (222Rn) or thoron (220Rn) escaping. Before gamma spectroscopy, these containers were kept at room temperature for a month in order to allow secular equilibrium radioactivity between 226Ra and its progenies to be reached.

Figure 1. The map of Black sand in Egypt.

Figure 2. Samples locations



Concentrations Measurement of Radionuclides

The study's samples had natural radionuclide quantities of 226Ra, 232Th, and 40K, which were detected within the active region of a shielded (HPGe) detector, the apparatus allowed for the traversal of two concentric cylinders positioned internally, which were constructed from lead, copper, and cadmium materials, along with electronic circuits. A vertical N-type HPGe detector with 40% relative efficiency was utilized to detect 1.33 MeV photons of 60Co. This detector was secured by a shield model 747 / 747E. The Genie 2000 programme was used to analyse the spectra. [1]. Peak efficiency was determined by employing standard point sources, and the spectrum was analyzed using Genie-2000 Spectroscopy. The concentration of radioactive activity of nuclide I, expressed in Becquerel per kilogram (Bq/kg), can be determined for a peak at energy E using the following formula:

$$A_{Ei}\left(\frac{Bq}{kg}\right) = \frac{NP}{t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M} \quad (1)$$

The parameters t, $I_\gamma(E_\gamma)$, and M are essential components in calculating the efficiency of gamma ray detection for a given nuclide. The counting time (t) is measured in seconds and a crucial factor in determining the accuracy of the measurement. The probability of gamma emission of the nuclide for a transition at energy I_γ (E_γ) is another significant factor that affects how efficient gamma-ray detection be. Finally, the sample mass (M) is measured in kg is necessary for ensuring quality of the measurement. The IAEA Soil-6 [2] reference material is often used in quality assurance procedures to ensure that measurements are accurate and consistent [2]. which has a known concentration of natural radioactivity, was analyzed using gamma spectroscopy. Each sample was counted for 72000 seconds to determine its specific activity, expressed in Bq/kg, of nuclide I. The acquired spectra were analyzed using Genie 2000 program V.3.2 provided by Canberra, which allowed for activity and uncertainty calculation as well as the determination of the Minimum Detectable Activity (MDA) based on Equation 2 [4,6-13].

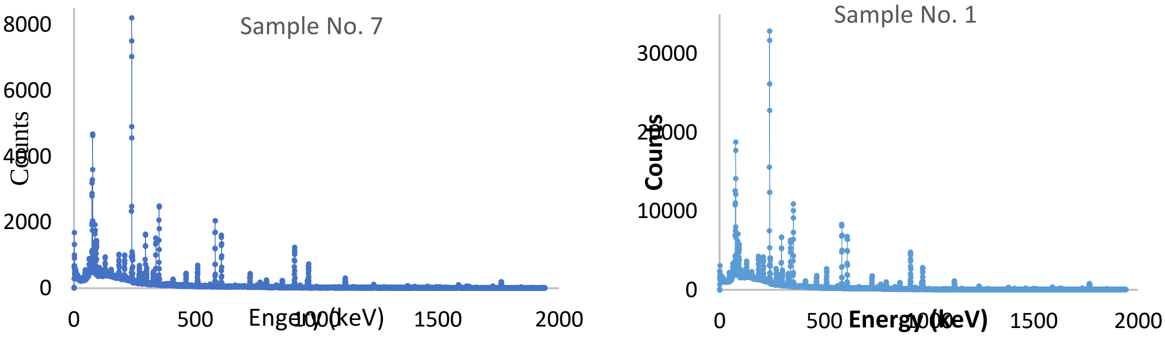


Figure 3. Typical gamma ray spectrum of Black sand samples natural radionuclides

II. RESULTS AND DISCUSSION

A summary of the study's results is provided in Table 1. In samples of Black Sands, the activity concentrations of 226Ra, 232Th, and 40K varied from 14 ± 0.97 (S06) to 195 ± 11.5 (S01) Bqkg−1 having a mean of 102.7 ±

6.2 Bq kg−1 for 226Ra, 15± 0.9 (S06) to 366 ± 16 (S01) Bq kg−1 having a mean of 173.7 ± 7.9 Bq kg−1 for 232Th and 53.5 ± 2.7 (S05) to 83.7 ± 4.1 (S06) Bq kg−1 having a mean of 66.6 ± 3.6 Bq kg−1 for 40K, in the chosen samples, as found in Table 1 & Figure 4.

