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ARAŞTIRMA MAKALESİ / **RESEARCH ARTICLE**

ASSESSMENT OF NATURAL RADIOACTIVITY IN CONCRETE BLOCK, EXTRUDED CLAY BRICK, AND MUD BRICK TAKEN FROM OGBOMOSO, SOUTHWESTERN, NIGERIA

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ABSTRACT

This study evaluates the natural radioactivity in concrete block, extruded clay brick, and mud brick taken from Ogbomoso city. The six samples were collected from different part of the city, and were analyzed using highly sensitive HPGe gamma spectrometer. The mean activity concentration in Bq Kg⁻1 of ^{40}K , ^{238} U (^{226}Ra) and ^{232}Th were 135.10 ± 3.23, 9.58 ± 3.16 and 14.30 ± 3.32 respectively in concrete block ; 66.34 ± 6.66, 6.81 ± 2.26 and 6.78 ± 2.58 respectively in mud brick; and 69.21 ± 6.88, 7.26 ± 2.54 and 3.51 ± 1.54 respectively in extruded clay brick. Also calculated were the radium equivalent activities, the hazard indexes, the absorbed dose rates and the effective dose rate. The extruded clay brick has the lowest value in all calculated parameters. The absorbed dose rate due to ^{238} U (^{226}Ra), ^{232}Th and ^{40}K at 1.0 m above the ground level in clay brick was 8.41 nGy h $^{-1}$, annual effective dose was 0.04 mSv yr^{-1} and also the internal and external hazard index was 0.07 and 0.02 respectively. All the measured parameters in all the samples were lower than the international criterion values, and therefore posses no radiological hazards.

Keywords: Radioactivity, Bricks, Dose, Radium, Thorium.

OGBOMOSO, GÜNEYBATI, NİJERYA'DAN ALINAN, BETON BLOK, BOYALI KIL TUĞLA VE KERPİÇ İÇİNDE DOĞAL RADYOAKTİVİTE DEĞERLENDİRİLMESİ

ÖZ

Bu çalışmada, Ogbomoso, Güneybatı, Nijerya'dan alınan, beton blok, boyalı kil tuğla ve kerpiç içinde doğal radyoaktivite değerlendirilmiştir. Altı örnek, Şehrin farklı kısımlarından altı örnek toplanmış ve son derece hassas HPGe Gama spektrometresi kullanılarak analiz edilmiştir. ^{40}K , ^{238} U (^{226}Ra) ve ^{232}Th Bq Kg⁻1 için ortalama aktivite konsantrasyonu, sırasıyla beton blok içinde; 135.10 ±

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3.23, 9.58 ± 3.16 ve 14.30 ± 3.32, kerpiç içinde; 66.34 ± 6,66, 6.81 ± 2.26 ve 6,78 ± 2,58, ve boyalı kil tuğla içinde; 69.21 ± 6.88, 7.26 ± 2.54 ve 3.51 ± 1,54 olarak ölçülmüştür. Ayrıca, radyum eşdeğer faaliyetleri, tehlike indeksler, absorbe edilen doz oranları ve etkin doz oranları hesaplanmıştır. Boyalı kil tuğla, tüm hesaplanan parametreleri için en düşük değerlere sahiptir. Absorbe edilen doz oranları 238 U (^{226}Ra), ^{232}Th ve ^{40}K için, kil tuğla zemin seviyesinden 1.0 m üzerinde, 8.41 nGy h $^{-1}$ ve yıllık etkin doz 0.04 mSv yr^{-1} ve sırasıyla iç ve dış tehlike indeksler 0,07 ve 0,02 dir. Bütün örneklerdeki ölçülen tüm parametreler, uluslararası ölçüt değerlerinden düşüktür ve bu nedenle hiçbir radyolojik tehlikeye sahip bir parça yoktur.

Anahtar Kelimeler: Radyoaktivite, Tuğla, Doz, Radium, Thorium.

