

Assessment of Environmental Radioactivity and Public Exposure Dose at Wonderland of Blue Nile Shore in Khartoum-Sudan

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Abstract Background and Objective: Radiation survey has been carried out at a wonderland of Blue Nile shore of Khartoum state as a protective and safety precautions for community. The objective was to assess the radiation exposure level and the committed dose by public compared with authorized one. Materials and Methods: the method used was an experimental survey covering 10 km² using Geiger Muller survey meter at surface and depth profile down to 100 cm with enhancement of hoe and drill for deeper samples that consists of 90 samples. The Results: the analyzed data showed that: the emitted radiation represented γ -radiation and particles as (β and α). The exposure level at surface due to γ - radiation and particles was 0.21 μ Sv/h that represents 0.021% of the maximum permissible dose for public. The committed dose by the entertained public at wonderland areas based on the number of trips was 40.3 μ Sv/year; at surface which is equivalent to 4.03% of the MPD due to γ -ray, α and β particles irradiation. The exposure dose was found to be increased following the depth increment based on equation: $y = 0.114e^{0.003x}$, where x refers to depth in centimeter and y refers to exposure in μ Sv/h. And at depth 100 cm; the exposure level was 0.17 μ Sv/h due to γ -ray, α and β particles and 0.14 μ Sv/h due to pure γ -radiation respectively. **Conclusion:** the study revealed considerable exposure level to frequent entertained public at Blue Nile shore in Khartoum beside Tooti city boundary.

Keywords: exposure, environmental, survey, radioactivity, wonderland

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1. Introduction

The earth crust from an ancient has been contaminated by different types of toxic and or radioactive elements that representing hazardous to mankind, animals and the plants as well. The common types of toxic elements in the earth crust are exemplar in (Mercury (Hg) induces nephrotoxicity and neurotoxicity, Arsenic (As) induces gastrointestinal disturbance, neoplasms of the skin, liver, kidney, lymphatic cancer and DNA damage [1], Lead (Pb) ≥ 10 μ g/L and ≤ 10 μ g/dL induces impaired cognitive, behavioral, and motor development in children with hypertension, nephropathy, and impaired fertility in adults [2,3]; while the common radioactive elements represented in (⁴⁰K, ²²⁶Ra and ²³²Th); [4]. The main emission from these radionuclides are alpha (α), beta (β) and gamma radiation (γ) from the ²²⁶Ra and ²³²Th; while ⁴⁰K emits beta and gamma radiation [5]. As has been reported by UNSCEAR, [6] and Facchinelli, and Mallen, [7]; that the average concentration of ²²⁶Ra, ²³²Th, and ⁴⁰K, were 35, 35, and

370 Bq/Kg respectively worldwide. The total exposure to world population due to natural environmental radiation has been stated by world nuclear association as 85-90% of annual exposure dose [8,9,10].

However not only radiation activity represents the hazards to mankind, but also the elemental toxicity (either intrinsic poison or due to over concentration); as the earth crust implies many toxic elements such as: (Selenium, Arsenic, Molybdenum, Fluorine, Boron, Manganese, Aluminum, Barium, Nickle, Copper, Zink and Lead) [11]. The most abundant element in the earth's crust is oxygen (O), making up 46.6% of the Earth's mass. Silicon (Si) is the second most abundant element (27.7%), followed by aluminum (Al) (8.1%), iron (Fe) (5.0%), calcium (Ca) (3.6%), sodium(Na) (2.8%), potassium(K) (2.6%). and Magnesium (Mg) (2.1%). These eight elements account for approximately 98.5% of the total mass of the earth's crust [12].

