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EVALUATION OF RADIOACTIVITY FROM COMMERCIAL CONSTRUCTION MATERIALS AND ITS RADON EXHALATION IMPLICATIONS ON RESIDENTS

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ABSTRACT

The activity concentrations obtained from the measured samples were used to estimate the radiological risks of radium equivalent activity (Raeq) in the construction substance. The activity concentrations of few samples were found to exceed the international recommended points. But, the largest radium equivalent activity (Raeq) acquired from this research is less than the peak dose limit of one as stipulated by global recommendation. The correlation coefficient between the dose rate and Ra_{eq} *activity indicated positive, revealing that increase in Raeq, enhances the dose exposure to the dwellers. Chi-square plot of* Ra_{eq} *activity against the samples revealed that royal ceramic tiles could be the most stable, having their raw materials (geologic material) components in equal and balanced proportions. It may also indicate that Royal ceramics has relationship with all other samples (as per composition). The whiskers indicate upper and lower quartiles, so the box spans the interquartile range. Qi = 115.66, median = 153.5, Q3 = 238, IQ = 122.34, whiskers = 115.66, 238*

Key words: Gamma Spectroscopy, Construction materials, Radium Equivalent.

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1. INTRODUCTION

The world we live in is intrinsic radioactive in nature. Several radionuclides exist in rocks, soils and in construction materials. As time evolves, the residents remain the primary victims of radionuclides menace (external radiation field) specifically when their undergoing natural or artificial disintegration. In recent time, the menace of the nuclides have been observed as germane contributor to the annual average doses of radiation exposure of the global inhabitants [1]. External exposure to environmental gamma sources is an important leeway of exposure for the people [2]. The external exposure is known as a by-product of emitted photons that occur during radioactive disintegration of nuclides in the ^{238}U, ^{232}Th and ^{40}K [1]. Various construction materials are used for inner and outer beautification and building reasons. Unlike Timber-based construction materials, which have low concentrations of natural radioactive substances, stone-based construction materials have concentrations which depend on the constituents (Kovler, 2007). All types of parent rocks used as aggregate, bulk materials or transformed into beautification specimens contain naturally occurring radioactive materials (NORMs), in the form of U- and Th-decay chain nuclides and 40K, characterized by half-lives (from ms to thousands of years), decay modes (α, β, γ, EC), decay energies (from a few keV to several MeV). Thus, the use of beautification substance as construction materials in a home and office may expose the inhabitants to a higher dosage of radiation due to their long hours of staying in either home or at office. Outer exposure is caused by gamma-rays from radionuclides 40K and ^{226}Ra (^{238}U) and ^{232}Th decay series, while the internal exposure is mainly caused by alpha-particles due to inhalation of radioactive inert gases radon and their short-lived products which are deposited on the respiratory tract tissues [1]. Generally, organic radon radiation has observed as a killing factor in the tumor of lung [1, 3]. Exhalation phenomenon is known to have associative relationship among the radon isotopes decay series such as ^{222}Rn and ^{220}Rn and ^{226}Ra and ^{232}Th. These radon isotopes are sourced from pores of grains which might later move from production source into construction materials and later evaporate to the atmosphere [4]. The uses of ceramics tiles is overwhelming specifically in Nigeria where construction materials are adopted for interior beautification. Interestingly, the replacement of concrete floor and flexy tiles with ceramic floor specifically in the home and offices is on increase. The ceramic tile is made up of kaoline, plasticity clay, feldspar, quartz, gellibackite, steatite. Thus, it scientifically and technologically correct to subject importance ceramic raw materials to series of processes such as grinding, moulding and calcination at elevated temperature to have a well fabricated ceramic tiles.

The purpose of this present study is to establish radiation exposure baseline confidential data from naturally occurring radionuclides in selected construction substances vended in Nigeria and to assess the potential radiological risks to enhance the setting established standards.

2. METHODOLOGY

2.1. Collection of Specimen and preparation for Gamma Examination

2.1.2. Specimen Preparation and Gamma Ray Examination

In the study, the construction materials such as marbles, cements and ceramic tiles that were foreign and indigenous made (Nigeria) were purchased from several building material sellers. These tiles were further, examined in accordance with international atomic energy agency TRS-295 (IAEA, 1989) standard. For secular equilibrium to make manifest, the tiles were left in an enclosure for the time frame of four weeks. Thereafter, the inspection of the tiles were carried out in the Activation Laboratory System Canada, through High-Resolution

