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Gamma Ray Spectrometric Analysis of Sedimental Deposits at the Shores of Lake Nakuru, Kenya

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Abstract
The main objective of this study was to assess human exposure to natural sources (U-238, Th-232 and K-40) of radiation on the shores of Lake Nakuru, Kenya. Gamma ray spectrometry of soil samples was done using NaI(Tl). The results obtained showed average activity concentrations of 36.9±9.1, 43.5±3.8 and 708±33.2 in $Bqkg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K respectively. A total dose rate of 71.97 $nGyh^{-1}$, annual effective dose rate (outdoor) of 0.088 mSv and average hazard index of 0.410 were obtained. The average dose rate for the northern sector was found to be 96.22±5.39 nGy/h while the southern sector has 26.69±0.69 nGy/h showing enhanced pollution at the northern sector. The findings from this study showed that radiation hazard from terrestrial naturally occurring radionuclides is low and human radiation exposure is within safe levels. Spatial difference in the activity concentration between the northern and southern sectors of Lake Nakuru was observed. There is need to closely monitor the northern sector and the rivers discharging water there in order to establish the source of the elevated activity.
Keywords: Radionuclides, NaI(Tl) γ-ray Spectrometer, Activity concentration, Dose rate, Lake Nakuru

1. Introduction

The concern on the environmental pollution caused by radiations has increased in the recent years. According to United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report of 2001 more data on exposures from natural, man-made and occupational sources at low levels are needed. Three main contributors to radiation doses from natural radiation to human body are cosmic rays, terrestrial gamma-radiation and potassium-40 within the body itself. Assessment of radiation doses in humans from natural sources is of special importance because their collective dose to world population is by far largest contributed by natural radiation (UNSCEAR, 1988). Exposure of human beings to ionizing radiation from natural sources is a continuous and inevitable occurrence on the earth.

According to UNSCEAR report of 2000, the average annual dose from natural sources of radiations is about 2.4 mSv and this accounts for about 79% of total human exposure worldwide**.** Human beings are affected by exposure to ionizing radiations. While some level of exposure to ionizing radiations can be permitted excessive exposure can injure and even be fatal. The knowledge of the absorbed dose rates at environmental level is necessary in determination of stochastic effects (Yoshimura *et al*., 2004). The study of the distribution of the primordial radionuclides (^{238}U, ^{232}Th and ^{40}K) and their daughters allows the understanding of the radiological implications of these elements due to the γ-ray exposure of the body (Xinwei and Zhang, 2006). Determination of the background levels in soil sediments is used to obtain absorbed dose rates in air.

The nuclides existing in bedrock are weathered off; chemically or physically and through transportation are finally deposited in lakes or seas. Other human activities like mining and processing increases the concentration both in end products or wastes to produce technologically enhanced naturally occurring radioactive material (TENORM). These radionuclides contribute to enhanced radiations exposure to humans and biota.

Artificial radiations originate mainly from fallout resulting from the nuclear weapons trial, airborne release from nuclear establishments and reactor accidents (Kabir *et al.,* 2008). Radioactive dust is released into the atmosphere, carried widely and later fall gradually to the earth surface or washed down in rain and eventually settles on land or in the sediments of water bodies. Therefore due to the natural and artificial processes radionuclides may accumulate and become concentrated in selected areas of environment (Kabir *et al.,* 2008). Environmental monitoring and assessment is important in regulatory and advisory policy making for the safety of the public due to radiation exposure.

Lake Nakuru is one of the lakes in the Great Rift Valley. It lies within Lake Nakuru National Park (LNNP) that was established in 1961. It is situated at 22^0 S, 36^0 05' E and at an altitude of 1,759 m above the sea level and to the south of dormant volcanic Menengai crater. It is a shallow saline lake that has a maximum depth of 2.8 m, an estimated area of 40 km^2 and water volume of 0.092 km^3. It is located in a closed basin without surface outlets making it possible sink for accumulation of radionuclides and other pollutants. The lake is fed by four seasonal rivers; Njoro, Nderit, Makalia, and Lamudhiak from eastern Mau Forest and a permanent Ngosur river. LNNP which acts as a buffer zone between human settlements and the lake offers one of the most exciting concentration of wildlife in Kenya consisting of many species of animals and birds. It is internationally

renowned for large concentration of lesser flamingos that use the lake as feeding ground. The scenery makes it a popular destination for local and international tourists, with approximately 200,000 visitors received annually.