For every detected radionuclides in the chosen samples, the highest activity levels are 195 ± 11.5 (S01) Bqkg−1 of 226Ra, 366 ± 16 (S01) Bq kg−1 of 232Th and 83.7 ± 4.1 (S06) Bq kg−1 of 40K. These results show that majority of the samples from Egypt that were chosen had specific activity concentrations in soil that exceeded the global median specific activity values, which UNSCEAR reported were 35, 30, and 400 Bq kg−1 for 226Ra, 232Th, and 40K, respectively. (4, 5).

Table 1. Specific activity concentrations of 226Ra, 232Th and 40K in the black sand samples in Egypt.

Sample (ID)	specific activities) Bq kg($^{1-}$		
	U-238	Th-232	K-40
S01	195 ± 11.5	366 ± 16	66 ± 3.3
S02	23.7 ± 1.8	24 ± 1.6	62.7 ± 4.1
S03	140 ± 8.3	218 ± 9.7	56 ± 2.8
S04	61 ± 3.7	80 ± 3.7	68.6 ± 3.3
S05	109 ± 6.5	164 ± 7.3	53.5 ± 2.7
S06	14 ± 0.97	15 ± 0.9	83.7 ± 4.1
S07	176 ± 10.7	349 ± 15.8	76 ± 4.8
Average	**102.7 ± 6.2**	**173.7 ± 7.9**	**66.6 ± 3.6**

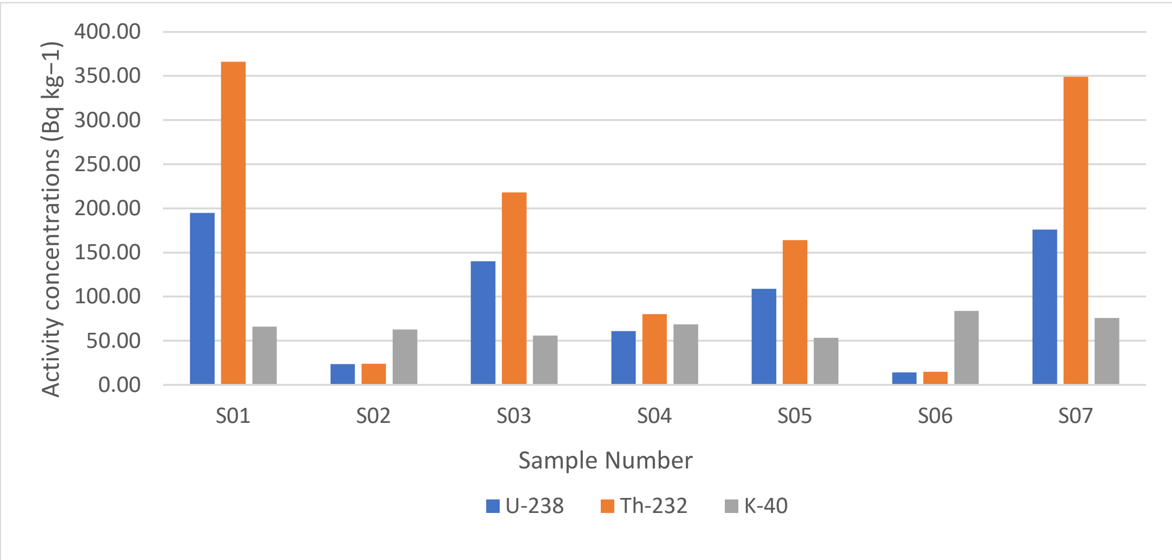


Figure 4. Activity concentrations of 238U, 232Th and 40K (Bq.kg−1) for samples

UNSCEAR introduced the radium equivalent activity (Raeq) to calculate the radiation hazards associated with materials maintained at different levels of 226Ra, 232Th, and 40K in a single quantity. (4, 5, 7), Eq. 2.

