Journal of the Nigerian Association of Mathematical Physics
Volume 65, ((October 2022– August 2023 Issue), pp1 – 10

RADIOLOGICAL IMPACT ASSESSMENT OF NATURAL RADIOACTIVITY OF CERAMIC WARES AND DECORATIONS IN ABEOKUTA, NIGERIA

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Abstract

Gamma ray spectrometry was carried out on twenty different ceramic tableware and flower vases procured from the local market in Abeokuta, using Sodium iodide detector to assess their natural radioactivities and ascertain likelihood of health hazards. The range of radioactivity of the ceramic samples for K–40 is 190.34 ± 12.419 to 2364.56 ± 128.9Bq/kg, for U–238 it is BDL to 108.34 ± 14.81Bq/kg and for Th–232 it is BDL to 8.33 ± 1.3Bq/kg. The mean specific activity for all the samples for K–40 is 1355.97 ± 71.28Bq/kg, for U-238 it is 39.49 ± 5.41Bq/kg and for Th–232 it is 3.94.± 0.46Bq/kg . The range of Radiumequivalent forth samples is 81.64 to 222.99 Bq/kg with mean of 149.53 ± 11.56Bq/Kg.The gamma indices were all less than unity, while the absorbed dose rates of mean value 77.17 ± 5.75 nGy/h as well as annual effective doses of mean value 0.38 ± 0.03 mSv/yr were below the standard maximum safety limit for all building materials and indoor radiation as recommended by World Health Organization (WHO) and International Atomic Energy Agency (IAEA), hence they are safe for human use.

Keywords: Natural radioactivity, Ceramic Tablewares, Health hazard, Gamma ray spectrometry, Abeokuta.
Word count: 211

INTRODUCTION

The art of ceramic production predates the Stone Age. Ceramics have been accompanying the human race since ancient times. Archaeologists have unearthed man-made ceramics that dated back to at least 5,000 BC from the Egyptian civilization potteries and mosaics. Primitive Ceramics were made of basic earthen materials like clay and were burnt in domes. Human inventiveness gradually started with firing them at higher temperatures to attain harder Ceramic which led to inventing better firing techniques [1].

As Ceramics are made of earthen materials, they are the most compatible products with the nature since they are free from decays, corrosion, erosion, abrasion, thermal shocks or being razed by fire. Ceramics being brittle; are the only materials which subsist to see the generations to come.

There are archaeological digs and founds which showed evidence that King Darius of the Assyrians used ceramic tablets like bill boards to advertise his exploits to the next generations about 521 BC to 485 BC while King Nebuchadnezzar of Babylon used ceramic to take down notes like diary about 604 BC to 539 BC and King Assurbanipal of Nineveh (647-626 BC) had a library of ceramic tablets [2] . Ceramic derived its origin from the Greek word 'Keramos' meaning 'potter' or 'pottery'. Keramos in turn was originated from a Sanskrit root – meaning 'to burn'. Hence, the word Keramos was to infer 'burned substance' or 'burned earth' (http//:www.wikipedia.org). Ceramics have many local names such as chinaware in England, tanganran in Yorubaland, porcelain in Europe and the Americas gernerally.

Ceramic Products are usually made up of clay, Kaolin (either white or red), Limestone, Silicon, animal bone (calcium) and feldspar, all are usually grinded together in a kiln. Earliest man-made Ceramics were pottery made from clay or mixed with other materials and hardened in fire [3]. Later Ceramics were glazed and fired to create a coloured, smooth, surface [4]. Ceramics are used in many areas which include domestic, industrial and building products and a wide range of artistery [5]. The modern ceramic engineering has identified monolithic ceramics and ceramic-matrix composite which are light weight,

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high temperature strength, corrosion and wear resistant, making them suitable for cladding and packaging electrical and electronic components [6].Since the 20th century, various Ceramic materials were developed for use in advanced Ceramics engineering for use in nuclear reactors and heavy duty insulators for high tension transmission due to outstanding physicochemical properties such as chemical inertness and stability, low thermal expansion and stable behavior under irradiation [7]. The futuristic applications of ceramics being envisioned are forms of cladding materials for gas-cooled fission reactors and space shuttles, immobilization case for nuclear/radioactive wastes and structural components for fusion reactors [8].

