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Estimation of Residents Exposure Risks to Radiological Parameters in Some Building Materials in Nigeria

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Abstract. Some of the brands of tiles commonly available in the markets in Nigeria, which are used for building purposes, were analysed in order to estimate the concentration of naturally occurring radionuclides. The analysis was done with the aid of High-Purity Germanium (HPGe) detector. The results revealed that the average activity concentrations in the sample of tiles, cement and sand varied from 41 ± 4 to 96 ± 8.3, 27 ± 9.5 to 76.5 ± 2.5 and 140 ± 7.9 to 940 ± 19.2 Bqkg^{-1} for ^{232}Th, ^{226}Ra and ^{40}K, respectively. The results obtained were used to determine the impact of these building materials on users. The radium equivalent activity (Ra_{eq}) ranged between 125 – 280 Bqkg^{-1} and were observed to be lower than 370 Bqkg^{-1} in all the samples tested, which is the recommended safe limit. Similarly, the absorbed dose rates were noted to vary from 51.00 – 122.52 nGyh^{-1}. However, one of the samples examined showed a result of 122.52 nGyh^{-} for the indoor absorbed dose rate (D_R), which is higher than the internationally recommended safe value of 80 nGyh^{-1}according to USEPA. The results revealed that the building materials investigated do not pose any danger to the end users.

Keywords: HPGe, Radium equivalent, Absorbed dose rate, Safe limit, Building materials.

1. Introduction
In recent times, one of the custodians of naturally occurring radioactive materials, which people are exposed to, is radiation from building materials. The atmospheric condition inside the homes and work places is a major contributor to human exposures to ionising radiation [1]. The most prominent among the naturally occurring radioactive substances commonly found in building materials are the potassium (^{40}K), thorium (^{232}Th) and radium (^{226}Ra). Studies have revealed that the concentrations of these radionuclides vary in different building materials; this affects the concentrations observed when the materials are used for both internal and external purposes [2]. Therefore, adequate knowledge of the levels of ionising radiation that people are exposed to in building materials such as tiles is of high necessity in order to determine their safety [3].

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Further research [4-9] has revealed that the level of exposure of people to these radioactive materials is a function of the degree of concentration of the natural radioactivity present in the building materials. There are two major sources of external radiation that people are exposed to; the first source of external radiation is the terrestrial gamma-rays, which are mainly encountered from the naturally occurring radionuclides listed above [10] [11]. The cosmic rays [12] are the second source of exposure. Righi and Bruzzi [3] agreed that building materials' radioactivity should be regulated. They also uncovered the necessity for improved alpha indexes that take into account common methods and levels of radioactive radiation in construction materials. Ghosh et al. [2] investigated the alpha activity of all commonly used building materials and discovered that ceramic tiles had the highest alpha activity.

Therefore, there is need to carry out regular checks on building materials that are produced locally and those imported for sale in Nigeria markets, in order to determine the concentration of their radioactive content and determine if they are safe for the use of the general public. On this note, the current study was done to evaluate the radioactive content of construction materials in order to predict the rate and potential repercussions of individuals being exposed to such tiles excessively.

2. Materials and Methods

2.1. Collection and Preparation of Samples for Analysis

The samples of building tiles popularly used in most homes in Nigeria were purchased from an international market in Nigeria. The samples were labelled for easy identification and for record purpose. The tiles samples were processed, sieved and packaged for laboratory analysis; the analysis was done using High-Purity Germanium (HPGe) gamma detector as reported in [13-15].

3. Results and Discussion

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

As shown in Figure 1, the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the material of samples of various brands intended for building purposes were not evenly distributed. The activity concentrations of 226Ra ranged from 27 ± 7.5 to 81.5 ± 7.5 Bq kg^{-1}, with Time ceramic tile having the lowest value of 27 ± 7.5 Bq kg^{-1} and Virony ceramic tile having the highest value of 81.5 ± 7.5 Bq kg^{-1}. The activity concentrations of ^{232}Th range from 41.5 ± 8.5 to 96 ± 8.3 Bq kg^{-1}, with the maximum value of 96 ± 8.3 Bqkg^{-1} being found in Virony ceramic tile and a lower value of 41.5 ± 8.5 Bqkg^{-1} being found in Virony ceramics. The activity concentration of ^{40}K in the samples ranges from 240 ± 9.5 to 940 ± 19.2 Bqkg^{-1}, with PNT ceramic tiles having the greatest value of 940 ± 19.2 Bqkg^{-1} and Royal ceramic tiles having the lowest value of 240 ± 9.5 Bqkg^{-1}.

