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Natural Gamma Radiation Exposures of the Populace In and Around the Ewekoro Cement Factory, Ogun State, Southwestern, Nigeria

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Abstract

Limestone, shale and gypsum known to constitute source of natural radioactivity, are the raw materials used for cement production. The natural radioactivity level in cement is characterized by the geological origin and setting of the area where these raw materials are obtained. These raw materials are found inlarge quantity in the bedrock of Ewekoro in Ogun State where a cement factory is located for commercial production of cement. Therefore, it is pertinent to measure the activity concentration in the cement product and determine the external and internal radiation exposure of the populace as a resultof the release of cement dust from Ewekoro Cement Factory to the environment.

The activity concentrations of radionuclides in the study are lower than the values reported in other literatures and the total effective dose is low when compared to the value of 18.1mSvy^{-1}reported for sieving columbium-tantalite from the Democratic Republic of Congo. Although the radiological impact on the populace is low, but efforts must be made to discourage indiscriminate radiation exposure of individuals in the area.

Keywords: Temperature**,** Rheological, Mud, Bentonite, Properties

1.0 Introduction

Natural radioactivity defined as the spontaneous disintegration of unstable nuclei in nature to release nuclear particles (α- and β-particles) together with neutral and lighter particles (neutrinos) in order to attain stability is the major source of environmental radiation exposure. The release of particles usually accompanied the emission of highly penetrating electromagnetic radiation γ-rays. Natural background radiation source originating from both terrestrial and extra-terrestrial accounts for 96.1% of the total radiation dose to world population and artificial source accounts for just 3.9%. The internal and external radiation received by individuals in the environment from the earth's crust (primordial) is about 85% of the natural background radiation and the remaining 15% is from cosmic rays[1].

In recent times human activities have tremendously improved the levels of radioactivity in the environment and enhanced the redistribution of the naturally occurring radionuclides [2].

High concentrations of radium-226 and thorium-232 are usually contained in the extracted ores from mining and milling operations [3]

The socio-economic development of a nation depends on her industrialization, which in effect associates negative consequences. The manufacture and use of cement products plays an important role in the Nigerian economy as evident in the annual consumption of over ten (10) million tons with consumption rate corresponds to 75kg per capita per annum and has been on the annual incremental rates of between 10% and 15% [4]. The essential raw materials in the production of cement like limestone ($CaCo_3$), shale and gypsum are mined from the earth's crust. These raw materials are reported to contain some natural radioactive elements characterized by the geological origin and setting of an area. The radionuclides including uranium (^{238}U), thorium (^{232}Th) and their progenies occur as trace elements in limestone and other raw materials in cement [5].The shale and gypsum found from the bedrock layers above limestone deposit are used as additives in the production of cement.

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The occurrence of vast deposit of limestone with its economic importance in mining for industrial purposes motivated the establishment of the cement factory in Ewekoro[6]and the presence of a substantial amount of natural radioactive elements in its bedrock has been reported[7].The limestone and shale mined from the area are therefore subject of (^{238}U, ^{232}Th and ^{40}K) radionuclide contaminants in the cement products from the factory. The raw limestone is dugfrom the earth's crust around Ewekoro and stockpiling in a warehouse or store from where it is conveyed to the raw mills and kilns for transforming into clinker. The clinker is ground at the cement mills and cement dust escapes into the environment. Besides cement dusts are generated during packaging and loading activities in the factory and found settled on different surfaces as far as several kilometers away from the milling plant. Although the workers in the factory always cover their faces and nostrils with safety glasses and masks to prevent inhalation of cement dusts but it is pertinent to determine the radiological impact assessment in the neighborhood ofEwekoro cement factory. The estimated population figure including the workers, outworkers and natives in Ewekoro area is about forty thousand (40,000)

The aim of the study therefore is to measure the activity concentrations of ^{40}K, ^{232}Th ^{and238}U radionuclides in the cement productsand determine the internal and external radiation dose rates due to the release of cement dust to the environment.

