Measurements of Natural Radioactivity Level in Black Sand and Sediment Samples of the Temsah Lake Beach in Suez Canal Region in Egypt

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Abstract

The level of natural radioactivity in black sand and sediment samples collected from Temsah Lake beaches of the Suez Canal district, Egypt were investigated. The natural activity concentration of $^{226}$Ra, $^{238}$U, $^{232}$Th and $^{40}$K for 20 black sand and 20 sediment samples were determined using gamma spectrometers based on HPGe detector with low background gamma-ray counting system. For assessing the environmental radiological impact to the public it is essential to evaluate the activity levels of these nuclides. The activity concentrations of the sediment and black sand samples ranges from (4.29 ± 1.66 to 30.06 ± 8.80), (4.29 ± 0.68 to 18.52 ± 5.22) Bq/kg with an average value (9.57 ± 2.92) and (11.63 ± 3.35) for $^{226}$Ra respectively. While the focus of activity for the sediment samples of black sand between (4.23 ± 1.33 to 16.56 ± 3.11), (5.31 ± 1. 90 to 17.46 ± 4.81) Bq/kg with an average value (8.64 ± 2.49) and (10.86 ± 2.18) of $^{238}$U respectively. The ranges of radioactivity concentration with $^{232}$Th vary from (6.69 ± 1.54 to 39.24 ± 9.80), (4.56 ± 1.07 to 18.65 ± 5.27) Bq/kg with an average value (13.11 ± 4.61), (11.41 ± 3.28) Bq/kg respectively. The radioactivity concentration ranges with $^{40}$K ranged from (37.17 ± 12.27 to 242.25 ± 70.94), (145.85 ± 43.30 to 441.15 ± 91.93) Bq/kg with an average value (141.64 ± 43.01), (327.65 ± 80.05) Bq/kg respectively. The radioactivity concentration ranges with $^{232}$Th vary from (6.69 ± 1.54 to 39.24 ± 9.80), (4.56 ± 1.07 to 18.65 ± 5.27) Bq/kg with an average value (13.11 ± 4.61), (11.41 ± 3.28) Bq/kg respectively. The radioactivity concentration ranges with $^{40}$K ranged from (37.17 ± 12.27 to 242.25 ± 70.94), (145.85 ± 43.30 to 441.15 ± 91.93) Bq/kg with an average value (141.64 ± 43.01), (327.65 ± 80.05) Bq/kg respectively. Radioactivity levels of both samples black sand and shore sediments within the recommended international values.

The estimation of radioactivity hazard indices radium equivalent (Ra$_{eq}$), external hazards (H$_{ex}$) and internal hazards (H$_{in}$) in black sand and shore sediment samples have been derived. Investigation reflects the deposition of less than minerals in the samples collected. Results were discussed with UNCEAR reports. The average of the radioactivity hazard Pointers and radium equivalent values are less than the restricted levels of the public. Gamma dose rate D in nGy/h and the annual effective dose rate (D$_{eff}$) in mSv/y were estimated. The effective annual dose rate (D$_{eff}$) in the samples under study varies from (0.01 to 0.05 mSv/y) with average value (0.02 mSv/y) for sediment samples, and from (0.01 to 0.05 mSv/y) with average value (0.03 mSv/y) for black sand samples, which are lower than the worldwide average for outdoor annual effective dose, 0.07 mSv/year. Results of radiation measurement, including analysis of the concentrations of uranium are equivalent to the e$_{U}$, the equivalent thorium e$_{Th}$, e$_{Ra}$, and K (%) of radionuclides, as well as the calculated e$_{Th}$/e$_{U}$ and e$_{U}$/e$_{Ra}$ of representative samples belonging to all samples study presents the lowest activity radiation potential. Positive correlation between uranium content and the rate of exhalation of radon has been observed. The concentrations of radon gas in the air were determined as well as the activity concentrations of $^{226}$Ra. The activity concentrations of the black sand and sediment samples which measured in the present work were compared with the values in other countries in the world, and it was found...
within the permissible limits, which indicates that the study area was radiologically safe for humans. Radon $^{222}\text{Rn}$ doses from inhalation gas for humans were estimated to be in the range of (0.13–13.09 µsV/y), for the Temsah Lake of Suez Canal, Egypt. On the basis of all obtained results, Temsah Lake in Suez Canal area should be considered as an enhanced natural radiation area (ENRA).

**Keywords:** Natural Radioactivity, Black Sand, Sediment, Gamma-Ray Spectrometry, Dose Rate, $^{222}\text{Rn}$ annihilation, Temsah Lake of Suez Canal, Egypt.

