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Full Length Research Paper

Radiometric assessment of natural radioactivity levels around Mrima Hill, Kenya

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Mrima Hill, located in the South coast of Kenya is known for high natural background radiation, due to the presence of radiogenic heavy minerals such as monazites and carbonatites. The activity concentration of ^{238}U, ^{232}Th and ^{40}K in soil samples from the hill have been determined by gamma ray spectrometry using NaI(Tl) detector and decomposition of measured gamma-spectra. As a measure of radiation hazard to the public, gamma radiation dose rates were also estimated. The average activity concentrations of ^{238}U, ^{232}Th and ^{40}K were 207.0±11.3, 500.7±20.0 and 805.4±20.0 Bqkg^{-1}, respectively. The mean absorbed dose rate in air is 440.7±16.8 nGyh^{-1} while the estimated annual average effective dose rate is 1.11±0.01 mSvy^{-1}. The absorbed dose rate due to gamma radiation from naturally occurring radioactive materials is above the global average value of 60 nGyh^{-1} (UNSCEAR, 2000).

Key words: High natural background radiation, gamma ray spectrometry, NaI(Tl) detector, Mrima Hill.

INTRODUCTION

Naturally occurring radionuclides of terrestrial origin are present on the earth's crust since its origin. They are believed to have been produced when the matter of which the universe is formed first came into existence. The young earth probably contained a large number of elements than they are today. The short-lived radioactive elements decayed leaving those with half-lifes comparable to the estimated age of the earth. The distribution of these radionuclides on the Earth depends on the distribution of rocks from which they originate and the processes which concentrate them (Mohanty et al., 2004). Human exposure to natural sources of ionizing radiation is a continuous and inescapable feature of life on the earth. The major sources responsible for exposure are naturally occurring radionuclides in the earth's crust such as ^{238}U, ^{232}Th and ^{40}K which occur in radiogenic minerals such as monazites and carbonatites.

Several studies (UNSCEAR, 2000; Malanca et al., 1993; Ramli et al., 2005; Mohanty et al., 2004) have shown that there are few regions in the world, which are known for high background radiation due to the local geology and geochemical effects that cause enhanced levels of terrestrial radiation.

Mrima Hill is located in the South coast of Kenya at $4^0 29' 10'' S; 39^0 15' 10'' E$. Patel (1991) measured radiation doses in the hill and reported high dose rates up to a maximum value of 106 mSvy^{-1}. However, no studies have been conducted in the villages around the hill to determine natural radionuclide levels and the associated dose rates. The objective of this work was to measure the levels of naturally occurring radionuclides (^{238}U , ^{232}Th and ^{40}K) in soil samples from the five villages surrounding the hill (Dzuni, Mchanongo, Mrima TM, Mwavobo and Bumbuni) and the associated radiation dose rates in air.

MATERIALS AND METHODS

Sampling and sample preparation

A total of 50 soil samples were randomly collected within a radius of 5 km from Mrima Hill at a depth of 10 to 15 cm. Figure 1 shows the sampling area. The samples were dried at 110°C overnight and ground to ensure homogeneity. The dried samples were sealed in plastic containers and kept for four weeks to achieve radioactive equilibrium between ^{226}Ra and ^{232}Th and their daughter radionuclides (Mustapha et al., 1999).