INTRODUCTION

The rate of housing development in Nigeria is fast increasing, especially in the western part of Nigeria. Ogbomoso is city in the southwestern part of Nigeria in Oyo state, where most houses are now being built with concrete blocks. Concrete blocks are made up a mixture of cement, aggregate and water, forming the major component of making of the wall (Ademola and Farai, 2005). Very few houses were built with extruded clay brick or are sometimes used along with concrete blocks as decorations on buildings. Mud houses found in the study area were built over a long period of time, many of which are now plastered with**.** Clay is a naturally occurring material consisting of mainly fine grain minerals formed by weathering of rocks; it becomes plastic and tenacious when moist and hard when dried or fired. Mud brick made is mixture clay and with about 25-30% of sand to reduce shrinkage, which is then fired or sun dried. Extruded clay brick are from clay mixed with 10-15 water (stiff extension) or 20-25 water (soft extension), forced through a die to create a cable of material of proper with and depth, then cut into bricks and hardened by drying for 20-40 hours at 50-150 ^{0}C before been fired.

All building materials either raw or finished products contain natural radionuclide of the uranium (^{238} U) and thorium (^{232} Th) series, and also the radioactive isotope of potassium (^{40} K) (Turhan and Gurbuz, 2008). These radioactive materials find their way into buildings through decay series, for example ^{238} U series decay starting with radium (^{226} Ra). Research has made it evident that these radioactive substances are hazardous to human health, especially through the inhalation of radon isotopes and their progeny.

This study therefore, investigates the level radioactivity in concrete blocks, extruded clay brick and mud brick, to affirm which of these building materials are most appropriate for building by comparing there activity concentration, internal and external hazards index, effective dose rate and radium equivalent activity.

MATERIALS AND METHODS

Sample Preparations

Six samples, two each for concrete block, mud brick and extruded clay brick were collected from buildings in different parts of Ogbomoso town. The samples were grounded differently into powder and were sieved by a sieve of 2 mm grid mesh (Awodugba et al., 2007, Mollah et al., 1986). The samples were dried at ambient temperature of about 30 ^{0}C for many day until constant weight was obtained, making sure that water content of the samples are its lowest level. The weighted samples were kept in a plastic container of about 8 cm × 7 cm, sealed with a tape and kept for 28 days (Ademola and Farai, 2005). This was done so that the ^{238} U and ^{232}Th in the sample will reach secular equilibrium with there respective daughters (Schotzing and Debetin, 1983).

Radiometric Analysis

The measurement of the activities of the present radionuclide in the sample was done with well shielded high purity Germanium detector (Ajayi, and Ajayi, 2009). The HpGe detector enclosed in a 100mm thick lead shield coupled to a 4096 channel Canberra Computer analyzer was used to analyze each sample for 20,000 seconds. Background gamma rays were shielded using the cylindrically shaped lead of 100mm thick (Islam et al., 1990,) the back ground spectra were collected and for 20,000 seconds for each sample and the counts were subtracted from the respective region of interest (Beck, 1972). The main obstacle to widespread use of detectors has been the non-linearity of its response to ionizing charged particles, therefore a detailed is necessary for the nuclear species to be detected over a whole energy range (Tchokossa, 2006). The energy calibration was done by measuring mixed standard sources with well defined energies within the energy range of interest usually 200 keV to 3000 keV mixed gamma ray standard, which were obtained from International Atomic Agency in Vienna Australia.

The 1460.8 keV gamma line was used to directly estimate ^{40}K, while 609.3 keV gamma line from ^{214}Bi and 1764.5 KeV from ^{214}Bi was used to determine ^{238} U activities and 583.19 keV from ^{208}Tl was used to determine the activity of ^{232}Th (UNSCEAR, 2000). The gamma spectroscopy is usually done by a computer based program, which matches gamma energies at various levels to a library of possible isotopes (Olomo et al., 2003).