$$Raeq = ARa + 1.43ATh + 0.077AK \qquad (2)$$

Where ARa, ATh and AK, the activity concentrations in (Bq kg−1) are representing 226Ra, 232Th and 40K, respectively. Based on the assumption that 370 Bq kg−1 of 226Ra, 259 Bq kg−1 of 232Th and 4810 Bq kg−1 of 40K produce the same equivalent dosage of gamma rays, the radium equivalent index was determined. To ensure safety, the material's Raeq activity concentration should be less than 370 Bq kg−1 in order to maintain the gamma ray dose below 1.5 mSv y^{-1} (8). As seen in, the range of radium equivalent concentration in samples was 42.1 ± 2.55 Bq kg^{-1} (S06) to 723 ± 34.9 Bq kg^{-1} (S01), with a mean value of 356.3 ± 17.7 Bq kg^{-1}. Figure 5, and Table 2.

Certain Black sand samples under investigation had greater levels of Radium equivalent than the recommended limit of 370 Bq kg^{-1}, implying that these materials may pose a radioactive hazard. The main source of radiation hazard is external gamma radiation from naturally occurring radionuclides of 226Ra, 232Th and 40K. The external hazard index (Hex), which was calculated using Equation (3), can be used to express the external hazard of gamma radiation. (6, 7)

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (3)$$

where, in Bq kg^{-1}, ARa, ATh and AK represent the activity of 226Ra, 232Th and 40K, respectively. Generally, a material's external hazard index should be smaller than unity to keep the external gamma radiation dose below 1.5 mSv y^{-1}. The external hazard index for samples in this investigation had an average value of 0.96 ± 0.05 (Tables 2). Certain examined samples had external hazard indices that were higher than the advised threshold, indicating that the risk of external radiation could not be disregarded. The findings indicate that certain locations can result in over-exposure, for instance, if the external hazard index (Hex) in some samples is greater than unity, it surpasses the maximum limit of exposure, Fig. (6). Internal hazard index should be considered in addition to the external hazard because of the potential hazard of radon and its progenies to the respiratory system. It is produced by 226Ra, 232Th and 40K radionuclides in addition to radon and its progenies of 218Po, 214Pb, 210Pb and 210Bi. (Hin) The index of internal hazard can be calculated using Equation (4), (6, 7);

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (4)$$

Hin should be less than unity for a substance to be used safely while ignoring the risks that radon and its products have to the respiratory system. For all samples, the average internal hazard index value was 1.24 ± 0.07 (Table 2), exceeding the recommended limits. Therefore, using black sand poses a risk of radiation. The Black Sand typically contains natural radionuclides, which means that workers and the general public may be exposed to radiation from it. Therefore, it would be advantageous for the public's health and safety as well as the workers' safety to regularly assess their radiation exposure. The primary cause of radiation exposure is the gamma radiation released by those substances. The absorbed dose rate (D) due to gamma rays in the air at one metre above the selected materials that maintains a uniform distribution of natural radionuclides of 226Ra, 232Th, and 40K can be calculated using the following equation (5).

$$D = 0.462\, A_{Ra} + 0.621\, A_{Th} + 0.042\, A_K \quad (5)$$

D $(nGy\, h^{-1})$

Table 3 and Figure 7 illustrate the results of the calculation of the absorbed dose rate for the samples. The absorbed dose rate of radiation is varied from 19.4 ± 1.17 nGy h^{-1} (S06) to 320 ± 15.5 nGy h^{-1} (S01) with average of 158 ± 7.9 nGy h^{-1} for samples. Most of the selected samples had an absorbed radiation dose values exceed the recommended values by UNSCEAR(4), i.e., 59 nGy h^{-1} as given in Table 3. Thus, those samples have pose of radiation exposure. Therefore, Black sand samples should be used under regulation precautions.

