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RADIOLOGICAL MEASUREMENT OF HAZARDOUS LEVELS IN CONSTRUCTION TILES IN BUNGOMA COUNTY, KENYA

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ABSTRACT

Twenty (20) different local and imported tiles were sampled from major hardware's in Bungoma. The samples collected were separately ground, sieved, through a 0.5mm mesh, dried at 110° C, weight and packed in a 200ml stoppered plastic bottles. The samples were stamped with identification numbers and kept for 30 days for secular equilibrium to be reached between the activity of ^{238}U,^{232}Th ,^{40}K radium and their progeny. The average activity concentration of ^{238}U, ^{232}Th and ^{40}K was found to be 109±5.48Bqkg^{-1}, 11±0.55 Bqkg^{-1} and 1574±78.7 Bqkg^{-1} respectively. The average absorbed dose rate was found to be 140±7.03 nGyh^{-1} which is higher than the worlds average value of 60 nGyh^{-1}. The average radium equivalent was found to be 288±14.44 Bqkg^{-1} which is lower than the world limit value of 370Bqkg^{-1}. External and internal hazard indices were found to be 0.70±0.03 msvy^{-1} and 0.80±0.04 msvy^{-1}respectively. Therefore, the sampled tiles used in Bungoma county for construction has minimal radiological threat to population.

I. INTRODUCTION

The average human being lives in an environment that is exposed to radiations of varying degrees. These radiations are primarily from two sources: earth's surface and the space [1]. One is therefore susceptible to interact with gamma rays emanating from the earth's surface and cosmic rays from space. It is the terrestrial gamma rays that one is likely to interact with when in contact with soil and rocks; and by extension, their by-products like tiles. The terrestrial gamma rays are emitted by natural radioactive nuclides (^{238}U, ^{232}Th and ^{40}K) found in the soil due to their decay [2]. Whereas the earth's crust is naturally radioactive due to the dispersion of naturally occurring radionuclides, there are other factors that could make these radionuclides radiological hazards. These include the continual accumulation of phosphate fertilizer in the soil, burning of fossil fuels, mining and construction activities [2]. Besides the human activities that affect the concentration of radionuclides in the environment, there are also natural processes like soil erosion and geological formations that also affect their accumulation, as noted by [2]. Even though these NORMS – naturally occurring radioactive materials – often occur at low concentration, soil materials (rocks, ceramics and minerals) that contain NORMs(naturally occurring radioactive materials) with elevated levels of radionuclides could be hazardous [3].

There is need for building materials to be examined for acceptable levels of radiation [4]. Research shows that humans spend close to 80% of their time indoors, hence much of the exposure to radiation that humans experience is highly connected to the building materials within houses [5]. These findings corroborate the WHO study conducted in 1972 that established that long-term exposure of humans to radiation from natural sources constitutes about 80% of the radiation dose an average person receives [6]. Humans are often exposed to radiation within houses when they come into contact externally with gamma emitting radionuclides (^{226}Ra) or internally when they inhale ^{222}Rn and ^{220}Rn from tiles within the room [1]. These radiations often originate from the walls and flooring that include tiles.

Ceramic tiles are common among many households, due to the beauty they provide. They can be used on any surface within the house that include the floors, walls and table surfaces for finishing. The building material for ceramic tiles is ceramic, which is derived from clay and tile glaze [7]. Even though the concentrations of natural radioactive nuclides in the ceramic materials depends upon the local topographical conditions [8], it has been established that under normal circumstances, their concentration is often higher than that of the natural soil [9]. Thus, even after the zirconium which contains traces of radioactive elements is purified and supposedly reduced to low levels [10] at the production stage, it has never been confirmed if imported tiles follow such guidelines. Besides, Tiles used for finishing also contain glazes, pigments and other intermediate products as those which are atomized, hence prone to decay and emit harmful radiations [11]. This therefore means that humans are always at risk of exposure to radiations that are above the recommended levels. To avert the life-threatening effects of ionizing radiation, several radiological surveys have been done using different detectors and the findings published widely.