RESULTS AND DISCUSSION

Activity Concentration

Tables 1 shows the mean activities in Bq Kg $^{-1}$of the radionuclide concentration level in the sample types 1 (concrete block), 2 (mud brick) and 3 (extruded clay brick). The mean concentration in Bq Kg $^{-1}$ of ^{40}K, ^{238}U (^{226}Ra) and ^{232}Th in sample 1 (concrete block) was 135 ± 13.23, 9.58 ± 3.16 and 14.3 ± 2.32 respectively; that of sample 2 (mud brick) was 66.3 ± 6.66, 6.81 ± 2.26 and 6.78 ± 2.58 for ^{40}K, ^{238} U(^{226}Ra) and ^{232}Th respectively; and that of sample 3 (extruded clay brick) was 69.21 ± 6.88, 7.26 ± 2.54 and 3.51 ± 1.54 for ^{40}K, ^{238} U(^{226}Ra) and ^{232}Th respectively.

From result obtained from above, it shows that the activity concentration of ^{40}K and ^{238}U are lower in mud brick than in the other two sample types, but the activity concentration of ^{232}Th in the extruded clay brick is lower in value than the two other sample types. The mean value of ^{232}Th in the extruded clay brick, which is lower than the other two sample contributed to the lower values obtained for radium equivalent activity, internal and external hazards and the effective dose rate. This difference is not farfetched from the fact that Radium, Thorium and Potassium are not uniformly distributed in the soil or rock from which building materials are derived, and the radioactivity varies often greatly, over a distance of some meter (Slunga, 1988). The mean activity obtained for all the samples under study are less than the corresponding global values of 50, 50 and 500 Bq Kg $^{-1}$ for ^{226}Ra, ^{232}Th and ^{40}K respectively (UNSCEAR, 1993).

Radium Equivalent

It is known that the distribution of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K are not uniform, therefore a relation has been introduced to evaluate the actual activity of ^{226}Ra, ^{232}Th and ^{40}K in the samples and also radiation hazard associated with radionuclide. This relation is the Radium equivalent (Ra_{eq}) (Beretka and Mathew, 1985), which was calculated by the following relation.

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \tag{1}$$

This considers the fact that 370 Bq Kg $^{-1}$ of ^{226}Ra , 299 Bq Kg $^{-1}$ of ^{232}Th and 4810 Bq Kg $^{-1}$ of ^{40}K produce the same gamma dose rate (Stranden, 1976), where $C_{Ra,}$ C_{Th} and C_K are the radioactivity concentration in Bq Kg $^{-1}$ of ^{226}Ra , ^{232}Th and ^{40}K respectively. Table 2 shows the average radium equivalent in Bq Kg $^{-1}$ of the samples, it is shown that samples 1 (concrete block) has Ra_{eq} value of 40.42 ± 19.63, sample 2 (mud brick) has Ra_{eq} value of 21.60 ± 0.30 and sample 3 (extruded clay brick) has Ra_{eq} value of 17.61 ± 0.43. The extruded clay brick has the lowest value of Ra_{eq}, this is because the value of the average activity concentration of ^{232}Th is lower than the ones of the two other sample types. The values obtained are less than the radium equivalent activity of 370 Bq Kg $^{-1}$ in building material which will produce an exposure of about 1.5 mSv y^{-1} to the inhabitants (UNSCEAR, 1982).

The Absorbed Dose Rate in Air

The absorbed dose rate in air at 1.0 m to the ground level in nGy y^{-1} due to the mean specific activity of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in Bq Kg^{-1} was calculated using the formula below (Beck, 1972),

$$D = 0.427C_U + 0.662C_{Th} + 0.0432C_K \qquad (2)$$

Where C_U, C_{Th} and C_K are the mean activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in Bq Kg^{-1} respectively. Table 2 shows the absorbed dose rate in air of the samples in nGy y^{-1}. The concrete block has 19.40 nGy y^{-1}, the mud brick has 10.23 nGy y^{-1} and the extruded clay brick has the lowest value of 8.41 nGy y^{-1} which is quite close to the mud brick. The calculated values of the absorbed dose rate in air for all samples types are less than the ICRP permissible level of 80 nGy y^{-1} (UNSCEAR, 2000).