2.0 Materials and Method

2.1 Sample Collection

Cement samples were collected directly from the production plants at Ewekoro Cement Factory in Ogun State. A total of 30 samples were collected for 30 different productionperiod. Each sample was collected at an interval of 5 to 7 daysso as to measure theradioactivity of the cement produced with raw materials mined from different locations for betterrepresentation and coverage of Ewekoro area. Each sample collected was packed in polythene bag, labeled and transported to the Radiation Physics Laboratory at LadokeAkintola University of Technology in readiness for smplpreparation.

3.0 Sample Preparation

Each sample was air dried to constant mass to remove the moisture in the cement product. A 200g of each sample was packed in a clean cylindrical plastic container, of dimension 8cm in height and 7cm in diameter that fits into the NaI detective crystal with good geometry. The containers were then carefully sealed and kept for 28 days to ensure secular equilibrium of^{226}Ra (^{238}U series) and ^{232}Th; and their respective gamma emitting progenies.

4.0 Specific Activity Measurements

The system employed in the measurements was gamma ray spectrometry. Any fast moving electron provides very useful information on energy and intensity of the incident γ-rays. The system for the conversion of these fast electrons into a flash of light, detected by optically matched electronic system to yield useful information concerning the primary γ-photon constitutes scintillation γ-ray spectroscopic system. The system also has the ability to differentiate between radiation energies and sources which is the basis of its application in this work.

The samples were analyzed using a 5.0 cm x 5.0 cm NaI(Tl) detector located in the Radiation Physics Laboratory, LadokeAkintola University of Technology, Ogbomosho (LAUTECH). The detector is enclosed in a graded 10.0cm thick PGT lead shield, which was coupled to a PGT Quantum multi-channel analyzer (MCA) (model 2100R) through a coaxial cable which was finally connected to a computer for display of results. Also to ensure a constant power supply, the system was connected to a 12V battery and an inverter.

. The detector has a resolution of about 6.2% in energy of 0.662Mev, which is considered adequate to distinguish the gamma ray energies of interest in the present study. The choice of radionuclides to be detected was predicated on the fact that the NaI(Tl) detector used in this study had a modest energy resolution; hence, the photons emitted by them would only be sufficiently discriminated if their emission probability and energy were high enough and the surrounding background continuum was low enough. While the activity concentration of ^{214}Bi determined from its 1.760MeV γ-ray peak was chosen to estimate the counts of ^{226}Ra (^{238}U) in the sample, the^{208}Tl radionuclide determined from its 2.615MeV γ-ray was chosen to estimate ^{232}Th. The ^{40}K radionuclide was determined by measuring the 1.460MeV γ-ray emitted during its decay. Each sample was counted for a period of 36000 seconds and the concentrations were obtained with the assistance of the software package in the computer.Equation (1) shows the expression of activity concentration [8]:

$$C = \frac{C_n}{\varepsilon_p I_\gamma m_s} \qquad (1)$$

where C is the activity concentration of the radionuclide in the sample ($Bqkg^{-1}$); C_n is the count rate under the photo peak, ε_p is the detector efficiency at the specific γ-ray energy, Iγ is the absolute transition probability of specific γ-ray and m_s is the mass of the sample (kg).

5.0 Determination of Effective Doses

The cement dust is found settled on objects including human bodies in the vicinity of the factory and large volume of the dust is naturally inhaled.This informedour focus on the external and internal exposure pathways to determine the total effective doses to the individuals in the study area. The pathwaysconsidered in the study include external doses due to dust deposited on surfacesand submersion in air; internal doses due to the inhalation of cement dust and inadvertent ingestion of cement.

6.0 External Dose Due to Surface Dispersal of Cement Dust

The externaleffective dose,D_{ext} (μSvy^{-1}) due to gamma-ray emitting radionuclides received by an individual resulting from the dispersal of cement dust on the body of individuals is calculated using the equation [9]:

$$D_{ext} = \sum A_R D\, C_{ext.R} CF_s T \quad (2)$$

where A_R is the activity concentration ($Bqkg^{-1}$) of gamma-emitting radionuclide R in the cement product and $DC_{ext.R}$ ($nSvh^{-1}perBqg^{-1}$) is the coefficient of dose rate per unit activity concentration of radionuclide R.The dilution or enhancement factor,$CF_s$of 1.0 is considered for cement dust and the time, T is assumed as $8766hy^{-1}$for the study.The external effective dose coefficients, $DC_{ext.R}$due to contaminated surfaces are shown in Table 1.