Additionally, using Eq. (6), the annual effective dose (E) from gamma rays which emitted from 226Ra, 232Th and 40k in samples was determined. (5, 6, 7).

$$E = D*8766*O*C/1000000 \quad (6)$$

$$E = D\,(nGy\, h^{-1}) \times 8766\,(h\, y^{-1}) \times O \times C\,(Sv/Gy)$$

where C is the absorbed to the effective dose conversion factor of of 0.7 Sv/Gy and O is the occupancy factor (9). The annual effective dose from gamma rays emitted by 226Ra, 232Th and 40K in the samples (for workers who exposed to maintained radionuclides of 226Ra, 232Th and 40K, for 1753 h y^{-1} (outdoor occupancy factor)), E is varied from 0.024 ± 0.001 mSv y^{-1} (S06) to 0.393 ± 0.019 mSv y^{-1} (S01), with a mean value of 0.194 ± 0.01 mSv y^{-1} for the samples. These results are summarised in Table 3 and Figure 8. The computed annual effective dose was lower than 0.48 $mSvy^{-1}$ (480 μSvy^{-1}) the global average annual effective dose (5). Furthermore, it is far less than the 20 mSv for workers or 1 mSv for the general public that the International Commission for Radiological Protection (ICRP-103) recommends (8).

The gamma index (Iγ) is a radioactivity level index that can be used to assess the potential risks of gamma ray radiation linked to naturally occurring radionuclides in materials. Guidelines from the European Commission state that for a gamma radiation exposure of 1 mSv y^{-1}, Iγ should be <1(10, 11). Equation (7) can be used to calculate the gamma ray index, or Iγ. (6, 7)

$$I\gamma = C_{Ra}/300 + C_{Th}/200 + C_K/3000 \quad (7)$$

The Iγ of the samples varied from 0.150 ± 0.01 for (S06) to 2.501 ± 0.120 for (S01) with average of 1.23 ± 0.06, as found in Table 3. Some of the measured samples had a radioactivity level index <1 so that these samples are without radiation risk and can be safely handled without special precautions, whereas the other samples have radiation risk and should be handled under radiation-regulation precautions (6). The alpha index (Iα), is the alpha radiation which results from the release of radon from samples, may be calculated using Equations (8), (6, 7). To represent a radium concentration value of less than 200 Bq kg−1 (the upper recommended value), which results in a maximum emitted radon concentration of less than 200 Bq m-3, the alpha index should be less than unity.

$$I\alpha = A_{Ra}/200 \quad (8)$$

Alpha index of the samples varied from 0.070 ± 0.005 (S06) to 0.974 ± 0.058 (S01) with average of 0.513 ± 0.031, as found in Table 3. As a result, the Alpha index values for every sample were less than unity, implying that there is no radiation risk to workers or the general public from any of the study samples. Given that a number of factors might influence a worker's radon exhalation rate, it is advised that workers' rates be measured for their safety. For example, the radium concentration has a significant impact on the rate of radon exhalation, but so do the grain size and texture as well as the material's permeability (12).