Making of Ceramic Products

The kind of application to which the ceramic is to serve usually determines procedure and heating level required. Most modern ceramics start as a mixture of powdered based material of zirconia binders and a suitable stabilizers .The mixture formed is dressed into shapes and different sizes. Ceramic materials tend to be strong, stiff, brittle, chemically inert and non-conductors of heat and electricity, but their properties vary widely for example, porcelain is widely used to make electrical insulator but some ceramic compound are super conductors.

Traditionally ceramic raw material includes clay minerals such as kaolinite, aluminumoxide commonly known as alumina. The modern ceramic include silicon carbide, both are valued for their abrasion resistance and hence find use in corrosive environment such as the wear plates of crushing equipment in mining operations where other ceramic materials would not be suitable. Advanced ceramic are also used in the medicine, electrical and aerospace industries. Refractories are the super heated form of ceramics which can withstand heat and not melt or crack up to 5000° C(just a bit less than the Sun's surface),a quality which makes them suitable for insulators for nuclear reactors and spacecrafts. [9].

Firing (sintering) at high temperature to create hard, dense materials is done using standard process such as pressing, extruding, moulding, tape casting or slip casting. Some of the better known ceramic manufacturing process combine sintering with forming. Sintering (firing) ceramic are consolidated into dense materials by exposing them to 18000c – 20000c for days or weeks at times [10] depending on the ceramic process detailed. The addition of thermal energy promotes strong bonds between the raw ceramic particles leading to densification. Ceramic manufacturers are very adaptive at accounting for metric shrinkage by short pressing. It combines the forming and firing step to produce relatively simple geometric shape. which are generated by placing the raw material in high temperature while under load.

Short pressing, it combines the forming and forming and firing step to produce relatively simple geometric shapes. The ceramic power is simultaneously subjected to sintering temperature and uniaxial pressure. Simple shapes are generated by placing the raw material in high temperature while under load.

Hot Isostatic Pressing (HIP) is a uniform pressure assisted method of sintering ceramic into simple and complex shape. The pressure usually applied via an inert gas like argon to prevent reactions. This significantly improves physical properties. Often times the pressurization process is preceded by evacuating all air to reduce moisture and impurities. In order for the hot isostatic pressured process to work the raw ceramic must be placed in a gas tight container. An alternative method to pre-sinter the ceramic is to remove porosity at thesurface. Hot isostatic pressing differs from isostatic pressing in that the former applies uniform pressure to the ceramic during sintering.

Chemical Vapor Deposition (CVD) chemical vapor deposition is the process of converting gases (called pre cursors) into solid by continuously depositing mono layers of materials into a heated substrate. This is a thermo dynamically driven process, so control of substrate temperature and chamber pressure is critical. Certain ceramic materials, such as silicon carbide and silicon nitricide, can be manufactured using sacrificial targets pre machined into the desired shapes of the part. Reaction bonding. It also uses a chemical reaction to bind ceramic powders into a solid form and then capillary pressure is used to infiltrate liquefied reactants (for different ceramics into the preform art temperature just about the ceramic melting point). This result in creating the solid ceramic form.Glazing this is usually done as part of the beautification and finishing touches. The ceramic product could be glazed or left unglazed.The major component used in glazing is Zircon and its various forms such as Zirconium silicate ($ZrSiO_4$) which could be gotten from zircon sand and Baddeleyite which is a natural form of zirconia qw(ZrO_2). The zircon materials are added to the glazes in concentration of 7% to 20% depending on the colours and decorations [11]. Zirconium ores are sources of technologically enhanced natural radionuclides TENR [12].This implies that much of the radioactivity from ceramic products is as a result of the glazing done to opalcify them [5]. Apart from being ceramic opacifier, zircon sands are also used in refractories of ceramics [11].

AIM AND JUSTIFICATION OF THIS STUDY

This study is carried out to critically investigate the level of radioactivity in Ceramic products in order to determine if the radiaoactivity level monitored in the products and establish if very minimal or above the acceptable standard.

