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Assessment of natural radionuclides and its radiological hazards from tiles made in Nigeria

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ABSTRACT

Activity concentration of 10 different brands of tiles made in Nigeria were analyzed using High purity Germanium gamma detector and its hazard indices such as absorbed dose rate, radium equivalent activity, external Hazard Index (Hex), internal Hazard Index (Hin), Annual Effective Dose (mSv/y), Gamma activity Index (Iγ) and Alpha Index (Iα) were determined. The result showed that the average activity concentrations of radionuclides (^{226}Ra, ^{232}Th and ^{40}K) content are within the recommended limit. The average radium equivalent is within the recommended limit of 370 Bq/kg. The result obtained further showed that the mean values for the absorbed dose rate (D), external and internal hazard index, the annual effective dose (AEDR) equivalent, gamma activity index and Alpha Index were: 169.22 nGyh^{-1}, 0.95 and 1.14, 1.59 mSv/y, 1.00 Sv yr^{-1} and 0.34 respectively. The result established that radiological hazards such as absorbed dose rate, internal hazard, annual effective dose rate, gamma activity index and Alpha Index for some samples are found to be slightly close or above international recommended values. The result for the present study was compared with tiles sample from others countries, it was observed that the concentration of tiles made in Nigeria and other countries are closer, however recommends proper radiation monitoring for some tiles made in Nigeria before usage due to the long term health effect.

1. Introduction

The exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth. For most individuals, this exposure exceeds that from all man-made sources combined. There are two main contributors to natural radiation exposures: high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides that originated in the earth's crust and are present everywhere in the environment, including the human body itself (UNSCEAR, 2000). Many exposures to natural radiation sources are modified by human practices. In particular, natural radionuclides are released to the environment in mineral processing and uses, such as phosphate fertilizer production and use and fossil fuel combustion, causing enhanced natural radiation exposures (UNSCEAR, 2000). Natural radioactivity in soils comes from ^{238}U and ^{232}Th series and natural ^{40}K. Uranium occurs in minerals such as pitchblende, uraninite, etc. It is also found in phosphate rock, lignite and monazite sands. Radon is formed from the decay of radium. The interested radionuclides in the research about environmental radioactivity are ^{226}Ra, ^{232}Th and ^{40}K (Ademola and Farai, 2006), among which ^{226}Ra is a radionuclide in the ^{238}U series and ^{232}Th is the first member in the ^{232}Th series. The natural radionuclides in building materials are responsible for the external and internal radiation exposures of individuals living in dwellings (Ali et al., 1996; Faheem et al., 2008; Ghosh et al., 2008; Turhan et al., 2008; Damla et al., 2011). Since the natural radionuclides are not uniformly distributed, the knowledge of the natural radioactivity in building materials is important for the determination of population exposure to radiation, as most of the residents spent 80–90% of their life time indoors (Lu, 2005; Lu and Zhang, 2008; Ghosh et al., 2008). Building materials are derived from both natural sources (e.g. rock and soil) and waste products (e.g. phosphogypsum, alum shale, coal flyash, oil shale ash, etc) and also from industry by-products (e.g. power plants, phosphate fertilizer and oil industry) (Baykara et al., 2011). The concentrations of ^{226}Ra, ^{232}Th and ^{40}K in building materials such as tiles vary depending on the local geological and geographical conditions as well as geochemical characteristics of those materials

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Table 1
Tiles of different types produced in Nigeria.

Sample name	Country	Sample size (mm)
BN Ceramics	Nigeria	60 × 60
PNT Ceramics	Nigeria	30 × 30
Golden Crown Ceramics	Nigeria	25 × 30
Royal Ceramics	Nigeria	40 × 40
Royal Crown	Nigeria	30 × 30
Goodwill Super Polish	Nigeria	60 × 60
NISPRO	Nigeria	40 × 40
Goodwill Vitrified	Nigeria	40 × 40
PNT Vitrified	Nigeria	25 × 40
Golden Crown	Nigeria	30 × 30

(Iqbal et al., 2000; Ghosh et al., 2008; Turhan et al., 2008). Therefore, it is important to measure the concentration of radionuclides in all the tiles used for building that was made in Nigeria and to estimate the radiological hazards to human health.