External Hazard Index

The upper limit of radiation arising from building materials as proposed by the ICRP (1977) is 1.5 mSv y^{-1} (ICRP, 1977), for a radiation dose to be limited to this value a model based on an infinitely thick wall without windows and doors was made, and the model serves as a criterion for estimating the external hazard index (H_{ext}) which is given as (Krieger, 1981),

$$H_{ext} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (3)$$

A correction was made to this model by considering a finite thickness of wall and the existence of windows and doors (Hewamanna et al., 2001). This is given as,

$$H_{ext} = \frac{C_{Ra}}{740} + \frac{C_{Th}}{520} + \frac{C_K}{9620} \qquad (4)$$

Where C_{Ra}, C_{Th} and C_K, are the activity concentration of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K respectively. From Figure 1 it is shown that the cement brick has a mean H_{ext} value of 0.06, mud brick has 0.03 and extruded clay brick has the lest mean H_{ext} value of 0.02. All samples have a Hex value that is less than unity, which implies that the radiation hazard is negligible. This corresponds to the fact that the radiation exposure due to radioactivity in these materials must be ≤ 1.5 mSv y^{-1} (ICRP, 1991)

Internal Hazard Index

The intake of air by residents in a room may also involve taking in radon and its short lived products, which are hazardous to the lung. Therefore, internal exposure to radon and its daughter progeny is quantified by the internal hazard index (H_{in}) given as (Nour, 1991),

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \qquad (5)$$

Where C_{Ra}, C_{Th} and C_K retain there usual meaning. From Figure 1, it is shown that concrete block has a H_{in} value of 0.14; mud brick has 0.08 and extruded clay brick has the lowest value of H_{in} with a value of 0.07. All in the sample have a H_{in} value less than unity.

Annual Effective Dose Rate

The effective dose rate in mSv y^{-1} was estimated taking into account the conversion factor and the indoor occupancy factor. A value of 0.7 Sv Gy^{-1} was used for the conversion factor from absorbed dose in air to effective dose received by adult and 0.8 was used as the indoor occupancy factor, since about 80% of time are spent indoors on the average around the world (UNSCEAR, 2000).The annual effective dose is given by the equation below,

$$H = D \times 8766h \times 0.8(occupancy - factor) \times 0.7SvGy^{-1}(conversion - factor) \times 10^{-6} \qquad (6)$$

where D in nGy h^{-1} is the previously estimated absorbed dose rate. From Figure 1, it is shown that the extruded clay brick has the lowest value of annual effective dose rate with 0.04 mSv yr^{-1}, while mud brick has a closer value of 0.05 mSv yr^{-1} and concrete block has 0.10 mSv yr^{-1}. The calculated values are in any case less than the ICRP dose criterion value of 1 mSv yr^{-1} (ICRP, 1991)

Table 1. Radioactivity of ^{40}K, ^{238}U and ^{232}Th in the samples.

	Average activity concentration (Bqkg $^{-1}$)		
Sample	^{40}**K**	^{238}**U (** ^{226}**Ra)**	^{232}**Th**
Concrete block (sample type 3)	135.10 ± 13.23	9.58 ± 3.16	14.3 ± 3.32
Mud brick (sample type 2)	66.34 ± 6.66	6.81 ± 2.26	6.78 ± 2.58
Extruded clay brick (Sample type 1)	69.21 ± 6.88	7.26 ± 2.54	3.51 ± 1.54

Table 2. The absorbed dose rate in air and radium equivalent activity (Ra_{eq}) in samples.

Samples	**Absorbed dose rate (nGy y** $^{-1}$**)**	Ra_{eq} **(Bq Kg** $^{-1}$**)**
Concrete block	19.40	40.42
Mud brick	10.23	21.60
Extruded clay brick	8.41	17.61