1. **Introduction**

   Background radiation levels are from a mixture of ground (from $^{40}\text{K}$, $^{232}\text{Th}$, $^{226}\text{Ra}$, etc.) and cosmic radiation (photons, muons, etc.). The level of fixed to some extent over the world, being 8-15 µrad / hour. All over the world despite the fact that there are some areas densely populated quite that has high levels of background radiation. Were found at the highest level in the first place in Brazil, India and China (UNSCEAR 1993). It is due to high concentrations of radioactive minerals in the soil of the high radiation levels. One of these minerals, monazite, is a non-high-soluble rare earth mineral that occurs in the sands of the beach with the mineral ilmenite, which gives the distinctive color of sand. Home radionuclides in monazite are of $^{232}\text{Th}$ series, but there are also some descendants of uranium, $^{226}\text{Ra}$. On the other hand, working the soil as a medium for Migration for the transfer of radionuclides to the biological system, and therefore, it is the primary indicator of radioactive contamination in the environment. Natural radionuclides in river sediments to generate important elements of background radiation exposure of the population (Suresh et al. 2011b). Therefore, the knowledge of the concentrations and distribution of radionuclides in the samples deposited are of great importance because it provides useful information on environmental pollution and its effects on human health associated with the monitoring of natural radioactivity.

   Naturally occurring radionuclides out of the earth in the river sediment as well (Krmar et al. 2009). Natural level of radioactivity in the sediment (soil) and sand is one of the major causes of external exposure to gamma rays. High background radiation level in the sands of the beach because of the presence of the metals and U afford such monazite and zircon. The main process for the deposition of the net from the sandy sediments suspended is overbank deposition in floodplains and the sea / tidal waves (Walling et al. 1992). The amount of deposition depends on the survival of the water at the seaside and the concentration of the sand from the sea shores of the time. Natural radioactivity in the sand and sediment from the seashore may cause exposure to people living or working near the beach or the tourists who come for a tour of this charming place (Akram et al. 2007). The accumulation of these substances in the marine coastal the environment raises many problems concerning the safety of the vital spirits, food chain, and ultimately humans. To address these problems, and assess the concentration of radioactivity in the marine environment is essential.

   Black sand concentrate of ilmenite consists, magnetite, zircon, rutile, garnet, and monazite. Show that at least 25 million tons of heavy metals black sand containing approximately 200,000 tons of monazite. It consists mainly sand beach of quartz, feldspar, and other metals corrosion resistance wave. They are the product of a combination of weather factors, fragmentation and degradation (Pettijohn et al. 1978). It is known beach placer deposits or "black sand" global economic concentrations of heavy metals such as monazite, zircon, ilmenite, rutile, garnet, sillimanite and allanite (Alam et al. 1977). The relatively high concentrations of radionuclides in these
deposits in the concentration found studies. Basically, these studies and sacked on the study of the feasibility of using these deposits of raw materials in thorium and uranium mining in the investigation of the effects of radiation on humans and the environment from natural radioactivity in these locations. And it can then be linked to this data to epidemiological studies that attempt to release harmful to human health effects of exposure to radiation. The main objective of the Marine radiological investigations is to contribute to the creation of the scientific basis for predicting the effect of radioactive isotopes (natural or synthetic), which can be released into rivers, lakes and seas on marine ecosystems. Black sand deposits at the Temsah Lake beach of the Suez Canal had gotten the attention of geologists, physicists, and other scientists for the last decades (Marwa Saad El-Din et al. 2013; Mohamed Zein Alabdein Nassar et al. 2014; El-Sherif et al. 2009 and Mohamed et al.2013). But none of these studies did not evaluate the radiological environment of Temsah Lake. Present work is the first study to assess the impact of the radiological environment of black sand and sediment on the shores of Temsah Lake.

Accordingly, the aim of the present work is to reinvestigate the radioactivity concentrations in sand and sediments collected from Temsah lake beaches in Suez Canal region, Egypt. And to be extracted parameters of a health hazard thoroughly discussed. It can be concluded that there is still a need for the implementation of environmental management practices in the Temsah Lake to protect these ecosystems of the most pollutants that can affect human health and the environment.

2. Experimental Technique.

2.1. Geographical Study Area.

Crocodile Lake, also known as Temsah Lake, is a lake in Egypt on the Nile delta. It lies in a basin developed along the fault extends from the Mediterranean Sea to the Gulf of Suez through the Lakes Region time with coordination 30.56667°N 32.28333°E (William et al. 1979). In 1800, a flood filled the valley Tumilat, which caused banks to bypass the taste and moved water from the south to the time the lakes about 14 km. The lake was filled with waters from the Red Sea, in 1862. Lake Temsah lies within a depression that spans the isthmus between the Red Sea and the Mediterranean Sea. The lowest point of depression is the natural lagoons, including one Temsah. Temsah Lake covers an area of 5.4 square miles. Most of the lake is marshy and depths rarely exceed 3 feet (1 meter). 1863, the city of Ismailia arose on Lake Tomah's northern bank. Several beaches overlook the lake. Temsah Lake is highly saline lake, which is facing significant differences in salinity. It was an important event for the community, since the lake from the economic importance of the city and its fishermen. In 2003, the number of groups tried to ease the lake from pollution (Yasmine 2009).

