Assessment of Radiation Dose Levels in Tiles Used for Decoration in Bungoma County, Kenya

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Abstract: **The natural radioactive content of tiles used in Bungoma County, Kenya was assessed using gamma ray spectroscopy in this study. The amounts of certain radioisotopes found in 20 samples of decoration tiles used in Bungoma County, Kenya were estimated using a NaI(Tl) detector. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for the tiles were determined to be 11±0.55, 109±5.85, and 1574±78.7Bq/kg respectively. Radiological hazard indices such as absorbed dose rate, radium equivalent activity, external Hazard Index (H_{ex}), internal Hazard Index (H_{in}), Indoor and outdoor Annual Effective Dose (mSv/y), were determined as 140±7.03 nGyh^{-1}; 288±14.44 Bq/kg, 0.7±0.03 mSv/y, 0.8±0.04 mSv/y; 0.5±0.02mSv/y; and 0.3±0.01mSv/yrespectively. The mean radium equivalent obtained in this investigation was lower than the worldwide reference value of 370 Bq/kg. Hence, use of tiles for decoration in Bungoma County, Kenya has minimal health threat to the population.**

I. INTRODUCTION

Terrestrial gamma rays and cosmic rays are the two principal natural sources through which human civilization is exposed to radiation from the outside. Natural radionuclides from the ^{238}U, ^{232}Th, and ^{40}K series found in the earth's crust produce terrestrial gamma rays (1). These radionuclides (^{238}U, ^{232}Th, and ^{40}K) are present in soils based on the distribution of these radionuclides in the rocks from which they originate, as well as the processes that concentrate the soils. Igneous rocks, such as granite, have higher radiation levels than sedimentary rocks, which have lower levels (2).The sorts of rocks from which soils are formed influence the amount of terrestrial background radiation. However, building materials such as tiles are derived from radioactive resources such as rocks, dirt, and so on. These isotopes can be found in all types of environments, but their activity levels are often higher in soils and rocks (3). However, the vast majority of these tiles are by-products of rocks and soils that contain varying levels of primordial radionuclides. Additional doses may be caused by increased or higher levels of natural radionuclides in building materials as a result of external and internal exposure (4). Radiation exposure is caused by naturally occurring radionuclides in building materials such as tiles in two ways: external radiation from the ^{238}U and ^{232}Th decay series, as well as ^{40}K, and internal radiation from radon inhalation, which leads to deposition of its decay products in the respiratory tract (5). The monitoring of natural radioactivity in building materials has received a lot of interest in recent years, especially in European, Asian, and some African countries. The goal of this study is to assess radionuclide concentrations and associated hazard indices in tiles used in Bungoma County, Kenya in order to determine the radiation dose level for health safety.

II. MATERIALS AND METHODS

2.1 Study Area

The study was conducted using tiles commonly found in the hardware from Bungoma County being a representative of what is on the Kenyan market. The tiles that were considered were those from Egypt, India, Uganda and those which are locally manufactured, i.e the Twyford and saj tiles. The random sampling method was used to collect samples.

2.2. Sample Description and Preparation

To assess the radiological hazard in both the local and imported tiles, a total of 20 samples of commercial tiles were sampled. The names of different samples of ceramic tiles are (India: T1, T2,T3,T4. Uganda: T5,T6,T7,T8. Egypt: T9,T10,T11,T12,T13. Kenya Twyford: T13,T14,T15,T16. Kenya Saj: T17,T18,T19 and T20). For each country four samples were taken. These particular countries were considered because they were the ones available on the market. All samples were crushed (separately) to a fine powder and sieved through a 0.5mm mesh. Each sample was oven-dried at 110°C for 3hours to reduce the moisture content (6). Weighed samples of 200g were placed in polyethylene cylindrical beakers, of about 300ml each. These beakers were sealed to prevent the escape of gaseous ^{222}Rn from the samples and stored for 30 days to attain secular equilibrium between ^{226}Ra and ^{232}Th and their decay products. At this point, the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) within the volume and the progeny also remains in the sample (7).

2.3. Activity Concentration

The calculations of the activity concentration (A_c) values for the radionuclides from^{235}U, ^{238}U and ^{232}Th series and ^{40}K present in the selected tile samples was determined as shown by equation 2.1 (8)

$$A_C = \frac{C_{net}}{\gamma \times \in \times m \times t} \qquad (2.1)$$

2.4. Absorbed Dose Rate

The absorbed dose rate in air in a room is usually calculated based on RP 112 by using the specific dose rates stipulated in EC (1999). The specific dose rates (in units $nGyh^{1}perBq\ kg^{-1}$) are given for ^{226}Ra, ^{232}Th and ^{40}K. The dose rate for indoors is calculated according to the EC (1999) for materials under investigation when applied as a tile on all walls by equation 2.2(5)

$$D\left(\frac{nGy}{h}\right) = 0.463A_{Ra} + 0.604A_{Th} + 0.0417A_K \qquad (2.2)$$

Where A_{Ra}, $A_{Th}$and A_K is the activity concentrations for ^{226}Ra, ^{232}Th and ^{40}K (in $Bq.kg^{-1}$) respectively.