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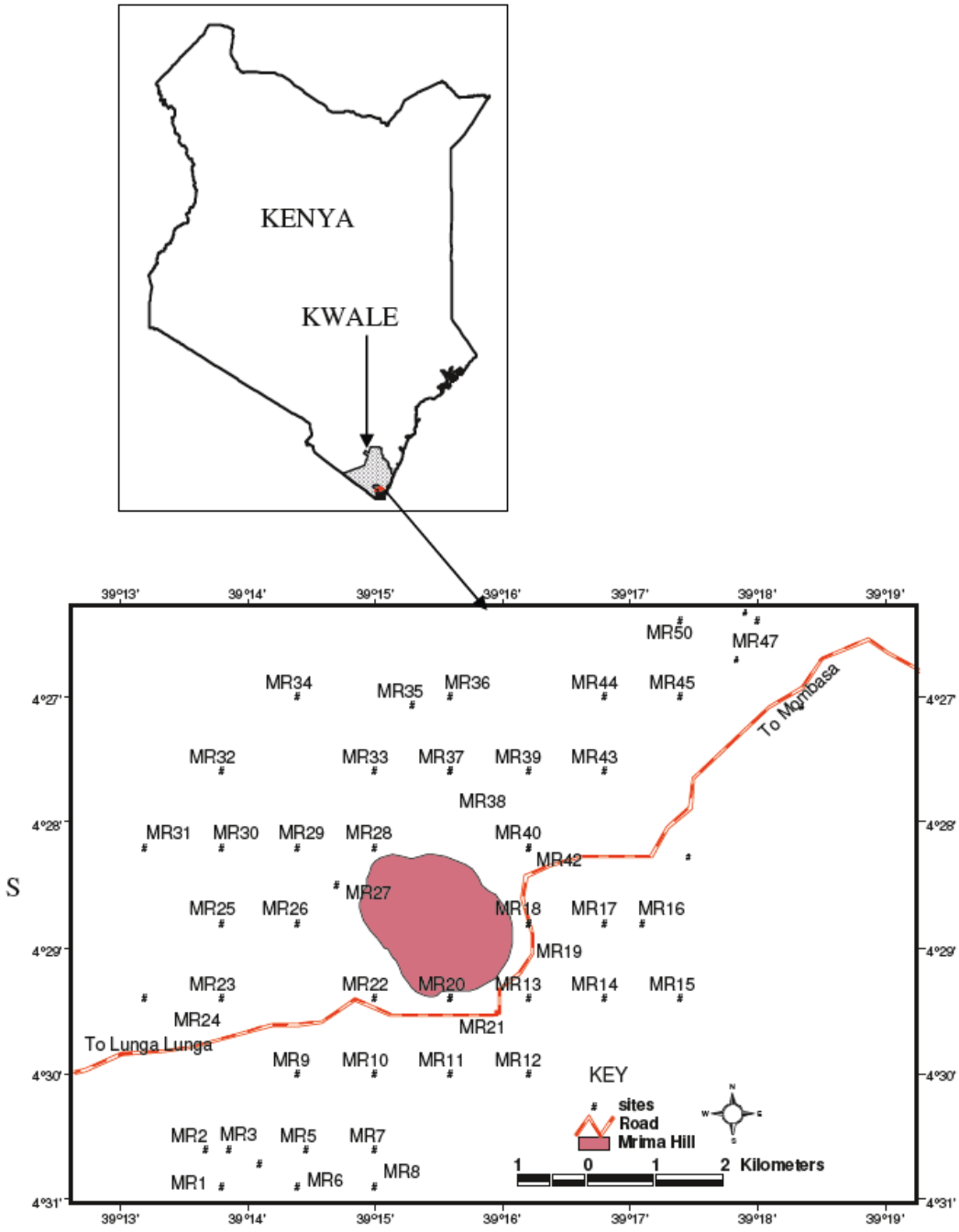

Figure 1. Sampling map.

NaI(Tl) gamma ray spectrometer

Calibration of NaI(Tl) gamma-ray spectrometer and decomposition of measured spectrum into components were done using three standard materials (RGK-1, RGU-1 and RGTH-1 for potassium, uranium and thorium, respectively) which were obtained from International Atomic Energy Agency (IAEA, 1987). Energy calibration of the spectrometer was performed using the following gamma-lines: ^{214}Pb (352 keV), ^{40}K (1460 keV), ^{214}Bi (1765 keV), and ^{208}Tl (2615 keV). In order to determine the background components in the spectrum, an inert sample comprising of a plastic container filled with distilled water was counted in the same geometry as the samples. This background spectral data was always subtracted from the counts obtained for each sample before further analysis. The time of acquisition of data for each soil sample was 30000 s.

Spectrum analysis

The spectrum of a soil sample was reduced to spectral components of its constituent radionuclides (^{238}U, ^{232}Th and ^{40}K) using the

