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Natural Radionuclide Contents in Raw Materials and the Aggregate Finished Product from Dangote Cement Plc, Obajana, Kogi State, North Central Nigeria

[1]J.O. Ajayi, [1]B.B. Balogun and [2]O. Olabisi
[1]Department of Pure and Applied Physics,
[2]Department of Science Laboratory Technology Ladoke Akintola University of Technology,
P.M.B. 4000, Ogbomoso, Oyo State, Nigeria

Abstract: Assessment of gamma ray activity in raw materials and the end product in Dangote Cement from Dangote Cement Plc, Obajana and Kogi State has been investigated in this study. Gamma ray spectrometry that possesses scintillation detector was used to analyze the samples collected from the company. Samples collected as raw materials are limestone, clay, gypsum and laterite and cement as finished product. The ^{40}K, ^{238}U, ^{232}Th activity concentration were detected. The concentration of ^{40}K range from 4649±366 to 0±65 Bq/Kg with highest value in limestone and lowest in laterite. The ^{238}U concentration is highest in gypsum range from 696±233 to 41±27 Bq/Kg in laterite. ^{232}Th activity is below detectable limit in all the raw materials but it has activity concentration of 40±26 Bq/Kg in the finished product which may be traceable to the fact that some finished additives are present which are not in the basic raw materials of this cement under investigation. It is concluded that the natural radionuclide measured for ^{40}K, ^{238}U and ^{232}Th has mean activities of 2189.75±219.5, 331.25±132.25 and 0±31 Bq/Kg respectively, while its corresponding mean absorbed dose rate in air at 1 m above the ground was calculated to be 235.61 nGy/h or 2.064 mSv/y and the aggregate finished product (cement) has absorbed dose rate of 342.22 nGy/h and an effective dose equivalent of 2.998 mSv/y. The calculated absorbed doses in nGy/h and mSv/y shows that Dangote cement under consideration has higher activities of the isotopes than the permissible level suggested by ICRP (80 nGy/h or 0.7 mSv/y)

Keywords: Cement, gamma ray, Nigeria, Obajana, radionuclide

INTRODUCTION

In the earth crust, there are availability of radioactive isotopes such as potassium -40 (^{40}K), uranium -238 (^{238}U), thorium -232 (^{232}Th), thallium-208 (^{208}Tl), bismuth-214 (^{214}Bi) which contribute to the small but measurable amount of Naturally Occurring Radioactivity (NORM). Since this may be present in materials quarried from the earth crust and use in the production of cement, this product may contribute to the overall exposure of a large number of people to radiations as a result of its major usefulness in building industries and various construction works

The most important exposure as regards health is to the isotopes of radon-radon-222 and radon-220. These are the decay products of radium-226 and radium-224, which are the members of the decay series of ^{238}U and ^{232}Th, respectively. They consequently become the major source of internal exposure when inhaled (Awodugba *et al*., 2007)

Estimation of radionuclide present in cement is essential and imperative because cement is a key component of both commercial and residential construction in Nigeria and other countries. Cement is the key ingredient in concrete product comprising roughly 12% of the average residential-grade ready-mix concrete (Olade, 1988).

Gamma radiation is electromagnetic radiation of high frequency (very short wavelength), denoted as γ and is produced by decay of high energy state in atomic nuclei and also energy sub-atomic particle interactions in natural processes and man-made mechanisms (Debertia and Helmer, 1980).

Dangote cement was incorporated as Obajana cement Plc on 4th November, 1992 by the Kogi State government to operate plant (s) for the preparation, manufacturing, control, research and contribution of cement and related products. It was acquired by Dangote Industries Limited (DIL) in 2002 and commenced the construction of the first cement production plant in 2004. In July 2010, the company's name was changed from Obajana Cement Plc to Dangote Cement Plc. (DCP). The plant is completely integrated and fully automated having all the raw materials needed for the production of cement except gypsum which is yet to be produced in commercial quantities, despite the huge natural deposit in Nigeria (Vetiva Capital Management Limited, 2010).

Corresponding Author: J.O. Ajayi, Department of Pure and Applied Physics, P.M.B. 4000, Ogbomoso, Oyo State, Nigeria

Objectives of this study is to examine the background radiation level from raw materials used in the production of this brand of cement and determine the percentage contribution of each component to the overall activity of the finished product.

MATERIALS AND METHODS

The investigated samples were cement (finished product) and its raw materials are Limestone, Clay, Gypsum and Laterite used for its production. Almost all of them are found in the vicinity of the factory, they are all mined from Obajana mines except gypsum which is imported. These raw materials, before processing were first cleaned of foreign materials such as wood, roots and so on, then they were separately ground to a degree that they could pass through a 2 mm-mesh sieve. The grinder was cleaned with distilled water after each sample was ground to prevent cross-contamination. The meshed raw samples were transferred to M1900). Counting of the radionuclide was done by a gamma spectrometric system which involved the use of a sodium iodide doped with Thallium NaI (Tl) detector. The analysis was performed using 4096 channel Canberra computer analyzer (Avwiri, 2005). All samples and the background were counted for 36000s (10 h) each and a Canberra lead shield, 10 cm thick and cylindrical in shape, was used to reduce the gamma-ray background (ICRP, 1983) arinelli beakers (1000 mL capacity) which were first washed with distilled water in preparation for radionuclide analysis.