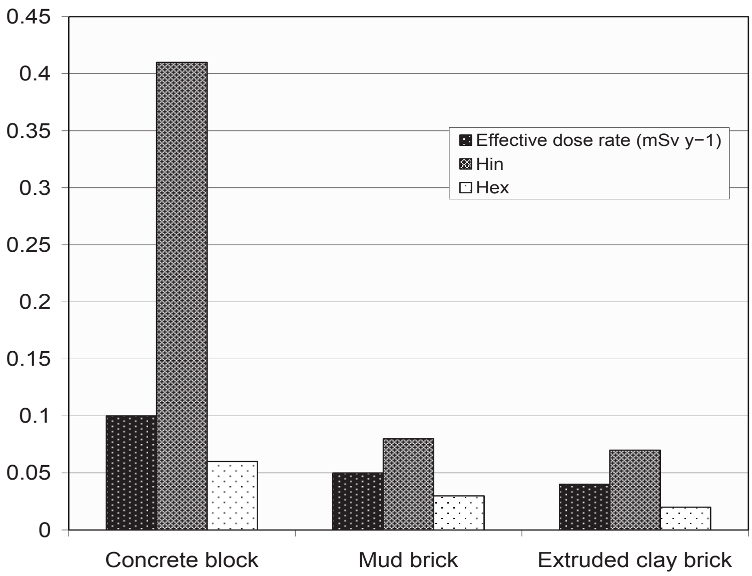

Figure 1. Effective dose rate and internal and external hazard indices of studied samples

The activity concentration of radionuclides found in concrete blocks taken from Ogbomoso by Ademola and Farai (Ademola and Farai, 2005) is approximately twice of that obtained in this study, which may be due to difference in gamma spectrometer used in both studies and the location of samples used for the analysis. Mehdizadeh et al. (Mehdizadeh et al., 2011) in their study of natural radioactivity building materials Iran found out that brick samples contained the highest values of ^{40}K while cement values contained the maximum value of ^{226}Ra and ^{232}Th. Pilkyte et al. (Pilkyte et al., 2006) also obtained higher activity concentration ^{40} K, ^{226}Ra and ^{232}Th in brick than in concrete in Lithuania. Furthermore, the study by Hizem et al (Hizem et al., 2005) shows that the activity concentration index of brick material used in Tunisian dwellings is quite close to 1, indicating that higher radioactivity is present in brick material found in this area.

Although this study shows that the activity concentration of the studied radionuclides in concrete block is higher than that of the two other materials studied many other studies around the world shows that bricks present a higher radioactivity than concrete and the other common building materials. This observation cannot be used as a general inference, since natural radioactivity of the soil varies from place to place. The study of the radioactivity in mud brick was not carried by these studies and information about it is scarce, therefore more research needs to be carried out on mud brick across different regions.

CONCLUSION

This study shows that the concentration of ^{238} U and ^{40}K are higher in concrete block and extruded clay brick than the mud brick, but the extruded clay brick has less concentration of ^{232}Th than the other two samples types. The assessment of radiological hazards from samples shows that extruded clay brick has the lowest value of radium equivalent activity, external and internal index, absorbed dose rate in air and annual effective dose. This indicates that the extruded clay brick posses less radiological hazards than the concrete block and the mud brick in the study area. Also, the fact that the gap in value hazard indices between the extruded clay brick and the mud brick is small shows that building material made with clay especially mixed with sand are less radiological hazardous, moreover it is cheap to get and abundant in nature.

All calculated values are less than international safety limits of 370 Bq Kg $^{-1}$ for maximum permissible value of radium equivalent concentration, 1 mSv yr^{-1} criterion limit for annual effective dose, 80 nGy y^{-1} for absorbed dose rate in air and unity for the external and internal hazards.

REFERENCE

Ademola, J.A. and Farai, I.P. (2005). Annual effective dose due to natural radionuclides in building blocks in eight cities of Southwestern Nigeria. *Radiation. Protection Dosimetry* 114(4), 524–526.

Ajayi, O.S. and Ajayi, I.R. (1999). Survey of environmental gamma radiation levels of some areas of Ekiti and Ondo State, Southwestern part of Nigeria. *Nigeria Journal of Physics* 11, 17-21.

Awodugba, A.O., Adelabu, J.S.A., Awodele, M.K. and Ishola, G.A. (2007). Material and the end product from West African Portland cement plc, Ewekoro, south western part of Nigeria. *Indoor and Built Environment* 16, 569.