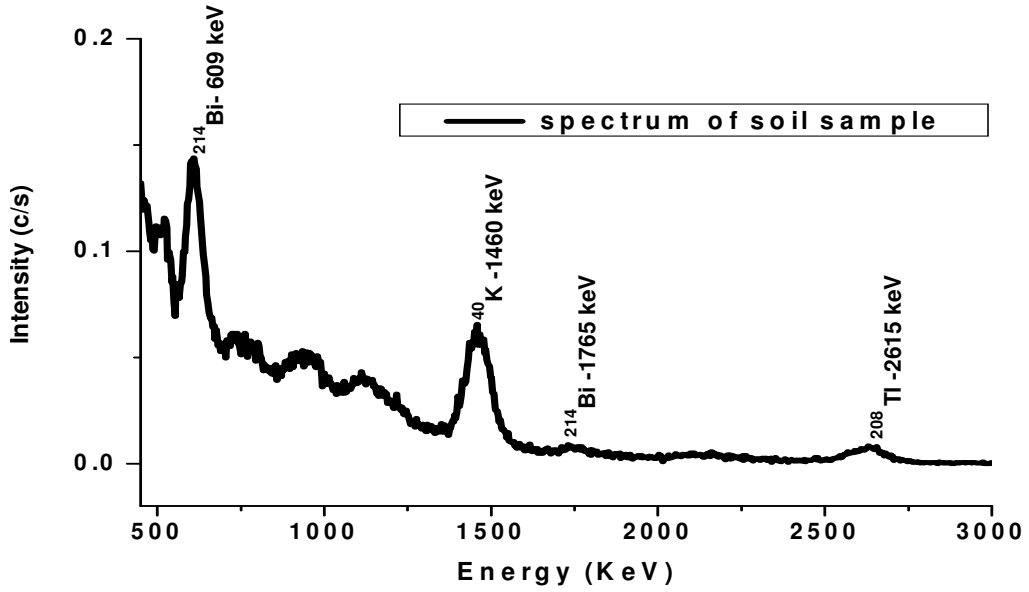

Figure 2. A typical gamma rays spectrum of a soil sample.

method of spectrum decomposition (Muminov et al., 2005). This was performed as follows: A spectrum Y of a natural sample was assumed to comprise of the spectra of the three natural radionuclides and the background spectrum as shown in Equation (1).

$$Y = Y_b + Y(U) + Y(Th) + Y(K) \quad (1)$$

where Y_b is the background spectra and Y(U), Y(Th) and Y(K) are the spectra of ^{238}U and ^{232}Th decay series, and ^{40}K respectively. By subtracting the background, Equation (1) becomes

$$Y_{net} = Y(U) + Y(Th) + Y(K) \quad (2)$$

To obtain the ^{232}Th component in the soil sample, 2615keV gamma-line of ^{208}Tl photo peak which weakly interferes with others was selected. The ratio of its peak intensity in a sample to the corresponding intensity in the thorium standard (RGTH-1) was computed by using Equation (3)

$$Y_{Th}(sample) = aE(RGTh - 1) \quad (3)$$

where a is a normalizing constant and E(RGTh-1) is the spectrum of the thorium standard. This procedure was repeated to obtain the uranium and thorium components in the sample. Net counts (area under photo peaks) were determined by Gaussian fitting of the gamma ray photo peaks in the spectrum using origin software. With this method, errors due to photopeak interference were highly minimised. Figure 2 shows a typical spectrum of a soil sample and Figure 3 shows a typical Gaussian fitted photopeak of a soil sample before and after spectrum decomposition.

Measurement of radioactivity

The activity concentrations of radionuclides (^{232}Th, ^{238}U and ^{40}K) were determined by using the gamma-lines: 2615 keV of ^{208}Tl, 1765 keV of ^{214}Bi and 1460 keV of ^{40}K respectively. The outdoor absorbed radiation dose rate in air at a height of 1 m above the ground surface was computed based on the guidelines provided by UNSEAR (2000). The absorbed dose rate was calculated in this study using the formula obtained from Abbady et al. (2005).

$$D = 0.427A_U + 0.622A_{Th} + 0.0432A_K \quad (4)$$

where A_{Th} ,A_U and A_K are average activity concentrations of ^{232}Th, ^{238}U and ^{40}K, respectively. To estimate the annual effective dose rates, the conversion factor of 0.7 SvGy^{-1} (UNSCEAR, 2000) and an outdoor occupancy of 0.4 were used. The following formula was used to determine the annual effective dose rates (Abbady et al., 2005).

$$H_E = DTF \quad (5)$$

where H, D ,T and F are effective annual dose rate in mSvy^{-1}, absorbed dose rate in nGyh^{-1} is the outdoor occupancy time and conversion factor respectively.

RESULTS AND DISCUSSION

The values of activity concentrations of radionuclides ^{238}U, ^{232}Th and ^{40}K in soil samples from the region around Mrima Hill have been computed. The minimum activities of ^{238}U, ^{232}Th and ^{40}K observed are 67.04±11.3, 298.2±3.4 and 506.75±3.45 Bqkg^{-1} and the maximum values are 354.3±6.1, 869±.04 and 1108.15±8.6, respectively. The average concentrations of ^{238}U, ^{232}Th and ^{40}K in the samples are 207.03±11.3, 500.7±20.3 and 805.38±20.7 Bqkg^{-1} respectively. The correlation between thorium and uranium is shown in Figure 4.