2. Materials and methods

2.1. Preparation of samples

10 samples of various tiles which were produced in Nigeria were used for this study. These tiles were purchased from Nigerian commercial market. This is shown in Table 1 with their sample names and ID (size). Initial labeling and cataloguing was done for easy identification. The tiles were broken into smaller pieces so as to allow further processing. All the samples were crushed using the Pascall Engineering Lab milling machine to pulverizable size. After each tile sample was crushed, the crusher or lab milling machine was thoroughly cleaned with high pressure blower (Wolf from Kango Wolf power tools, made in London, type 8793 and serial no: 978A) before the next sample was crushed. This whole process was repeated until all the samples were completely crushed into powder. The pulverizer used is the disk 'grinder/pulverizer' by Christy & Norris Limited. After each pulverizing process, the machine was cleaned properly and blown with high pressure blower to avoid cross contamination of the samples. A very fine power was achieved from the pulverized samples, but for homogeneity, a 250 µm sieve size was used and 1 kg of the sieved sample was weighed out. It was then placed in polythene nylon and labeled accordingly. High density polyethylene bottles (HDPB) were used to package the samples for radioactivity study. The bottles were washed with water and detergent and then rinsed six times with ordinary borehole water before finally rinsing with distilled water. The sieved samples of tiles that were contained in each bottle weighed 200 g.

2.2. Gamma spectrometric analysis of the selected samples

The tiles produced in Nigeria of different brands was purchased from different suppliers, were prepared according to IAEA TRS-295 (IAEA, 1989). The samples were put in a plastic beaker container sealed for four (4) weeks secular equilibrium. Analysis of the samples were conducted in Canada (Activation Laboratory System) using High Purity 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 prevent high background counts with 50% relative efficiency and resolution of 2.1 keV at 1.33 MeV gamma energy of ^{60}Co. The Genie-2K V3.2 software locates and analyzes the peaks, subtracts background, identifies the nuclides. The efficiency curves for this analysis were corrected for the attenuation and self-absorption effects of the emitted gamma photons. CAMET and IAEA standards (DL-1a, UTS-2, UTS-4, IAEA-372 and IAEA-447) were used for checking the efficiency calibration of the system. For the activity measurements, the samples were counted for 86,400 s with the background counts subtracted from the net count. The minimum detectable activity of the detector was determined with a confidence level of 95%. The uncertainty errors were estimated keeping into account the associated errors from gamma courting emission probability and efficiency calibration standard of the system. The progeny of radium, ^{214}Bi and ^{214}Pb emits gamma line 609 keV, 934 keV, 2204 keV, 1764 keV and 351 keV, 295 keV were used but the resolution of radium was from the emission of 1764 keV since it has low self-attenuation effect at high energy. Since ^{232}Th cannot be directly detected, the estimated activity via its progeny ^{208}Tl and ^{228}Act using 2614.53 keV, (35.63%) 583 keV (30.3%) and 911 keV, 338 keV, 463 keV. The gamma line of 1461 keV (10.7%) was used to resolve ^{40}K.

Table 2
Radioactivity concentration in tiles made in Nigeria in (Bq/kg).

Sample name	Sample size	Activity concentration (Bq/kg)		
		^{226}Ra	^{232}Th	^{40}K
BN Ceramics	60 × 60	37.5	101.5	670.0
PNT Ceramics	30 × 30	241.0	77.5	510.0
Golden Crown Ceramics	25 × 30	49.5	57.5	460.0
Royal Ceramics	40 × 40	65.5	44.0	390.0
Royal Crown	30 × 30	51.5	41.0	440.0
Goodwill Super Polish	60 × 60	44.0	51.5	270.0
NISPRO	40 × 40	59.5	461.0	860.0
Goodwill Vitrified	40 × 40	70.5	445.5	540.0
PNT Vitrified	25 × 40	35.5	346.5	370.0
Golden Crown	30 × 30	27.0	113.0	390.0
Mean Value		68. 2	173.9	490.0