Germanium detector, Canberra Lynx™ Digital Signal Analyzer (DSA), a 32 K channel integrated signal analyzer and a top-opening lead shield (4” lead, copper/tin liner). To avert the surrounding radiation counts with efficiency of 50 % and resolution of 2.1 keV at 1.33 MeV gamma energy of ^{60}Co. The Genie-2K V3.2 software positions and analyzes the peaks, minuses surrounding, indicates the nuclides. In addition, the self-absorption and the attenuation implication of the emitted gamma photons were fully addressed. CAMET and IAEA standards (DL-1a, UTS-2, UTS-4, IAEA-372 and IAEA-447) were used for judging the effectiveness of the calibrated devices. The activity levels of the specimens were counted for 86,400 seconds with the surrounding counts deducted from the left-over count. A confidence level of 95 % was applied to examine the least detectable activity of the detector [6]. Further, the gamma courting emission probability and efficiency calibration standard of the system were used to estimate the uncertainty errors of the system. In spite of low self-attenuation that is associated with resolution of radium (1764 keV) at elevated energy, this study has adopted the protégés of radium (^{214}Bi and ^{214}Pb) 609 keV, 934 keV, 2204 keV, 1764 keV and 351 keV, 295 keV gamma lines. Therefore, with the property of ^{232}Th to remain undetected an estimated activity through its daughters ^{208}Tl and ^{228}Act alongside with 2614.53 keV, (35.63%) 583keV (30.3%) and 911 keV, 338 keV, 463 keV. The gamma line of 1461 keV (10.7%) was adopted to proffer solution to ^{40}K. The activity concentration was calculated using [7, 8].

3. RESULTS AND DISCUSSION

3.1. Activity concentrations of ^{238}U, ^{232}Th and ^{40}K Measured in Building Material Specimens

This study noticed discrepancies in the points of activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K of the various tiles examined specifically in the Figures 1, 2 and 3. The activity concentrations of ^{226}Ra ranges from 25.5 ± 7.5 to 81.5 ± 7.5 Bqkg^{-1} with the least point of 27 ± 7.5 Bqkg^{-1} as validated in the dimensionality of Time ceramic tile of 40 × 40, mean while the higher point of 81.5 ± 7.5 Bqkg^{-1} was recored in virony ceramic tile of size 60 × 60 mm. Second, the activity concentrations of ^{232}Th, ranges from 41.5 ± 8.5 to 101 ± 8 Bqkg^{-1} with the peak point of 101 ± 8 Bqkg^{-1} observed in JK White Cement (UAE) whereas a least point of 41.50 ± 8.50 Bqkg^{-1} noted in Golden Crown . Third, the activity concentration of ^{40}K recorded in the tiles is in the limit of 240.0 ± 9.50 Bqkg^{-1} to 940.0 ± 19.20 Bqkg^{-1} with the maximum point of 940.0 ± 19.20 Bqkg^{-1} recorded in PNT ceramic tiles while the least point of 240.0 ± 9.50 Bqkg^{-1} in the scale of 40 × 40 mm was noted in royal ceramic tiles. Significantly, the activity concentration of the two chosen marbles for this work range from 56.50 ± 4.80 Bqkg^{-1} to 60.0 ± 3.50 Bqkg^{-1} , 59.50 ± 4.50 Bqkg^{-1} to 95.50 ± 6.50 Bqkg^{-1} and 140.0 ± 15.20 Bqkg^{-1} to 330.0 ± 10.50 Bqkg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K. This study showed that Rose marble (India) ceramics of size, 60 × 30 mm has the peak point of ^{226}Ra, while the least point was noted in Mable imported from India specifically of dimension 60 × 30. In addition, a peak point of ^{232}Th was harvested from imported Rose marble (India) ceramics of size, 60 × 30 and a least point was recorded in Mable India of size 60 x 30. Further, a huge amount of ^{40}K was noted in the foreign Marble from India with the dimension of 60 × 30, meanwhile the least point was noted in Rose Marble from India of dimension 60 × 30 This study also, recorded the radionuclides activity concentrations of ^{238}U, ^{232}Th and ^{40}K as 25.0 ± 7.50 Bqkg^{-1} to 65.50 ± 7.50 Bqkg^{-1} for 238U. Ibeto cement was noted to have the maximum point of 65.50 ± 7.50 Bqkg^{-1} while Dangote product (cement) has the least point of 25.0 ± 7.50 Bqkg^{-1}. The activity level of ^{232}Th in the indigenous Elephant Portland cement was found with maximum point of 51.0 ± 9.60 Bqkg^{-1} to 73.00 ± 4.10 Bqkg^{-1} , while Indigenous Superfix white cement had the least point. Interestingly, the activity concentrations for ^{40}K was observed within the limit of 170.0 ± 8.20 $Bqkg^{-1}$ to 850.0 ± 15.40 $Bqkg^{-1}$ and a maximum point of 850.0 ± 15.40 $Bqkg^{-1}$ was not in the imported JK White cement meanwhile, an indigenous Elephant Portland cement portrayed the least activity point of 170.0 ± 8.2.0 $Bqkg^{-1}$. Radioactivity concentrations were noted in the Sharp sand aggregated from Igboloye community in Ota, Ogun state as 76.50 ± 1.50 $Bqkg^{-1}$, 87.0 ± 8.50 $Bqkg^{-1}$ and 670.0 ± 13.60 $Bqkg^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K.