The beakers were then sealed tightly for a minimum of 28 days to attain secular equilibrium between thorium, radium and their decay products (Tufai *et al*., 1900). Counting of the radionuclide was done by a gamma spectrometric system which involved the use of a sodium iodide doped with Thallium NaI (Tl) detector. The analysis was performed using 4096 channel Canberra computer analyzer (Avwiri, 2005). All samples and the background were counted for 36000s (10 h) each and a Canberra lead shield, 10 cm thick and cylindrical in shape, was used to reduce the gamma-ray background (ICRP, 1983)

The background spectrums were collected and the counts were subtracted from the respective region of interest (Beck, 1972). The calibration efficienc for the different energy peak measured using (IAEA, 2010) reference samples. The energy of 1764.5 KeV (^{214}Bi) was used to determine the activity of ^{238}U and energy 2614 KeV (^{208}Tl) was used to determine the activity of ^{232}Th and energy 1461.0 KeV gamma ray for ^{40}K (UNSCEAR, 1988) 1461.0 KeV gamma ray for ^{40}K (UNSCEAR, 1988) Using the relation; (Beck *et al*., 1972):

$$D\ (\text{nGy/h}) = 0.042C_U + 0.662C_{Th} + 0.043C_K$$

The absorbed dose rates D at 1m above the ground were calculated: where C_U, C_{Th} and C_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K, respectively in the mineral samples. Using the conversion factor of 0.70 Sv/Gy (Shousha, 2006) the dose equivalents in mSv/y were calculated.

RESULTS AND DISCUSSION

In Table 1 and 2 the mean specific activity radionuclide concentration level and the calculated absorbed dose for all the samples were presented. The concentration for ^{40}K range from 4649±366 to 0±65 Bq/Kg. It shows the highest level in limestone and Below Detected Limit (BDL) in clay and laterite. The activity concentration of ^{238}U is highest in Gypsum ranging from 696±233 to 41±27 in laterite, while ^{232}Th activity concentration is completely below detectable limit in all samples. The mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in the basic raw materials are 2189.75±219.5, 331.25±132.25 and 0±31 Bq/Kg, respectively as presented in Table 3. The finished product (cement) has activity concentration for ^{40}K as 4622±386 Bq/Kg, ^{238}U as 274±269 Bq/Kg and ^{232}Th as 40±26 Bq/Kg.

Its corresponding mean absorbed dose rate in air at 1m above the ground are calculated to be 235.61 nGy/h or 2.064 mSv/y as evident in Table 4 and the aggregate finished product (cement) has absorbed dose rate of 342.22 nGy/h and an effective dose equivalent of 2.998 mSv/y. The result when compared with average concentration of measured radionuclide in the different cement sample from Ewekoro (Awodugba *et. al*, 2007).

Table 1: Activity concentration in Bq/Kg

Samples	^{40}K	^{238}U	^{232}Th
Limestone	4694±366	547±242	0±32
Gypsum	4110±382	696±233	0±32
Clay	0±65	41±27	0±30
Laterite	0±65	41±27	0±30
Finished product (cement)	4622±386	274±269	40±26

Table 2: Mean activity concentration in Bq/Kg

^{40}K	^{238}U	^{232}Th
2189.75±219.5	331.25±132.25	0±31.00

The mean activity concentration of the basic raw materials investigated

Table 3: Absorbed dose rate (D)

Samples	D (nGy/h)	D (mSv/y)
Limestone	433.48	3.797
Gypsum	473.92	4.152
Clay	17.510	0.153
Laterite	17.510	0.153
Finished product (cement)	342.22	2.998

Table 4: Mean dose rate (D)

Mean dose rate	235.61 (nGy/h)	2.064 (mSv/y)

The mean dose rate of the basic raw materials investigated which are 1014.39±50, 363.46±14 and 125.71±5 Bq/Kg for ^{40}K, ^{238}U and ^{232}Th, respectively are much lower than the values in Dangote brand cement with values 4622±386, 274±269 and 40±26 Bq/Kg , respectively. The measured concentration of ^{40}K, in the Dangote brand cement which is 4622±386 Bq/Kg is three times higher than the reported for the Portland cement from Ewekoro.

Likewise, the average concentration of ^{238}U is a bit lower than the reported value from Ewekoro and ^{232}Th is Below Detectable Limit (BDL) unlike the reported value from Ewekoro cement which is 363.46±14 Bq/Kg and 125.71±5 Bq/Kg. However, the calculated absorbed doses in nGy/h and mSv/y show that Dangote cement under consideration has its calculated absorbed dose rate higher than the activity level of 80 nGy/h (0.7 mSv/y) permissible by ICRP (Beck *et al.*, 1972).

CONCLUSION

We have carried out in our investigation the assessment of gamma ray activity in raw materials and the end product in Dangote Cement from Dangote Cement Plc, Obajana and Kogi State. The ^{40}K, ^{238}U, ^{232}Th activity concentration were detected. The concentration of ^{40}K range from 4649±366 to 0±65 Bq/Kg with highest value in limestone and lowest in laterite. The ^{238}U concentration is highest in gypsum range from 696±233 to 41±27 Bq/Kg in laterite. ^{232}Th activity is below detectable limit in all the raw materials but it has activity concentration of 40±26 Bq/Kg in the finished product which may be due to the fact that some finished additives are present which are not in the basic raw materials of this cement under investigation.

The result of this study has revealed that the natural radionuclide measured for ^{40}K, ^{238}U and ^{232}Th has mean activities of 2189.75±219.5, 331.25±132.25 and 0±31 Bq/Kg, respectively while its corresponding mean absorbed dose rate in air at 1 m above the ground was calculated to be 235.61 nGy/h or 2.064 mSv/y and the aggregate finished product (cement) has absorbed dose rate of 342.22 nGy/h and an effective dose equivalent of 2.998 mSv/y. The calculated absorbed doses in nGy/h and mSv/y shows that Dangote cement under consideration has higher activities of the isotopes than the permissible level suggested by ICRP (80 nGy/h or 0.7 mSv/y)

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