7.0 External Dose Due to Submersion in Air Contaminated by Cement Dust

The air submersion of cement dust is another important pathway that is considered in the determination of external dose in the study. The external dose D_{sub}(μSvy^{-1}) due to the air submersion is calculated by:

$$D_{sub} = \sum A_R D C_{sub.R} C_d I_w T \quad (3)$$

where A_R is the activity concentration ($Bqkg^{-1}$) of gamma-emitting radionuclide R in the cement product and $DC_{sub.R}$($nSvh^{-1}$per Bqm^{-3})is the effective dose coefficient per unit activity concentration of radionuclide R. The external effective dose coefficients due to air submersion are shown in Table 1. The dust load $C_d$of $1x10^{-2}$and $CF_s$of 1.0 [9]were used for cement dust and the time, T is presumed as $8766hy^{-1}$ for the study.

8.0 Internal Dose Due to Inhalation of Cement Dust

Cement dust inhaled by populace in the factory and its environ subject the individuals to internal effective dose. The internal dose D_{inh}(μSvy^{-1}) due to the inhalation of cement dust is calculated using the equation

$$D_{inh} = \sum A_R D\, C_{inh.R} C_d I_w T \quad (4)$$

where$DC_{inh.R}$ is the internal effective dose coefficient and other terms have the usual meaning as described in Equation 3. The internal effective dose coefficients for inhalation of different radionuclides in the environment are shown in Table 2.

9.0 Internal Dose Due to Inadvertent Ingestion of Cement

The effective dose, D_{ing} (Sv/yr) due to inadvertent ingestion of radionuclide is calculated using the equation

$$D_{ing} = \sum A_R D\, C_{ing.R} I_{w.ing} CF_s T \quad (5)$$

where$I_{w.ing}$is the ingestion rate and other terms have the usual meaning as described in Equation 4. The internal effective dose coefficients for ingestion of radionuclides are shown in Table 2.

10.0 Results and Discussions

The activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the cement samples from Ewekoro Cement Factory are presented in Table 3. The activity concentrations were recorded with statistical errors of the detector.Figures 1, 2 and 3 illustrate the frequency distributions for ^{40}K, ^{238}U and ^{232}Thin the cement samples.

As stated in Table 3, the activity concentrations of the radionuclides in the cement products ranged from(311.2 to 790.5) x 10^{-3} Bqg^{-1} with a mean value of (555.2±133.6) x10^{-3} Bqg^{-1} for^{40}K, (6.4 to 26.4)x10^{-3} Bqg^{-1} with a mean value of (13.3±5.3) x10^{-3} Bqg^{-1} for ^{238}U and (5.0 to 15.1) x$10^{-3}Bqg^{-1}$ with a mean value of (11.0±3.4) x10^{-3} $Bqg^{-1}$for ^{232}Th. The results showed that ^{40}K exhibited the highest activity concentration while ^{232}Th exhibited the least. The activity concentration of ^{40}K in the studyis about $0.135Bqg^{-1}$ higher than the world average value of $0.420Bqg^{-1}$. The mean activity concentration of ^{238}U and ^{232}Th in the study is found to be significantly lowwhen compared with the reported world average values of $0.032Bqg^{-1}$for ^{238}U and $0.040Bqg^{-1}$for^{232}Th.Farai and Ejeh[10] reported the mean activity concentrations of 0.0524 Bq/g and $0.0041Bqg^{-1}$ for ^{238}U and ^{232}Th respectively. These values were higher than the values obtained in the present study.The values of (35.9±0.8) x$10^{-3}Bqg^{-1}$and (25.4±0.8) x$10^{-3}Bqg^{-1}$ for ^{226}Ra and ^{232}Th respectively reported by [11]were higher than the values obtained in the study.

The surface external dose determined from the activity concentration of ^{40}K, ^{238}U and ^{232}Th in the cement product ranged from 3.36-8.21μSvy^{-1} with a mean value of 5.83±1.36μSvy^{-1}. This value is lower than the value of 6.5μSvy^{-1}reported for columbite-tantalitein the Democratic Republic of Congo [9].

