Outdoor external doses in the high background radiation areas of Lambwe east location in southwestern Kenya


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Abstract. Soils and rocks from a number of areas underlied by carbonatite rocks in Kenya have been associated with high radioactivity. A study, comprising background radiation measurements, and radioecological and health surveys in some of these areas was initiated recently. In this paper we provide a preliminary result of the background radiation measurements carried out in three areas: Ruri, Kuge and Sokolo in the Lambwe east location of Suba district, southwestern Kenya. These areas are roughly between latitudes 0°30'S and 1°00'S, bounded on the east by longitude 34°30'E and on the west by the shores of Lake Victoria and the Kavirondo gulf. Altitudes range from about 1000 m on the shores of Lake Victoria to above 1800 m on top of the Ruri hills. Absorbed dose rates in outdoor air in the areas were measured using survey meters. The values range from 614 to 6000 nGyh⁻¹ with an overall mean of 2106 nGyh⁻¹. Gamma-ray spectrometric analyses of samples of soils and rocks were also carried out using high-purity germanium (HPGe) detector. The mean activity concentrations in the samples are 1215 Bqkg⁻¹; 123 Bqkg⁻¹ and 511 Bqkg⁻¹ for ²³²Th, ²²⁶Ra, and ⁴⁰K, respectively. The results show that external doses in air in these areas are many times higher than in the normal background radiation areas. The main contribution is from the naturally occurring radionuclides in the soils and rocks, particularly those associated with carbonatites, but it was also found that the contribution from Cosmic rays is enhanced at these altitudes.

KEYWORDS: High background radiation areas; external doses; naturally occurring radionuclides.

1. Introduction

The largest contributions to human exposures to ionizing radiation are from natural sources[1]. These exposures are normally of no radiological concern except when they are enhanced by human activities, such as mining or in areas of high geomagnetic latitudes and high altitudes, where exposures to cosmic radiation are enhanced, and in areas where the local geology contain high concentrations of the primordial radioactive elements – the so called high background radiation areas (HBRA). There are many HBRA in the world[2]. Studies carried out in some of them showed that inhabitants receive elevated radiation doses. In Ramsar for example, some inhabitants receive up to 260 mSv/y due to ²²⁶Ra in hot springs water[3]. Occurrence of these HBRA has also provided rare opportunity for scientists to investigate the responses to low doses of radiation in human populations, although many of the findings are still largely inconclusive[4]. One of the lessons learnt is that future studies should consider sex, and age, as well as differences in the socio-economic and cultural backgrounds of the populations[4,5]. High natural background radiation have been reported in some areas in Kenya. These include Mrima hill[6,7] near the port city of Mombasa in the south, Ruri, Kuge, Sokolo and Rangwa on the shores of Lake Victoria in south west. The high radioactivity in all these areas is associated with carbonatite rocks containing high concentrations of thorium and uranium[8-11]. A project to conduct dosimetric, radioecological and health surveys in these areas was initiated recently. In this paper we provide a preliminary result of the background radiation measurements carried out in Ruri, Kuge and Sokolo, and compare the external dose rates with those reported from the other HBRA in the world.

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2. Materials and Methods

2.1 Study Area

2.1.1 Geographic location and Geology

Ruri hills, Kuge and Sokolo are in Lambwe east location of Suba district (formally called Gwasi region). The study area is bounded by latitudes 0°30'S and 1°00'S, longitude 34°30'E, and the shores of Lake Victoria and the Kavirondo gulf[10]. Fig.1 shows Ruri near Lake Victoria, as well as the other major towns and landmarks in Kenya. Altitudes in this areas range from about 1000 m on the shores of the Lake to about 1600 m on top of the hills.

**Figure 1:** Geographical map showing study area and the major towns and landmarks of Kenya[12]

There are human settlements around the foot of the hills and up the hill case of South Ruri settlements are found up to study area in Kenya. The major economic activity is fishing and farming. The geological map of the area is shown in fig. 2 below. The oldest rock in the Ruri hills is the
Precambrian metabasalt of the Nyanzian type[10]. There are two types of intrusives in the Precambrian; the ijolites and nepheline syenites of tertiary age and syenodiorites of the Nyanzian age. Carbonatites of lower tertiary age form perfect ring-shaped intrusions in the Ruri hills. They are dominantly composed of calcite with iron rich segregations. These range from ferriferous carbonatites to almost pure iron-ore (magnetite-Fe₃O₄) or the “iron stone”. They contain monazite and pyrochlore minerals, with the monazite containing principally thorium, uranium and their radioactive daughters along with several rare earth elements.

