

Natural Radioactivity Concentration and Radiological Evaluation in Soil Samples Around Dangote Cement Factory Ibese, Ogun State, Nigeria

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Abstract: Background: Natural-occurring radioactive materials (NORMs) provide significant sources of human exposure to ionizing radiation but in certain cases, anthropogenic activities, like mining, have produced wastes that contain radiation above background levels in the environment, a situation that is of great concern for radiation protection. Around Dangote cement factory both mining and production have been on-going for some years, therefore there is need to evaluate the extent of the possible risk of the radionuclides to the health of the population in this study area. Measurements of radioactivity concentrations were carried out around Dangote Cement Factory Ibese. Samples of surface soil were measured using gamma-ray spectroscopy NaI (TI) scintillation detector. Results: Measurements showed that activity concentrations ranged from $18.33 \pm 1.91 \text{ Bqkg}^{-1}$ to $29.14 \pm 4.42 \text{ Bqkg}^{-1}$, with an average of 23.40 Bqkg^{-1} for (^{238}U - ^{226}Ra), $10.93 \pm 5.43 \text{ Bqkg}^{-1}$ to $21.52 \pm 2.16 \text{ Bqkg}^{-1}$ with an average of 16.50 Bqkg^{-1} for ^{232}Th , and $291.78 \pm 15.50 \text{ Bqkg}^{-1}$ to $338.60 \pm 3.922 \text{ Bqkg}^{-1}$ with an average of 314.11 Bqkg^{-1} for ^{40}K . Similarly, the absorbed dose ranged from 28.63 nGy/h to 38.24 nGy/h with an average of 33.14 nGy/h . The calculated annual effective dose ranged from 0.035 mSv/y to 0.047 mSv/y with an average of 0.040 mSv/y . Conclusions: The average value of Radioactivity concentrations obtained for ^{238}U , ^{232}Th and ^{40}K are lower than the corresponding global values reported in UNSCEAR publication. The calculated absorbed dose and annual effective dose values are also less than the recommended safe levels.

Keywords: Radioactivity Concentration, Spectroscopy, Dangote Cement Factory, Ibese

1. Introduction

Man since formation of the earth is exposed to many diverse sources of radiations. These sources may be natural or as a result of human activities. The radiation from natural sources include cosmic radiation, external radiation from radionuclide in earth's crust and internal radiation from radionuclide's inhaled or ingested and retained in the body [1]. According to the United Nations Scientific Committee on effects of Atomic Radiation Report (UNSCEAR), the greatest contribution to mankind's exposure comes from natural background radiation [2]. Gamma radiations emitted from Natural Occurring Radioactive Materials (NORMS) such as uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K) are generally known as terrestrial background radiation and is the main external of irradiation of the human body. External

exposures outdoors arise from terrestrial radionuclides present at trace levels in all soils. The specific levels are related to the geological and geographical conditions of those areas. Higher radiation levels are associated with igneous rock such as granite and lower levels with sedimentary rocks [2]. Also, the presence of NORMS in soil generally originates from the disintegrating rocks that are carried to soil by rain and flows [3]. Cement main constituents are clay, shale and limestone. These constituents of cement are found in the soil. Kim in 1995 reported the presence of radionuclide of thorium's and uranium series in limestone and also same traces concentration of thorium, uranium and potassium in black shale in some regions [4]. Radiation from soil environment is one of the main source of exposure to humans hence it is important to know the distribution of gamma radiation from radionuclide's such as ^{40}K and also from ^{238}U

and ^{232}Th series [5]. The radionuclide's in limestone and shale and their overlying soil materials can become pollutant when present in greater levels than the natural concentrations. These higher concentrations in radionuclide in limestone and shale or cement raw materials may be detrimental to humans' health [6]. The presence of these radionuclides in different food crops grown on the soil around the cement factory may also constitute a health hazard. Gene damage is the greatest threat of radionuclide [7].

This study, assess the radioactivity concentrations in soil samples around Dangote Cement factory in Ibese, Ogun State, Nigeria and evaluate radiological hazard indices. The results obtained were compared with the previous results of some countries around the world.