3. Result and discussions

3.1. Determination of radioactivity concentration

Table 2 presents the radioactivity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for the tiles samples produced in Nigeria and their average value respectively. The observed activities concentration of the radionuclides content in the tiles ranged from 27 to 241 Bq/kg for ^{226}Ra, 41–461 Bq/kg for ^{232}Th and 270–860 Bq/kg for ^{40}K respectively. The PNT ceramics tiles of size 30 × 30 mm was noted to have the highest value of 241 Bq/kg for ^{226}Ra; NISPRO tile of size 40 × 40 mm have 461 Bq/kg for ^{232}Th and 860 Bq/kg for ^{40}K respectively. The lowest values of 27, 41 and 270 Bq/kg are found to be for tiles samples BN ceramics, Royal crown and Goodwill super polish while mean value of the radionuclides ^{226}Ra, ^{232}Th, and ^{40}K are 68. 2, 173.9 and 490 Bq/kg respectively. These average values were found to be within international reference value when compared with IAEA (2003) report. This present study was compared with others countries as reported elsewhere using the activity concentrations measured and are presented in Table 3. In contrast, it can be observed that the concentration of tiles in Nigeria and other countries are closer for ^{226}Ra, ^{232}Th and ^{40}K radionuclides as reported by Amin and Naji (2013) except for ^{40}K which is a little bit higher but still within the recommended value.

3.2. Radiological assessment

3.2.1. The absorbed dose rate

In this present study, the absorbed dose rates obtained from the calculated activity concentrations are shown in Table 4. The total air absorbed dose rate received in an open air 1 m above the ground due to gamma emission from the radionuclides of ^{226}Ra, ^{232}Th and ^{40}K in BqKg^{-1} available in an environment is calculated using Eq. (1) (UNSCEAR, 1998, 2000)

$$D(nGyh^{-1}) = 0.642C_{Ra} + 0.604C_{Th} + 0.0417C_k \angle 80nGyh^{-1} \quad (1)$$

Table 3
Comparison of Radioactivity concentration in tiles made in Nigeria with other tiles from other countries.

Sample name	Country	^{226}Ra	^{232}Th	^{40}K	Reference
BN Ceramics	Nigeria	37.5	101.5	670.0	Present study
PNT Ceramics	Nigeria	241.0	77.5	510.0	Present study
Golden Crown Ceramics	Nigeria	49.5	57.5	460.0	Present study
Royal Ceramics	Nigeria	65.5	44.0	390.0	Present study
Royal Crown	Nigeria	51.5	41.0	440.0	Present study
Goodwill Super Polish	Nigeria	44.0	51.5	270.0	Present study
NISPRO	Nigeria	59.5	461.0	860.0	Present study
Goodwill Vitrified	Nigeria	70.5	445.5	540.0	Present study
PNT Ceramics	Nigeria	35.5	346.5	370.0	Present study
Golden Crown	Nigeria	27.0	113.0	390.0	Present study
Taulell	Italy	135	487	547	(Amin and Naji, 2013)
Cerypsa	Spain	92.3	427	816	(Amin and Naji, 2013)
Alfujera	UAE	60	13	463	(Amin and Naji, 2013)
Atlas	India	452	227	237	(Amin and Naji, 2013)
Refan	Yemen	125	21	376	(Amin and Naji, 2013)
Meran	China	61	**0**	24	(Amin and Naji, 2013)
Al jouda	Kingdom of Saudi Arabia	**0**	267	258	(Amin and Naji, 2013)
Roman	Indonesia	114	47	223	(Amin and Naji, 2013)

Table 4
The absorbed dose, radium equivalent (Raeq), external hazard index (Hex) and internal hazard index (Hin).

Sample name	Sample size	Ra_{eq} (Bq/kg)	D ($nGyh^{-1}$)	H_{ex}	H_{in}
BN Ceramics	60 × 60	234. 24	113.32	0.63	0.73
PNT Ceramics	30 × 30	391.09	222.79	1.06	1.71
Golden Crown Ceramics	25 × 30	167.15	85.69	0.45	0.59
Royal Ceramics	40 × 40	158.45	84.89	0.43	0.61
Royal Crown	30 × 30	144.01	76.18	0.39	0.53
Goodwill Super Polish	60 × 60	138.44	70.61	0.37	0.49
NISPRO	40 × 40	784.95	352.51	2.11	2.28
Goodwill Vitrified	40 × 40	749.15	336.86	2.02	2.21
PNT Ceramics	25 × 40	559.49	247.51	1.51	1.61
Golden Crown	30 × 30	218.62	101.85	0.53	0.66
Mean Value		354.56	169.22	0.95	1.14

