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RADIOLOGICAL HEALTH RISK ASSESSMENT AT ASHAKA CEMENT COMPANY, GOMBE STATE, NIGERIA

[*1]Habu Tela Abba and [2]Abbas Babakura

[1]Department of Physics, Yobe State University, Damaturu, Yobe State.
[2]Department of Physics, University of Maiduguri, Borno State.

[*]Corresponding author's Email: htelaabba@gmaail.com

ABSTRACT

Enhanced natural radioactivity due human activities can be harmful to the environment and human health depending on the amount of exposure. A sensitive gamma spectrometry system consisting of 7.6cm x 7.6cm Nal(Tl) scintillation detector coupled with Canberra series 10 plus multichannel analyzer was used to determine the radioactivity concentration of natural radionuclides ^{232}Th, ^{238}U, and ^{40}K in soil samples collected from the five communities around Ashaka Cement Company. The results obtained showed that the radionuclides are present in the soil samples in varying concentrations ranging from 11.36 Bq kg^{-1} measured in Badabdi to 98.06 Bq kg^{-1} in Ashaka Cement for ^{238}U, from 13.21 Bq kg^{-1} in Jajami to 44.36 Bq kg^{-1} in Ashaka Cement for ^{232}Th and from 65.50 Bq kg^{-1} in Gwangila to 415.62 Bq kg^{-1} in Julgwal Barkono for ^{40}K. Absorb dose rate and annual effective dose rate due to these radionuclides are in the range 36 nGy h^{-1} in Badabdi to 50 nGy h^{-1} in Ashaka Cement and 0.132 mSv to 0.194 mSv in Badabdi and Ashaka Cement, respectively. These results are within global limits recommended by UNSCEAR. Therefore, the environmental matrices around the factory could be used without any restrictions

Keywords: Radiological health risk, Soil samples, Natural Radionuclides, Ashaka Cement Company.

INTRODUCTION

All organisms on the earth's surface are always exposed to background radiation from both natural and artificial sources. The natural source is mainly contributed by the radionuclides ^{232}Th, ^{238}U and ^{40}K which exist in rocks, soil, water, air, and building materials (Gbadebo, 2011). The worldwide annual effective dose received by the population from all natural and artificial sources is 2.8 mSv, out of which 85% of the dose (2.4 mSv) comes from only natural background radiations (Singh *et al.*, 2017). The amount of the radionuclides in rocks and soil of a particular region determine the level of radiation exposure of individuals in that area which depends on the geochemical and geographical characteristics of that region (UNSCEAR, 2000). In most cases, natural levels of radionuclides concentrations are within safe limits (except where there is human actives that can expose the earth crust akin the activities of cement companies (Baykara and Doğru, 2009). However, human activities such as mining and milling of uranium and phosphate, tobacco smoking, oil exploration, air transportation, coal-fired power station, and so on can trigger Technologically Enhanced Naturally Occurring Radioactive Materials (TENORMs). The most common raw rocks used in cement production are limestone (supplies the bulk of the lime), clay, and shale (supplies the bulk of the silica, alumina and ferric oxide). These are known to contain natural radionuclides with shale having a considerable quantity of the radionuclides (El-Arabi *et al.*, 2006)

Assessment of natural radiation has been on the increase globally because of the health hazard it pose to the populace. Özdiş *et al.* (2017), determined the activity concentration of natural radionuclides in cement used as building material in Turkey and reported values of 18−143 Bq kg^{-1} for ^{226}Ra, 5–66 Bq kg^{-1}for ^{232}Th and 142–540 Bq kg^{-1} for ^{40}K. In a similar study, Isola and Moni (2015), evaluated the terrestrial gamma dose and annual effective dose at Obajana cement factory, Kogi state, Nigeria and reported absorbed dose rate and effective dose in the range of 42.68±2.3 to 53.49±2.18 nGy h^{-1} and 46.18±3.19 to 62.92±2.08 µSv/y, respectively. A study by Gbadebo and Amos (2010) reported specific mean activity values of 8.07, 5.75 and 35.86 Bq kg^{-1} for ^{238}U, ^{232}Th and ^{40}K, respectively in limestone from Ewekoro cement factory in Ogun state, Nigeria. In another study by Usikalu *et al.* (2018), estimated radiological parameters around a cement company and reported that exposure is within recommended limits. Usikalu *et al.* (2016), measured the activity concentration of natural radionuclides in drinking water (bore holes) from areas around cement factory and evaluated annual effective dose for different age groups which revealed that the water is safe for consumption for all age groups except 0-1 year.