The trend of this survey research is focusing on the assessment of radiation exposure level to public who enjoy entertainment at wonderland area at Blue Nile shore in Khartoum state, that located in Tooti island. Relative to

this surveying study Saad et al, [13]; carried out a radiation survey for assessing natural radioactivity in different regions of Sudan; where it was from 10.6 to 30.45 Bq/Kg, from 7.38 to 23.95 Bq/Kg, and from 246.8 to 412.5 Bq/Kg dry weight for ^{232}Th series, ^{226}Ra (^{238}U) and ^{40}K respectively in Dongla city (Northern Sudan). In Al-Burkal city mountain; it was from 6.2 to 39.18 Bq/Kg, from 9.65 to 31.86 Bq/Kg, and from $< \text{D.L.}?$ Bq/Kg to 210.95 Bq/Kg dry weight respectively, and in addition to Mernna city mountains (Southern Sudan) and Kurrun city mountains (eastern Sudan). And they conclude that: the radioactive level was high at mountains sectors with exception to mid-Sudan.

In this realm; Arafat et al, [14] also, introduced study aimed to assess the radioactivity levels and the associated hazards of water, soil and shore sediments samples in Marsa Alam-Shalateen area, Red Sea. They found that: the Ra-226 activity concentrations ranged from <0.7 to 7.6 Bq L^{-1} and from <0.7 to 6.31 Bq L^{-1} for groundwater and sea water samples, respectively. And in the soil, they found that: Ra-226, Th-232 and K-40 represented 18.45, 16.78, and 334.35 Bq/Kg , respectively. While the shore radioactivity for Ra-226, Th-232 and K-40 were 10.76, 9.86 and 304.74 Bq/Kg respectively. And based on radiation hazards indices they realized that: only at Marsa Alam-Shelateen Road km 33), where the activity level index was 1.052 Bq/Kg and the absorbed gamma dose rate was 66.5 nGy/h which exceeds the maximum permissible limits. Other related study had been done by Najat and Mohamed, [15]; in which the concentration levels for each of ^{238}U , ^{232}Th and ^{40}K in Northern zone (57 ± 5 , 36 ± 3 and 616 ± 113), Southern zone (52 ± 4 , 41 ± 3 and 558 ± 10) and in Central zone was (46 ± 3 , 32 ± 3 and 519 ± 7) Bq/Kg respectively; which was from Likuyu village in Tanzania. In which the central part of the village showed the lowest concentration; while at northern zone there was high concentrations of ^{238}U and ^{40}K , which were each 1.2 times higher than their values of central zone and southern zone showed the highest mean value of ^{232}Th which was 1.3 times higher than at central zone. For the sake of mankind protection, Saalsberry climate and friendly environment; an environmental survey has to be done by the ministry of environment and tourist among

different countries in order to assess radiation exposure level with relative radiation thickening and as well to carryout geological and archeological dating.

2. Material and Methodology

The study has been carried out as environmental survey at public entertainment area at Blue Nile shore in Khartoum state, that located in Tooti island as shown in google map Photo (1). The surveyed area covered 10 Km^2 at surface and different depths (0, 20, 40, 60, 80 and 100 cm). The collected samples in plastic packs imply sands in equal weight of Kilogram (Kg) consisting of 90 samples; which have been divided into three main samples (S_1 , S_2 and S_3); each 'S' contains 30 samples and five (5) samples for each depth. The used radiation survey meter was a (RedEye B20-version – 2,19V E.2.05 / 2012-09-07); for α , β , γ -radiation supplied with optional gamma energy filters, and deep or shallow dose rate measurements from 17 – 1300 KeV can be performed as shown in Figure 1. The Aluminum foil filter is used to measure the γ -radiation only and filtering out the particles such as α , and β , particles or at a whole exposure dosimeter. The samples also, have been analyzed by gamma spectroscopy with multi-channel analyzer (MCA); from which the radioactive elements being determined.

Measurements have been done for all samples at surface (15 samples) and relative to depths profile (0 – 100 cm) using the radiation survey meter with and without filter. For each depth there were five (5) readings for five samples which have been averaged in $\mu\text{Sv/h}$; that furtherly transferred to EXCELL software for analysis and plotting in form of bars and correlation.