It is observed that the activity concentrations are above

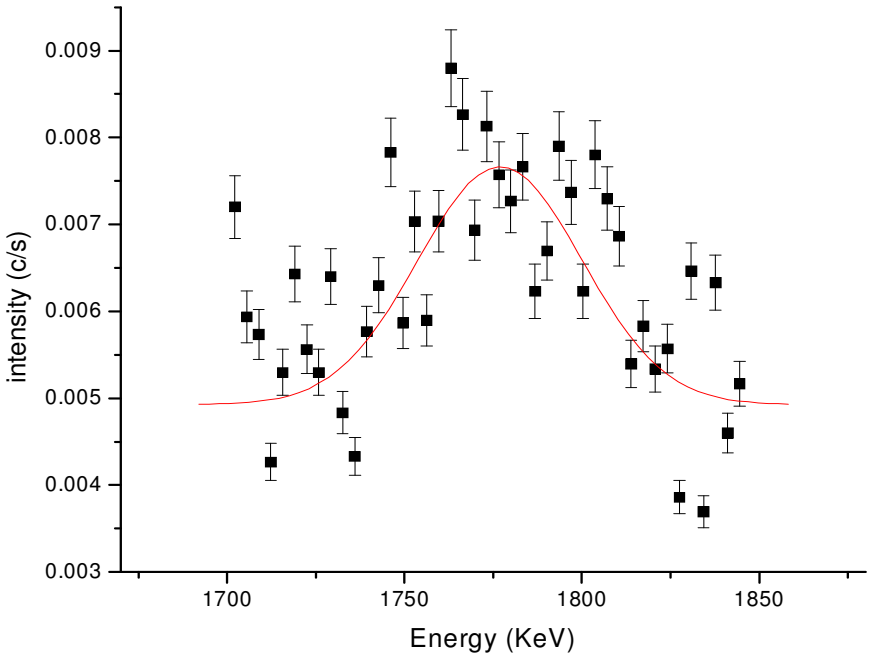

Figure 3a. Gaussian fitted photopeak of 1765 keV (214Bi) before decomposition.

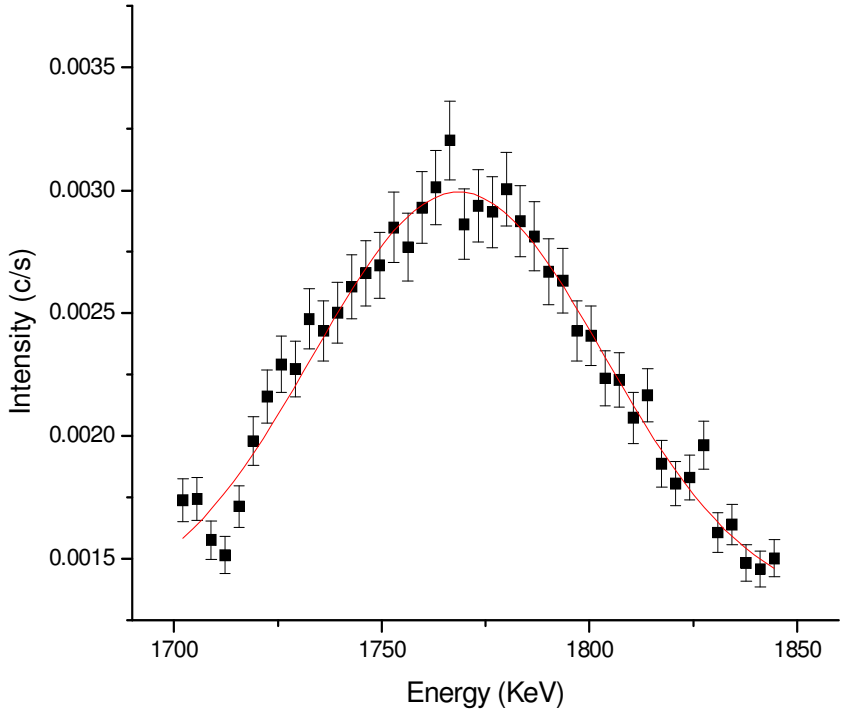

Figure 3b. Gaussian fitted photopeak of 1765 keV (^{214}Bi) after decomposition.