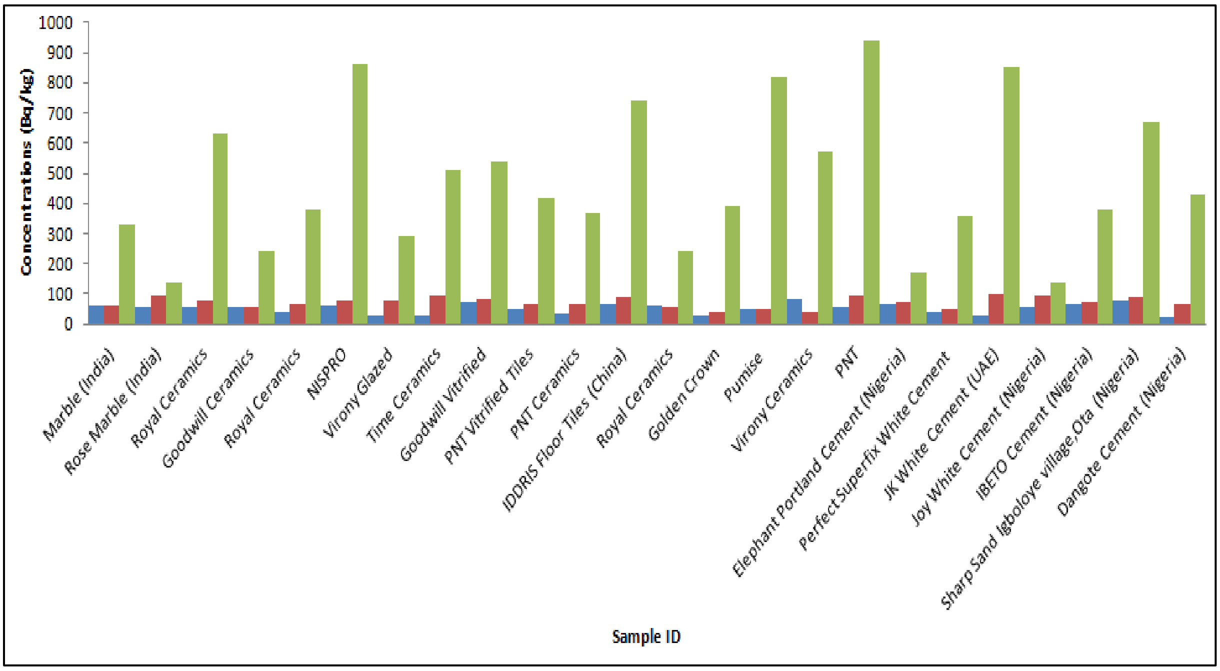

Figure 1: Activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K with each represented by colours blue, brown and green, respectively

3.2. Evaluation of Parameters

3.2.1. Radium equivalent activity (Ra_{eq})

To compare the activity of each of the ^{226}Ra, ^{232}Th, and ^{40}K contents in the construction materials with the prescribed standard, the Ra_{eq} activity of the measured radionuclides is employed. Equation (1) can be used to calculate the radium equivalent activity:

$$Raeq = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (1)$$

The particular activity of ^{226}Ra, ^{232}Th, and ^{40}K, measured in Bq kg^{-1}, are C_{Ra}, C_{Th}, and C_K, respectively. The weighted total of the separate activities of ^{226}Ra, ^{232}Th, and ^{40}K is defined as this radium equivalent activity. Ra_{eq} in building materials should have a maximum value of less than 370 Bq kg^{-1}, according to [16]. In [16] [17] this is equivalent to 1.5 mGryy-1. In this study, the values of radium equivalent activity estimated ranged between 115.66 and 273.9 Bqkg^{-1} with the maximum value of 273.9 Bq kg^{-1} observed in Perfect Superfix White Cement whereas the minimum value of 115.66 Bqkg^{-1} was noted in Royal Ceramic tile as shown in Figure 2. It can be seen that none of the results of Ra_{eq} in all the measured samples of building materials exceeded the recommended limit of 370 Bq kg^{-1} by [18]