Considering the absorbed dose rates presented in Table 4, it can be observed that the highest value of 352.51 $nGyh^{-1}$ was reported in NISPRO tiles whereas the lowest value of 70.61 $nGyh^{-1}$ was noted in Goodwill super polish tile. Comparing the absorbed dose rate in this present study with the standard value of 80 $nGyh^{-1}$ recommended by UNSCEAR (1998), the highest value obtained in this present study is higher by a factor of 4.4.

3.2.2. Determination of radium equivalent (Raeq)

The level of radionuclides from ^{226}Ra, ^{232}Th and ^{40}K in the analyzed building materials is non- uniformly distributed. The Raeq activity of the measured radionuclides is used to compare the activity of each of ^{226}Ra, ^{232}Th and ^{40}K contents in the building materials. Raeq with unit as BqKg-1 was calculated using Eq. (2).

$$R_{aeq} = AC_{RA} + 1.43C_{Th} + 0.077AC_K \quad (2)$$

where AC_{RA}, AC_{Th} and AC_K are the activities concentration of ^{226}Ra, ^{232}Th and ^{40}K measured in $BqKg^{-1}$ respectively. This radium equivalent activity defines the weighted sum of the individual activities of ^{226}Ra, ^{232}Th and ^{40}K with the idea that for ^{226}Ra, Raeq is 10 Bq/kg, for ^{232}Th, Raeq is 7 Bq/kg and for ^{40}K, Raeq is 130 $Bqkg^{-1}$. The maximum value of Raeq in tiles materials must be less than 370 Bq/kg as recommended by UNSCEAR (1998) and UNSCEAR (2000). The radium equivalent activity values obtained from this present study varies from 138.44 to 784.95 $BqKg^{-1}$with the highest value of 784.95 $BqKg^{-1}$ reported in NISPRO whereas the lowest value of 138.44 $BqKg^{-1}$ was noted in Goodwill super polish tile and the mean value of 354.56 $BqKg^{-1}$ is noted. It can be observed that some tiles samples such as PNT Ceramics (30 × 30), NISPRO, Goodwill Vitrified and PNT Ceramics (25 × 40) have the Raeq value that exceeds the recommended limit of 370 $BqKg^{-1}$ by UNSCEAR (1998) and UNSCEAR (2000) as presented in Table 4.

3.2.3. Evaluation of external hazard index

The gamma ray radiation hazards index due to the specified radionuclides were assessed by external radiation hazard and was calculated using Eq. (3) according to UNSCEAR (2000).

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

where,

C_{Ra}, C_{Th} and C_K are the average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in $Bqkg^{-1}$ respectively. For the radiation hazard to be acceptable, it is recommended that the Hex be less than unity. The estimated H_{ex} for all the samples varies from 0.37 to 2.11with highest value noted in NISPRO tile whereas the lowest value reported in Goodwill super polish. This highest value from the present study is higher than the recommended value of ≤ 1 according to UNSCEAR (2000) by a factor of 5.7.

3.2.4. Determination of Internal Hazard Index

The hazard which is defined in relation to internal hazard is represented by H_{in} respectively and can be determined using Eq. (4) (Beretka and Mathew, 1985):

$$H_{in} = (C_{Ra}/185) + (C_{Th}/259) + (C_K/4810) \quad (4)$$

where C_{Ra}, C_{Th} and C_K are activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq/kg. For the safe use of a building material such as tiles for decorative purposes in construction, H_{in} should be less than unity. The calculated values of H_{in} for tile samples used are shown in Table 4. The values ranged between 0.53 and 2.28 and the mean values of 1.14 for internal hazard (H_{in}). The obtained results for H_{in} for PNT ceramic, NISPRO, Goodwill super polish and PNT ceramic (25 × 40) tiles are above recommended limit of unity. The results for other tile samples are less than unity and are in agreement with the recommended international values.