Nakuru town is the fourth largest town in Kenya and is one of the fastest growing towns in terms of increased industrial development and residential constructions in its suburbs. There is increased settlement and farming activities in the Mau catchment area. All these activities contribute to environmental pollution. The recent geothermal project development in the Menengai area is a concern in terms of the environmental effects. This research was therefore done to assess the concentration levels of radionuclides in the lake and establish base levels for future reference.

In this study the activity concentration of naturally occurring radionuclides in the sediments along the shores of Lake Nakuru were measured. The absorbed dose rate and annual effective dose rates were estimated from the measured activity concentrations.

2. Materials and Methods

2.1. Sampling and preparation

Thirty samples from ten selected sites along the shore were collected. The map of sampling points is shown in figure 1. The method applied in sampling is simple random sampling to achieve statistical sensitivity of sampling (IAEA, 2004; UNEP/MAP, 2006). A trowel was used to collect samples to a depth of about 10 cm. Each sample of mass about 500 g was collected and placed in a well labeled polythene bag. Each polythene bag was then sealed to avoid cross contamination of the samples during transportation to the laboratory. The samples were dried in an oven at 110 ^{0}C for 8 hours to completely dry the samples. Each sample were then grounded into powder using mortar and pestle and sieved with a 1 mm mesh to obtain homogenized samples. They were put in hermetically sealed containers for one month to achieve secular equilibrium between Ra-226 and its short lived decay products (Ramasamy *et al., 2009*).

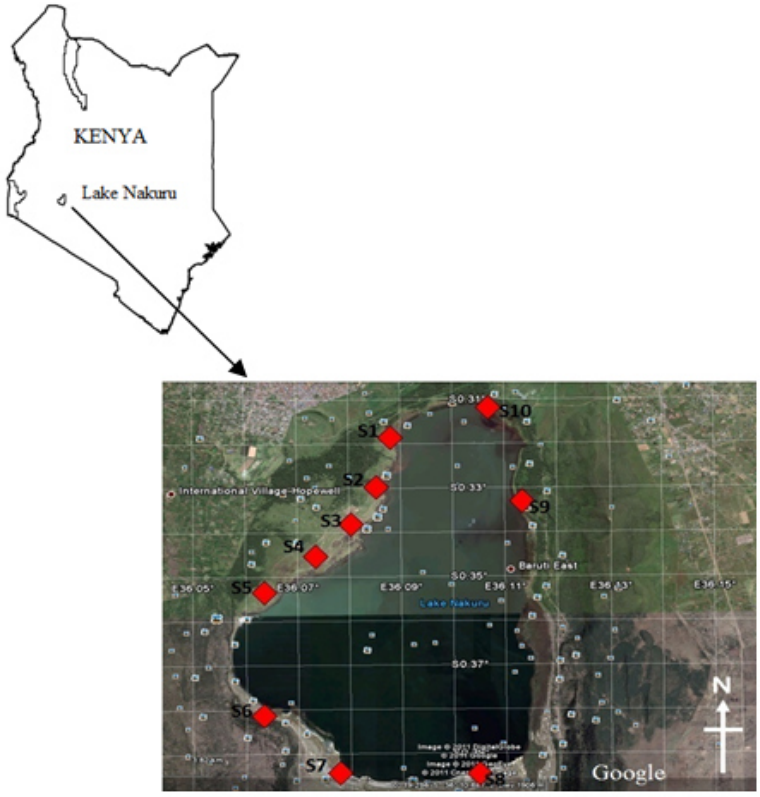

Figure 1: Map of Kenya showing Lake Nakuru and the sampling sites around the lake (Google map 22-12-2011).

2.2. Detection technique

The gamma-ray spectrometer used in this study consists of a 76 mm × 76 mm NaI(Tl) crystal detector and an Oxford PCA-P card for the spectral data acquisition and analysis. The detector has energy resolution of 7.15 % at 661 keV Cs -137 energy peak. Calibration of the NaI(Tl) detection system was done using the standard samples RGU-1, RGTh-1 and RGK-1 supplied by International Atomic Energy Agency (IAEA). The background activity was determined by running an inert sample which comprised of distilled water in a polythene bag and the duration of measurement was 30000 seconds. The same time was used for spectral data

acquisition for each sample including the standard reference sample. The background intensity was subtracted from the measurements of samples to obtain residual intensity for use in activity calculation.