2.5. Annual Effective Dose

To estimate the annual effective dose received by the population attributable to radioactivity in the tailings the conversion factor of 0.7 Sv/Gy will be used ((8). This conversion factor will be used in the conversion of the absorbed dose in the air to an effective dose by adults. Therefore, in this research, the indoor and outdoor occupancy factors will be given as 0.8 and 0.4 respectively (8). The indoor and outdoor annual effective doses were calculated by equation 2.3 (a) and 2.3 (b) respectively.

$$E_{in}\,(mSvy^{-1}) = ADR(nGyh^{-1}) \times 8760(hy^{-1}) \times 0.8 \times 0.7(SvGy^{-1}) \times 10^{-6} \qquad (2.3\,(a))$$

$$E_{out}\,(mSvy^{-1}) = ADR(nGyh^{-1}) \times 8760(hy^{-1}) \times 0.4 \times 0.7(SvGy^{-1}) \times 10^{-6} \qquad (2.3\,(b))$$

Where; E_{in} and E_{out} are Annual Effective Doses for indoor and outdoor environments respectively, ADR ($nGyh^{-1}$) is the absorbed dose rate in air, 8760($h\ y^{-1}$) is the time in hours for one year, 0.7($SvGy^{-1}$) is the conversion factor which converts the absorbed dose rate in the air to an effective dose, 0.8 is the indoor occupancy factor and 0.4 is the outdoor occupancy factor (9).

III. RESULTS AND DISCUSSION

3.1 Activity Concentrations of Natural Radionuclides

The average values of Thorium, uranium and potassium were 109±5.48 $Bqkg^{-1}$, 11±0.55 $Bqkg^{-1}$ and 1574±78.7 $Bqkg^{-1}$ respectively. The minimum activity concentration for ^{232}Th, ^{238}U and ^{40}K was found to be 52±2.62 $Bqkg^{-1}$,6±0.32 $Bqkg^{-1}$and 1165±58.29 $Bqkg^{-1}$ while the maximum values were 254±12.7 $Bqkg^{-1}$,31±1.57 $Bqkg^{-1}$ and 2193±109.65 $Bqkg^{-1}$ respectively were obtained as given in table 3.1.

Table 3.1: *Activity Concentrations of the Radionuclides in the Sampled Tiles*

	ACTIVITY CONCENTRATION (Bq/kg)		
RADIONUCLIDE	**40K**	**232Th**	**238U**
MAXIMUM	2193±109.65	254±12.7	31±1.57
MINIMUM	1149±57.47	52±2.62	6±0.31
AVERAGE	1574±78.7	109±5.48	11±0.55

The activity concentration of ^{232}Th and ^{40}K exceeded the world's agreed average values of 45 $Bqkg^{-1}$ and 400 $Bqkg^{-1}$ respectively (10). The high values of 40K are attributed to the fact that raw materials for tile samples might have been collected from agricultural farms where there is the continuous application of inorganic fertilizers rich in potassium. High potassium levels could also be attributed to the presence of minerals such as potash feldspar like orthoclase, micas like biotite (11). The activity concentration of ^{238}U evaluated was lower than the world's average of 33 $Bqkg^{-1}$ (11). Figure 2.1 shows the activity concentration of ^{40}K from the sampled construction tiles used in Bungoma County.

From figure 2.1, the activity levels of ^{40}K ranged from 1149±57.47Bq/kg to 2170±108.5Bq/kg with an average of 1574±78.7Bq/kg.

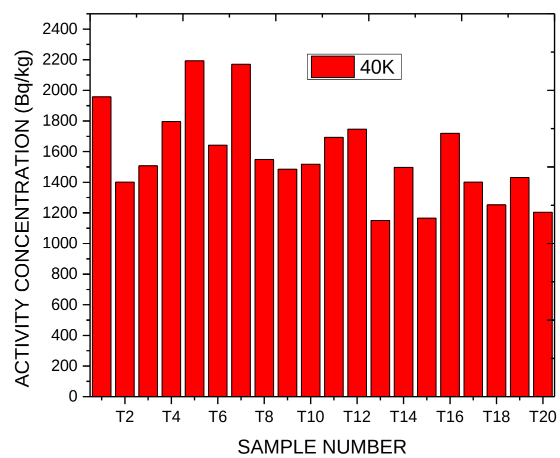

Figure 2.1: Activity Concentration of ^{40}K in the collected Tile Samples.