Next section of method depended on the questionnaire; where the wonderland and entertainment take place. The addressed question was about the frequency of trip to enjoy entertainment at wonderland. From the questionnaire analysis; 90% of the targeted sample they got trip to wonderland four times per month and the trip last for 4-5 hours i.e. 36 times per year and 192 hours per year. This information has been considered in calculating the radiation exposure dose received by the entertained population.



Figure 1. The Aluminum filter, holder with adjustable screwed arm, radioactive sources and radiation survey detector (RedEye B20-version – 2,19V E.2.05 / 2012-09-07)



Photograph 1. Shows the satellite Google map for Blue Nile shore at Tooti city in Khartoum Sudan; the orange color showing the surveyed area

3. Results

The following representing the results related to selective area (10 Km²) of wonderland at Blue Nile shore in Tooti island-Khartoum - Sudan. The data presented the exposure dose from environmental survey at surface and

different depths (0 – 100 cm) which have been correlated and averaged with the maximum permissible dose stated by international authority. The exposure from radioactivity at Blue Nile shore in Khartoum at Tooti city boundary has been measured in $\mu\text{Sv/h}$ and estimated relative to maximum permissible dose for the public per year.

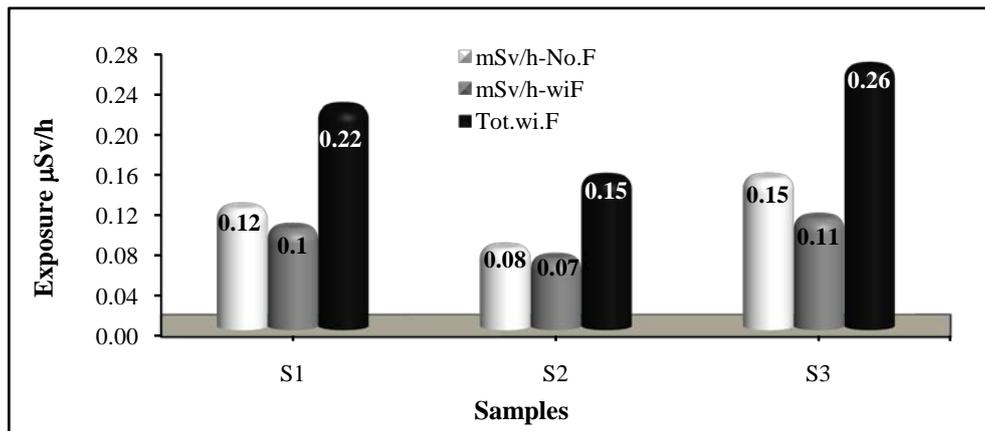


Figure 2. Shows the average exposure dose in $\mu\text{Sv/h}$ with and without filtration at surface for three main samples (S₁, S₂, and S₃) and each of 'S' sample consists of 30 rocky and sand samples