2. Materials and Methods

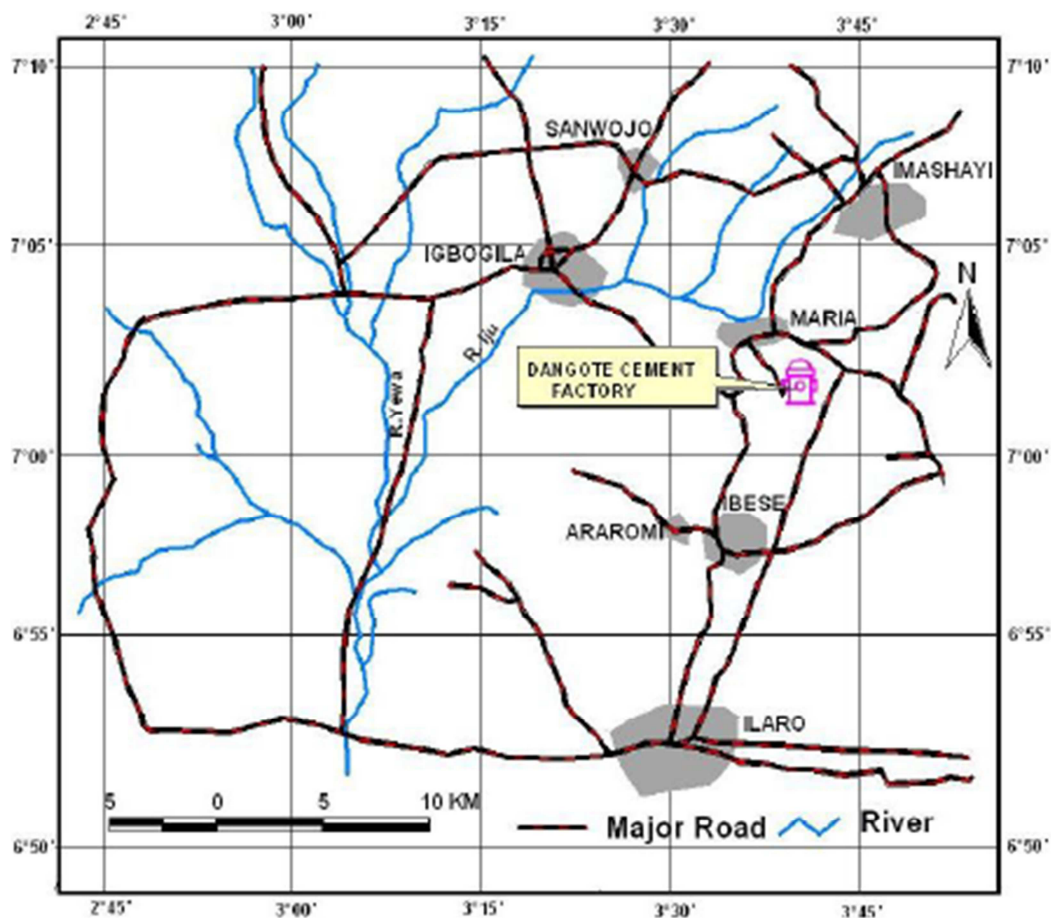
Study Area. Ibese is locate in Yewa North local government Area, Egbado North, area of Ogun State, Southwest Nigeria. Its geographical coordinates are $6^{\circ}58'10''$ North, $3^{\circ}2'10''$ East. The people living these are predominantly farmers and traders. It's about 35km from Abeokuta the Ogun State Capital and 45km from Lagos.

The geology of Ibese and environs consists of Ewekoro formation which is marine and paleocene age. It consists of a

limestone unit several meters in thickness which is overlain by a shale unit almost three times as thick as the limestone. In terms of regional geology, the study area belongs to the Eastern part of Dahomey Basin extending from the Volta Delta (South eastern Ghana) to the western flank of the Niger Delta in Nigeria [8]. Dangote cement factory is situated about a kilometer away from Ibese town.

2.1. Sample Collection and Processing

Samples were collected randomly during dry season of 2018. After the soil position where the soil samples are to be taken was determined, the ground was cleared of stones pebbles, vegetation and roots 2kg of soil sample were collected from a soil positioned about 10cm below the soil surface. A total of fifteen soil samples were taken and placed in a coded polythene bag. The fifteen soil samples were taken to the laboratory where they were first air dried and then grounded in to a fine powder of $200\text{ }\mu\text{m}$ in size after been oven dried at a temperature of 105°C for 8 hours. 100g of the homogeneous soil samples were then packed in polythene plastic, weighed and carefully sealed and stored for at least 4 weeks before counting to allow time for ^{238}U and ^{232}Th to reach equilibrium with their respective radionuclide daughters'.