Table 2. Radium equivalent, External and Internal hazard indices of Black sand samples

Sample Code	**Radium equivalent (Ra_{eq} ( )Bq Kg($^{1-}$**	**Internal index (H_{in}(**	**External index (H_{ex}(**
S01	723 ± 34.9	2.48 ± 0.13	1.95 ± 0.09
S02	63.1 ± 4.37	0.24 ± 0.02	0.17 ± 0.01
S03	456 ± 22.3	1.61 ± 0.08	1.23 ± 0.06
S04	181 ± 9.20	0.66 ± 0.04	0.49 ± 0.03
S05	348 ± 17.1	1.23 ± 0.06	0.94 ± 0.05
S06	42.1 ± 2.55	0.15 ± 0.01	0.11 ± 0.01
S07	681 ± 33.7	2.32 ± 0.12	1.84 ± 0.09
Average	**356.3 ± 17.7**	**1.24 ± 0.07**	**0.96 ± 0.05**

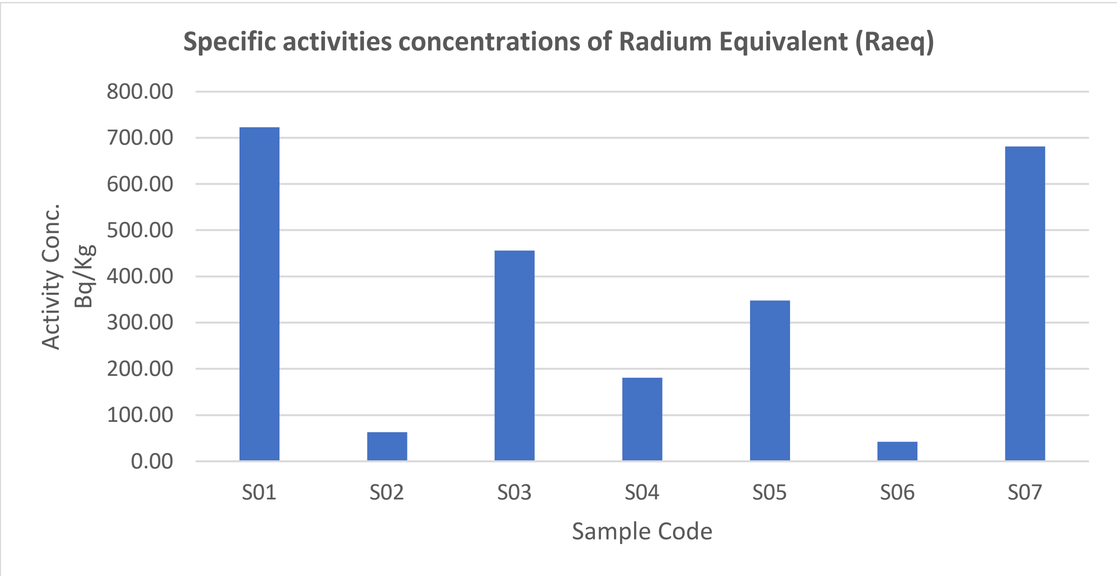


Figure 5. Radium equivalent activity concentrations of Black sand samples.