the world population weighted average of 33 Bqkg^{-1} for ^{238}U, 45 Bqkg^{-1} for ^{232}Th Bqkg^{-1} and 420 Bqkg^{-1} for ^{40}K as reported in UNSCEAR (2000). The values are also higher than those recorded by other researchers from other parts of Kenya as shown in Table 1. The high concentration of radionuclides in the area around the hill can be attributed to the washing away of minerals from the hill. Weathering of underlying rocks and erosion are

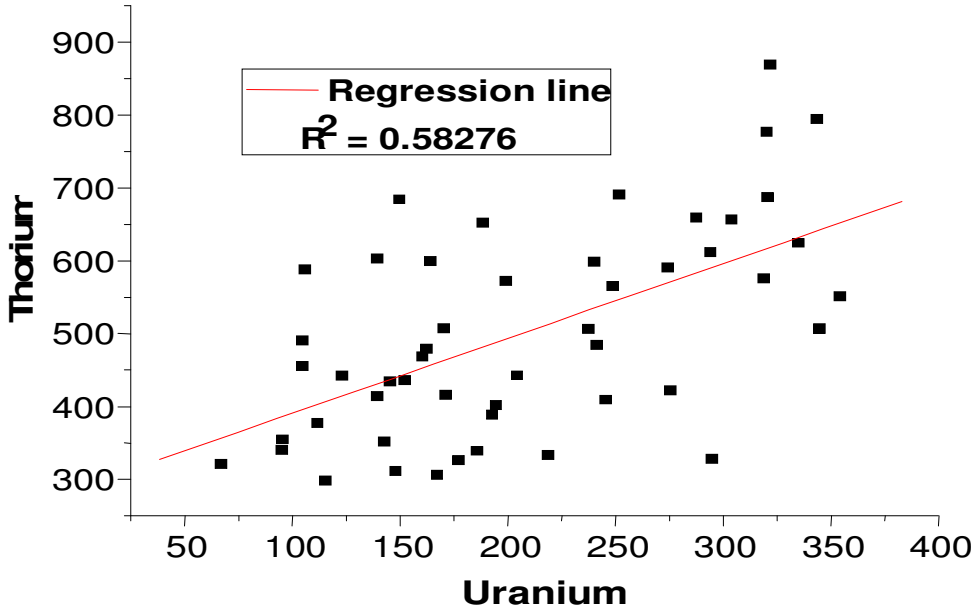

Figure 4. Regression plot showing correlation between activity concentrations of ^{232}Th and ^{238}U.

Table 1. Average activity concentration of natural radionucludes.

Place	Activity concentrations (Bqkg^{-1})		
	^{238}U	^{232}Th	^{40}K
Mrima Hill	207.03±11.3	500.7±20.3	805.38±20.7
Mombasa[a]	22.8±1.8	26.2± 1.7	479.8±24.2
Malindi[a]	21.3 ± 3	19.1 ± 3.5	519.2 ± 42.1
Gazi[a]	11.9 ± 1.4	10.8± 1.0	206.1± 26.4
Other places[b]	28.7± 3.6	73.3± 9.1	255.7 ± 38.5

[a]Hashim et al. (2004); [b]Mustapha et al. (1999).

also attributed to these high levels. In fact, the high concentration of ^{232}Th is strongly attributed to the weathering and washing away of carbonatite rocks from the hill (Patel and Mangala, 1994). It is observed that the correlation between ^{232}Th and ^{238}U is not very strong (R^2 = 0.58276). This Indicates that the two radionuclides are from two different minerals.

The absorbed dose rate in air at a height of 1 m above the ground level obtained from different sampling points ranged from 253.8±2.5 to 733.1±3.4 nGyh^{-1} with an average of 440.7±16.8 nGyh^{-1}. This value is higher than the worldwide average of 60 nGyh^{-1} (UNSCEAR, 2000). The annual outdoor effective dose ranged from 0.64 to 1.849 mSvy^{-1} with an average of 1.11 mSvy^{-1}.

Conclusions

The activity concentration of the three radionuclides ^{238}U, ^{232}Th and ^{40}K in the area around Mrima hill was higher compared to those reported by other researchers from other parts of the country. However these values are within the range observed by other researchers in regions of high natural background (Ramli et al., 2005; Mohanty et al., 2004). This can be attributed to the washing away of minerals from the hill to the area surrounding it. The absorbed dose rate due to gamma radiation from natural radioactivity is above the global average of 60 nGyh^{-1} (UNSCEAR, 2000). Since ionising radiation is known to cause health problems, an epidemiological study is necessary in this area.

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