Ceramics products are used in residential apartments, establishments and other important industries such as the power generation and distribution, in which people show more interest in ceramic products to beautify their houses and offices . Hence, it is pertinent and very important for them to have the knowledge and understanding about the danger that may be traceable to Ceramic product being likely radioactive.

RADIO ACTIVITY OF CERAMIC PRODUCTS

In Italy a certain glazed wall tile recorded specific activities of 278U 79 ± 3, 232_{Th} 66 ± 3 and 40_K 890 ± 38, another glazed floor tile recorded 238U 58 ± 2, 23_{Th} 52 ± 2 and 40_K 830 ± 35 and a certain porcelain stoneware recorded 238_U 50 ± 2, 232_{Th} 59 ± 2 and 40_K 520 ± 22 (all the activities in Bq/kg) [11].

Similarly in Serbia, the specific activity for 238_U ranged from 3 to 114 Bq/kg for floor tiles, and 43 to 143 Bq/kg for wall tiles. While the specific activity for 232_{Th} ranges from 53 to 72 Bq/kg for floor tiles and 50 to 101 Bq/kg for wall tiles. The activity for 40K lies between 560 to and 1030 Bq/kg for floor tiles and 590 to 1070Bq/kg for wall tiles [13].

The natural radionuclide { 238U, 232_{Th} and 40_K} content of ceramic wall and floor tiles commonly produced in Nigeria determined by a gamma ray spectroscopy system using sodium iodide detector with activity concentration of 238U, 232_{Th} and 40_K ranged from 7.89 ± 2.41 to 64.31 ± 8.66, ND to 2.81 ± 0.15 and 647.24 ± 33.9 to 1619,75 ± 85.00 with specific activities of 25.15 ± 3.52 , 1.11 ± 0.01, and 950.38 ± 48.39 (Bq/kg) respectively for the wall tiles while the activity concentration for the floor tiles for 238U, 232_{Th} and 40_K varied from BDL to 197.37 ± 21.0, ND to 27.64 ± 1.32 and ND to 1339.53 ± 56.26, with specific activities of 60.22 ± 7.33, 4.46 ± 0.28 and 777.39 ± 31.41 (Bq/kg) respectively[5].

Similarly, specific activity of 61.1 ± 5.5, 70.2 ± 6.08 and 52.7 ± 59.8 Bq/Kg for 226Ra, 232Th and 40K respectively, with a Radium equivalent of 204.42 Bq/Kg, absorbed dose rate of 177.6nGy/h and annual effective dose of 0.96 mSv/yr for commercial ceramic tiles in Nigeria was recorded [14].

Record shows Radium equivalent which ranged between 194 to 328 Bq/Kg for imported ceramic wall tiles and 176 to 306 Bq/Kg for the floor tiles, the specific activities for wall tiles are 72±14, 84±18 and 629±198 Bq/Kg for 226Ra, 232_{Th} and 40_K respectively, while for the floor tiles, the specific activities are 70±31,82±24 and 618±231Bq/Kg for 226Ra, 232_{Th} and 40_K respectively [15].

MATERIALS AND METHODS

Description of the Study Area

The study area is Abeokuta, the Ogun State capital city, located in Southwestern Nigeria. Abeokuta lies within latitude 6.9980°N and 7.1475°N, longitude 3°E and 3.3619°E.

The geology of the areas within and surrounding Abeokuta are of basement rock complex of Precambrian age; composed primarily of metamorphic and igneous rock, such as granite, gneisses and migmatites which are rich in natural radionuclide like 40_K, 238_U and 232_{Th} [16].

Fig 1. Geographic map of Abeokuta city and it's environ showing nearby locations.

Sampling

Some factories in the city also produced ceramic product locally with raw materials sourced within the locality and hence endeavor were made to procure both local and foreign ceramic products.

Twenty different samples of ceramic tablewares and flower vases were obtained for the investigation of their radioactivity measurement. The wares vary in sizes, colours and textures.