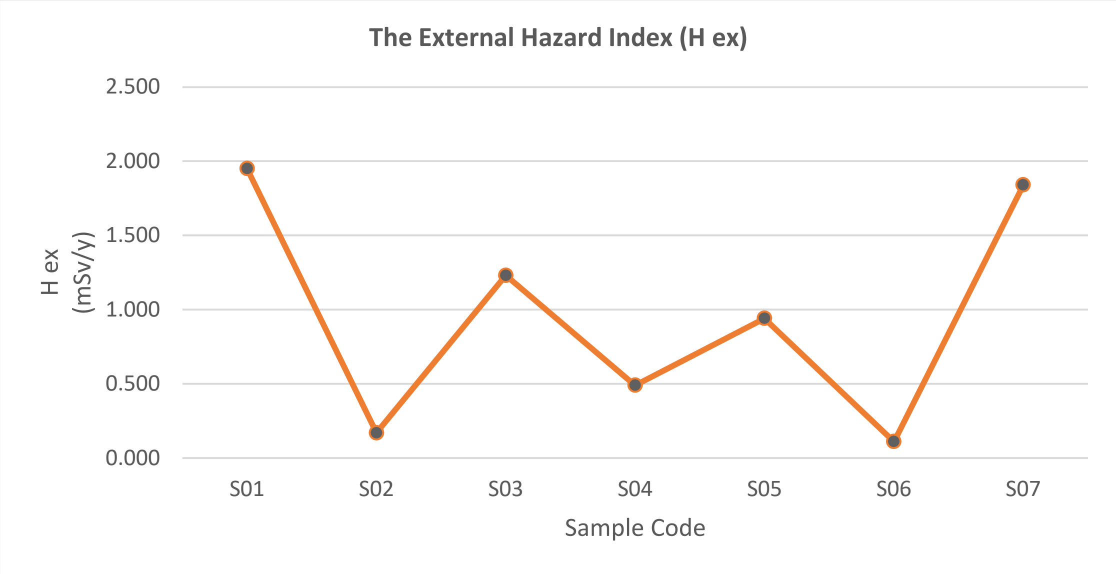


Figure 6. External Hazard Index (Hex) for Black sand samples.

Table 3. The Absorbed dose rate, The Annual Effective dose, Gamma and Alpha Indices for samples of Black sand

Sample Code	The absorbed dose rate (D, nGy h^{-1})	The annual effective dose (E, mSv y^{-1})	Gamma Index: radioactivity level index (I_γ)	Alpha Index I_α
S01	320 ± 15.5	0.393 ± 0.019	2.501 ± 0.120	0.974 ± 0.058
S02	28.6 ± 1.98	0.035 ± 0.002	0.221 ± 0.015	0.119 ± 0.009
S03	202 ± 9.94	0.248 ± 0.012	1.574 ± 0.077	0.698 ± 0.041
S04	81.0 ± 4.13	0.099 ± 0.005	0.628 ± 0.032	0.306 ± 0.018
S05	154 ± 7.64	0.190 ± 0.009	1.201 ± 0.059	0.545 ± 0.032
S06	19.4 ± 1.17	0.024 ± 0.001	0.150 ± 0.009	0.070 ± 0.005
S07	301 ± 15.0	0.370 ± 0.018	2.357 ± 0.116	0.881 ± 0.054
Average	158 ± 7.9	0.194 ± 0.009	1.23 ± 0.06	0.513 ± 0.031

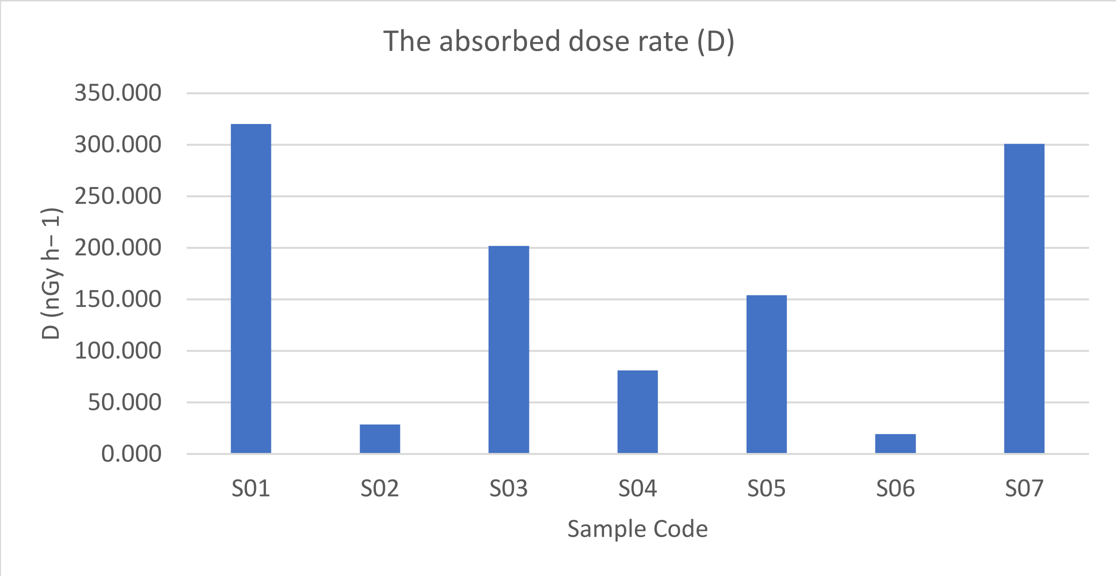


Figure 7. The absorbed dose rate of Black sand samples.