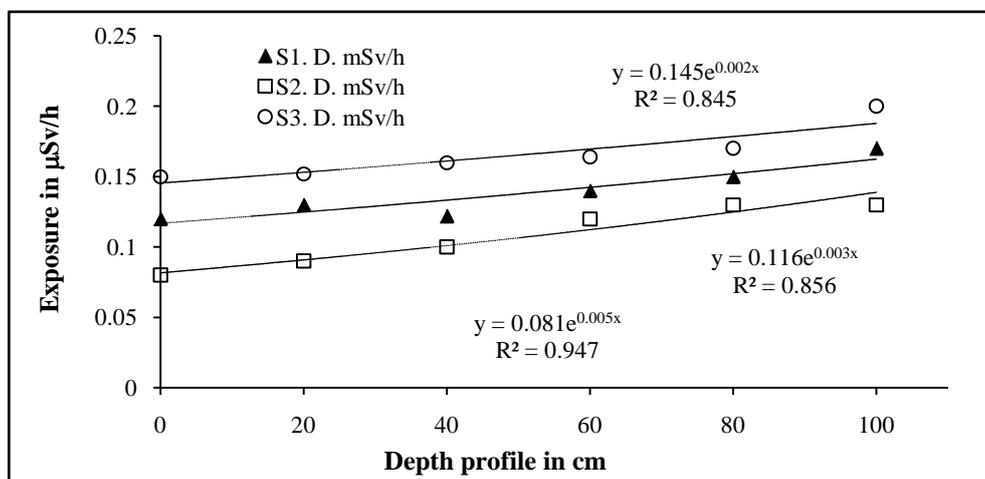


Figure 3. Shows the exposure dose in $\mu\text{Sv/h}$ versus depth profile (cm) for individual samples S₁, S₂ and S₃ (each S consist of 30 samples) (No filter applied i.e. exposure due to γ -radiation & particles α and β)

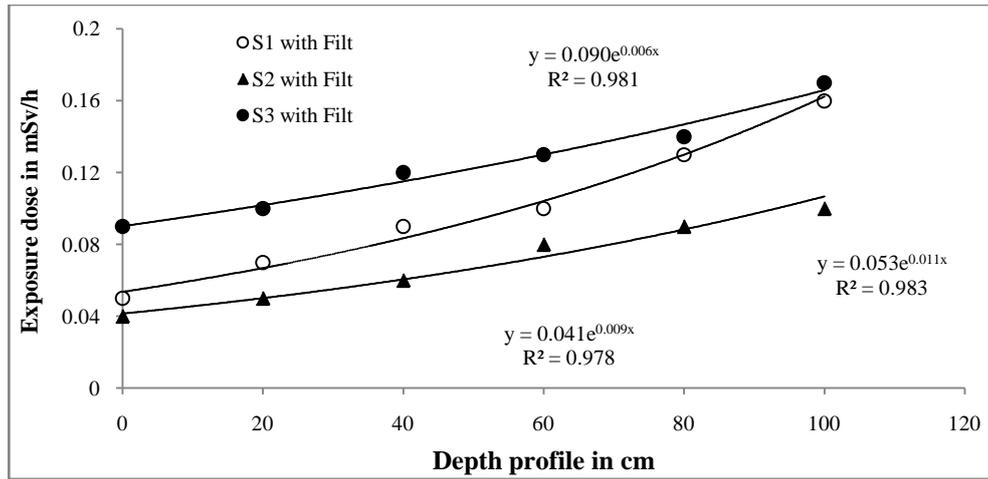


Figure 4. Shows the exposure dose in $\mu\text{Sv/h}$ versus depth profile (cm) for individual samples S_1 , S_2 and S_3 (each S consist of 30 samples) (filter applied i.e. exposure due to pure γ -radiation)

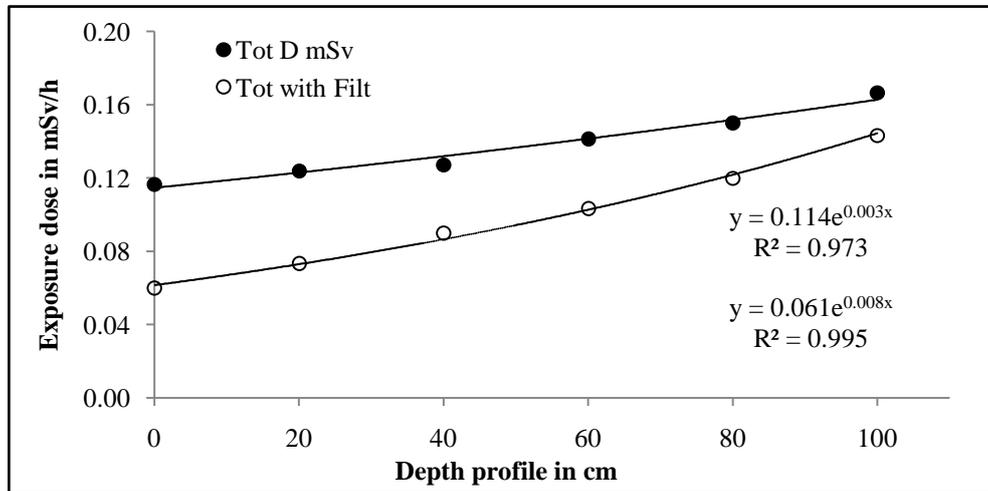


Figure 5. Shows the average exposure dose in $\mu\text{Sv/h}$ versus depth profile (cm) for all samples (S_1 , S_2 and S_3) (each S consist of 30 samples) with and without filter