Various commercial names are given to each of the products. The procured samples were coded as follows in table 1:

Table 1: Coding of the Samples

S/N	SAMPLES	CODE
1.	Black flower vase	VAS 1
2	White flower vase	VAS 2
3	Grey flower vase	VAS 3
4	Green flower vase	VAS 4
5	Speckled mug	MUG 1
6	Plain white mug	MUG 2
7	Striped white mug	MUG 3
8	White Teacup	TCP 2
9	Gold striped Teacup	TCP 3
10	Brown Teacup saucer	SAC 1
11	White Teacup saucer	SAC 2
12	Gold striped Teacup saucer	SAC 3
13	Cream Soup bowl	SOP 1
14	Plain white soup bowl	SOP 2
15	Brown soup bowl	SOP 3
16	Blue flowered serving plate	SPL 1
17	Gold striped white serving plate	SPL 2
18	Plain Brown serving plate	SPL 3
19	Blue striped white serving plate	SPL 4

Procedure

The samples were crushed using a laboratory mortar and pestle. The crushed samples were sieved with a 2mm mesh and weighed with an electronic scale. Weighted samples of 200g were placed in a polyethylene cylindrical beaker of 350cm3 each and sealed with adhesive tapes. The twenty samples were left on the laboratory shelf for 4 weeks to achieve seqular equilibrium such that the decay rate of both the parent and daughter radionuclides are equal and whatever radon gas emitted is confined within the volume. Then, the samples were taken to the environmental laboratory of the Nigerian Nuclear Regulation Agency for the gamma ray spectrometry.

Radioactivity measurements:

Gamma ray spectrometry was carried out for the measurement of the radioactivity counting using a well shielded and calibrated sodium Iodide (activated with Thallium), NaI(Tl) detector coupled to a computer resident quantum MCA2100R multichannel Analyzer for 36,000s. An empty container of identical geometry was also counted at the same time to adjust for background counts. The 1460KeV gamma radiation of 40K was used to determine the concentration of 40K. the gamma transition energy of 1764.5KeV of 214Bi was used to determine the concentration level of 238U while gamma transition energy of 2614KeV of 208Tl was used to determine the concentration of 232Th. The efficiency collaboration of the detector was done using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA) which has certified activities of the selected radionuclides and geometrical configuration identical to the samples' containers. The activity concentration of the radionuclides in the samples were calculated using equation

$$Asp = \frac{Nsam_{exp}\,(lTd)}{PE \times e\,(Eg) \times Tc \times M} \quad \ldots\ldots(1)$$

Where,

Nsam = Background corrected net counts of radionuclide in the sample

Td = Delay time between sampling and counting.

exp (lTd) = Correction factor between sampling and counting

PE = Gamma ray emission probability (gamma yield)

e(Eg) = Counting efficiency of the detector

Tc= Sample counting time
M = Mass of sample [17]

RESULTS AND DISCUSSIONS

Gamma ray spectrometry were carried out on the ceramic wares which are categorized into flower vases VAS, drinking mugs MUG, teacups TCP, teacup saucers SAC, soup bowls SOP and serving plates SPL.The results of the natural radioactivity counts are as stated in the table 2 to table 7 respectively. Note that BDL refers to below detectable limit and ND nothing detected.

Table 2: Natural Radioactivity count of Flower vases in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Black flower vase	VAS 1	270.35±14.70	7.29±1.19	4.39±0.27
2	White flower vase	VAS 2	349.24±18.52	86.98±10.99	4.73±0.28
3	Grey flower vase	VAS 3	190.34±12.41	8.22±2.31	4.23±0.98
4	Green flower vase	VAS 4	410.76±23.39	99.84±12.98	7.80±1.21
	Mean ± SD		305.17 ± 17.26	50.58 ± 6.87	5.28 ± 0.69

Table 3: Natural Radioactivity count of drinking mugs in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Speckled mug	MUG 1	1444.24±75.94	97.43±12.18	5.96±0.35
2	Plan white mug	MUG 2	1579..23±86.77	108.34±14.81	7.28±0.61
3	Striped white mug	MUG 3	1347.62±65.43	99.39±13.64	5.81±0.33
	Mean ± SD		1457..03 ± 76.05	101.72 ± 13.54	6.35 ± 0.43