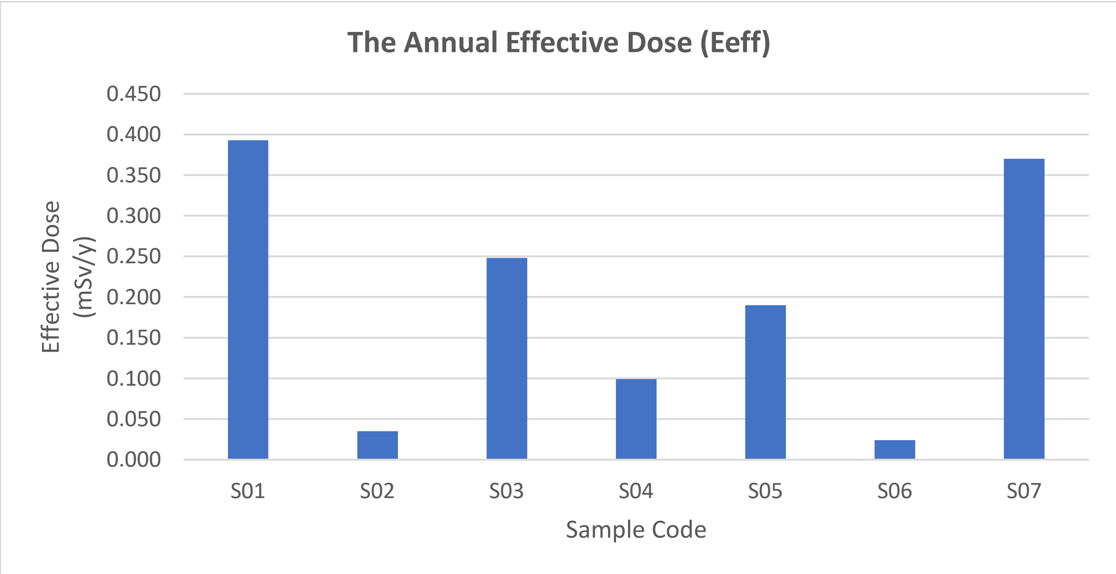


Figure 8. Annual effective dose of gamma rays for samples of Black sand.

CONCLUSION

226Ra, 232Th and 40K naturally occurring radioactivity concentrations in black sand samples taken from north of the Nile Delta near Egypt's Rosetta Beach, were ranged from 14 ± 0.97 (S06) to 195 ± 11.5 (S01) Bqkg−1 for 226Ra, 15± 0.9 (S06) to 366 ± 16 (S01) Bq kg−1 for 232Th and 53.5 ± 2.7 (S05) to 83.7 ± 4.1 (S06) Bq kg−1 for 40K. The sample concentrations of radionuclides exceeded the IAEA recommended levels as well as the UNSCEAR and ICRP recommended limits for the earth's crust. Furthermore, the recommended limits of 370 Bq kg−1, 1, 1, and 0.48 mSvy−1 were exceeded by the radiological hazard indexes of radium equivalent activities (Raeq), external and internal indexes, gamma and alpha indexes, and annual effective doses of some samples. The majority of the examined samples had absorbed doses higher than the advised 59 nGy h−1. These findings so suggest that there is a risk of radiation exposure for the workers, underscoring the significance of radiation regulations precautions.