2.3. Analysis of samples

The primordial radionuclides ^{238}U and ^{232}Th are alpha emitters hence their activity concentration cannot be measured directly using gamma-ray spectrometer and therefore their daughter radionuclides emitting gamma-rays was used. The activity concentration of ^{214}Bi (1765 keV) a gamma ray emitter was used to determine the activity concentration of ^{238}U. The energy peak of ^{208}Tl (2615 keV) was used to determine the activity concentration of ^{232}Th. The energy peaks were chosen because they are least interfered by other peaks. This is necessary because of low resolution of the NaI(Tl) detector. The activity concentration of ^{40}K was measured using its 1460 keV gamma ray peak. Region of interest (ROI) was carefully selected at the peak regions to obtain the net counts of the full energy peak.

2.4. Radiological calculations

The activity, A_s of sample was calculated using equation 1 (Mustapha, 1999).

$$A_S = \frac{A_r \times M_r \times I_s}{M_s \times I_r} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where A, M and I are activity, mass and intensity respectively and subscripts r and s stand for reference sample and sample respectively.

The external gamma dose rate ($nGyh^{-1}$) in air at 1 m above ground level was calculated using (UNSCEAR, 2002)

$$D = 0.462A_U + 0.604A_{Th} + 0.0417A_K \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where A_U, A_{Th} and A_K are the activity concentration in $Bqkg^{-1}$ of uranium, thorium and potassium respectively.

The external hazard index H_{ex} was obtained using the formula (Hafezi *et al., 2005*)

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where A_U, A_{Th} and A_K are the activity concentration in $Bqkg^{-1}$ of uranium, thorium and potassium respectively.

The annual effective dose rates, AEDR were estimated using equation 4 (Hafezi *et al.,* 2005).

$$AEDR\,(nSvy^{-1}) = D \times 8760 \times 0.2 \times 0.7 \times 10^{-6} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where D is dose rate in $nGyh^{-1}$, the value 8760 are the hours in a year, the conversion coefficient from the absorbed dose in the air to the effective dose is 0.7 $SvGy^{-1}$ and outdoor occupancy factor is 0.2 as proposed by UNSCEAR (2000).

The external hazard index, H_{ex} or Radium equivalent activity, Ra_{eq} was calculated using relations in 5 and 6 respectively (Ramasamy, 2009).

$$H_{ex} = \left(\frac{C_U}{370}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_K}{4810}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$Ra_{eq}\,(Bqkg^{-1}) = C_{Ra} + \frac{10}{7}C_{Th} + \frac{10}{130}C_K \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (in $Bqkg^{-1}$) of ^{226}Ra, ^{232}Th and ^{40}K respectively.

Radium equivalent activity is the weighted sum of the activities of ^{226}Ra, ^{232}Th and ^{40}K based on the assumption that 10 $Bqkg^{-1}$ of ^{226}Ra, 7 $Bqkg^{-1}$ of ^{232}Th and 130 $Bqkg^{-1}$ ^{40}K deliver equal gamma dose rates (Tufail *et al.,* 2007).

3. Results and Discussions

The activity concentrations of the three radionuclides K-40, U-238 and Th-232 from every sampling site were calculated (table 1) in which the average for K-40, U-238 and Th-232 are 708.3±33.2 $Bqkg^{-1}$, 36.9±9.1 $Bqkg^{-1}$ and 43.5±3.8 $Bqkg^{-1}$ respectively. Fig 2 shows shows the bar graph for the activity values for the three radionuclides.

Table 1. Activity concentration of the three primordial radionuclides in all sampling sites.