3.2.5. The annual effective dose rate

The indoors annual effective dose equivalent received by human is estimated from the indoor internal dose rate (Din), occupancy factor which is defined as the level of human occupancy in an area in proximity with radiation source; is given as 80% of 8760 h in a year, and the conversion factor of 0.7 Sv Gy^{-1} which is used to convert the absorbed does in air to effective dose (UNSCEAR, 2000). The annual effective dose equivalent is estimated using Eq. (5).

$$AEDR = (0.49C_{Ra} + 0.76C_{Th} + 0.048C_K) \times 8.76 \times 10^{-3} \quad (5)$$

The value of the AEDE ranges from 0.65 to 3.69 mSv y^{-1} with a mean value of 1.59 mSv y^{-1}. The mean values from the samples surpass the world's average value of 0.07 mSv y^{-1} by a factor 5.7. Details of all the samples are presented in Table 5.

3.2.6. Gamma index determination (Iγ)

Gamma index is used to evaluate the γ-radiation hazard related to the natural radionuclide in the particular samples under investigation.

Table 5
The annual effective dose (mSv/y), gamma activity index (Iγ) and alpha index (Iα).

Sample name	Sample size	Annual effective dose (mSv/y)	Gamma activity index (Iγ)	Alpha index (Iα)
BN Ceramics	60 × 60	1.12	0.76	0.19
PNT Ceramics	30 × 30	1.76	1.36	1.21
Golden Crown Ceramics	25 × 30	0.79	0.61	0.25
Royal Ceramics	40 × 40	0.74	0.57	0.33
Royal Crown	30 × 30	0.68	0.52	0.26
Goodwill Super Polish	60 × 60	0.65	0.49	0.22
NISPRO	40 × 40	3.69	2.79	0.29
Goodwill Vitrified	40 × 40	2.84	0. 18	0.35
PNT Ceramics	25 × 40	2.61	1.97	0. 18
Golden Crown	30 × 30	1.03	0.79	0. 14
Mean Value		1.59	1.00	0.34

The gamma index representation (Iγ) is estimated using Eq. (6) as presented by OECD (1979).

$$I_\gamma = C_{Ra}/300(Bq/kg) + C_{Th}/200(Bq/kg) + C_K/3000(Bq/kg) \quad (6)$$

The estimated results are presented in Table 5. The controls on the radioactivity of building materials according to RP122 (EC, 1999) is based on the dose criterion for control and exemption. The dose effective exceeding the criterion level of 1 $mSvy^{-1}$ should be taken into account for radiation protection. It recommends that controls of dose range of 0.3–1 $mSvy^{-1}$, which is the excess gamma dose to that received outdoors. The gamma activity index is used to identify whether a dose criterion is met (EC, 1999). This gamma activity index accounts for the ways and amounts in which the materials used in building, with limit value of their indices not exceeding the recommended value and depends on the dose criterion shown in Table 5. In this present study, the dose has been calculated excluding the background dose which was shielded by the building materials when used in bulk but does not still exclude when building materials used as a superficial material. This is because the thin layers of superficial material do not reduce significantly the background dose. The gamma activity index $\leq$ 1, corresponds to annual effective dose less than or equal to 1 $mSvy^{-1}$, while gamma activity index $\leq$ 0.5 corresponds to 0.3 $mSvy^{-1}$ if the materials are used in bulk quantity. At the same time, gamma activity index $\leq$6 corresponds to annual effective dose of 1 $mSvy^{-1}$ and gamma activity index $\leq$ 2 corresponds to an annual effective dose $\leq$ 0.3 $mSvy^{-1}$ if the bulk materials are used in a superficial way. In this study as shown in Table 5, the results for superficial materials such as tiles vary from 0.18 $mSvy^{-1}$ (Goodwill vitrified tile) to 2.79 $mSvy^{-1}$ (NISPRO tile) with average value of 1.00 $mSvy^{-1}$. Building materials such as tile should be exempted from all restrictions regarding radioactivity if the excess gamma radiation emanating from them increases the annual effective dose of a member public by 0.3 mSv at the most. Considering the criterion of unity that corresponds to annual effective of 1 mSv, all the present values are below the criterion which corresponds to the protection level except PNT ceramic (30 × 30), NISPRO and PNT ceramic (25 × 40) tiles.