11.0 Conclusion

The study has provided data on radioactivity levels in cement samples from Ewekoro Cement Factory in South West Nigeria. The results show that average values of ^{40}K, ^{238}U and ^{232}Th concentrations were (555.2±133.6)x10^{-3} Bq/g, (13.3±5.3)x10^{-3} Bq/g and (11.0±3.4)x10^{-3} Bq/g respectively. The mean of the total dose rate to the population in the study area was 36.70±9.40μSv/yr. The radioactivity level in the cement sample is low when compared to other studies; therefore no serious radiological health detriment on the population in the area is expected. However, human activity such as exploration or

mining that increases the radioactivity levels in the environment must be controlled or discouraged so as to minimize the radioactivity level of the study area in the future.

12.0 Acknowledgement

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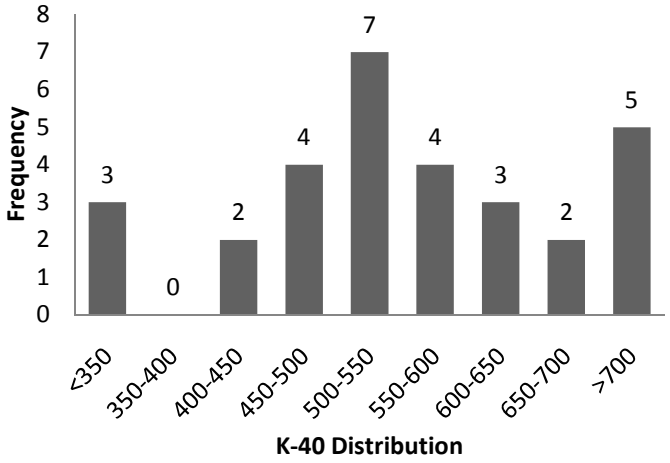

Fig 1: Frequency distributions of ^{40}K in the cement samples

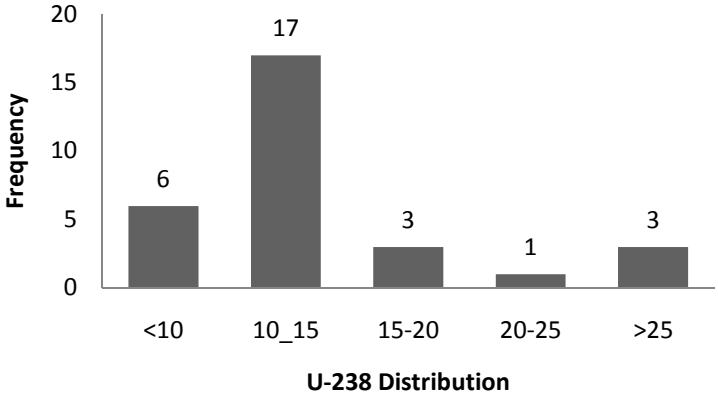

Fig 2: Frequency distributions of ^{238}U in the cement samples

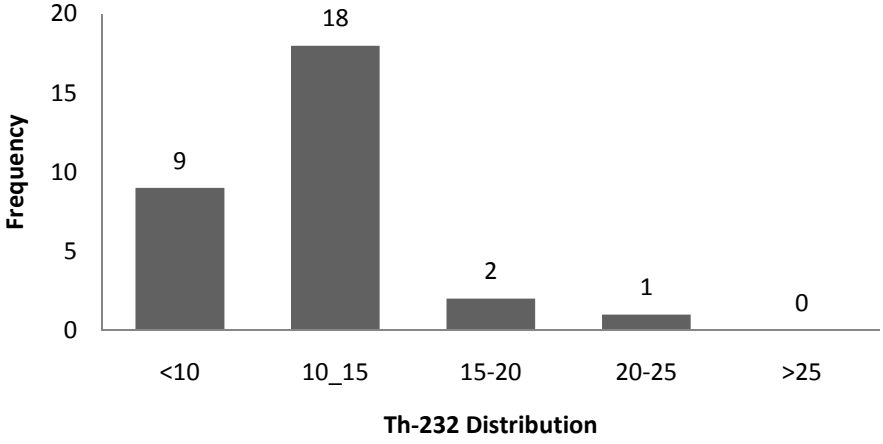

Fig 3: Frequency distributions of ^{232}Th in the cement samples

Table 1: Effective dose coefficients to natural radionuclides [12]