	Activity ($Bqkg^{-1}$)		
	K-40	**U-238**	**Th-232**
SITE	**MEAN**	**MEAN**	**MEAN**
S1	830.1±19.5	92.5±2.5	48.7± 3.7
S2	738.7±28.8	81.4±8.3	40.1± 2.2
S3	689.6±35.7	38.5±6.7	38.0±1.8
S4	702.5±16.0	17.0±1.9	36.4±4.4
S5	534.3±36.1	11.2±1.8	35.5±2.1
S6	586.8±22.6	12.5±2.1	40.9±0.9
S7	605.4±15.1	45.4±1.9	35.4±1.6
S8	641.9±12.1	34.1±1.4	43.8±0.9
S9	684.3±4.10	16.0±0.7	42.0±1.1
S10	837.4±26.0	20.0±2.6	74.6±2.1
AVG	**708.3±33.2**	**36.9±9.1**	**43.5±3.8**

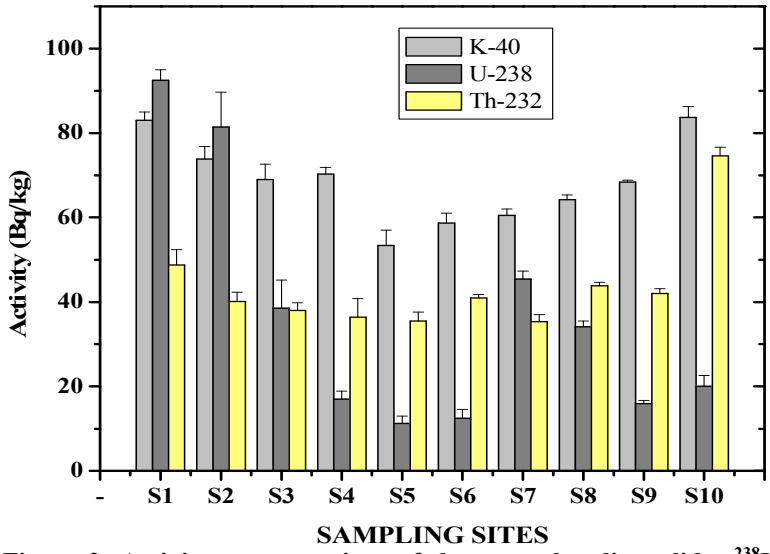

Figure 2: Activity concentrations of the natural radionuclides ^{238}U, ^{232}Th and ^{40}K in sediments samples measured in this work. The values of K-40 are scaled down by a factor 10.

Dose rate values obtained (table 2) showed a range of 48.86-106.8 with sampling sites S1, S2 and S10 on the northern part of Lake Nakuru having average value of 96.22±5.39 nGy/h. The average dose rate for all the sampling sites is 71.97 $nGyh^{-1}$.

The AEDR, H_{ex} and Ra_{eq} values were all calculated for all the sampling sites (table 3) in which mean of 0.088±0.007 $mSvy^{-1}$ for AEDR was obtained. Hazard index H_{ez} of 0.410±0.034 and radium equivalent value of 151.9±12.5 $Bqkg^{-1}$ averages was found.

Table 2: Average dose rates of the natural radionuclides and the total dose rates measured in this work for all sampling sites. The total dose rates were estimated using equation 2.

	DOSE RATES ($nGyh^{-1}$)			
SITE	**K-40**	**U-238**	**Th-232**	**TOTAL**
S1	34.61±0.81 (33.64-36.22)	42.75±1.15 (40.47-44.12)	29.43±2.24 (25.91-33.58)	106.8
S2	30.80±1.20 (28.69-32.85)	37.62±3.83 (30.12-42.74)	24.24±1.34 (21.93-26.58)	92.67
S3	28.76±1.49 (26.17-31.33)	17.80±1.78 (15.34-21.25)	22.97±1.09 (20.84-24.46)	69.53
S4	29.29±0.67 (27.96-29.97)	7.84±0.86 (6.98-9.56)	22.03±2.64 (18.30-27.12)	59.16
S5	22.28±1.50 (20.21-25.21)	5.16±0.82 (4.34-6.79)	21.42±1.30 (18.84-22.95)	48.86
S6	24.47±0.94 (23.35-26.34)	5.78±0.98 (4.53-7.72)	24.72±0.57 (23.98-25.85)	54.97
S7	25.82±0.22 (25.46-26.21)	20.96±0.89 (19.64-22.59)	21.4±0.10 (19.63-23.07)	68.18
S8	26.77±0.50 (25.88-27.63)	15.77±0.66 (14.74-17.00)	26.46±0.54 (25.37-27.00)	68.99
S9	28.54±0.17 (28.22-28.81)	7.39±0.33 (6.75-7.81)	25.39±0.68 (24.22-26.58)	61.32
S10	34.92±1.08 (33.79-37.08)	9.22±1.20 (7.72-11.60)	45.04±1.29 (42.52-46.75)	89.18
	28.63±1.28 (22.28-34.92)	17.03±4.23 (5.16-42.75)	26.31±2.23 (21.40-45.05)	71.97±5.84 (48.86-106.80)

