Natural Radioactivity and Associated Radiation Characteristics of the New High Background Radiation Area of Lambwe East, Southwestern Kenya

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Abstract

Rocks and soils from a number of areas underlied by carbonatite rocks in Kenya have been associated with high levels of natural background radioactivity. People in such high background radiation areas (HBRA), are exposed to abnormally high annual absorbed dose (that have health implications) than the global normal 1 mSvyr^{-1}. In this paper, results of field background radiation measurements, activity concentrations of primordial radionuclides in (mainly carbonatite rock and soil) matrices, and estimated annual external effective dose rates are presented for South and North Ruri hills in Lambwe East location of Suba District, which lies roughly between latitudes 0ę30ôS and 1ę00ôS, bounded on the east by longitude 34ę30ôE and on the west by the shores of Lake Victoria and Winnam Gulf. Altitudes in the region range from about 1000 m on the shores of Lake Victoria to above 1800 m on top of the Ruri hills. The main geological features are carbonatite formations. Twenty one samples were analyzed using high-purity germanium (HPGe) gamma-ray spectrometer. The activity concentrations ranged 14.18 - 6559.99 Bqkg^{-1} (average: 1396.85 Bqkg^{-1}) for Th-232; 2.73 - 499.24 Bqkg^{-1} (average: 178.69 Bqkg^{-1}) for U-238; and 56.67 - 1454.73 Bqkg^{-1} (average: 508.67 Bqkg^{-1}) for K-40. The variability in Th distribution could be due to another contributing factor apart from carbonatite: Homa hills geothermal field fluids might be responsible for delivery of Th to surface rocks; some hot spots have travertine deposits. Measured absorbed dose rates in air outdoors range 700 - 6000.00 nGyh^{-1} (mean: 2325.84 nGy h^{-1}); assuming 0.4 occupancy factor, these values correspond to individual annual effective dose rates of 1.717 - 14.717 mSvyr^{-1} (mean: 5.705 mSv yr^{-1}). Measured absorbed dose rates are higher than calculated values since they include the contribution of cosmic rays. The natural radioactivity is fractionated with higher levels in the soils than carbonatite rocks probably because the soils are mainly deposited, weathered carbonatites. The annual external effective dose rates are twelve (12) times higher than the global average of 0.46 mSvyr^{-1}, hence the region may for the first time, be characterized as HBRA. In view of these findings, it is justifiable to recommend further radiological research in this area especially measurement of indoor radon concentration, radon in water from the boreholes. There are seasonal rivers in this region and residents depend majorly on borehole and lake waters. Research on the health implications is also recommended because, if a few hundred mSv of radiation exposure is detrimental to health, it should be evident in the inhabitants of the region given a large enough study (cohort) population.

KEYWORDS: High background radiation areas(HBRA); external doses; naturally occurring radionuclides

1. Introduction

The largest contributions to human exposures to ionizing radiation are from natural sources[1,5,12]. 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 ï the so called high background radiation areas (HBRA). There are many HBRA in the world[4,10]. 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 ^{226}Ra in hot springs water[14,13]. 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 these findings are still largely inconclusive[11,15]. 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[15]. High natural background radiation have been reported in some areas in Kenya. These include Mrima hill [2,8] near the port city of Mombasa in the south, Ruri, Kuge, Soklo and Rangwa on the shores of Lake Victoria in south western

Kenya. The high radioactivity in all these areas is associated with carbonatite rocks containing high concentrations of thorium and uranium[3,6,9]. A project to conduct dosimetric, radioecological and health surveys in these areas was initiated recently. In this paper we provide results of the background radiation measurements carried out in Ruri, Kuge and Soklo point, and compared to the external dose rates with those reported from other HBRA in the world.