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REFERENCES

1. **Canberra Industries, USA, Genie™ 2000 Spectroscopy Software, Operations V3.1** in 1 Apr 2003.
2. **Pszonicki, L., A.N. Hanna, A.N., and Suschny, O., (1984):** Report on Intercomparison IAEA/SOIL-6, International Atomic Energy Agency, IAEA/RL/111.
3. **N. M. Hassan, B. A. Tartor, Nasr Elsayed and W. M. Abdellah, (2023):** Evaluation of Natural Radioactive Levels and Its Related Potential Radiological Impact of Black Sand in the North of Nile Delta, Egypt, Arab J. Nucl. Sci. Appl., Vol. XX, X, (2023), DOI: 10.21608/ajnsa.2023.198886.1739
4. **United Nations Scientific Committee on the Effects of Atomic Radiation. (2000):** Sources and Effects of Ionizing Radiation, Report to the General Assembly. United Nations.
5. **United Nations Scientific Committee on the Effects of Atomic Radiation. (2008):** Sources and Effects of Ionizing Radiation, Report to the General Assembly. United Nations.
6. **N. M. Hassan& J. S. Chae. (2019):** Radioactivity and radiological impact of industrial raw materials in Korea. International Journal of Environmental Science and Technology, pp. 1–8
7. **N. M. HASSAN ET AL. (2019):** ASSESSMENT OF RADIOLOGICAL HAZARDS OF USING PETROLEUM RAW MATERIALS AND THEIR WASTE. Radiation Protection Dosimetry, pp. 1–13
8. **ICRP, International Commission on Radiological Protection. (2007):** The 2007 Recommendation of the International Commission on Radiological Protection (Oxford: ICRP; ICRP Publication)103.
9. **UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation (1993):** (New York: Sources and effects of ionizing radiation).
10. **International Atomic Energy Agency. (1994):** International basic safety standards for the protection against ionizing radiation and for the safety of radiation sources. GOV/2715/Vienna.
11. **International Atomic Energy Agency., (2014):** Radiation protection and safety of radiation sources: international basic safety, standards. Part 3 No. GSR Part 3. IAEA, Vienna, Austria.
12. **Hassan NM, Ishikawa T, Hosoda M, Sorimachi A, Tokonami S, Fukushi M, Sahoo SK (2010):** Assessment of the natural radioactivity using two techniques for the measurement of radionuclide concentration in building materials used in Japan. J Radioanal Nucl Chem 283:15–21
13. **Torres Astorga, R., Rizzotto, M.G., Velasco, H. (2019):** Improving the efficiency in the detection of gamma activities in environmental soil samples: influence of the granulometry and soil density. Journal of Radioanalytical and Nuclear Chemistry Vol. 321:805–814.
14. **Hassan, N. M., Mansour, N. A., Fayez-Hassan, M. and Fares, S. (2017):** Assessment of radiation hazards due to exposure to radionuclides in marble and ceramic commonly used as decorative building material in Egypt. Indoor Built Environ. 26(3), 317–326.
15. **Abdellah, W. M., (2019):** Sequential Radiochemical Procedure for Isotopic Analysis of Uranium and Thorium in Egyptian Monazite. Radiochemistry, Vol. 61, No. 4, pp. 470–477
16. **Pimpl M, Yoo B, Yordanova I. (1992):** Optimization of a radioanalytical procedure for the determination of uranium isotopes in environmental samples. J Radioanal Nucl Chem; 161:437–441
17. **Abdellah W. M., Diab H. M., El-Kameesy S. U., Salama E. & El-Framawy S., (2017):** Natural radioactivity levels and associated health hazards from the terrestrial ecosystem in Rosetta branch of the River Nile, Egypt. ISOTOPES IN ENVIRONMENTAL AND HEALTH STUDIES, http://dx.doi.org/10.1080/10256016.2017.1293668
18. **A. El-Taher, H.A. Madkour, (2013):** “Texture and environmental radioactivity measurements of Safaga sand dunes”. Indian Journal of Geo-Marine Sciences Vol. 42(1), pp. 35-41, February 2013