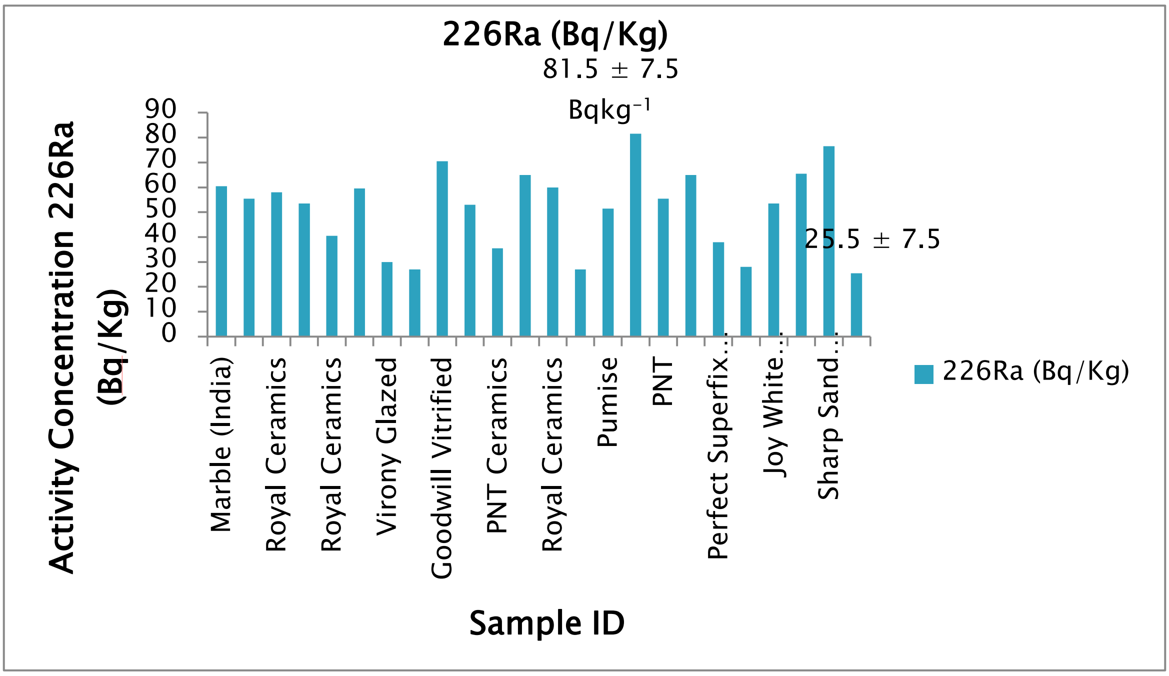

Figure 1 Activity Concentration of ^{226}Ra against the Specimen ID

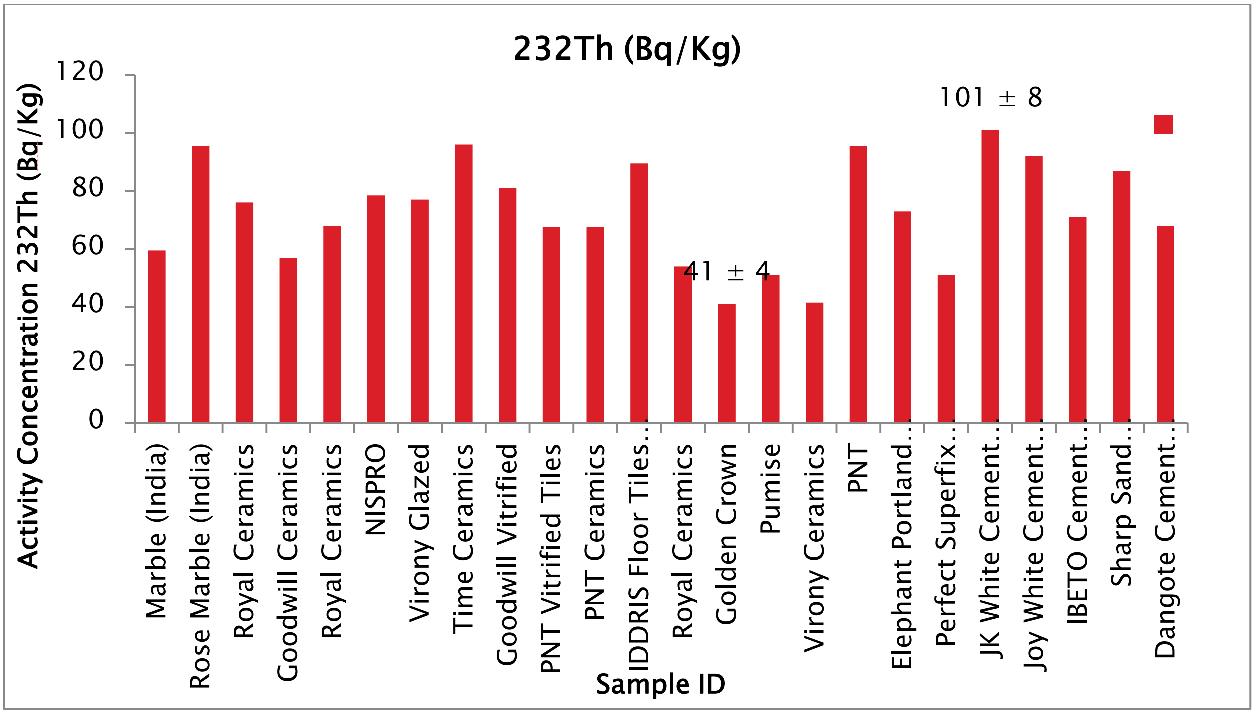

Figure 2 Activity Concentration of ^{232}Th against the Specimen ID

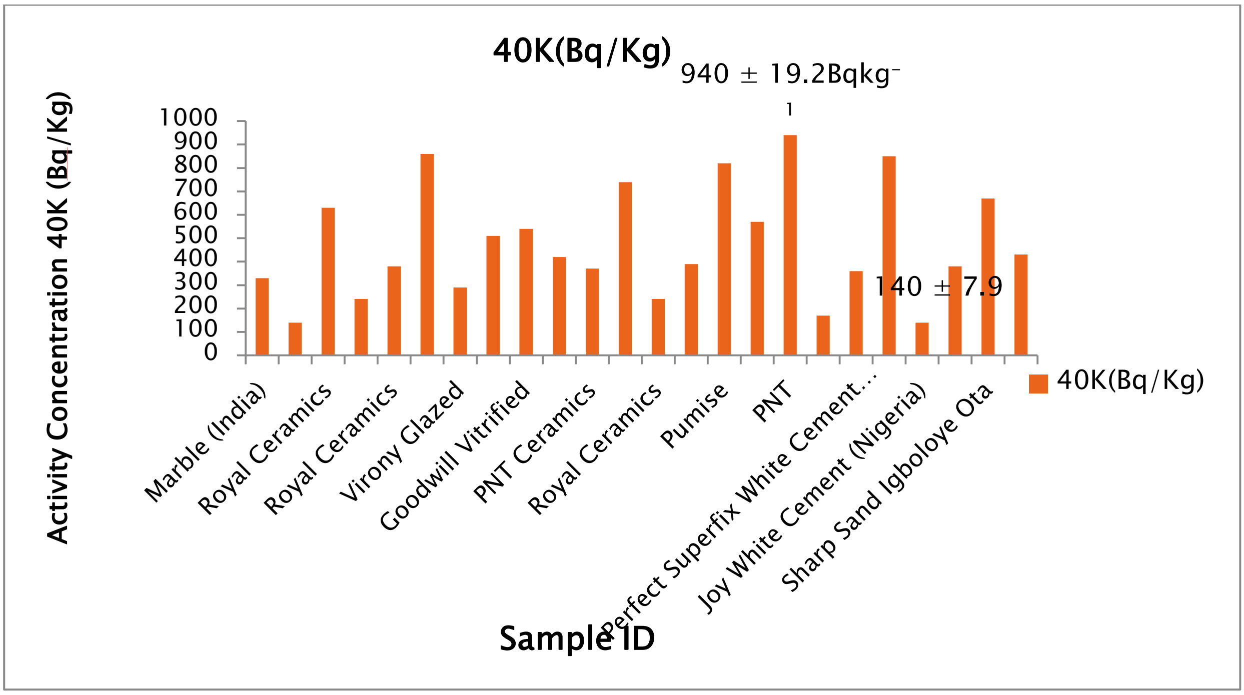

Figure 3 Activity Concentration of ^{40}K against the Specimen ID

3.1. Global Outlook of Activity Concentrations of ^{226}Ra, ^{232}Th and ^{40}K on Chosen Specimens

The statistical study of the recorded activity concentrations in the construction materials in the context of this study and previous studies are depicted in Figures 4, 5 and 6. Therefore, the activity concentration in tiles and marbles are nearer to a previous work in Nigeria and other country's reports for ^{226}Ra, ^{232}Th and ^{40}K radionuclides such as the points reported by [9] and for [10]. Figures below except for ^{226}Ra with the peak point of 81.50 ± 7.50 Bqkg^{-1} observed in virony ceramics tiles, peak point of 96.0 ± 8.30 Bqkg^{-1} of ^{232}Th noted in virony ceramic tile of size 60 × 60 mm and the peak point of 940.0 ± 19.20 Bqkg^{-1} for ^{40}K recorded in PNT ceramic tiles. Figure 6 shows the comparing between the peak point of ^{40}K in Tiles and Marble specimens obtained in this study with the previous studies which has shown a significant point twice higher than the reference points

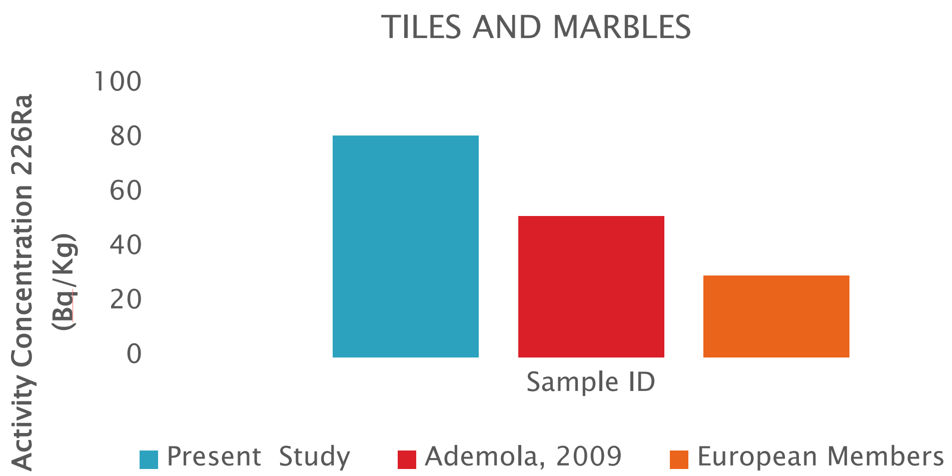

Figure 4 Comparing the Peak point of Ra-226 in Tiles and Marble specimens with the Previous Studies