Table 3. Annual effective dose rate, hazard index and radium equivalent for all sampling sites.

SITE	**AEDR (mSv/y)**	**H_{ex}**	**Ra_{eq} (Bq/kg)**
S1	0.131±0.001	0.611±0.005	226.0±1.9
S2	0.114±0.006	0.529±0.030	195.6±11.0
S3	0.085±0.002	0.394±0.008	145.9±3.1
S4	0.073±0.005	0.332±0.023	123.1±8.6
S5	0.060±0.003	0.278±0.016	102.9±5.9
S6	0.067±0.002	0.314±0.010	116.1±3.8
S7	0.084±0.002	0.385±0.011	143.6±4.2
S8	0.085±0.009	0.395±0.004	146.0±1.6
S9	0.075±0.001	0.348±0.004	128.6±1.5
S10	0.109±0.003	0.516±0.014	190.9±5.0
AVG	**0.088±0.007**	**0.410±0.034**	**151.9±12.5**

Figures 3 and 4 shows dose rates and annual effective dose rates respectively in which the sampling points S1, S2 and S10 which are on the northern part of the lake have their values above the average. Rivers Njoro and Ngosur discharge their water onto the northern part of Lake Nakuru.

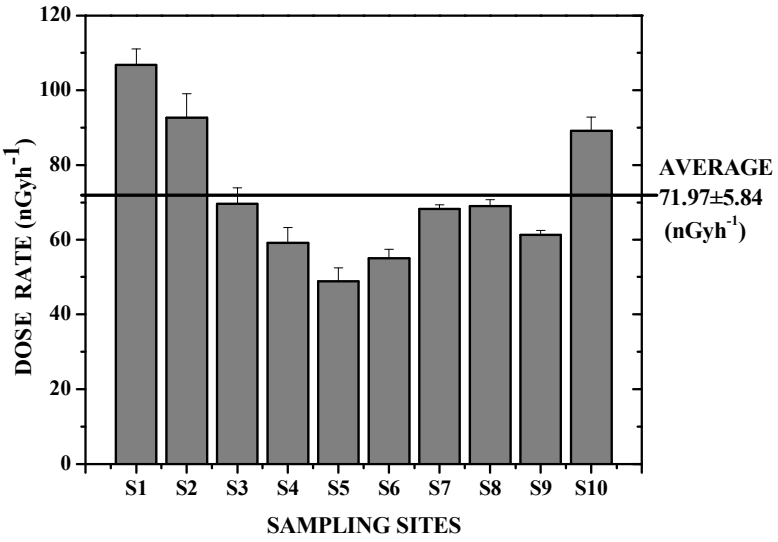

Figure 3. Bar graphs showing dose rate in all sampling sites.

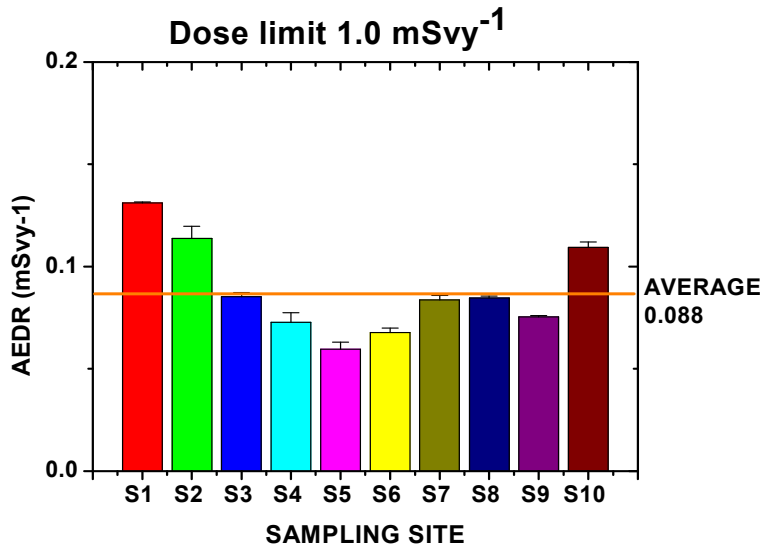

Figure 4. Bar graphs showing AEDR in all sampling sites.