Table 4: Natural Radioactivity count of Teacups in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Brown Teacup	TCP 1	1167.18±66.01	11.95±3.33	1.06±0.07
2	White Teacup	TCP 2	1071.59±54.63	12.60±4.10	2.28±0.14
3	Gold striped Teacup	TCP 3	1112.85±60.19	23.14±5.11	5.27±1.01
	Mean ± SD		1117.21 ± 60.28	15.90± 4.18	2.28±0.14

Table 5: Natural Radioactivity count of Teacup Saucers in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Brown Teacup Saucer	SAC 1	1162.89±61.92	BDL	2.19±0.13
2	White Teacup Saucer	SAC2	1261.87±70.12	11.23±3.02	1.89±0.09
3	Gold striped Teacup Saucer	SAC 3	1127.46±57.81	10.61±2.92	2.06±0.11
	Mean ± SD		1184.07 ± 63.28	7.28 ± 1.93	2.05± 0.11

Table 6: Natural Radioactivity count of Soup bowls in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Cream soup bowl	SOP1	2364.56±128.93	4.37±0.25	BDL
2	Plain white soup bowl	SOP2	2110.84±111.46	4.93±0.76	0.86±0.05
3	Brown soup bowl	SOP 3	2211.19±117.35	6.84±0.41	1.02±0.11
	Mean ± SD		2228.86± 119.25	5.38±0.47	2.05± 0.11

Table 7: Natural Radioactivity count of Serving Plates in Bq/kg

S/n	Description	code	K - 40	U - 238	Th-232
1	Blue flowered serving plate	SPL 1	1762.28±86.67	51.70±4.9	6.51± 0.99
2	White flower vase	SPL 2	1954.21±90.14	58.26±5.01	8.33±1.32
3	Grey flower vase	SPL 3	2109.69±110..37	60.15±6.98	6.61±1.01
4	Green flower vase	SPL 4	1547.63±79.08	54,30±4.67	4.23±0.91
	Mean ± SD		1843.45 ± 91.57	56..10± 5.41	6.42± 1.06

The mean specific actifity concentration of the ceramic wares for Potassium-40, Uranium-238 and Thorium-232 are as recorded in Table 7.

Table 8: Specific Activity of Ceramic Tablewares in Bq/kg

S / N	ITEMS	A_K	A_U	A_{TH}
1	VASE	305.17±17.26	50.58±6.87	5.29±0.69
2	MUG	1457.03±76.05	101.73±13.54	6.35±0.43
3	TCP	1117.21±60.28	15.90±4.18	2.87±0.41
4	SAC	1184.07±63.28	7.28±1.98	2.05±0.11
5	SOP	2228.86±119.25	5.38±0.47	0.63±0.04
6	SPL	1843.45±91.57	56.10±5.41	6.42±1.06
	Mean ± SD	1355.97±71.28	39.49± 5.41	3.94± 0.46