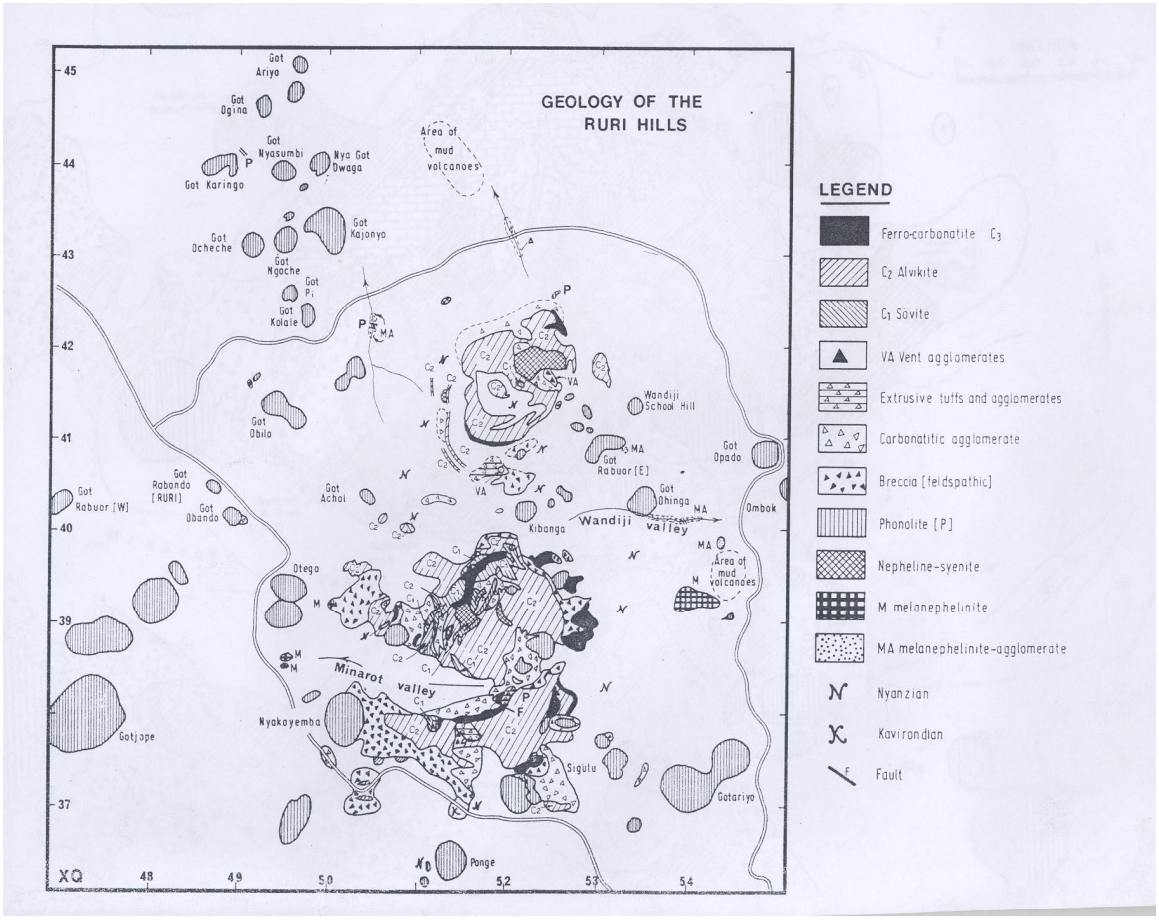
2. Materials and Methods

2.1 Study area

2.1.1 Geographic location and Geology

Ruri hills, Kuge and Soklo Point are in Lambwe east location of Mbita district (formally part of Gwasi region). The study area is bounded by latitudes 0°30ô*S* and 1°00ô*S*, longitude 34°30ô*E*, and the shores of Lake Victoria and the Winnam gulf[3]. Altitudes in these areas range from about 1000 m on the shores of the Lake to about 1800 on top of the hills. There are human settlements around the foot of the hills and up the hill in case of South Ruri. The major economic activity is fishing and farming. The geological area of the map is shown in fig. 1 below. The oldest rock in the Ruri hills is the Precambrian metabasalt of the Nyanzian type[3,6,7]. There are two types of intrusives in the Precambrian; the ijolites and the nepheline syenites of tertiary age and the 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-Fe_3O_4) or the óiron stoneö. They contain monazite and pyrochlore minerals, with the monazite containing principally thorium, uranium their radioactive daughters along with several rare earth elements.

Figure 1: Geology of the Ruri hills and other study areas



2.2 In-situ Measurement of Absorbed Dose in Air

The hills especially the habited sections, were traversed on foot. Absorbed dose rates in air were measured in 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 (i.e. hot spots).

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 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 76 mm × 76 mm NaI(Tl) detector, and has a resolution of 1.8 keV (FWHM) at 1.33 MeV peak of ^{60}Co.

2.3.2 Dose Rate Calculation from Activity Concentration in Soil

Absorbed dose rate, D($nGyh^{-1}$) in air at about 1 m above ground was calculated using the equation:

$D = (0.621C_{Th} + 0.462C_U + 0.0417C_K)$, where C_{Th}, C_U, and C_K are the average activity concentrations of ^{232}Th, $^{238}U_{equiv}$ (^{226}Ra) and ^{40}K, respectively, in the soil and 0.621, 0.462, and 0.0417 $nGyh^{-1}$ per $Bqkg^{-1}$ are the corresponding activity-to-dose conversion factors[1].