2.2. Sample Collection and Preparation

Black sand and sediment samples in the present study are obtained from rich deposits of black sands, which occur along beaches of the TEMSAH LAKE on the Suez Canal region. The areas where the deposition of these sands is favored are near by the Mediterranean Sea and Read Sea. Each sample containing with grain weighing about 250 g was stored and after drying in an oven at 115 °C, it in standardized polyethylene containers. It was closed containers to avoid any potential for radon gas out and leave for 28 days to ensure that the samples have achieved a balance between radiations $^{226}\text{Ra}$ with its decay products of uranium in the series. It was supposed to $^{232}\text{Th}$ is in the case of secular equilibrium with $^{226}\text{Ra}$.
2.3. Measurements of Radioactivity

Measuring the activity concentrations of naturally occurring radionuclides from $^{226}$Ra, $^{238}$U, $^{232}$Th, and $^{40}$K in the black sand and sediment samples, using high-purity germanium (HPGe) spectrometer-based detection of gamma rays with the relative efficiency of 40%. HPGe detector coupled with Canberra multichannel analyzer (MCA). The resolution of the spectrometry system was 1.8 keV at 1332 keV gamma-ray line of $^{60}$Co. Spectrum were collected for each sample in 54000 seconds (15 hours). Spectrum analysis was performed with the computer programs and activity concentrations of U, Ra, Th and K natural radionuclides were determined. To limit the influence of the background, the detector was shielded with 10 cm lead cover wall lined with copper 2 mm and 2 mm cadmium chips. Estimated activities of $^{226}$Ra (or activities of $^{238}$U samples supposed to be in the case of radiation balance) were from $^{214}$Pb (351.9 keV), $^{214}$Bi (609.3, 1764.5 keV) and $^{226}$Ra (185.99 keV). It was also monitoring several $^{214}$Pb peaks and $^{214}$Bi. The use of gamma-ray energies of $^{212}$Pb (238.6 keV) and $^{228}$Ac (335.4, 911.07, 968.90 keV) to estimate the concentration of $^{232}$Th, and was using the energy value of gamma of 1.465 MeV to determine the concentration of $^{40}$K in all samples. In order to determine the distribution of background radiation in the environment surrounding the detector, it has counted a closed container empty for 10 hours (NCRP 1975; Lavi et al. 2004).

3. Results and Discussion.
3.1. Activity Concentrations $A$ (Bq/kg)

Activities concentrations were determined by measuring its decay daughters (Kurnaz et al. 2007). The activity concentrations evaluate the intensity of each line taking into account the mass of the sample, it was brought branching ratios of $\gamma$ decay, counting time and efficiency of the detector and the net count of the sample was brought about by subtracting a linear background distribution of the corresponding peak energy area (Keyser 1995). The activity concentrations account of the study sample consisted of the equation:

$$A = \frac{(CPS)_{net}}{I \times \varepsilon \times M} \quad (1)$$

Where $A$ is the concentration of activity in Bq/kg, $(CPS)_{net}$ is (count per second). I am the intensity of the $\gamma$-line in a radionuclide, $\varepsilon$ is the detector efficiency for each $\gamma$-line and $M$ is the mass of the sample in kilograms. Tables 1, 2 shows that the activity concentrations for all samples together with the standard deviation from the several values and their average for a radionuclide. The activity concentrations for the sediment and black sand samples ranges from (4.29 ± 1.66 to 30.06 ± 8.80), (4.29 ± 0.68 to 18.52 ± 5.22) Bq/kg with an average value (9.57 ± 2.92) and (11.63 ± 3.35) for $^{226}$Ra respectively. While the activity concentrations for the sediment and black sand samples ranges from (4.23 ± 1.33 to 16.56 ± 3.31), (5.31 ± 1. 90 to 17.46 ± 4.81) Bq/kg with an average value (8.64 ± 2.49) and (10.86 ± 2.18) of $^{238}$U respectively. Radioactivity concentration ranges with $^{232}$Th varied from (6.69 ± 1.54 to 39.24 ± 9.80), (4.56 ± 1.07 to 18.65 ± 5.27) Bq/kg with an average value (13.11 ± 4.61), (11.41 ± 3.28) Bq/kg respectively. The radioactivity concentration ranges with $^{40}$K ranged from (37.17 ± 12.27 to 242.25 ± 70.94), (145.85 ± 43.30 to 441.15 ± 91.93) Bq/kg with an average value (141.64 ± 43.01), (327.65 ± 80.05) Bq/kg respectively.
The global average radioactivity concentration ranges of $^{232}$Th, $^{238}$U and $^{40}$K in sediment samples have been 40, 40,580 Bq/kg respectively (UNSCEAR 1993).

It is clear that the radioactivity concentration (for $^{226}$Ra, $^{238}$U, $^{232}$Th and $^{40}$K) in the black sand and sediment samples from different sites under study can be considered, taking into account the nature of the Egyptian soil. Radioactivity in the lake sediment content depends on the type of the rock from which the formation of sediment, and atmospheric deposition (dry and wet), and the distribution of water flow in the lake, the physical and chemical characteristics of the sediments.