The existing data on radiometric surveys show that, though human beings receive radiation doses of varying ranges from different sources, the radon gas and its accompanying short lived decay daughters contribute the largest percentage of the mean absorbed dose, followed by building rocks and soil, then man made activities and cosmic rays [12]. These tiles could be a source of radiation within Kenyan homes unless proper measures are undertaken to safeguard the public against tiles with unacceptable levels of radiation. This work delved into investigating the following hazard parameters that has been employed to assess the levels of radiation exposure. These parameters include Radium Equivalent; The Annual Effective Dose; The Absorbed Dose Rate; The Internal Hazard Index and the External Hazard Index.

II. MATERIALS AND METHODS

II.1 STUDY AREA

The study was conducted using tiles commonly found in the hardware's 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.

II.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 [13]. 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.

II.3 SAMPLE ANALYSIS

II.3.1 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 1 [14].

$$A_C = \frac{C_{net}}{\gamma \times \in \times m \times t} \quad (1)$$

II.3.2 The Radium Equivalent Activity

There is unequal distribution of ^{226}Ra, ^{232}Th and ^{40}K in ceramics. Uniformity of distribution-based exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in $Bqkg^{-1}$and is used to compare the specific activity of materials containing different amounts of^{226}Ra, ^{232}Th and ^{40}K. It was calculated by the following relation shown by equation 2 [8].

$$Ra_{eq} = C_{Ra} + 1.42C_{Th} + 0.0778C_K \quad (2)$$

Where C_{Ra}, C_{Th} and C_k are the mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in tile samples respectively expressed in $Bqkg^{-1}$.

II.3.3 External Hazard

To limit the external gamma radiation dose from ceramic materials to $1mSvy^{-1}$, the external hazard index (H_{ex}) is determined by equation 3 [10].

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq 1 \quad (3)$$

In this equation, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in tile samples in $Bq.kg^{-1}$ respectively.

III. RESULTS AND DISCUSSIONS

III.1 ACTIVITY CONCENTRATIONS OF NATURAL RADIONUCLIDES

The activity concentrations levels of the three primordial radionuclides of the samples were analyzed using equation 2.1 [14]. The average activity concentration of ^{232}Th for all the samples collected from major hardware's within Bungoma County were calculated and presented in Figure 1. The distribution of the radionuclides was non uniform due the varying activity concentration from the tile samples.

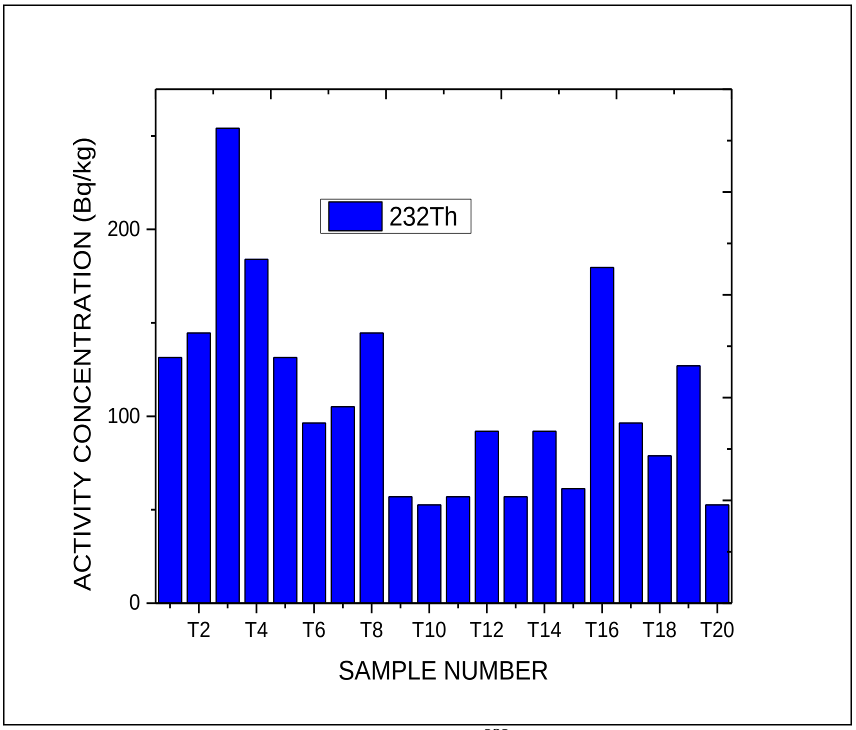

Figure 1: Comparative Bar Graph Showing Activity Concentration of ^{232}Th in the Tile samples from major hardware in Bungoma County.

