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Full Length Article

Assessment of radioactivity and radiological hazards in commercial ceramic tiles used in Ife-Central, local government area of Osun State, Nigeria

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ABSTRACT

The activity concentrations of the natural radionuclides (^{40}K, ^{232}Th and ^{238}U) in ceramic tiles use in homes and offices in Ile-Ife were investigated using a NaI (Tl) detector as the detecting device for gamma spectrometry. The gamma absorbed dose rate (D_R), radium equivalent activity (Ra_{eq}), annual effective dose (A_d), activity concentration index (I), external radiation index (H_{ex}), internal radiation hazard index (H_{in}), alpha index (I_α), activity concentration index (I_γ), excess lifetime cancer risk (E_C), and annual gonadal dose equivalent (AG_d) associated with the radionuclides were evaluated in order to assess the radiation hazard of ceramic tiles used in Ile-Ife. The mean activity concentrations of 850, 24, and 128 Bqkg^{-1} were obtained for ^{40}K, ^{232}Th, and ^{238}U, respectively. These resulted in an annual effective dose that ranged from 0.07 to 0.2 mSvy^{-1} with a mean value of 0.14 mSvy^{-1}. The results showed that all the calculated radiological parameters are within the recommended safety limit, hence, do not pose significant radiological hazard when used as building materials.

In order to determine the similarities and correlations among various samples, all the radiological variables above were subjected to correlation analysis.

1. Introduction

Ceramic tiles are derived from a mixture of clay, sand, and other natural materials that are shaped into slabs and fired at high temperatures, up to 1250 °C. A glaze surface layer is commonly applied. The glaze is essentially a glass covering, usually a mixture of raw materials such as zinc oxide, feldspar, kaolin, and zircon an opacifier dispersed in water. Their composition is the same as that of all ceramic

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materials, from tableware and sanitary ware to roofing tiles [1,2].

Ceramic tiles are generally preferred for indoor finishing due to their ornamental properties along with their relatively cheap cost. Ceramic tiles may be glazed or unglazed. Zircon is a common opacifying constituent of glazes applied to ceramic tiles and is also used as an opacifier in porcelain tiles by incorporating it directly into the mixture used for forming the body of the tile. All zircon sand contains radionuclides of natural origin, primarily those in the uranium and thorium decay series. Although the concentrations of these radionuclides are low, they are significantly higher than those in normal rocks and soil. Due to the presence of zircon in the glaze, ceramic tiles can show elevated concentration of natural radioactivity [1,3,4]. The fact that ceramic tiles are fundamentally building materials, an assessment of their radiological impact on members of the public is necessary with emphasis on gamma radiation and inhalation of radon released from the product as the main exposure pathways [1].

Ceramic tiles have been extensively used in Nigeria as building materials. The knowledge of the level of natural radioactivity in ceramic tiles as building material is of great importance to determine the associated radiological hazards to human health and to develop a reference data of radiological parameters in ceramic tiles used in Ile-Ife.

Several studies have been done on building materials in Nigeria [5,6]. However, there are few works on ceramic tiles in Nigeria. In Ekiti State, Nigeria, the mean activity concentrations measured in ceramic tiles for ^{226}Ra, ^{232}Th, and ^{40}K were 74 ± 31, 82 ± 24, and 618 ± 231 Bq kg^{-1}, respectively [7]. Jwanbot et al. [8] assessed the indoor and outdoor gamma dose rate associated with commercial building materials in Jos, Plateau Nigeria. For floor tiles, they reported an effective dose range of 0.258–0.264 mSv/yr and 0.218–0.226 mSv/yr for indoor and outdoor, respectively. These values were far below the recommended safe limit set by the International Commission on Radiological Protection (ICRP).

In this work, gamma-ray spectrometry was used to measure the activity concentrations of natural radionuclides in seven varieties of ceramic tiles that are used as flooring materials in Ile-Ife, Osun State Nigeria. Their associated radiological hazards were assessed by calculating the absorbed dose rate, radium equivalent activity, and the external and internal hazard indices. The possibility of the activity concentration associated with ceramic tiles to elicit anomalous response from body tissues was assessed by determining the corresponding Gonadal dose equivalent as well as the excess lifetime cancer risk.

2. Materials and methods

2.1. *Sample collection and preparation*

A total of 7 different varieties of tiles were collected from the dealers in Ile-Ife based on their type and place of origin. The sample preparation was carried out in Centre for Energy Research and Development (CERD). Each of the samples with a mass of 200 g was weighed into cylindrical polyvinylchloride (PVC) containers, hermetically sealed and kept for 28 days in order to attain secular equilibrium between the parent and the daughter nuclides present.

2.2. *Gamma ray spectroscopic technique*

The activity concentration of natural radioactivity in the selected samples were determined using a 7.62 cm × 7.62 cm NaI (Tl) detector surrounded with adequate lead shielding that reduces the background by a factor of approximately 95%. A counting time of 25,200 s was used. The activities of various radionuclides were determined in Bq kg^{-1} from the count spectra obtained from each of the samples using the gamma ray photo peaks corresponding to energy of 1120.3 keV (^{214}Bi), 911.21 keV (^{228}Ac) and 1460.82 keV (^{40}K) for ^{238}U, ^{232}Th and ^{40}K, respectively. For a counting time of 25,200 s, the detection limits of the NaI (Tl) detector system were calculated as 6.77, 11.40, and 12.85 Bq kg^{-1} for ^{40}K, ^{232}Th, and ^{238}U, respectively.

3. Results and discussion

3.1. *Activity concentrations of ^{238}U, ^{232}Th, and ^{40}K*

The specific activity concentration of ^{232}Th, ^{238}U, and ^{40}K in the samples is presented in Table 1. As can be seen in Table 1, the activity concentration of ^{40}K ranged from 58 to 1768 Bq kg^{-1} while a range of 16 to 43 Bq kg^{-1} and 84 to 168 Bq kg^{-1} were observed for ^{238}U and ^{232}Th, respectively.

Besides the mean values of ^{238}U, the mean values of ^{232}Th and ^{40}K are higher than the worldwide average values of 35, 30, and 400 Bq kg^{-1} for ^{232}Th, ^{238}U, and ^{40}K, respectively [9]. As shown in Table 1, the distribution of the activity concentration in the samples is not uniform; this is likely due to their region of origin and processing composition. The higher activity concentrations found in the studied ceramic tiles may be due to the presence of zircon in the glaze [1,10].

Table 1 – Sample code and the specific activity concentration of the different variety of tiles used in Ile-Ife.

Sample code	Tile Variety	K-40 Bqkg^{-1}	U-238 Bqkg^{-1}	Th-232 Bqkg^{-1}
Ida1	Vitrified	758 ± 5	26 ± 1	168 ± 29
Ida2	Semi vitrified	1768 ± 8	43 ± 1	135 ± 23
Ida3	Colored local	1120 ± 6	22 ± 1	111 ± 21
Ida4	Plain imported	271 ± 3	16 ± 1	84 ± 17
Ida5	Terracotta	1124 ± 6	23 ± 1	150 ± 26
Ida6	Plain local	58 ± 3	16 ± 1	85 ± 19
Ida7	Colored imported	852 ± 5	22 ± 1	163 ± 28
Arithmetic mean		850	24	128

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