3.2. The Absorbed Dose Rates $D$ (nGy/y).

Calculated absorbed dose rate in air in nGy/y due to terrestrial gamma rays in 1m above the surface of the earth, black sand and sediments collect sites, according to the equation:

$$D = R_{Ra}A_{Ra} + R_{Th}A_{Th} + A_K$$

Where: $R_{Ra}$, $R_{Th}$ and $R_K$ are conversion factors in (nGy/h)/(Bq/kg) of $^{226}$Ra, $^{232}$Th and $^{40}$K. The activity concentrations $A_{Ra}$, $A_{Th}$ and $A_K$ are in Bq/kg of $^{226}$Ra, $^{232}$Th and $^{40}$K in black sand and sediment samples. The calculated values of absorbed dose rate were found to be ranged in black sand samples between (11.49 to 37.71) nGy/h with average value 26.12 nGy/h, and in sediment samples were in range (10.01 to 39.81) nGy/h with average value 18.88 nGy/h.

3.3. Annual Effective Dose Rate (Deff mSv/y).

The annual effective dose received by the $D_{eff}$ (mSv/y) (outdoor) was calculated using a conversion factor of 0.7 Sv/Gy which was used to convert the absorbed dose rate to the equivalent effective dose for human occupancy with outdoor than 20%. Using the following equations, the outdoor annual effective dose could be determined [1]:

$$D_{eff} \text{ (outdoor) } (\text{mSv/y}) = D \text{ (nGy/h)} \times 8760 \text{h} \times 0.7 \text{ Sv/Gy}^{-1} \times 0.2 \times 10^{-3}$$

The results of the calculated $D_{eff}$ are given in Table 1 for sediments samples and in Table 2 for black sand samples. The annual effective dose results vary between 0.01 to 0.05 mSv/y for sediments samples and from 0.01 to 0.05 mSv/y for local black sand samples. The mean values of the annual effective dose were found to be 0.02 and 0.03 (mSv/y) in sediment and black sand samples, respectively, which means that the average values of outdoor $D_{eff}$ for all samples are lower than the world average values (70 μSv/y) (UNSCEAR 1988).

3.4. Radium Equivalent Activity ($Ra_{eq}$), External and Internal Hazard Index ($H_{ex}$, $H_{int}$):

Radium activity is equivalent to the widely hazard index used when comparing the specific activity of the samples containing different amounts of $^{226}$Ra, $^{232}$Th and $^{40}$K. It is supposed to be 370 Bq/kg of $^{226}$Ra, 259 Bq/kg of $^{232}$Th and Bq/kg 4810$^{-1}$ of $^{40}$K, the same dose rate of gamma rays produce a maximum value allowed to considerations of public dose according to (Beretka and Mathew 1985):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K$$
Where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activity concentration of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg, respectively. Estimation of $Raeq$ for all collected sediment and black sand samples are given in Tables 1, 2. The calculated average values of $Raeq$ were found to be 39.24 and 52.16 Bq kg$^{-1}$ in sediment and black sand samples, respectively. The estimated average values of $Raeq$ in the present study are lower than the average values from some of the other countries and the recommended world maximum value of 370 Bq/kg.

To limit the annual external gamma-ray dose from materials to 1.5 mSv/y for the samples under investigation, the external hazard index $H_{ex}$ is given by the following equation:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} < 1$$

(5)

The internal exposure to $^{222}Rn$ and its radioactive progeny is controlled by internal hazard index, $(H_{in})$ which is given by.

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_{K}}{4810} < 1$$

(6)

The results of $H_{ex}$ and $H_{in}$ are based on the criterion formula Eq. (5) and Eq. (6), and are given in Tables 1, 2 for sediments and black sand samples. The internal hazard exposure $H_{in}$ in the black sand samples are ranged from (0.07 to 0.26) with average (0.17), and the external hazard ranged from (0.06 to 0.21) with average (0.14). The $H_{in}$ values in the sediment samples are ranged from (0.07 to 0.32) with average (0.13), and $H_{ex}$ values ranged from (0.05 to 0.24) with average (0.11). In general, $H_{ex}$ and $H_{in}$ were not exceed the limit of unity for all samples in the present work, indicating negligible hazards effects of radon and its short-lived progeny to the respiratory organs (UNSCEAR 2000).

3.5. Activity Indices (Gamma-index (Iγ) and Alpha Index (Iα)):

It has been proposed a number of indicators dealing with internal and external radiation origin of building materials evaluation and indexes gamma rays focus a number of researchers (Righi and Bruzzi 2006; Cutshall et al. 1983; Ibrahiem et al. 1993). In this study, it was awarded a gamma index as proposed by the European Commission (European Commission of Radiation Protection RP112. EC 1999):

$$I_{\gamma} = \frac{A_{Ra}}{150} + \frac{A_{Th}}{100} + \frac{A_{K}}{1500}$$

(7)