The activity concentration ranged from 52±2.62Bq/kg to 254±12.7 Bq/kg with an average activity of 109±5.48Bq/kg for ^{232}Th and 6±0.31Bq/kg to 31±1.57Bq/kg with an average of 11±0.55 Bq/kg for 238U (Figure 2.1). The results indicate a great variation in the mean activity level of the analyzed naturally occurring radionuclides (^{40}K, ^{232}Th and ^{238}U) in the tile samples. The variation in the activity concentrations in the tile samples varied with the country of origin which could be attributed to the geological formations of the host countries.

3.2 Absorbed Dose Rate

The average dose rate was found to be 140±7.03 $nGyh^{-1}$ which is higher than the permissible average global value of 80$nGyh^{-1}$. The minimum value of the absorbed dose is 87±4.37$nGyh^{-1}$ and the maximum value being of 226±11.33 $nGyh^{-1}$. Figure 2.2 shows the absorbed dose rate values of all the sampled tiles used for construction in Bungoma County

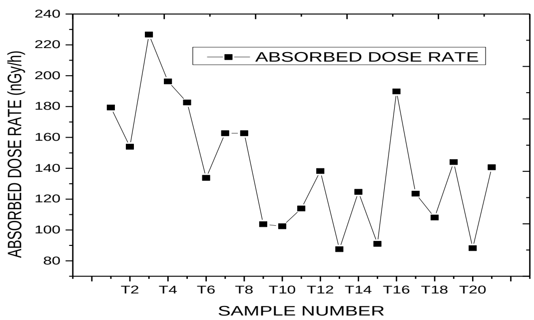

Figure 2.2: A graph of the absorbed dose rate for tile samples selected from major hardware in Bungoma County.

From figure 2.2 the absorbed dose rate was found to be highest in tile sample T3 (from India) and lowest in tile sample T13 (from Kenya). Most of the tile samples recorded a higher value than the world's average value of 60nGy^{-1}(11). This could signal out that our locally manufactured tiles have lower radiation effects.

3.2. Annual Effective Dose Rate (AED)

The annual effective dose ranged from1±0.06 mSv/y to 3±0.18 mSv/y, with a mean value of 2±0.11 mSv/y. To determine the radiological risks per individual exposure, conversion factors suggested were used to convert the absorbed dose rate to an annual effective dose which is a sufficient representation of the likely hazard effects to the human population (12).

The average indoor annual effective dose rate for all tile samples was 0.5±0.02 mSvy^{-1}. This value of the indoor AED reported in the tile samples collected was below the global average of 1mSvy^{-1} (13). The minimum and maximum indoor annual effective dose rates from twenty collected tile samples were 0.3±0.01 mSvy^{-1}and 0.8±0.04 mSvy^{-1} respectively.The average outdoor AEDR for the twenty collected tile samples was 0.3±0.01 mSvy^{-1} while the maximum and minimum values were 0.5±0.02mSvy^{-1}and 0.2±0.01 mSvy^{-1} respectively. Figure 2.3 shows the annual effective dose rate values obtained from the analysis the sampled tiles used in Bungoma County.

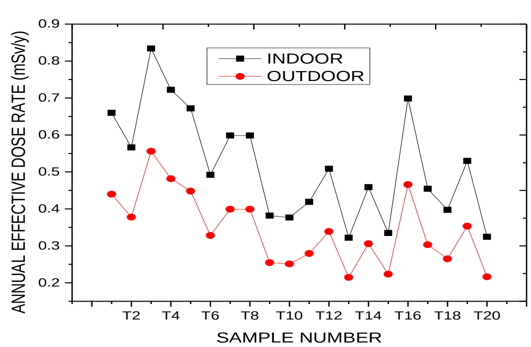

Figure 2.3: A Comparative Graph showing indoor and outdoor annual effective dose rate for the collected tile samples

All the tile samples collected from major hardware in Bungoma County registered an outdoor annual effective dose rate below the permissible limit of 1mSvy^{-1} hence use of tiles for decoration has minimal potential health risk to the general population (14).

IV. CONCLUSION

The activity concentration of ^{238}U, 40K, and 232Th from the collected sampled tiles used for decoration in Bungoma County were evaluated in this study. The activity concentration of 40K and 232Th were above the world average value but below the recommended permissible values of 10, 000 Bq/kg and 1000Bq/kg respectively. The average value of gamma-ray absorbed dose rate in air obtained from tile samples was 140± 7.03 nGyh-1 and thus higher than the world ranges 60 nGyh^{-1}. The average indoor and outdoor annual effective dose rate for all the tile samples was 0.5±0.02 mSvy^{-1}and0.3±0.01 mSv/y respectively. The results therefore, indicated that most of the tiles used for decoration in Bungoma County do not pose any significant source of radiation hazard, however, similar study need to be carried out to determining the trends in the natural radioactivity especially in the upcoming new tile brands on the market.

ACKWNOLEDGEMENT

The authors thank Kenyatta university physics department for carrying measurement of the samples. Kibabii university department of science, engineering and technology for providing materials that were used in sample collection and preparation.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding publication of this article.

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