The measured activity concentrations for K-40 are generally high than those of U-238 and Th-232 in all the sampling sites. Average activity concentration is higher than world average for K-40 and within world average for U-238 and Th-232. There is generally higher activity concentration of K-40 at the northern region of the lake (table 1). U-238 activity is higher at sites 1 and 2 which are close to Njoro river inlet. These can be attributed to rivers from intensive agricultural catchment with large scale farms. There are generally higher dose rates at the northern sector and less towards south as shown in fig. 3. There is greater contribution of dose rates by Th-232 and K-40 than U-238 (table 2).

4. Conclusions and recommendations

The values of external hazard index from all sampling sites does not exceed safety limit of 1 (table 3) and this shows that the radiation hazard from terrestrial naturally occurring radionuclides around Lake Nakuru is low and human radiation exposure is within safe levels. Results from this study are useful as baseline data for future monitoring of the radiation pollution of Lake Nakuru. More studies in the surrounding catchment area could be done to establish the source of pollutants. Close monitoring of the northern sector and the rivers that discharges their water there needs to to be done in order to establish the source of the enhanced activity.

References

Hafezi, S., Amidi, J. and Attarilar, A. (2005). Concentration of natural radionuclides in soil and essential exposure to the public in Tehran, *Iran. J. Radiat. Res.*: 3 (2): 85-88.

Hafezi, S., Amidi, J. and Attarilar, A. (2005). Concentration of natural radionuclides in soil and essential exposure to the public in Tehran, *Iran. J. Radiat. Res.*: 3 (2): 85-88.

IAEA (2004). International Atomic Energy Agency, Soil sampling for environmental contaminants, IAEA-TECDOC-1415 IAEA: Vienna, Austria.

Kabir, K.A., Islam, S.M.A., and Rahman, M. M. (2008). Samples in the District of Jessore, Bangladesh and Evaluation of Radiation Hazard, *Jahan. Uni. J. of Sc.* 32 (1): 81-92.

Mustapha A.O., Patel J. P, Rathore IVS (1999). Assessment of human exposures to natural sources of radiation in Kenya, *Rad. Prot. Dos.*: 82(4): 285-292.

Ramasamy, V., Senthil S., Meenakshisundaram, V. and Gajendran, V. (2009). Measurement of natural radioactivity in beach sediments from north east coast of Tamilnadu, India, *Res. J. Appl. Sc. Engin. Tech.* 1 (2): 54-58.

Tufail, M., Akhtar, N., Javied, S. and Hamid, T. (2007). Natural radioactivity hazards of building bricks fabricated from saline soil of two districts of Pakistan, *J. Radiol. Prot*. 27: 481-492.

UNEP/MAP (2006). United Nation Environmental programme/Mediterranean Action Plan, Methods for sediment sampling and analysis, Athens, Greece.

UNSCEAR (1988).United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionization radiation, Report to the General Assembly, with Scientific Annexes B: Exposures from Natural Radiation Sources New York.

UNSCEAR (2000). United Nations Scientific of Committee on the Effect of atomic Radiation, Effects and risks of ionizing radiation, United Nations, New York.

UNSCEAR (2002). United Nations Scientific of Committee on the Effect of atomic Radiation, Effects of Atomic Radiation (2001 Report), United Nations, New York.

Xinwei, L. and Zhang, X. (2006). Measurements of natural radioactivity in sand collected from the Baoji Weihe sands park, China, *Environ. Geol*. 50: 977-982.

Yoshimura, E. M., Otsubo, S. M. and Olivera, R. E. R. (2004). Gamma ray contribution to the ambient dose rate in the city Sảo Paulo, Brazil, *Rad. Meas.* 38: 51-57.

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