Study of natural radioactivity in Lake Miri in South West of Sudan

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Abstract

The focus of this study is to investigate the suitability of Lake Miri, a lake with high natural radioactivity in the southwest of Sudan, as a water source for nearby villages. Soil, water, foodstuffs and vegetable samples were collected and analyzed. The results indicate that the mean natural radioactivity level in the study area is 450 nGy/h, which is ten times greater than other places in Sudan with normal background (40 nGy/h) natural radioactivity, and these findings demonstrate that the average annual exposure of the population is 38.4 mSv.

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Keywords: Environmental; Natural radioactivity; Annual exposure; External exposure

1. Introduction

Environmental radiation monitoring is highly important for protecting human health, and many countries have conducted studies to ensure that areas in which people live are habitable. The area we studied is mountainous, and contains a high level of natural radionuclides, including \textsuperscript{238}U, \textsuperscript{232}Th, \textsuperscript{137}Cs and \textsuperscript{40}K. More than half of the natural radioactivity in the world is from the natural uranium decay chain, and the radiation level from natural terrestrial sources of radioactivity differs from one place to another. In some places, such as Kerala, in India [1,2], and Tapire, on the Brazilian coast [3], the natural background radiation level is one or two orders of magnitude greater than in other places [4–6].

This work is intended to study an inhabited place in the Nubian Mountains known as Lake Miri, which has a high natural radioactivity level. Lake Miri is located in the middle of southern Sudan and is 17 km from the town of Kadugli (Fig. 1). It is surrounded by mountains where the water level rises in the autumn. Some crops that feed humans and animals are grown in the area, especially in the dry season. Lake Miri is an artificial lake with dimensions of 5 km × 20 km that formed after a dam was built on a uranium–thorium mineralization zone. The lake is of vital importance to the surrounding inhabitants. Therefore, it is imperative to investigate the local natural radiation level, its effect on the inhabitants, and possible remedies [7,8].
2. Sample collection and preparation

2.1. Soil samples

Soil samples were collected from different sections of the surrounding area such that they should be representative of the whole area. A half-kilogram of soil was collected from each location, both from the surface and at a depth of a few centimeters. The first 10–15 cm of soil layers were discarded because they will hinder the measurement of the true value. Near the lake bank samples were also collected at different distances from the water to determine if there is any correlation between the radioactivity levels and the lake water.

The samples were sun-dried, finely powdered and then sealed in Marinelli beakers for about three weeks to attain secular equilibrium for the short-lived uranium and thorium daughters.

2.2. Water samples

Water samples were collected in bottles and acidified with 0.1 m hydrochloric acid to reduce the adsorption of radionuclides by the walls of the container. Water was collected from the water edge of the lakeside and from the top of the dam.

Water samples were also collected from wells in the area. The samples were measured one month later to ensure the decay of radon gas.

2.3. Vegetable and food samples

Vegetables, fruits, sorghum, and egg samples were also collected. Some samples were sun-dried, and the others were air-dried. The dry matter was powdered and sealed for measurement.

3. Experimental methods

The activity concentration of each sample was measured directly by gamma spectrometry without chemical separation.

The spectrometer consists of liquid–nitrogen-cooled coaxial germanium with an active volume of 82 cc, a diameter of 46 mm, and a length of 51 mm with a resolution of 1.8 keV for the \(^{60}\)Co 1332.5 keV gamma line. A microcomputer was adapted with an ADC (Analog-Digital Converter) card to function as an MCA (Multichannel Analyzer) and as a data processor using GDR (Gamma ray Data Reduction, Quantum technology, USA) and WORKSHEET (Central Institute of Physics, Hungarian Academy of Science) Software [9,10].

Energy calibration of the system was performed using an Amersham Marinelli standard source containing the following radionuclides: \(^{109}\)Cd, \(^{57}\)Co, \(^{139}\)Ce, \(^{203}\)Hg, \(^{113}\)Sn, \(^{85}\)S, \(^{137}\)Cs, \(^{60}\)Co, and \(^{88}\)Y. The measurement time for different samples ranged from 7200 to 100,000 s depending on the activity and the weight of the sample. The accuracy of each measurement was in the range
of 5–30%, depending on the energy of the characteristic gamma line of each radionuclide, the activity of the sample, and the collection time. External exposure was measured by a BGS (Broadband amma ray Scintillometer) – ISL (Igneous, Sedimentary and Metamorphic Scintillometer) calibrated with a $^{60}$Co standard source. Readings were taken with the scintillometer at each site booth at the ground level and at 1 m above the ground (see last column of Table 1).