3.2.7. Determination of alpha index (Iα)

The assessment of the alpha index is another important aspect of hazard assessment that deals with the estimation of that excess alpha radiation due to radon inhalation originating from building materials. The alpha index calculated using Eq. (7) (Righi and Bruzzi, 2006; Xinwei et al., 2006) is:

$$I_\alpha = C_{Ra}/200(Bq/kg) \quad (7)$$

where C_{Ra} is the activity concentration of radium $Bqkg^{-1}$ in building materials. If the radium activity level in building material exceeds the values of 200 $Bqkg^{-1}$ there is possibility that the radon exhalation from the material could cause indoor radon concentrations exceeding Bqm^{-3}. Table 5 presents the values for alpha index. The International Commission on Radiation protection recommends an action level of 200 Bqm^{-3} for radon in dwellings (ICRP, 1994). At the same time, if this radium activity level is below 100 $Bqkg^{-1}$, it shows that radon exhalation from building materials may not likely cause indoor concentration greater than 200 Bqm^{-3} (Xinwei et al., 2006). It is reported that the recommended exempted value and the recommended upper limit for radon concentrations are 100 $Bqkg^{-1}$ and 200 $Bqkg^{-1}$ respectively in building materials (RPA, 2000). It is noted that the upper limit of radon concentration (Iα) is equal to 1 (Tufail et al., 2007). The results of the present study show that the radon concentration varies from 0.14 to 1.21 respectively with average value of 0.34. With this lower value, it indicates that the radon exhalation from all the analyzed samples would cause indoor concentration lower than 200 $Bqkg^{-1}$.

4. Conclusions

The measurement of natural radioactivity concentration and its associated radiological risks from 10 investigated tiles samples made in Nigeria for buildings purposes were evaluated using gamma ray spectrometry. These following endpoints can be drawn:

1. The mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K have been found to be 68.2, 173.9 and 490 Bq/kg respectively. On the average, activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were found to be below recommended value.
2. The radium equivalent activity for most of the tiles samples used is less than the recommended value of 370 Bq/kg set in by UNSCEAR (2000) report excluding PNT ceramic (30 × 30), NISPRO, Goodwill Vitrified, PNT Ceramics (25 × 40) tiles sample with a value of 391. 10, 784.95, 749.15 and 559.49 Bq/kg respectively.
3. The absorbed dose rate in air was found to be in the ranged of 70.61–352.51 $nGyh^{-1}$ with mean value of 169.22 $nGyh^{-1}$ which is higher than international value of 55 $nGyh^{-1}$ by factors of 3.2 and 2.1 according to UNSCEAR (1998) and 80 $nGyh^{-1}$ by UNSCEAR (2000) respectively.
4. The average value of H_{ex} and H_{in} are 0.95 and 1.14 respectively. The mean value of H_{ex} is lower than unity as recommended by UNSCEAR (2000) while H_{in} is higher. It was also observed that PNT ceramic (30 × 30), NISPRO, Goodwill Vitrified and PNT Ceramics (25 × 40) have values higher that international reference value.
5. The result of annual effective dose rate show higher value in tile samples BN ceramic, PNT ceramic (30 × 30 mm), BN ceramic, NISPRO, Goodwill Vitrified, and PNT ceramic (25 × 40) above recommended value of 1 mSv/yr as well as on the average value.
6. The mean value of gamma activity index is 1 and is still within the world recommended value and the Alpha Index (Iα) is 0.34. From the result above, it shows that the tiles sample such as PNT ceramic (30 × 30), NISPRO, Goodwill Vitrified and PNT Ceramics (25 × 40) should be monitored before usage for building purposes.
7. The higher values of NISPRO produced along Abuja-Kaduna express way could be attributed to the nature of the basement complex of the Pan-African Orogeny of the sourced raw material of the granitic rock materials. Goodwill vitrified and PNT ceramics (25 × 30 mm) may be attributed to the marine transgression and regression of metamorphosed sediments from far and near granitic tectonically and highly dissolved rock minerals in and round the Atlantic Ocean in Lagos.

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