(Adapted from Ayedun et al., 2012).

Figure 1. Location map showing the study area.

2.2. Experimental and Calibration

Using a well calibrated NaI (TI) and well shielded detector couple to a computer resident quantum MCA2100R Multichannel analyzer for analyzer for 36000s.

An empty container under identical geometry was also counted for the same time. The 1460 KeV gamma- radiation of ^{40}K was used to determine the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5KeV ^{214}Bi was used to determine the concentration of ^{238}U while the gamma transition energy of 2614 KeV ^{20}Th was used to determine the concentration of ^{232}Th while ^{137}Cs was detected by its 661.6KeV gamma transition. The efficiency calibration of the detector was done using a reference standard dose, associated with the cement production. The energy calibration was also performed by using the peaks of the radionuclide's present in the standard sources. The channel scale was then converted to an energy scale. This produces energy calibration curve i.e energy versus channel.

The activity concentration of the radionuclides in the samples was calculated after decay correction using the expression:

$$A_C = \frac{N_{sam}}{F_E \mu(E) T_{CMsam}} \quad (1)$$

Where A_C is the activity concentration of the radionuclides in Bq/kg, M_{sam} is the mass sample (kg), N_{sam} is the sample net count in peak range, F_E is the gamma emission probability, $\mu(E)$ is the photo peak efficiency and T_C is the counting time. The minimum detectable activity (MDA) for each radionuclide ^{238}U , ^{232}Th and ^{40}K was calculated using the equation:

$$MDA = \frac{1.645 \sqrt{NB}}{F_E \mu(E) T_{CM}} \quad (2)$$

Where 1.645 is the coverage factor at 95% confidence level, N_B is the background count at the region of interest, T_C is the counting time, F_E is the gamma emission probability, $\mu(E)$ is the photopeak efficiency and M is the mass of the sample. The MDA for each radionuclides were calculated as 0.30 Bq/kg for ^{238}U , for 0.12 Bq/kg for ^{226}Ra , 0.11 Bq/kg for ^{232}Th and 0.90 Bq/kg for ^{40}K . respectively.

2.3. Dose Rate Calculation

The absorbed dose rates at 1m above the ground are calculated by converting the activity concentration of ^{238}U , ^{232}Th and ^{40}K into dose by using the formula (UNSCEAR2000) below.

$$D \text{ (nGyh}^{-1}\text{)} = 0.0427A_U + 0.043A_K + 0.662A_{Th} \quad (3)$$

Where A_K , A_U and A_{Th} are activity concentration of K, U and Th in each sample respectively

2.4. The Annual Effective Dose Rate Calculation

The annual effective dose was calculated from the

absorbed dose rate by applying the dose conversion factor of 0.7SvGy^{-1} and an outdoor occupancy factor of 0.2 recommended by UNSCEAR [2]. Thus, annual effective dose was obtained using equation:

$$\text{Annual Effective Dose Rate (AEDR)} = D \text{ (nGyh}^{-1}\text{)} \times 8760 \text{ (hy}^{-1}\text{)} \times 0.2 \times 0.7\text{SvGy}^{-1} \times 10^3 \quad (4)$$

Where D is the absorbed dose rate in air and this calculation takes into account that the people spend 20% of their time outdoors.

2.5. External Hazard Index H_{ex}

The external hazard index H_{ex} is an assessment of the hazard of the natural gamma radiation. H_{ex} for samples in this study was calculated using equation defined by Ghazwa et al., [9].

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \leq \quad (5)$$

Where C_{Ra} , C_{Th} and C_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bq/kg respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 Bq/kg).

2.6. Radium Equivalent Activity (Ra_{eq})

Ra_{eq} is used to assess the gamma radiation hazards associated with materials that contain in ^{226}Ra , ^{232}Th and ^{40}K . It is assumed that 1 Bq/kg of ^{226}Ra , 0.7Bq/kg of ^{232}Th and 1.3 of ^{40}K produces the same gamma radiation dose rates. The Ra_{eq} is given as:

$$Ra_{eq} = C_{Ra} + (1.43 C_{Th}) + (0.077C_K) \quad (6)$$

Where C_{Ra} , C_{Th} and C_K are the average activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K in Bq/kg respectively.