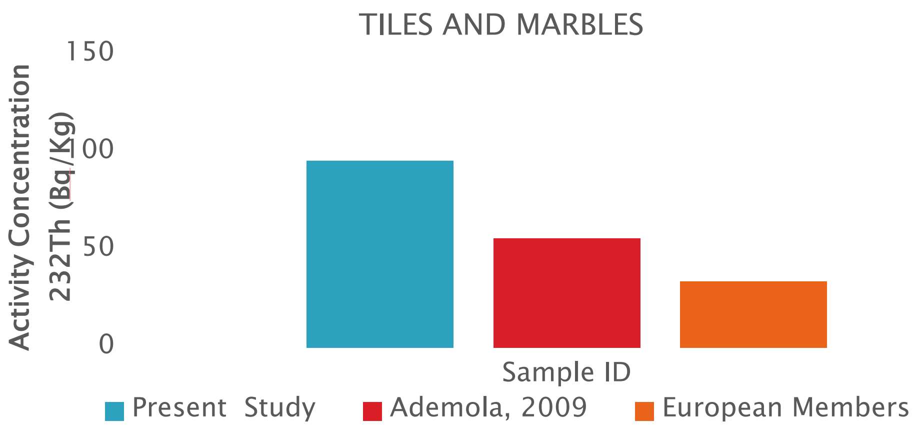

Figure 5 Comparing the Peak point of Th-232 in Tiles and Marble Samples with the Previous Studies

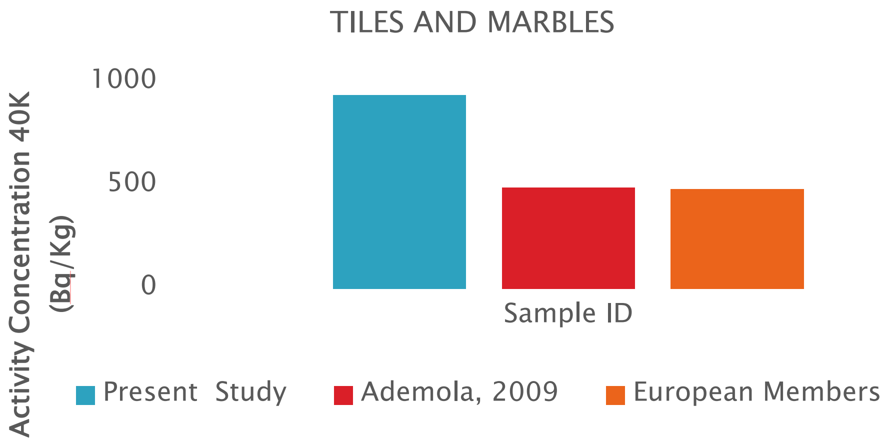

Figure 6 Comparing the Peak Point of K-40 in Tiles and Marble Specimens with the Previous Studies

Comparing the cements under this study with other points obtained in other countries as presented in Figures 7,8 and 9 respectively, it can be observed that they are in good agreements and within the range except for ^{226}Ra in Ibeto Cement with the peak point of 65.5 ± 7.5 Bqkg^{-1}, 73.0 ± 4.1 Bqkg^{-1} point of ^{232}Th reported in Elephant Portland cement (Nigeria) and 850 ± 15.4 Bqkg^{-1} of ^{40}K observed in JK White cement (UAE).

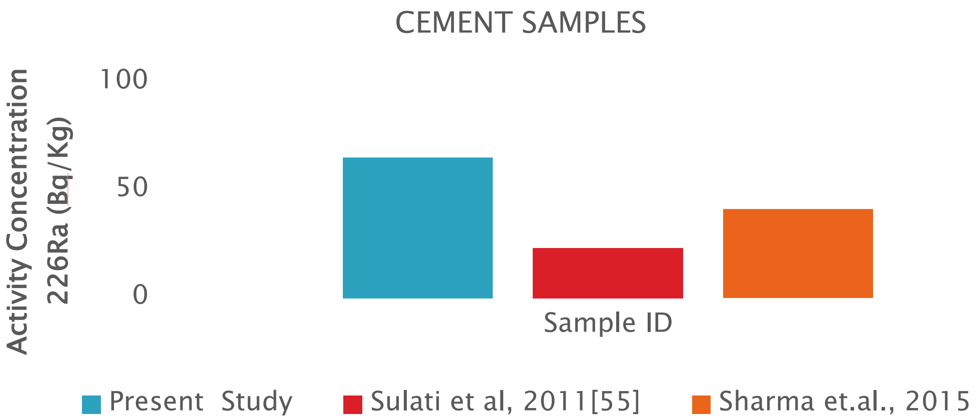

Figure 7 Comparing the Peak Points of Ra-226 in Cement Specimens with the Previous Studies