Radionuclides	Contaminated surface ($nSvh^{-1}perBqg^{-1}$)	Air submersion ($nSvh^{-1}perBqm^{-3}$)
^{40}K	1.175	0.029
^{226}Ra	9.929	0.302
^{228}Ra	5.409	0.162
^{228}Th	8.299	0.276
^{230}Th	0.004	0.000
^{232}Th	0.003	0.000
^{234}U	0.003	0.000
^{238}U	0.688	0.005

Table 2: Effective dosesper unit intake of radionuclides [13]

Radionuclides	Inhalation ($nSvBq^{-1}$)	Ingestion ($nSvBq^{-1}$)
^{226}Ra	5600	1200
^{228}Ra	1700	670
^{228}Th	34500	106
^{230}Th	7200	87
^{232}Th	12000	92
^{234}U	6800	8
^{238}U	5700	12

Table 3: Activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the cement samples from Ewekoro Cement Factory

Sample No	^{40}K ($x10^{-3}Bqg^{-1}$)	^{238}U ($x10^{-3}Bqg^{-1}$)	^{232}Th ($x10^{-3}Bqg^{-1}$)
1	651.4±38.0	11.4±3.2	11.0±5.2
2	341.2±45.8	26.3±2.1	9.1±2.7
3	722.2±70.0	9.2±3.0	10.1±3.1
4	460.1±60.6	10.6±2.4	11.9±5.4
5	532.9±85.1	13.0±4.1	9.5±1.2
6	518.9±59.1	6.4±±1.2	5.0±3.2
7	465.2±47.0	9.0±3.6	8.7±1.1
8	321.5±25.9	10.7±6.3	10.9±2.4
9	790.2±69.9	11.8±6.5	6.2±6.3
10	626.8±57.4	26.4±3.8	23.1±4.1
11	770.8±39.2	15.1±8.5	15.1±1.1
12	595.1±48.8	11.8±4.1	12.4±5.3
13	495.2±38.8	10.3±4.1	12.4±5.3
14	525.6±48.8	12.8±4.1	12.4±5.3
15	595.9±22.8	12.3±2.1	12.4±5.3
16	621.4±31.0	17.4±3.2	11.0±5.2
17	311.2±45.8	26.3±3.9	12.1±2.7
18	672.2±70.0	9.2±3.0	12.1±2.1
19	420.1±60.6	13.6±6.4	10.9±5.4
20	522.9±85.1	11.0±4.1	9.5±6.2
21	418.9±59.1	6.4±1.9	5.0±3.2
22	465.2±27.0	9.0±3.6	8.7±1.1
23	521.5±25.9	10.7±6.3	10.9±2.4
24	790.8±19.9	11.8±6.5	6.2±6.3
25	626.8±57.4	20.4±3.8	11.1±4.1
26	770.8±39.2	16.1±2.5	15.1±1.1
27	582.9±41.8	12.3±4.1	12.2±5.3
28	515.2±38.3	12.8±1.1	11.4±5.1
29	595.3±48.8	11.2±3.1	12.1±6.3
30	505.0±48.8	12.8±4.1	12.4±5.3
Mean	555.2±133.6	13.3±5.3	11.0±3.4

Table 4: External and Internal dose (μSvy^{-1}) due to the cement dust in the vicinity of Ewekoro Cement Factory

	External dose (μSvy^{-1})		Internal dose (μSvy^{-1})		Total dose (μSvy^{-1})
	Surface	Air submersion	Inhalation	Ingestion	
Range	3.36-8.21	0.0008-0.0020	14.30-63.50	0.02-0.11	18.70-70.2
Mean±σ	5.83±1.36	0.0014±0.0003	30.80±9.20	0.05±0.02	36.70±9.40

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