It is envisage that the by-products resulting from the process of cement production may find ways into the underground water systems or settle on the soil surface that could represent direct and indirect path ways to human. Ashaka Cement Company is known for one of the largest producer of cement in Nigeria. Until now, there has not been a study evaluating background radiation levels in Ashaka Cement Company and environs. Therefore, this study seek to evaluate the gamma radiation dose rates and the annual effective dose due to radioactivity concentration of natural radionuclides in soil samples from five communities around Ashaka Cement Company.

Study area

Ashaka Cement Company was incorporated in 1974 and commenced production in 1979 as cement manufacturing company. The study area comprises of five communities, this include Ashaka Cement, Gwangila, Badabdi, Julgwal Barkono and Jajami. Its geographical location lies between latitudes 10.919 −10.929 N and Longitudes 11.465 – 11.477 E. The study area falls within the Gongola Basin, North-eastern Nigeria. The regional geology of the study area comprises of the basement complex and the Cretaceous to Tertiary sediments (Usman *et al.*, 2018). These sediments are characterised with substantial deposits of sandstone and limestone (Mayomi *et al.*, 2018). Figure 2 is a Map of the study area.

Fig. 2: Map showing the study area.

MATERIALS AND METHODS

Sample collection and Preparation

A total of 60 soil samples from the five communities at a depth of 0 −30 cm were collected for the analysis. Samples were collected at distances in such a way radionuclide detected in the samples were expected to be influenced by activities of the factory and any possible leaching of radionuclides materials would be captured. Each sample was collected in a polyethene bag, sealed and labelled; and transported to laboratory for preparation. The samples were dried at 105 ℃ in an oven to a moisture free content. A fine powder of each sample was obtained using a crusher which were later sieved through 2 mm mesh to keep uniform grain size and obtain a homogenous soil samples for measurements. About 500 g of each sample was packed in a suitable container, hermetically sealed and stored for four weeks for ^{238}U to attain secular equilibrium with its decay products (El-Gamal *et al.*, 2007). The measurement was carried out at Centre for Energy research and Development (CERD), Obafemi Awolowo University, Ile −Ife.

Experimental Procedure

The concentration of the radionuclides in the samples were determined using a gamma spectrometer consisting of 7.6cm x 7.6cm Nal(Tl) scintillation detector coupled with Canberra series 10 plus multichannel analyzer (MCA) which was well calibrated and shielded. The counting time for each was 36,000 seconds. The gamma transition energy of 1460 keV of ^{40}K and 1764.5 keV of ^{214}Bi were used to determine the concentration of ^{40}K and ^{238}U, respectively, while the gamma transition energy of 2614 keV of ^{208}TI was used to determine the concentration of ^{232}Th. In order to strip the background count, an empty container of same geometry was counted for the same time. The efficiency calibration of the detector was done using a reference standard mixed sources. Specific concentration of each radionuclide in the sample was calculated using the following equation (Kapanadze *et al.*, 2019).

$$A = \frac{C_E}{C_{eff} \times \gamma \times m \times t.} \quad (1)$$

where C_E is the total count of a peak at energy E, C_{eff} is the detection efficiency at energy E, γ is the percentage of gamma emission probability for radionuclide for a transition at energy E, m is the mass in kg of the measured sample and t is the counting time.