The table 8 is represented with a bar chart below

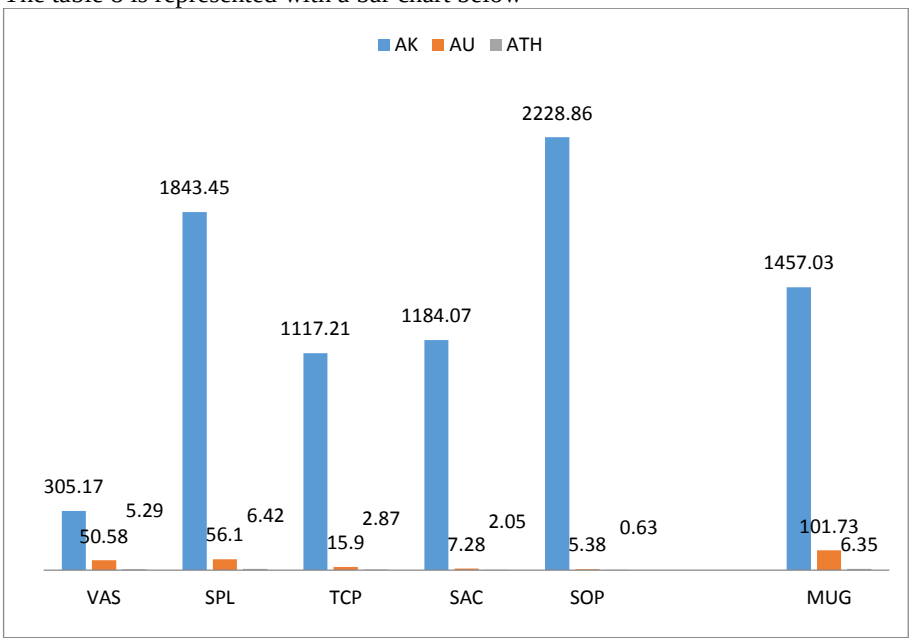

Fig 2. Specific Activity of Ceramic Tablewares in Bq/kg

According to [13], the world average specific activity in building (indoor) materials is given as 226_{Ra} (50Bq/kg), 232_{Th} (50Bq/kg) and 40_K (500Bq/kg). This is as recommended by [18].

Radium Equivalent Activity

The Radium equivalent (Raeq) is calculated using equation 2 such as follows :

$$Raeq = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where A_{Ra}, A_{Th} and A_K are the specific activities of 226Ra, 232_{Th} and 40_K in Bq/kg respectively [12] and [19]. The calculated values are recorded in table 9.Radium equivalent activity is a quantity which takes cognizance of the specific activities of 238_U, 232_{Th} and 40_K in respect of their joint radiation hazard. The calculated value must be less or equal to 370Bq/kg but never above for safety [20].

Absorbed Dose Rate

The Monte Carlo method adopted in New York 1998 [21] and [18] considered conversion factors to transform specific activities of A_{Ra}, A_{Th} and A_K into absorbed dose rate at 1m above the ground in nanoGray (nGy) per hour by Bq/kilogram with equation (3) and Radium is responsible for about 98.5% of radiological effects of uranium decay series [22]. Thus, assuming that contributions from all the other naturally occuring radionuclides to the absorbed dose are not really significant, then, the actual dose rates is ;

$$D(nGyhr\text{-}1) = 0.462\ A_{Ra} + 0.604A_{Th} + 0.0417A_K \quad (3)$$

The world average is 55 nGyhr-1 [23]. The values calculated for these samples are shown in table 9.

External Hazard Index

The external Hazard Index Hex is given by equation 4.

$$Hex = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \leq 1 \quad (4)$$

This presupposed that 370Bq/kg of 226Ra, 259Bq/kg of 232_{Th} and 4810Bq/kg of 40_K, produces the same gamma dose rate. This imply that the index value must be less than unity in order to keep the radiation hazard insignificant, [24]. The calculated value for the External Hazard Index Hex is as presented in Table 8.

Internal Hazard Index

This is the limit of the gamma radiation dose permissible as internal exposure to carcinogenic radon and its short lived progeny through the respiratory organs.

$$HIN = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \leq 1 \quad (5)$$

The lnternal Hazard lndex (Hin) is calculated by reducing the normal limit of 226_{Ra}, by half (185 Bq/Kg) .[25] and [19]. The lnternal hazard index is given by equation 5 and the calculated values for the samples are recorded in table 8.

The Annual Effective Dose DE

ln order to estimate the annual effective dose rates, we need to consider the 0.8 indoor occupancy and the conversion coefficient from absorbed dose in air to effective dose 0.7Sv/Gy [21 and [18]. The annual effective time used is given by 365.25 days multiplied by 24 hours (8766h/y). Hence the annual effective dose is as calculated using equation 6.

$$DE = D(nGyhr^{-1}) \times 10\text{-}9 \times 8766\ h/y \times 0.8 \times 0.7Sv/Gy \quad (6)$$

The calculated annual effective dose for the samples are recorded also in table 9