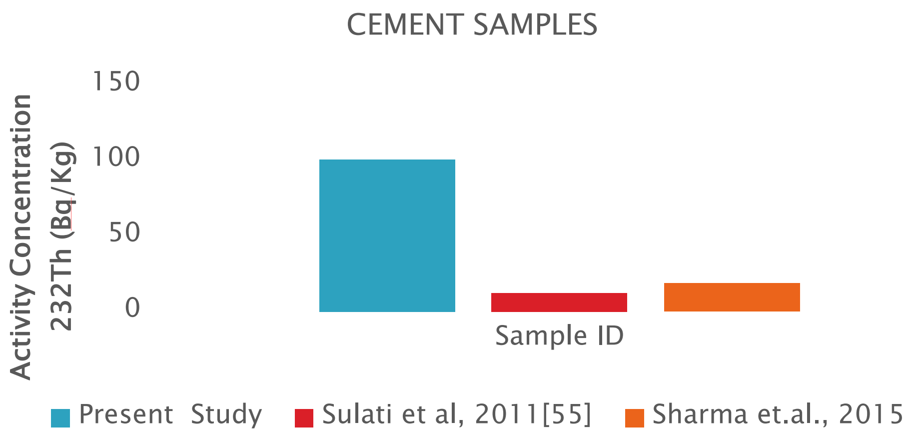

Figure 8 Comparing the Peak Point of Th-232 in Cement Specimens with the Previous Studies

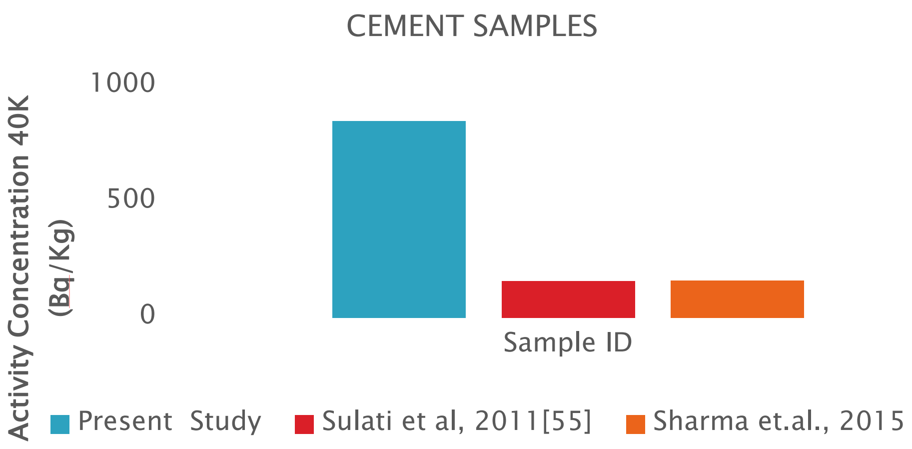

Figure 9 Comparing the Peak Point of K-40 in Cement Specimens with the Previous Studies

Values noted in the sand specimen examined are less than some points of ^{226}Ra, ^{232}Th and ^{40}K radionuclides obtained in other studies except 76.5± 1.5 Bqkg^{-1} for ^{226}Ra, 87 ± 8.5 Bqkg^{-1} for ^{232}Th and 670 ± 13.6 Bqkg^{-1} for ^{40}K . Specifically with two points far higher by factors of 1.18 and 1.50 respectively for sands obtained from China and South Korea as shown in Figures 10, 11 and 12 respectively.

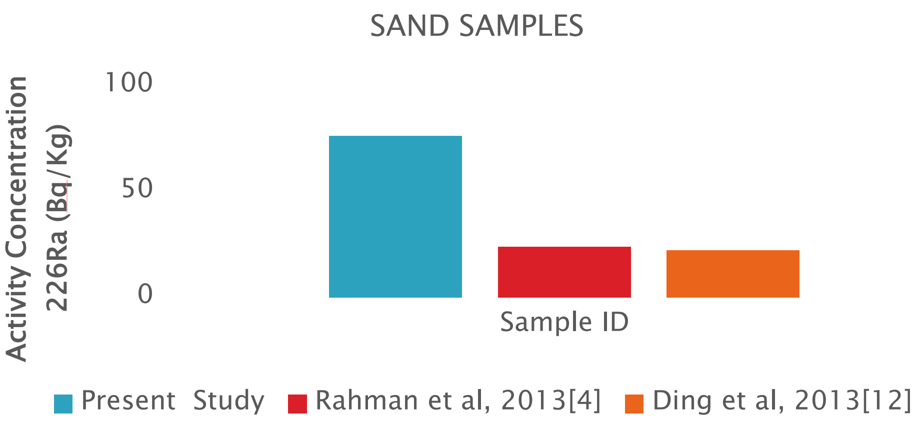

Figure 10 Comparing the Peak Point of Ra-226 in Sand Specimens with the Previous Studies