**Figure 2:** Geology of the Ruri and the other study areas

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**2.2 In-situ Measurement of Absorbed Dose in Air**

The hills, particularly the habited sections, were traversed on foot. Absorbed dose rates in air were measured at suitable intervals with a Berthold Y-Analyzer LB-125 survey meter held at approximately 1 m above the ground. Emphasis was placed on the areas with high potential human occupancy, e.g., around dwellings, farmland, water sources, schools, etc. Samples of soil and rocks were taken, particularly when high dose-rates were encountered.
2.3 Evaluation of Absorbed Dose Rate from Soil/Rock Radioactivity

2.3.1 Gamma-ray Spectrometric Analysis of Soil/Rock Samples

Activity concentrations of the naturally occurring radionuclides in pulverized soil and rock samples was performed with a hyper pure germanium (HPGe) gamma-ray detector of 144 ml active volume and 76 mm outside diameter. The detector has an efficiency of 30% relative to 76mm x 76mm NaI(Tl) detector, and its resolution of 1.8keV (FWHM) at 1.33 MeV peak of 60Co. Detailed description of the gamma-ray spectrometric analysis of geological samples with this detector has been given in earlier publications[13].

2.3.2 Dose Rate Calculation from Activity Concentration in Soil

Absorbed dose rate, \( D(n\text{Gy} h^{-1}) \) in air at about 1 m above ground was calculated using the equation:

\[
D = 0.621C_{\text{Th}} + 0.462C_{\text{Ra}} + 0.0417C_{\text{K}}
\]

(1)

Where \( C_{\text{Th}} \), \( C_{\text{Ra}} \), and \( C_{\text{K}} \) are the activity concentrations of \(^{232}\text{Th},^{226}\text{Ra},\) and \(^{40}\text{K}\), respectively, in the soil and 0.621, 0.462, and 0.0417 nGy h\(^{-1}\) per Bq kg\(^{-1}\) are the corresponding activity-to-dose conversion factors[1].

3. Results and Discussion

3.1 Activity Concentration of Radionuclides

The results of the gamma-ray spectrometric measurements are summarized in Table 1. It show that the largest contributions to radioactivity levels in the study areas are from \(^{232}\text{Th}\).

Table 1: Activity concentrations of the primordial radionuclides in soil samples from Ruri.

<table>
<thead>
<tr>
<th>Activity Concentration (Bq/kg)</th>
<th>Range</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{40}\text{K})</td>
<td>57 – 1455</td>
<td>511 ± 19</td>
</tr>
<tr>
<td>(^{226}\text{Ra})</td>
<td>15 – 499</td>
<td>123 ± 10</td>
</tr>
<tr>
<td>(^{232}\text{Th})</td>
<td>14 – 6560</td>
<td>1215 ± 38</td>
</tr>
</tbody>
</table>

3.2 Outdoor Absorbed Dose

The measured absorbed dose rate in air vary from 71.4 nGy h\(^{-1}\) inside a boat on Lake Victoria to a maximum value of 6.0 \(\mu\text{Gy h}^{-1}\) measured near a homestead at the foot of the north Ruri hill. The value measured on lake Victoria was attributed to contributions from cosmic radiation at that level (about 1000 m above sea level). It is noted that there are many settlements above this elevation, therefore it can be conveniently stated that the average absorbed dose from the directly ionizing and photon component of cosmic ray is greater than 71.4 nGy h\(^{-1}\) in the study area. The corresponding average value at sea level for latitudes < 30\(^{\circ}\) is 30 nGy h\(^{-1}\)[1].

The overall mean of the calculated absorbed dose rates due to terrestrial gamma rays is 2.1 \(\mu\text{Gy h}^{-1}\), which is more than 35 times the world population-weighted average of 60 nGy h\(^{-1}\)[1]. This clearly sets the study area apart from the other normal natural background radiation areas. In table 2 the values obtained in this study are presented along those reported from some of the world HBRA for comparison.
Table 1: Effective doses in some of the reported HBRA[3].

<table>
<thead>
<tr>
<th>Area</th>
<th>Effective dose (mGy y^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Ramsar, Iran</td>
<td>10.2</td>
</tr>
<tr>
<td>Guarapari, Brazil</td>
<td>5.5</td>
</tr>
<tr>
<td>Kerala, India</td>
<td>3.8</td>
</tr>
<tr>
<td>Yangjiang, China</td>
<td>3.5</td>
</tr>
<tr>
<td>Lambwe east, Kenya^{(a)}</td>
<td>7.4</td>
</tr>
</tbody>
</table>

^{(a)} Present study based on assumption of 0.4 outdoor occupancy factor and 0.7 Sv/Gy conversion factor[1]

4. Conclusion

Results of background radiation measurements in Ruri, Kuge, Sokolo, and Lwala in the Lambwe east location of Suba district, southwestern Kenya have been presented. It has been shown that natural background radiation levels in these areas are comparably enhanced as in some of the well known HBRA in the world. Further work, including indoor exposure assessments, personal dosimetry, as well as epidemiological studies, are planned to investigate the radiological implication of the enhanced levels of radiation on the local populations.

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