Table 9: The Radium Equivalent (Raeq), External Hazard Index (Hex), Internal Hazard Index (Hin), Absorbed Dose Rate (D) and Annual Effective Dose DE

Table 9. Table of Calculated Radiological Parameters

Type of Ceramic	Raeq (Bq/kg)	External Hazard Index (Hex)	Internal Hazard Index (Hin)	Absorbed Dose Rate (nGyhr-1)	Annual Eff. Dose DE (mSv/y)
VAS	81.64	0.22	0.36	32.29	0.16
MUG	222.99	0.60	0.88	111.59	0.55
TCP	106.01	0.29	0.33	55.67	0.27
SAC	101.39	0.27	0.29	53.98	0.26
SOP	177.90	0.48	0.49	95.81	0.47
SPL	207.23	0.56	0.71	106.67	0.52
Mean ±SD	149.53±11.56	0.40±0.03	0.51±0.05	77.17±5.75	0.38±0.03

Discussion

The activity concentrations recorded for all the ceramic samples show that a certain soup bowl had the highest concentration of 40_K at 2364.56±128.93 Bq/Kg while the lowest was a flower vase at 190.34±12.41 Bq/Kg. The concentration recorded for 238_U showed that a mug had the highest activity at 108.34±14.81Bq/Kg and the lowest was the same soup bowl (with highest concentration of 40_K) at 4.37± 0.25 Bq/Kg. The activity concentration for 232_{Th} indicated that a serving plate had highest concentraion with 8.33±1.32 Bq/Kg and another soup bowl recorded the lowest at 0.86±0.05 Bq/Kg.)

The Radium equivalent (Raeq) values calculated from the specific activities revealed that the drinking mugs have the highest radioactivity (222.99) .followed by the serving plates (207.23), the soup bowl (177.90), teacups (106.01), teacup saucers (101.39) , and the flower vases have the lowest (81.64). Their mean Radium equivalent (Raeq) is 149.53±11.56(all in Bq/Kg). These values are all save and well below the safety limit of 370 Bq/Kg .

The gamma indices of external Hazard Index (H_{ex}) and internal Hazard Index (H_{IN}) are all less than unity. The range for external Hazard Index (H_{ex}) is 0.22 to 0.60 with average of 0.40±0.03 , while the range for the internal Hazard Index (H_{IN}) is 0.29 to 0.71 with average 0.51± 0.05.

Radium equivalent (Raeq) values that are less than 370 Bq/Kg , which will produce exposure less than 1.5mSv/h (safety limit set in 1979) according to the Organization for Economic Cooperation and Development [26]. The Absorbed dose rates D(nGyhr-1) ranged between 32.29nGy/h for flower vases to 111.59 nGy/h for the drinking mugs and average of 77.17±5.75nGy/h. The annual effective dose DE for the samples ranged between 0.16mSv for flower vases to 0.55mSv for the drinking mugs and average of 0.38±0,03mSv. These results show values which are well below the safety limit and compared favorably with works of other researchers such as Jankovich who in 2013 recorded a range of 160 to 290 nGy/h for absorbed dose rate and a range of 0.8 to1.43 mSv as annual effective dose for imported ceramic tiles used in Serbia. The world average according to literature ranged betweenf140 to 260 nGy/h and a range of 0.48 to1.26 mSv respectively for absorbed dose rate and annual effective dose.

Conclusion

The gamma spectrometry results were used to estimate some associated radiological parameters which enable the determination of necessary facts on the health implications involved with radioacttlivity from the ceramic samples. All the health hazards parameters estimated were well below the maximum safety limits and the external and internal hazard indices were less thsn unity at 0.40± 0.03 and 0.51± 0.05 respctively. Hence all the ceramic samples investigated are safe for decorative and culinary/luncheon usages.

Recommendation

Nigerians love to use ceramic products because of the aestatic values these products bring into their household. This research work as well as some others carried out on ceramic products in Nigeria, either imported or locally produced show that the radioactivity involved are really lower than the safety limits, hence these ceramic products are safe. However ceramic products that appear too glassy should be avoided for radiological concerns because of the zirconium used in glazing them as regarding internal exposure through inhalation [27].

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