Where $A_{Ra}$, $A_{Th}$ and $A_{K}$ are the activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg$^{-1}$, respectively. Average $I_{\gamma}$ values calculated from the measured activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ are presented in Tables 1, 2 for different black sand and sediment samples and the regions from where they were collected. The calculated values of $I_{\gamma}$ for the sediment and black sand samples varied in the range from (0.16 to 0.62), and (0.18 to 0.59) respectively. It is clear that, the calculated mean value of the activity index $I_{\gamma}$ is (0.30, 0.41) for sediment and black sand samples which is less than the critical limit for $I_{\gamma} < 1$. In the present work, $I_{\gamma} < 0.5$ for most sediment and black sand samples, except for (Sd14, S3, S4) samples, which corresponds to a dose creation of 0.3 mSv y$^{-1}$, and it safe for human to carry out their activities in the area of the study. To assess the exposure level due to radon inhalation originating, alpha indices have been proposed by (European Commission of Radiation Protection RP112. EC 1999). The alpha index was determined using the following formula:
\[ I_\alpha = \frac{A_{Ra}}{200} \text{ (Bq kg}^{-1}) \]  \tag{8}

Where: \( A_{Ra} \) (Bq/kg) is the activity concentration of \(^{226}\text{Ra}\) assumed in equilibrium with \(^{238}\text{U}\). The recommended exemption and upper level of \(^{226}\text{Ra}\) activity concentrations in black sand are 100 and 200 Bq/kg, respectively, suggested by (ICRP 1994). These considerations are reflected in the alpha index. The recommended upper limit concentration of \(^{226}\text{Ra}\) is 200 Bq/kg, for which \( I_\alpha = 1 \). The computed \( I_\alpha \) values of the studied samples are given in Tables 1,2 for the different sediment and black sand samples and the regions where they were collected. The calculated values of \( I_\alpha \) for sediment and black sand samples were ranged from (0.02 to 0.15) and (0.03 to 0.09), with mean values of (0.05 and 0.05) respectively \( I_\alpha \) less than unity. However, the results of radiation activity hazard indices reflect that the area under investigation of Temsah Lake seems to be radiologically safe for human being.

3.6. Elemental Ratio, \( e_{\text{Th}}/e_{\text{U}} \), \( e_{U}/e_{\text{Ra}} \), \( A_{K}/A_{U} \), and \( A_{K}/A_{\text{Th}} \), with Correlation Studies.

The \( A_{\text{Th}}/A_{U} \) ratio has also proven to be useful in the recognition of “geochemical faces”. Based on their analyses of numerous soil and sediment samples, Adams and Weaver (Adams and Weaver 1958), prove the feasibility of uranium to thorium ratio as an indicator of relatively oxidizing conditions or reduction. Uranium has a tetravalent state is soluble, which are fixed under reducing conditions, it turns into a soluble hexavalent state and that can be mobilized in the solution. In contrast, thorium has a tetravalent state is soluble and one which is geochemically associated with uranium. Therefore, it is a useful standard for comparison purposes (Macfarlane et al. 1989; Doventon and Prensky 1992) and (Adams and Weaver 1958), further suggested that ratios <2 were very suggestive of the relative enrichment of uranium, and the involvement of reducing conditions, as contrasted with ratios > 7, which refers to the removal of preferential enrichment, perhaps by leaching.

The measured activity concentrations ratio of \(^{226}\text{Ra}, \text{ }^{238}\text{U}, \text{ }^{232}\text{Th}, \text{ and } 40\text{K} \) in (Bq/kg) were converted to elemental activity concentrations values of \( e_{\text{Ra}}, e_{U} \) and \( e_{\text{Th}} \) in ppm as well as K in percent %, using the conversion factors provided by the International Atomic Energy Agency (IAEA 1989). Activity concentration of the sample containing 1 ppm by weight of \(^{238}\text{U} \) is 12.35 (Bq/kg) 1 ppm of \(^{232}\text{Th} \) is 4.06 (Bq/kg) 0.1 ppm of \(^{226}\text{Ra} \) is 11.1 (Bq/kg) and 1% of \(^{40}\text{K} \) is a 313 (Bq/kg). In the present study, the calculated values of the \( e_{\text{Th}}/e_{U}, A_{K}/A_{U} \) and \( A_{K}/A_{\text{Th}} \) elemental ratios may provide an indication whether relative depletion or enrichment of radioisotopes had occurred Table 3. The corresponding calculated range of \( e_{\text{Th}}/e_{U} \) ratio is wide (1.10 to 6.80 ppm) for black sand samples and (2.80 to 8.57 ppm) for sediment samples, Table 3. \( e_{\text{Th}}/e_{U} \) ratio average of black sand samples is 3.43, often slightly lower than the average continental crust value of approx. 3.8 (Rogers and Adams 1969; Clark S.P, Peterman and Heier 1966), suggesting that these black sand are enriched in U. On the contrary \( e_{\text{Th}}/e_{U} \) average ratio of sediment samples are 5.18, higher than the average continental crust value, suggesting that this black sand is enriched in Th.

The equilibrium factor, which was defined by (Hussein et al. 1992), as P-factor and it was in the ratio of uranium, is equivalent to measuring radiometrically and radium equivalent \( (e_{U}/e_{\text{Ra}}) \) was calculated in all black sand and sediment samples. This factor is more or less than the unit which shows a state of disequilibrium, while P-factor equal unity indicated the state of equilibrium. Of the estimated values Table
we note that the calculated mean value of the ratio \((A_{U}/A_{Ra})\) P-factor, for black sand and sediment samples are in a good equilibrium where its value close to unity (0.98 and 0.95) respectively.