3. Results and Discussion

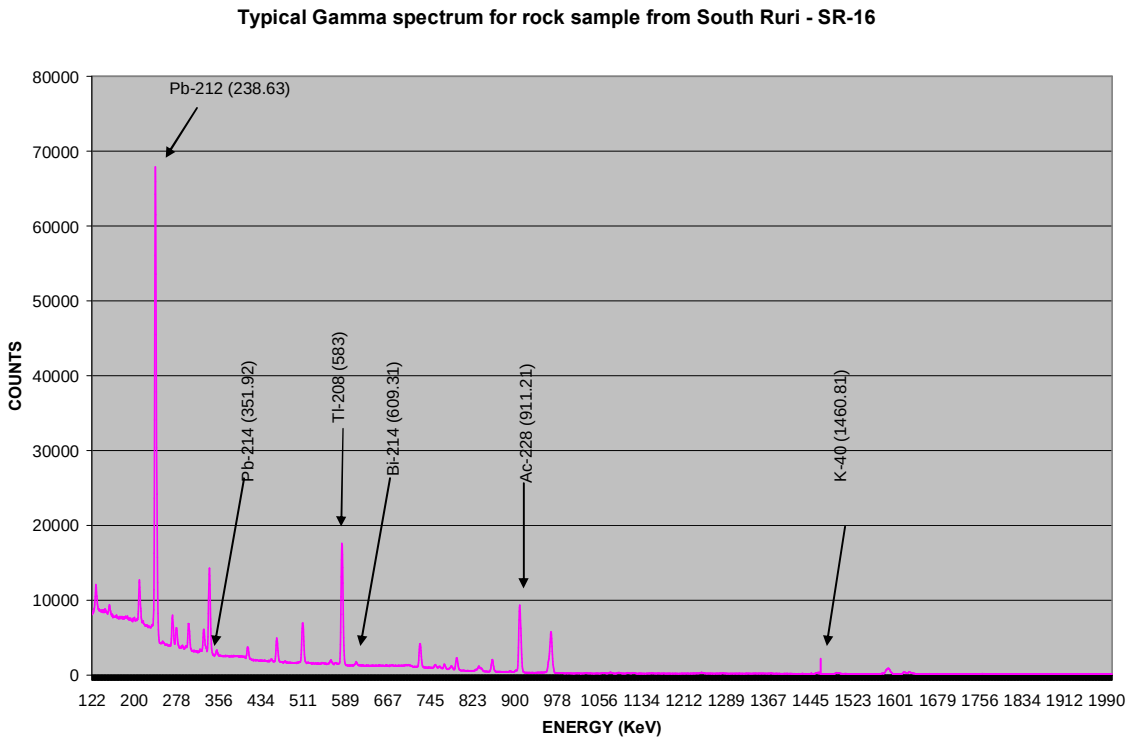
3.1 Activity concentration of Radionuclides

The results of the gamma-ray spectrometric measurements are summarized in table 1. The measured external dose rates in Ruri hills are relatively higher than in some of the other high background radiation areas (HBRAs,). It shows that the largest contributions to radioactivity levels in the study areas are from thorium-232. The variability in thorium distribution could be due to another contributing factor apart from carbonatite: Homa hills geothermal field fluids might be responsible for delivery of thorium to surface rocks; some hot spots have travertine deposits. In this area, presence of ^{232}Th in the rocks contributed most (66%) to the total absorbed dose rate in air, followed by ^{40}K (27%) and ^{238}U (7%). The activity concentrations of ^{232}Th and ^{226}Ra (^{238}U equivalent) were calculated from the gamma photo-peaks of ^{212}Pb (238.63 keV), ^{228}Ac (911.21 keV) and ^{214}Pb (351.92 keV), ^{214}Bi (609.31 keV), for thorium and uranium equivalent respectively. Otherwise, the peak of ^{40}K was used for determining activity concentration of potassium. Typical gamma spectrum for South Ruri hill sample i.e. SR-16 is shown fig. 2 below.

Table 1: Activity concentrations of the primordial radionuclides in soil samples from Lambwe east location (Ruri).

	Activity Concentration ($Bqkg^{-1}$)	
	Range	Mean
^{40}K	57 - 1455	511 ± 19
^{226}Ra	15 - 499	123 ± 10
^{232}Th	14 - 6560	1215 ± 38

Figure 2: Typical gamma spectrum for south Ruri hill sample.



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 µGy 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' $30^{Ü}$ is 30 nGy h^{-1}[1,12].

The overall mean of the calculated absorbed dose rates due to terrestrial gamma rays is 2.1 µGy h^{-1}, which is more than thirty five times the world population-weighted mean of 60 nGy h^{-1}[1,12]. 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 2: Effective doses in some of the reported HBRA[14].

Area	Effective dose (mGy y^{-1})	
	Mean	Maximum
Ramsar, Iran	10.2	260
Guarapari, Brazil	5.5	35
Kerala, India	3.8	35
Yangjiang, China	3.5	5
Lambwe east, Kenya[(a)]	7.4	21

[(a)] The study is 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, Soklo Point and Lwala in Lambwe east location of Mbita district, southwestern Kenya have been summarily 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. The natural radioactivity is fractionated with higher levels in the soils than carbonatite rocks probably because the soils are mainly deposited, weathered carbonatites. The annual external effective dose rates are twelve (12) times higher than the global average of 0.46 $mSvyr^{-1}$, hence the region may for the first time, be characterized as HBRA. Further work, including indoor exposure assessments, personal dosimetry, as well as epidemiological studies, are underway to investigate the radiological implication of the enhanced levels of radiation on the local populations.

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