The Minimum Detectable Activity (MDA) for each radionuclide, ^{238}U, ^{232}Th and ^{40}K was calculated using the following equation.

$$MDA = \frac{1.645\sqrt{N_B}}{F_E \mu(E).t_c.M} \quad (2)$$

where 1.645 is the statistical coverage factor at 95% confidence level, N_B is the background counts at the region of interest, F_E is the transition probability of the gamma line, μ(E) is the photopeak, t_c is the counting time and M is mass of the sample. The MDA for each radionuclide was calculated as 2.30 Bq kg^{-1} for ^{238}U, 2.15 Bq kg^{-1} for ^{232}Th and 12.9 Bq kg^{-1} for ^{40}K.

Absorbed Dose

The mean absorbed dose rate in air 1 m above the ground surface was evaluated from the mean activity concentration of the radionuclides using the equation below (Ajayi, 2008).

$$D = 0.429C_U + 0.666C_{Th} + 0.042C_K \quad (3)$$

where C_U, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K, respectively.

Annual Effective Dose

The total absorbed dose rate accumulated over a year, is reported as the annual effective dose (mSv), which was calculated using the below equation (Kandari *et al.*, 2016).

$$AE = D \times F \times 0.6 \times 24 \times 365 \times 10^{-6} \quad (4)$$

where F is the conversion factor (0.7 Sv/Gy) and 10^{-6} is to convert nano Sievert to mili Sievert. It assumed that people in the area spend 60% of their time outside.

RESULTS AND DISCUSSION

The results of this study highlights the presence and the activity concentration of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) in the overlain soils from five communities around Ashaka Cement Company. The range of values of the radionuclides for the five communities are presented in Table 2 while the mean values are presented in Table 3. Generally, the activity concentration of the radionuclides ranged between 11.36 Bq kg^{-1} measured in Badabdi and 98.06 Bq kg^{-1} in Ashaka cement for ^{238}U, between 13.21 Bq kg^{-1} in Jajami and 44.36 Bq kg^{-1} in Ashaka Cement for ^{232}Th and between 65.50 Bq kg^{-1} in Gwangila and 415.41 Bq kg^{-1} in Julgwal Barkono for ^{40}K. The closeness of Ashaka cement village to the company may be the reason for higher concentration values of ^{238}U and ^{232}Th. The mean values of each radionuclides indicates that there is higher values of ^{40}K in all the samples followed by ^{238}U and least ^{232Th} in all samples.

Table 2: Range of activity concentration in soil samples of each community

Community	^{238}U		^{232}Th		^{40}K	
	Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Julgwal Barkono	23.31	58.45	16.44	34.50	102.70	415.41
Badabdi	11.36	84.04	15.55	37.66	101.12	340.82
Ashaka Cement	23.32	98.06	20.70	44.36	109.36	405.62
Jajami	19.66	67.50	13.21	35.41	86.50	145.72
Gwangila	21.40	81.50	16.30	41.34	65.40	156.80

Table 3: Mean activity concentration in soil samples of each community

Community	^{40}K	^{238}U	^{232}Th
Julgwal Barkono	301.73+2.9	29.92+2.2	26.62+2.42
Jajimi	275.52+3.2	40.82+1.82	27.49+1.52
Ashaka Cement	235.97+2.7	46.28+1.68	30.26+2.18
Badabdi	221.54+1.8	25.00+3.2	23.60+2.0
Gwangila	114.89+3.16	41.12+1.84	22.59+2.56

The calculated absorbed dose rate in air ranged from 36 nGy h^{-1} in Badabdi to 53 nGy h^{-1} in Ashaka Cement. Annual effective dose was evaluated to range from 0.132 mSv to 0.194 mSv in Badabdi and Ashaka Cement, respectively. The results of the absorbed dose and annual effective dose are comparatively within the recommended standard limits as shown in Figure 2 and 3. This revealed that, the radiological burden or adverse health effects due to operation of cement factory on the human populace and the entire environment is insignificant.