In fact, knowing the conditions of the secular equilibrium necessary in order to make correct assumptions assessments dose (Salem and El Fouly 2000). In order to find the extent of the presence of these radioactive nuclides together in a certain place, correlation studies were performed between the combinations of radionuclides like \(^{226}\text{Ra}\), \(^{238}\text{U}\), \(^{232}\text{Th}\), and \(^{40}\text{K}\). A search was carried out to detect the presence of a statistically significant correlation between the measured radionuclides in the present black sand and sediment samples.

In this context and considering all samples, regarding Figure 2(a), which shows linear regression of the activity concentrations of \(^{238}\text{U}\) (ppm) versus \(^{232}\text{Th}\) (ppm) for all black sand samples. Since the P-value is less than 0.05 in the ANOVA table, there is a statistically significant relationship between \(^{232}\text{Th}\) activity concentration (ppm) and \(^{238}\text{U}\) activity concentration (ppm) at the 95.0% confidence level. According to statistical R-Squared that the model as fitted explains processed 22.2816 % of the variability in \(^{232}\text{Th}\) activity concentration (ppm). The correlation coefficient equals 0.472034, indicating a moderately weak relationship between the variables (Fairbridge 1972). Figure 2 (b), the output shows the results of fitting a linear model to describe the relationship between \(^{238}\text{U}\) (ppm) and \(^{232}\text{Th}\) (ppm) in sediment samples. The R-Squared statistic indicates that the model as fitted explains 42.7058% of the variability in \(^{238}\text{U}\) (ppm) sediment sample. The correlation coefficient equals 0.653497, indicating a relatively a moderately strong relationship between the variables.

Figure 3(a) shows moderately strong among correlation between uranium and radium in black sand samples under investigation (correlation coefficient = 0. 84513, \(R^2 = 71.4245 \%\)) which indicate the secular equilibrium between \(^{238}\text{U}\) and \(^{226}\text{Ra}\). While Figure 3(b) shows the moderate strong correlation between the concentrations of the two radioactive isotope (\(^{238}\text{U}\), \(^{226}\text{Ra}\)) in sediment samples (correlation coefficient = 0.818103, \(R^2 = 66.9293 \%\)).

As can be seen in Figure 4 (a), activity concentrations of \(^{232}\text{Th}\) and \(^{40}\text{K}\) in black sand sample showed a statistically significant. The correlation coefficient equals 0.491238, indicating a relatively weak relationship between the variables. R-square indicates that the adjusted model explains 24.1315 % of the variability in Potassium activity concentration, indicating week correlation coefficient of the \(^{232}\text{Th}/^{40}\text{K}\) activity [35]. Figure 4 (b), The output shows the results of fitting a linear model to describe the relationship between \(^{232}\text{Th}\) (ppm) and \(^{40}\text{K}\) (%) in sediment samples. The R-Squared statistic indicates that the model as fitted explains 4.5001% of the variability in \(^{40}\text{K}\) (%) sediment sample. The correlation coefficient equals -0.212134, indicating a relatively weak relationship between the variables.

Figure 5(a), the output shows the results of fitting a linear model to describe the relationship between \(^{238}\text{U}\) (ppm) and \(^{40}\text{K}\) (%) in black sand samples. R-square indicates that the adjusted model explains 22.2433 % of the variability in Potassium activity concentration. The correlation coefficient is equal to 0.471628, indicating a relationship relatively weak between the variables. While Figure 5(b) for sediment samples, the output shows the results of R-square indicates that the adjusted model explains 5.49585% of the variability in Potassium activity concentration. The correlation coefficient is equal to 0.234432, indicating a relationship relatively weak between the variables. The correlation between \(^{40}\text{K}\) and \(^{226}\text{Ra}\) (\(^{238}\text{U}\) series) and \(^{232}\text{Th}\) series may be explained by the competitive chemical behavior and the concentration
of the stable isotopes (K, Ra and Th) that could affect the adsorption of these ions on clay particle.

3.7. Radon Concentration Evaluation.

Radon-222 is a natural radioactive gas formed from radium (\(^{226}\)Ra), with a half-life of 3.8 days, derived from geologic materials. Has been linked to inhalation of short-lived decay products of radon increases the risk of cancers of the lung if present at high levels (UNSCEAR 1993). Called on the rate at which radon escapes from the soil or stems of radon emanation rate or radon exhalation rate. These studies can be useful to assess the overall performance of the radiation dose and epidemics as well as for the maintenance of reference data records, to make sure that change in environmental radioactivity caused by human industrial, nuclear and other activities.