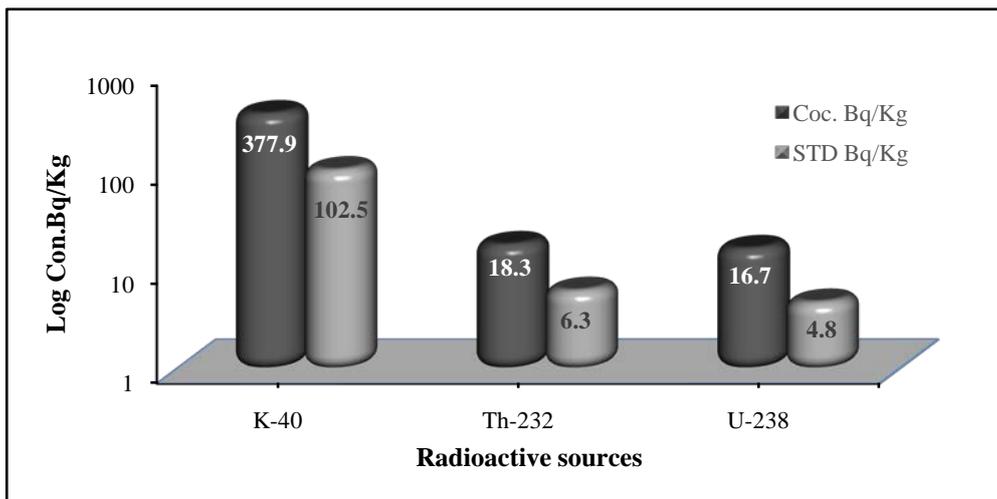


Figure 6. Shows the common radioactive sources and relative activity level at Blue Nile shore in Khartoum-Sudan

4. Discussion and Analysis

The radiation survey that cover 10 Km^2 implies 90 samples divided into three main samples (S_1 , S_2 and S_3); revealed that: the average exposure doses with filtration were 0.1, 0.07 and 0.11 $\mu\text{Sv/h}$ and without filtration were

0.12, 0.08 and 0.15 $\mu\text{Sv/h}$ at the surface respectively (Figure 2). The usage of filter to guarantee the detection and measurement of pure γ -radiation at surface without particles (α and β). The total averaged exposure dose at surface due to all types of radiation was equal to 0.21 $\mu\text{Sv/h}$. Such exposure represents 0.021% of the

maximum permissible dose (MPD) stated by authority for whole body, Hand, forearm, foot, ankle, Skin and crystalline lens [16,17]. The precipitated radioactivity at Blue Nile shore in Khartoum could be ascribed to the drifted radioactive elements from the Ethiopian mountains where the source of the Nile; one phenomenon observed was the increase of radioactivity during Nile flood that drifting heavy muddy current of water.

Since the radiation exposure leading to either stochastic effects or non-stochastic one i.e. carcinogenic factor with dependent on radiation weighting factor; it is so of great value to determine it is level relative to maximum permissible level or the probability of cancer induction based on the concept of the probability of causation (PC) (*fraction of the risk at the age of occurrence for the given cancer that is attributable to the exposure*); which is given in equation (1) [18,19,20].

$$PC = \frac{\Delta r(D, t, e, S)}{r_0(a, S) + \Delta r(D, t, S)} \quad (1)$$

where $r_0(a, s)$ is the cancer rate for age a and sex s for the particular cancer type under consideration and $\Delta r(D, t, e, s)$ is the excess cancer rate due to exposure to a dose of radiation D at age e and time since exposure $t (= a - e)$. The rate for a given cancer is the probability per unit time for a person of sex 's' and age 'a' to develop the cancer.