Source: Authors, (2021).

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 were 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. The activity concentration of ^{232}Th and ^{40}K exceeded the worlds agreed average values of 45 Bqkg^{-1} and 400 Bqkg^{-1} respectively. The activity concentration of ^{238}U evaluated was lower than the world's average of 33 Bqkg^{-1} [15]. The mean activity of ^{40}K was generally higher than ^{238}U and ^{232}Th for all the collected samples which are a common behavior in the crustal contents. High potassium levels could be attributed to the presence of minerals such as potash feldspar like orthoclase, micas like biotite [12].

III.2 RADIUM EQUIVALENT AND EXTERNAL HAZARD INDEX

The radium equivalent values calculated by equation 2 ranged from 176 ±8.8 to 487± 24.39. The highest radium equivalent values were obtained from tiles from India which were 487± 24.39 Bq/kg and 411± 20.59 Bq/kg. These values were greater than the world's permissible maximum value of 370 Bq/kg [16]. The average value of radium equivalent in this research was 288±14.44 Bq/kg.

Table 1: Radium equivalent and External hazard index values of the sampled construction tiles.

	Ra_{eq} (Bq/kg)	**H_{ex} (mSvy^{-1})**
MAXIMUM	487± 24.39	1.3± 0.06
MINIMUM	176 ±8.8	0.4± 0.02
AVERAGE	288±14.44	0.8± 0.04

Source: Authors, (2021).

The evaluation of the external hazard index from activity concentration of the twenty samples was calculated using equation (2.3). The mean value from all the samples was 0.8± 0.04 mSvy^{-1}. The maximum and minimum values calculated were 1.3± 0.06 mSvy^{-1} and 0.4± 0.02 mSvy^{-1} respectively as shown from table 3.1. The average value calculated for the external hazard index was below the permissible level of one unit [17]. Therefore, the use of tiles for finishing has minimal radiological risk since the average value of radium equivalent in the sampled tiles is less than the world's permissible maximum value of 370 Bq/kg [16].

IV. CONCLUSIONS

In this study the activity levels for twenty tiles in Bungoma Kenya has been determined using Thalium doped sodium iodide gamma ray spectrometer. The average activity concentration 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 were 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. The activity concentration of ^{232}Th and ^{40}K exceeded the worlds agreed average values of 45 Bqkg^{-1} and 400 Bqkg^{-1} respectively. The activity concentration of ^{238}U evaluated was lower than the world's average of 33 Bqkg^{-1} [12]. The average radium equivalent and external hazard index were below the permissible values of 370 Bq/kg and 1mSv/y respectively. Hence construction tiles used in Bungoma County posses' minimal radiological health risk to the population. Future radiological assessments should be done in order to evaluate the high radioactivity values obtained in some construction tiles.

V. AUTHOR'S CONTRIBUTION

Conceptualization: John Simiyu Nalianya, Michael Nakitare Waswa and Francis Maingi.

Methodology: John Simiyu Nalianya and Conrad Khisa Wanyama.

Investigation: John Simiyu Nalianya and Conrad Khisa Wanyama.
Discussion of results: John Simiyu Nalianya, Michael Nakitare Waswa, Francis Maingi and Conrad Khisa Wanyama.
Writing – Original Draft: John Simiyu Nalianya.
Writing – Review and Editing: John Simiyu Nalianya and Michael Nakitare Waswa.
Resources: John Simiyu Nalianya and Conrad Khisa Wanyama.
Supervision: Michael Nakitare Waswa and Francis Maingi.
Approval of the final text: John Simiyu Nalianya, Michael Nakitare Waswa, Francis Maingi and Conrad Khisa Wanyama.

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VII. CONFLICT OF INTEREST

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

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