With the above important points in mind, a study was undertaken for the assessment of natural the activity concentrations of \(^{222}\)Rn in the air with the activities of \(^{226}\)Ra that contents in vegetables, as well as the doses that result from the consumption of vegetables and inhalation of radon gas rates considered. For the purpose of calculating \(^{222}\)Rn concentration levels in black sand and sediment samples was determined by measuring activity concentrations of \(^{226}\)Ra (Tables 1,2), (Chung et al. 1989), with theoretical considerations of mathematical equations models are used as in the following eq.[9]:

\[
C_{Ra(n)} = C(E_n) - B(E_n)/m.f.t.P(E_n) \tag{9}
\]

\(n\) : is the number of black sand or sediment sample, 1, 2, 3, .... etc  
\(C_{Ra(n)}\) : is the radioactive concentration of \(^{226}\)Ra in black sand and sediment sample (n) in (Bq/Kg) which be measured and calculated in Tables 1,2.  
\(C(E_n)\) : is the net \(\gamma\)-counts above continuum at the characteristic energy \((E_n)\).  
\(B(E)\) : Is the background counting in \((E_n)\).  
\(m\) : The sample mass in (Kg).  
\(f\) : Is the branching ratio of \(\gamma\) emissions in the energy in mind.  
\(t\) : is the measuring live time in (sec).  
\(P(E_n)\) : is the absolute efficiency at energy \((E_n)\).

Firstly it must be estimate the radioactive concentration of \(^{222}\)Rn inside the black sand or sediment samples by:

\[
Gs(n) = F_r . \rho . C_{Ra(n)} \tag{10}
\]

\(Gs(n)\) : concentration of radon gas inside the soil for sample(n) in (Bq/m\(^3\)).  
\(F_r\) : the constant of emission of Rn\(^{222}\) from the soil that is equal to (0.1).  
\(\rho\) : is the soil density that is equal to (1800 Kg/m\(^3\)).  
\(C_{Ra(n)}\) : is a radioactive concentration of \(^{226}\)Ra in the soil sample (n) in (Bq/Kg).  
The formula that used to measuring the radioactive concentration of \(^{222}\)Rn in the air as follows (Quindos et al. 1988):

Now we can calculate the concentration of \(^{222}\)Rn in air using equation (11):

\[
Ca(n) = Gs(n) \cdot (d_{soil} / D_{air})^{1/2} \tag{11}
\]

\(Ca(n)\) : is the concentration of \(^{222}\)Rn in air for sample (n) in (Bq/m\(^3\)).  
\(Gs(n)\) : concentration of radon gas inside the soil for sample(n) in (Bq/m\(^3\)).  
\(d_{soil}\) : is the diffusion rate constant of \(^{222}\)Rn in the soil \((0.5 \times 10^{-4} \text{ m}^2/\text{sec})\).  
\(D_{air}\) : is the diffusion rate constant of \(^{222}\)Rn in the air \((5 \text{ m}^2/\text{sec})\).
Expense of radioactivity in vegetables was determined by using the following equation [12]:

\[ C_P = A_n \cdot C_{Ra(n)} \]  

(12)

\( C_P \) : is the concentration of \(^{226}\text{Ra}\) in vegetables in (Bq/Kg) (IAEA 1990).
\( A_n \) : is the transfer coefficient of \(^{226}\text{Ra}\) from soil to Vegetables that is equal to (0.04).
\( C_{Ra(n)} \) : is the radioactive concentration of \(^{226}\text{Ra}\) in soil sample (n) in (Bq/Kg).

The doses rates that coming from inhalation of radon gas and vegetables consumption was determined by using the below equation [13]:

\[ H_p = C_p \cdot I_p \cdot DCF \]  

(13)

\( H_p \) : is the dose rate resulting from inhalation of radon gas or vegetables consumption in (µsv/y) (European Commission of Radiation Protection RP112 EC 1999).
\( C_p \) : is the concentration of \(^{226}\text{Ra}\) in vegetables (Bq/Kg) or the concentration of \(^{222}\text{Rn}\) in the air (Bq/m\(^3\)).
\( I_p \) : is the amount of consumption of vegetables in year (90Kg/y) and for air outside the home (1600 m\(^3\)/y) (IAEA 1990).
\( DCF \) : is the dose conversion coefficient: for \(^{226}\text{Ra}\) equal to \((2.8 \times 10^{-7} \text{ sv/Bq})\) and for \(^{222}\text{Rn}\) equal to \((1.3 \times 10^{-9} \text{ sv/Bq})\), (IAEA 1996).

The annual effective dose, \( H_E \), due to radon inhalation, which corresponds to the values of indoor air radon concentrations, was calculated according to the expression of (UNSCEAR , 2000). Hence, the annual effective dose rate indoors \( H_E \), in units of mSv/y\(^{-1}\) is calculated by the following formula:

\[ H_E = C_{Rn} \cdot E_F \cdot T \cdot D_C \]  

(14)

where \( C_{Rn} \) is the average indoor air radon concentration, in Bq/m\(^3\), \( E_F \) is the indoor equilibrium factor between radon and its progeny (=0.4), \( T \) is the exposure time to this concentration (0.8×24h×365.25 = 7010 hy\(^{-1}\) and 0.8 for the indoor occupancy factor ) and 9 mSv (Bq h m\(^{-3}\))\(^{-1}\) is the dose conversion factor \( D_C \) (effective dose received by adults per unit \(^{222}\text{Rn}\) activity per unit of air volume). Above formula produces the equivalent of effective dose of the population which is equal to 1.0 mSv\(^{-1}\). As an example, the arithmetic, the concentration of \(^{222}\text{Rn}\) measured 40.0 Bq/m\(^3\), the above formula produces the equivalent of effective dose of the population which is equal to 1.0 mSv\(^{-1}\).