4. Results and discussion

4.1. External exposure

The estimation of the external exposure was based on two methods:

1. On the activity concentration of the samples and the dose/hour per Bq/kg at one meter height above the ground.

2. The count rate measured by the BGS-ISL scintillometer.

The following table is quoted from the UNSCEAR after conversion to S.I. units.

To determine the exposure at a site, the activity concentration of each of the three radionuclides at the site is multiplied by the appropriate factor from the table, and the sum of these products gives the exposure at 1 m height above the ground at that site. For the second method the scintillometer was calibrated by a $^{60}$Co standard source.

The exposure in the Lake Miri area was found to be in the range of 180–720 nGy/h, with an average exposure of 450 nGy/h.

$$D_{\text{Air}} = (0.462C_U + 0.621C_{\text{Th}} + 0.0917C_K) \text{nGy/h}$$

$C_U$, $C_{\text{Th}}$, $C_K$ is the concentration of U, Th and K, respectively.

External exposure rates for places with normal background radiation levels are quoted in the range of 36–90 nGy/h with an average of 45 nGy/h [11,12]. External exposure rates for places with high natural radioactivity 450 nGy/h [13–15].

The external exposure rates in the Lake Miri area are on average ten times greater than they are in places with normal natural radioactivity (40 nGy/h) [16,17,18].

Table 1

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>The exposure at 1 m in nGy/h per Bq/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-40</td>
<td>0.043</td>
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<tr>
<td>U-238</td>
<td>0.444</td>
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<tr>
<td>Th-232</td>
<td>0.656</td>
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Table 2

<table>
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<th>Code</th>
<th>Ra-226</th>
<th>Pb-214</th>
<th>Pb-212</th>
<th>Ac-228</th>
<th>K-40</th>
<th>Counts/s (at 1 m)</th>
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</thead>
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<tr>
<td>Mr1</td>
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<td>0.19</td>
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<td>0.12</td>
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<tr>
<td>Mr3</td>
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<td>0.03</td>
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<td>0.14</td>
<td>0.16</td>
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<td>400/320</td>
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<tr>
<td>Mr5</td>
<td>0.23</td>
<td>0.18</td>
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<td>0.30</td>
<td>1.10</td>
<td>500/460</td>
</tr>
<tr>
<td>Mr6</td>
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<td>0.08</td>
<td>0.13</td>
<td>0.64</td>
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<tr>
<td>Mr7</td>
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<td>0.22</td>
<td>0.26</td>
<td>0.66</td>
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<tr>
<td>Mr8</td>
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<td>0.37</td>
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<tr>
<td>Mr9</td>
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<td>0.19</td>
<td>0.21</td>
<td>1.00</td>
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<td>Mr10</td>
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<td>0.16</td>
<td>0.61</td>
<td>210/200</td>
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Table 3

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<tr>
<th>Code</th>
<th>Ra-226</th>
<th>Pb-214</th>
<th>Pb-212</th>
<th>Ac-228</th>
<th>K-40</th>
<th>Counts/s (at 1 m)</th>
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</thead>
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<td>0.019</td>
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<tr>
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<td>0.002</td>
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</tr>
<tr>
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<td>0.030</td>
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<td>0.05</td>
<td>0.25</td>
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4.2. Soil samples results

The measurement results of soil samples collected from the Lake Miri area are shown in Table 2. The measurement results of soil samples from other cities in Sudan are presented in Table 3 for comparison.

5. Conclusions

For vegetable and foodstuff samples, no correlation was found between natural radioactivity and uptake of foodstuff. The results of this study agree with the study in Ref. [19] as the study area in that reference has high natural radioactivity and with the study in Ref. [20] as Jabal Alnar has high natural radioactivity. In Lake Miri the average concentration of Ra-226 is high (0.158 kBq/kg) compared with other cities in Sudan. This high value is correlated with the high natural radioactivity due to existence of U-238, as reported in UNSCEAR 2000. The average concentrations of Pb-214 and Pb-212 of 0.150 kBq/kg and 0.160 kBq/kg, respectively, are also high compared to those of other cities in Sudan, also due to the decay of U-238.

The maximum count/s rate recorded – in the Lake Miri area at 1 m above the ground is 500/460 in sample region 5; for other cities the maximum count/s rate is 50/45 in the Blue Nile area.

6. Discussion and recommendation

The first proposal to treat the water is chemical treatment, which is costly; the second proposal is to create an artificial lake to transfer water from Lake Miri before it becomes contaminated by the high radioactivity in the soil. Accordingly, we recommended the evacuation of people from the Lake Miri area, and we recommend not to use local water or foodstuffs.

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References