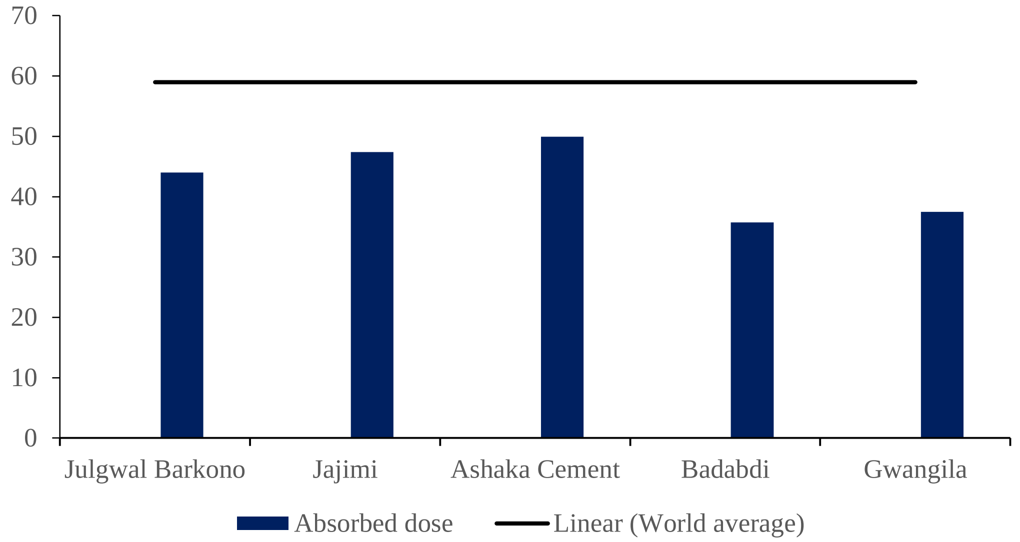

Fig. 2: Absorbed dose for each community compared to world average

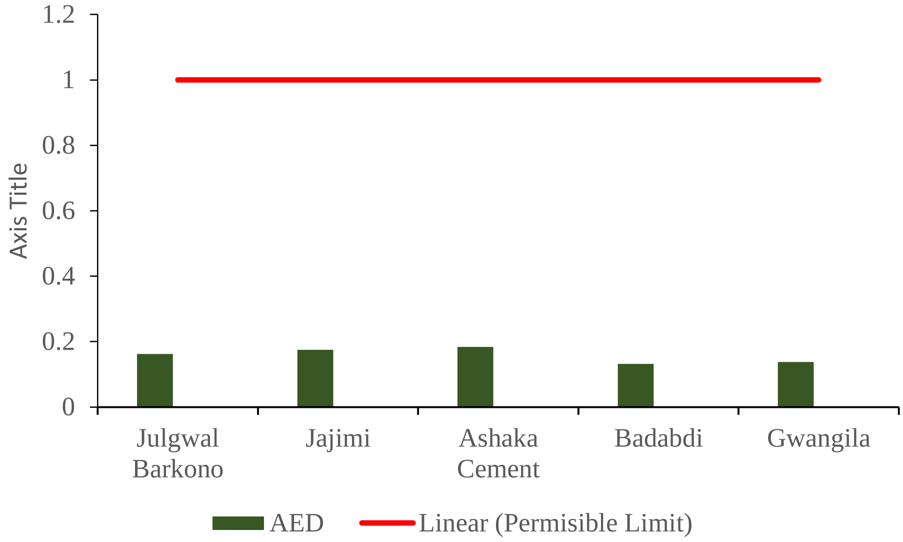

Fig. 3: Annual effective dose for each community compared to permissible limit.

CONCLUSION

Assessment of radiological health risk in five communities around Ashaka Cement Company has been carry out. The mean activity concentration of radionuclides in soil samples, absorbed dose rate and the annual effective dose for each community were determined. The absorbed dose rate is within the recommended average value of 59 nGy h^{-1} while annual effective dose is lower than the maximum permissible limit of 1 mSv y^{-1} (public) and 20 mSv y^{-1} (occupational) recommended by UNSCEAR. Hence, the activities of the company may not pose adverse health implication on the populace and the environment. Therefore, it is however recommended that there should be public awareness on the health hazard of natural radiations especially of limestone mining and the production of cement in the environment. Routine monitoring of background radiation should also be part of environmental assessment for industries and mining projects.

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