Tables 4, 5 represents \( C_R(n) \) the concentration of \(^{222}\text{Rn}\) in air (Bq/m\(^3\)), \( C_{Rn} \) the average indoor air radon concentration (Bq/m\(^3\)), \( H_p \) the dose rate resulting from inhalation of radon consumption in (µsv/y) and the annual effective dose, \( H_E \), due to radon inhalation (mSv/y) for the sediment and black sand samples in different sits. The average radon gas concentration in air varied from (12.21 to 85.55 Bq m\(^{-3}\)) and from (4.32 to 18.67 Bq m\(^{-3}\)) respectively. Moreover, the annual effective dose \( H_E \) (mSv y\(^{-1}\)) varied from (0.86 to 2.21 mSv\(^{-1}\)) and (0.16 to 0.53 mSv y\(^{-1}\)), with mean values of (0.74, 0.35 mSv y\(^{-1}\)) respectively. To characterize the risk of exposure to radon in indoor air of residences as a result of emissions from soil samples, indoor air concentrations estimated from the measured radon flux (14.38 to 87.72 Bq m\(^{-3}\)) and (6.49 to 20.84 Bq m\(^{-3}\)) with mean (29.40, 13.89 Bq m\(^{-3}\)) respectively, were compared to relevant benchmarks that included exposure guidelines for radon, background
levels of radon, and quantitative estimates of health risk. The U.S. Environmental Protection Agency, for example, has established an action level of 148 Bq m$^{-3}$ (4.0 pCi L$^{-1}$), for radon in residential indoor air (EPA 1993b). Similarly, the ICRP recommends an action level for radon in indoor air of dwellings that is no lower than 200 Bq m$^{-3}$ (5.4 pCi L$^{-1}$) (ICRP 2005). All samples from black sand and sediment with corresponding radon concentration results show that the radon gas concentration are lowest than the allowed limit (International Commission of Radiation Protection) (ICRP 1990) agency. The annual effective dose $H_E$ within the allowed limits that equal (1msv/y) for all samples and all regions that selected in the present search.

4. CONCLUSION

Environmental monitoring should be carried out for black sand and sediment that taken from all beach regions from TEMSAH LAKE, where people might be exposed to radioactivity. Present work is the first study to assess the impact of the radiological environment of black sand and sediment on the shores of Temsah Lake. The activity concentrations were compared of the mean value of $^{226}$Ra inside the black sand which measured in the present work with the values of the other countries in the world and it is found that within the permissible limits. The radiation hazards (absorbed dose rate, radium equivalent activity, the annual effective dose equivalent, hazard indices, and gamma, alpha) are calculated and compared with the previously reported data. None of the black sand sediment analyzed from beaches on Temsah Lake were considered a radiological risk. It is important to point out that these values were not the representative values for the Egypt, but for the regions from where the samples were collected. Values of natural radioactivity and $\gamma$-absorbed dose rates that have been obtained from the activity concentrations of black sand and sediment in the air show that none of the studied samples is considered a radiological hazard.

The equilibrium factor is P-factor and expressed in the ratio between radiometrically measured equivalent uranium and equivalent radium ($c_U/c_{Ra}$) was calculated in all black sand and sediment samples. From the estimated values, we note that the calculated mean value of the ratio ($A_U/A_{Ra}$) P-factor , for black sand and sediment samples are in a good equilibrium where its value close to unity (0.98 and 0.95) respectively . Radon $^{222}$Rn doses from inhalation gas for humans were estimated. The average radon gas concentration in air varied from (12.21 to 85.55 Bq m$^{-3}$) and (4.32 to 18.67 Bq m$^{-3}$) respectively. Moreover, the annual effective dose $H_E$ (mSv y$^{-1}$) varied from (0.86 to 2.21 mSv y$^{-1}$) and (0.16 to 0.53 mSv y$^{-1}$), with mean values of (0.74, 0.35 mSv y$^{-1}$) respectively, it is in within the permissible limits. All samples from black sand and sediment with corresponding radon concentration results show that the radon gas concentration are lowest than the allowed limit (International Commission of Radiation Protection) (ICRP) agency [42]. The annual effective dose $H_E$ within the allowed limits that equal (1msv/y) for all samples and all regions that selected in the present search. The results indicate that the values that were obtained fall below under the international maximum acceptable limits and no risk of radiation significantly in the study area. The results indicate that the values obtained fall below the internationally accepted maximum limits and do not pose any significant radiation hazard to individuals in the study area. Soils can be safely used of any used without posing any significant radiological threat to population.From these results, a radiological baseline map of Egyptian beaches in Temsah Lake can be drawn and used as reference information to assess any future alterations in the radioactivity of beach sands due to any changes in the sea sediments.
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