Beck, H.L. (1972). The physics of environmental radiation fields, Natural Radiation environment II. CONF-720805p2. Proc second Intl. Symp. *Natural Radiation Environ* 101-133.

Beretka, J. and Mathew, P.J. (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products. *Health Phys.* 48, 87-95.

Hewamanna, R., Sumithrachchi, C.S., Mahawatte, P., Nanayakkara, H.L.C. and Ratnayake, H.C. (2001). Natural radioactivity and gamma dose from Sri Lankan clay bricks used in building construction. *Applied Radiation Isotopes* 54(2), 365-369.

Hizem, N., Ben Fredj, A. and Ghedira, L. (2005). Determination of natural radioactivity in building materials used in tunisian dwellings by gamma ray spectrometry. *radiation protection dosimetry* 114**,** 533-537.

ICRP, (1977). International Commission on Radiological Protection, Recommendations of ICRP, Publication 26. Pergamum Press, Oxford.

International Commission on Radiological Protection, (1991). 1990 Recommendations of the International Commission on Radiological Protection. Publication 60. 21(1–3).

Islam, M.N., Alam, M.N., Mustafafa, M.N., Saddiqua, N., Miah, N.M.H., Chowdbury, M.I., Shah, S.H., Ali, L. and Roy, P.K. (1990). Characteristics of shielding arrangement for a HPGe detector designed and fabricated locally. *Chittagong University Studies, part II: Science*. 14(2), 105-111.

Krieger, R. (1981). Radioactivity of construction materials. *Betonwerk Fertigteil-Technology* 47, 468-473.

Mehdizadeh, S., Faghihi, R. and Sina, S. (2011). Natural radioactivity in building materials in iran. *Nukleonika,* 56**,** 363−368.

Mollah, A.S., Ahmad, G.U., Hussain, S.R. and Rahman, M.M. (1986). The natural radioactivity of some building materials used in Bangladesh, *Health Physics* 50, 849–851.

Nour, K.A. (1991). Measurement of natural radioactivity in building material in Quena city, upper Egypt. *Journal of environmental Radioactivity* 83, 91-99.

Olomo, J.B., Tchokossa, P. and Aborisade, C.A. (2003). Study of radiation protection guidelines in the use of building materials for urban dwelling in southwestern Nigeria. *Nigeria Journal of Physics* 15(1), 7-13.

Pilkyte, L., Butkus, D. and Morkunas, G. (2006). Assessment of external dose indoor in lithuania. *radiation protection dosimetry* 121**,** 140–147.

Schotzing, V. and Debetin, K. (1983). Photon emission probabilities per decay of ^{226}Ra and ^{232}Th equilibrium with there daughter products, *Internationa Journal Applied Radiation Isotopes* 34, 533-538.

Slunga, E. (1988). Radon classification of building ground. *Radiation Protection Dosimetry* 24(114), 39-42.

Stranden, E. (1976). Some aspects on radioactivity of building materials, *Health Physics* 8, 167-177.

Tchokossa, P. (2006). Radioactivity in food materials in Delta area and River State, Nigeria. PhD thesis, Obafemi Awolowo University, Ile Ife.

Turhan, S. and Gurbuz, G. (2008). Radiological significance of cement used in building construction in Turkey. *Radiation Protection Dosimetry* 129(4), 391-396.

United Nations Scientific Committee on the Effects of atomic Radiation, Sources and effects of ionizing radiation, UNSCEAR, (1993). New York.

United Nations Scientific Committee on the Effects of Atomic Radiation, Sources and effects of ionizing radiation, UNSCEAR (2000) Report, New York.

UNSCEAR, (1982). Ionizing radiation sources and biological effects, United Nations Scientific Committee on the Effects of Atomic Radiation, Report to General Assembly, With Annexes, United Nations, New York.

UNSCEAR, (1988). Sources, effects and risks of ionizing radiation, United Nations Scientific Committee on The Effects of Atomic Radiation. Annex A, B United Nations, New York.