3.2.2. Absorbed dose rate (D_R)

Equation (2) [19] [18] is used to compute the amount of air absorbed dose rate received in an open air environment 1 m above the ground due to gamma radiation from radionuclides ^{226}Ra, ^{232}Th, and ^{40}K in Bq kg^{-1} accessible in the environment.

$$D_R = 0.462\ C_{Ra} + 0.604C_{Th} + 0.0417C_K < 80nGyh\text{-}1 \quad (2)$$

Virony ceramic tiles had the greatest value of 122.52 nGyh^{-1}, while Royal ceramic tiles had the lowest value of 53.50 nGyh^{-1}, as shown in Figure 2. When the maximum value obtained in this investigation is compared to the standard value of 80 nGyh^{-1} advised by [18], the greatest value obtained in this study is 1.5 times more than the recommended safe limit.

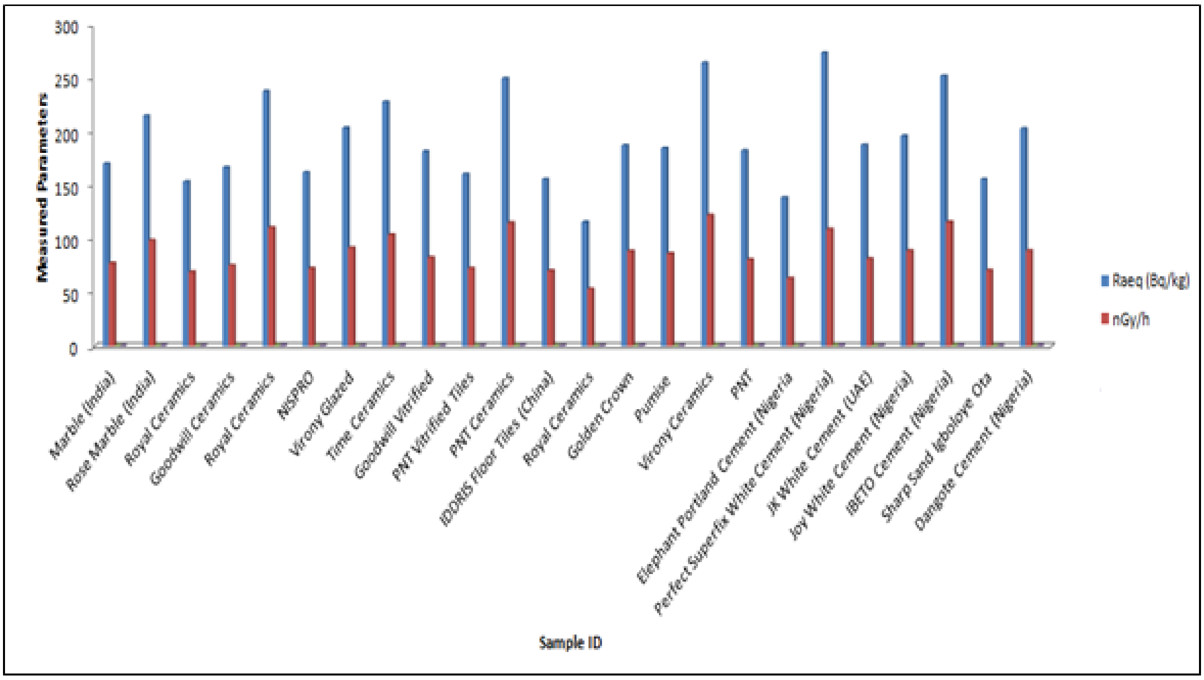

Figure 2. Radium equivalent activity and absorbed dose rate

4. Conclusion

The mean activity concentrations of naturally occurring radionuclides in assessed construction materials were 51.5 ± 9.3, 72.46 ± 17.65, and 217.05 ± 44.31 Bq kg^{-1}, respectively, in this investigation. The radium equivalent is less than the 370 Bq kg^{-1} acceptable value. With the exception of Virony ceramic tiles, the observed absorbed dose rate in the samples was determined to be less than the suggested safe limit of 80 nGy/h. Building materials like Virony ceramic tiles, on the other hand, have considerable values that can expose inhabitants to radioactive dangers, but the values are still less than 1 mSv per year. Finally, the materials examined meet the estimated parameters indicated in relevant national and international building material policies.

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