Accordingly, and based on the questionnaire; the number of trips for entertainment at wonderland was 4 time per month which last for 4 hours in average; therefore, the total committed exposure dose at surface per year was $(0.21 \times 4 \times 4 \times 12) = 40.3 \mu\text{Sv/year}$ at surface; which is equivalent to 4.03% of the MPD due to γ -ray, α and β particles irradiation. Indeed, such public exposure dose increases during Blue Nile flood increases; whether due to long seating of entertainment at Nile shore or could be to usage and consumption of Blue Nile water. This study finding has been agreed with the study carried out by Reda et, [21]; in which they stated that the Annual effective doses (AED) in soil around non-nuclear industries of Abu Karqas Sugar Factory on agricultural soil in Egypt was $30 \mu\text{Sv/year}$.

The exposure level also has been measured in depth profile without filter (Figure 3); which revealed that: the exposure level increases as the depth increases in an exponential form fitted to equation: $y = 0.215e^{0.114x}$ (Figure 5) as average total exposure dose (*exposure to α , β and γ -radiation*), where y refers to exposure level in $\mu\text{Sv/h}$ and x refers to depth in centimeter; hence the exposure dose at 100 cm was $0.17 \mu\text{Sv/h}$. While in case of measurement with filtration i.e. (*exposure to pure γ -radiation*) (Figure 4); the average exposure level at surface was $0.06 \mu\text{Sv/h}$ which increases following the depth profile down to 100 cm; and the relationship could be fitted to the form of the following equation: $y = 0.061e^{0.008x}$ (Figure 5) where y refers to exposure level in $\mu\text{Sv/h}$ and x refers to depth in centimeter; and the exposure dose at 100 cm was $0.14 \mu\text{Sv/h}$. The increment of exposure level at depths could be ascribed to the accumulation of precipitated sands that riches with radioactive elements carried by heavy current of Blue Nile water during flood season. Figure 6 represented the common radioactive sources as ^{40}K , ^{232}Th and ^{238}U with

their relative activity level as 377.9 ± 109.5 , 18.3 ± 6.3 and $16.7 \pm 4.8 \text{ Bq/Kg}$ respectively which are in accordance with the fact stated by IAEA, [22]. Also, the activity level for these elements have been varied by season along the shore of the Blue Nile shore which is ascribed to seasonal drifting of sediments by Nile flood.

Since there were variable radiation exposure level from point to another over the entire surveyed area; there could certain point may exceed the permissible exposure limits stated by the authority and further may leads to certain radiation diseases. And for community protection and safety; there should be a recommendation to those who enjoy entertainment in wonderland or those who camped in the desert rocky land have to possess simple radiation survey meter so as to assess their camped area or entertainment before enjoyment.

5. Conclusion

The wonderland for entertainment at Blue Nile shore at Tooti island boarder in Khartoum contains an annual radiation exposure level equal to $40.3 \mu\text{Sv/year}$ at surface; that equivalent to 4.03% of the MPD due to γ -ray, α and β particles irradiation and at depth 100 cm the exposure level was $0.17 \mu\text{Sv/h}$ for γ -ray, α and β particles and $0.14 \mu\text{Sv/h}$ due to pure γ -radiation.

Competing Interests

The author declares that: he has no competing interests.

Significance Statement

This study discovers the natural radioactivity levels at Blue Nile shore in Khartoum at Tooti boundary city and it is percentage contribution to annual exposure dose for public who entertained at wonderland of Blue Nile shore. This study is the first assessment done in this area, and can be used as a baseline data for future investigations in pollution assessment and natural radioactivity mapping and could serve as a reference data for monitoring pollution studies in future.

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