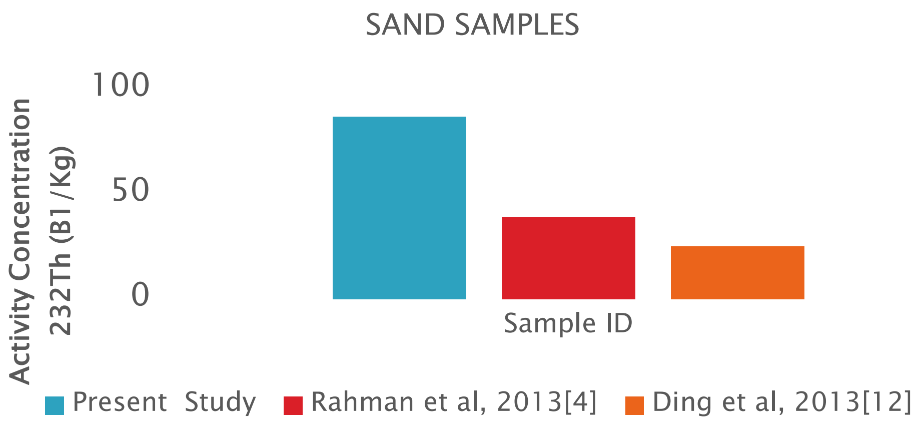

Figure 11 Comparing the Peak Point of Th-232 in Sand Specimens with the Previous Studies

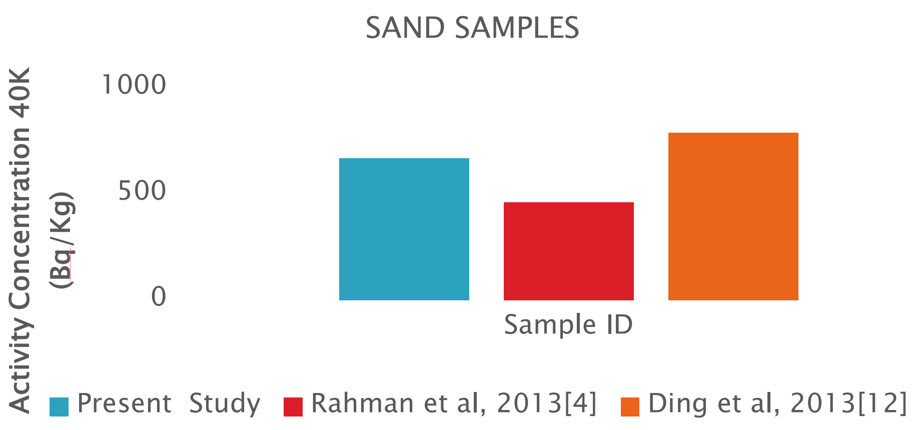

Figure 12 Comparing the Peak Point of K-40 in Sand Specimens with the Previous Study

4. LEVEL OF RADIUM EQUIVALENT ACTIVITY IN THE CONSTRUCTION MATERIALS

The presence of uneven distribution of radionuclides from ^{226}Ra, ^{232}Th and ^{40}K was noted in the selected construction materials. The importance of Ra_{eq} activity of the measured radionuclides is employed to fit the activity of each ^{226}Ra, ^{232}Th and ^{40}K content on the construction materials. This Ra_{eq} that is measured in Bqkg^{-1} was found from Equation 1[13, 14]

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

where $C_{Ra}$is the specific activity for ^{226}Ra, C_{Th} is the specific activity for ^{232}Th and C_K is the specific activity for ^{40}K in the unit of BqKg^{-1} [13, 14]. This radium equivalent activity defines the weighted sum of the individual activities of ^{226}Ra, ^{232}Th and 40K with the idea that for ^{226}Ra is 10.0 Bqkg^{-1}, ^{232}Th is for 7.0 Bqkg^{-1} and 130.0 Bq$kg^{-1}$is for ^{40}K produce the same outer and inner gamma dose rate [13,14]. The peak point of Ra_{eq} in construction materials is less than 370 Bqkg^{-1} as recommended by [15]. This amount is equivalent to 1.5mGry^{-1} (Krisiuk et al., 1971, Krieger, 1981) [16,17]. The radium equivalent activity points obtained from this present study varies from 115.66 to 273.9 BqKg^{-1} with the peak points of 273.9 BqKg^{-1} reported in Perfect Superfix White Cement (Nigeria) whereas the lowest point of 115.66 BqKg^{-1} was noted in Royal Ceramics tile. Figure 13 indicates the Chi-square plot of Ra_{eq} activity against the specimens ID. It was plotted to determine the relationship between the proportions of geologic materials used in the production of the specimens under study. It revealed that royal ceramic tiles could be the most stable, having their geologic material components in equal and balanced proportions. It may also indicate that Royal ceramics has relationship with all other specimens (as per composition). The whiskers indicate upper and lower quartiles, so the box spans the interquartile range. Qi = 115.66, median = 153.5, Q3 = 238, IQ = 122.34, whiskers = 115.66, 238. This could help in purchasing a material with a stable feature with low radioactive exposure.

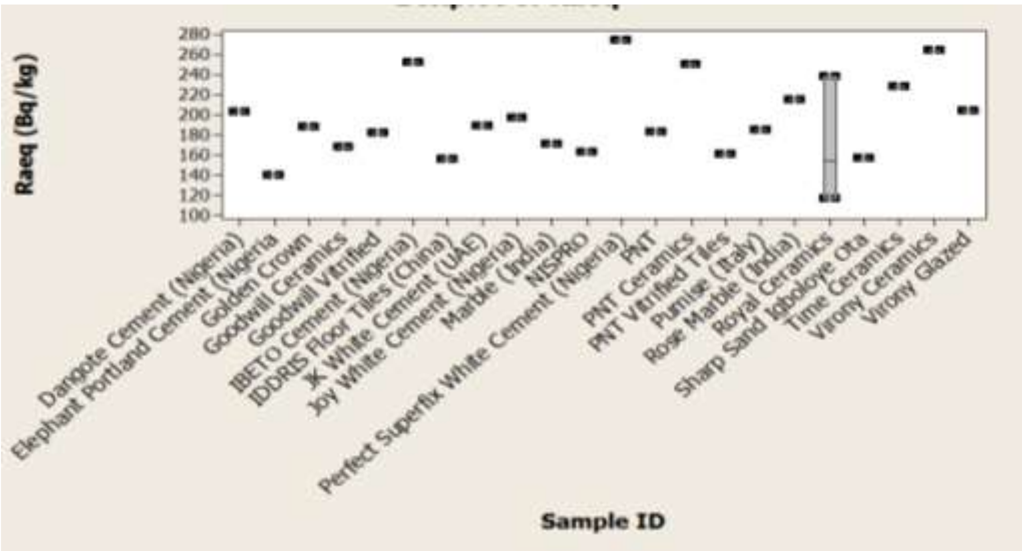

Figure 13 The Chi-Square test of Raeq plot against Sample ID

5. CONCLUSIONS

In this present study, the radium equivalent is lower than the recommended point of 300 $Bqkg^{-1}$. The materials analyzed comply with the estimated parameter of radium equivalent outlined in relevant national and international legislation and guidance. The specimens in this present study do not affect the practices of Nigerian builders but the way is open for legislation restricting according to European Commission guidance for the use of construction materials.

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REFERENCES

[1] United Nations Scientific Committee on the effect of Atomic Radiation (UNSCEAR) (2000), Report to the General Assembly. Annex B: Exposure from Natural Radiation Sources.

[2] Saito, K., Petoussi, N., Zankl, M., (1998). Calculation of the effect dose and its variation from environmental gamma ray sources. Health Phys. 74 (6), 698–706.

[3] World Health Organization. (2009). *WHO handbook on indoor radon: a public health perspective*. World Health Organization.

[4] Hassan N.M., et al (2010) Assessment of the natural radioactivity using two techniques for the measurement of radionuclide concentration in construction materials used in Japan, J. Radioanal. Nucl. Chem.283, 15-21.

[5] IAEA (International Atomic Energy Agency) (1989). Measurement of radionuclides in food and environmental samples. IAEA Technical Report Series 295.IAEA, 1989

[6] Currie LA. (1968) Limits for qualitative detection and quantitative determination. Application to radiochemistry. Anal. Chem.;40(3):586-93.

[7] Debertin, k. and Helmer, R.G. (1998), Gamma- and X-Ray spectrometry with semi conductor detectors, Elsevier science publishers, 1988.

[8] Davisson, Charlotte Meaker and Evans, Robley D. (1952), Gamma- Ray Absorption Coefficients Rev. Mod. Phys. 24 (2):79.

[9] Ademola J.A. (2009), Natural Radioactivity and Hazard Assessment of imported Ceramic Tiles in Nigeria *Afr. J. Biomed res Vol. 12,No.3,2009*

[10] EC (European commission). (1999) Radiological protection principles concerning the natural radioactivity of construction materials. Radiation Protection 112, Directorate-General: Environment. Nuclear Safety and Civil Protection, 1999.

[11] Rahman S.U., e t al (2013), Rafique M, Jabbar A, Matiullah. Radiological Hazards due to naturally occurring radionuclides in the selected building materials used for the construction of dwellings in four districts of the Punjab province, Pakistan. Radiat prot Dosim. 2013:153(3):352-360

[12] Ding, X., Lu, X., Zhao, C., Yang, G., & Li, N. (2013, 01). Measurement of natural radioactivity in building materials used in Urumqi, China. *Radiation Protection Dosimetry, 155*(3), 374-379. doi:10.1093/rpd/nct002

[13] Anjos, R. M., Ayub, J. J. Cid, A. S.,Cardoso, R. and Lacerda, T. (2011). External gamma-ray dose rate and radon concentration in indoor environments covered with Brazilian granites. *Journal of Environmental Radioactivit*y, 102, (2011), 1055-1061.

[14] Asaduzzaman, Kh, Khandaker, M. U., Amin, Y. M. and Bradley. (2014). Natural radioactivity levels and radiological assessment of decorative building materials in Bangladesh. *Indoor and Built Environment*, 25(3), 541-550.

[15] UNSCEAR (1988) Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the effects of Atomic Radiation, United Nations, New York.

[16] Krisiuk, E.M., Tarasov, S. I., Shamov, V. P, Shalak, N. I., Lisachenko, E.P., Gomeisky, L.G. (1971). A study of Radioactivity in Building Materials Research Institute for Radiation, Hygiene Leningrad.

[17] Krieger R. (1981), Maduar M. F., Hiromoto G. (2004), Radioactivity of construction materials. Betonwerk Fertigteli techn 47, 468.

[18] Beck, H.I., Decombo, J., Gologak, J., 1972 in situ Ge(Li) and Nai (TI) gamma ray spectrometry. Report HASI285.Heaslth and safety laboratory AEC, New York.