2.7. Calculation of Lifetime Cancer Risk

Lifetime cancer risk (ELCR) was calculated using equation below

$$\text{ELCR} = \text{AED} \times \text{DL} \times \text{RF}$$

Where DL is the life expectancy (The life expectancy for Nigeria in 2019 is 54.49) and RF is the risk factor (Sv^{-1}), it is fatal cancer risk per Sievert. For stochastic effects from low dose background radiation, ICRP 103 suggested the value of 0.057 for the public exposure [10].

3. Results and Discussion

Activity concentrations, external annual effective dose and absorbed dose rate of are soil samples shown in the table 1. The corresponding comparisons with similar studies carried out in other countries are displayed in table 2.

Activity concentrations in the soil samples measured in this study varied from 18.343qKg^{-1} to 29.14BqKg^{-1} with an average value of 23.4BqKg^{-1} as indicated in table 1.

Activity concentrations of ^{232}Th also ranged from 10.93BqKg^{-1} to 29.14BqKg^{-1} with an average of 16.47BqKg^{-1} . The activity concentrations of ^{40}K varied from 291.78BqKg^{-1} to 338.60BqKg^{-1} with an average of 314.11BqKg^{-1} . The average values of activity concentrations of ^{238}U , ^{232}Th and ^{40}K are lower than the 40BqKg^{-1} for both ^{238}U and ^{232}Th and 370BqKg^{-1} for ^{40}K recommended by

UNSCEAR (2000). It should be noted that despite the activity concentrations not higher than the recommended limit, they varied from one location to other as reported by UNSCEAR, (1993).

These average activity concentrations are found to be lower compared to values obtained elsewhere in Nigeria and in other countries in African. See table 2.

Table 1. Activity Concentrations (in Bq/kg) and absorbed dose rate and annual effective dose in nGyh^{-1} and mSv/y respectively.

Sample	K-40 (Bqkg^{-1})	U-238 (Bqkg^{-1})	Th-232 (Ra 228) (Bqkg^{-1})	Absorbed dose (nGyh^{-1})	Annual Effective Dose (mSv/y)
A1	302.16±30.01	22.19±3.01	19.13±2.08	28.63	0.035
A2	300.09±60.16	20.61±6.40	10.93±5.43	28.64	0.035
A3	321.38±45.07	22.13±4.95	18.42±3.16	34.75	0.043
A4	326.37±30.10	18.35±1.91	14.03±3.24	30.56	0.037
A5	308.22±47.03	28.97±3.57	15.22±1.38	30.52	0.037
A6	319.32±47.41	20.24±3.75	14.14±4.09	31.25	0.038
A7	338.60±39.22	26.05±5.19	14.13±1.09	34.70	0.043
A8	312.61±22.15	22.21±2.37	15.42±2.33	32.61	0.040
A9	300.14±25.86	23.13±4.20	14.39±2.40	31.90	0.039
A10	320.48±39.28	21.20±5.28	18.18±3.34	34.10	0.042
A11	334.68±25.01	21.32±1.40	16.24±2.38	33.61	0.041
A12	308.94±16.20	24.21±3.12	20.01±1.06	36.25	0.044
A13	291.78±27.03	26.62±2.13	21.52±2.16	37.50	0.046
A14	317.52±23.90	29.14±4.42	19.11±1.24	38.24	0.047
A15	308.98±21.14	24.21±2.22	16.24±2.24	33.88	0.041

Table 2. Comparison of average activity concentrations with these of similar studies carried out in Africa.

^{238}U	^{232}Th	^{40}K	Country	References
2.38	32.36	383.8	Nigeria	Abdulahi et al., [11]
2.39	52.0	390.9	Nigeria	Abdulkarim et al., [12]
55.3	26.4	505.1	Nigeria	Ademola et al., [13]
8.37	11.4	232.7	Sudan	Sam et al., [14]
15.2	26.9	157.1	Ghana	Faanu et al., [15]
13.6	24.2	162.1	Ghana	Faanu et al., [16]
40.1	29.4	217.0	Cameroon	Dallou et al., [17]
47.28	27.26	302.97	Nigeria	Isola & Moni [18]
23.4	16.2	314.6	Nigeria	Present Study

The absorbed dose calculated ranged from 28.63nGg/h to 38.24nGg/h with a mean of 33.14nGy/h also the values of annual effective dose varied from 0.035mSv/y to 0.047mSv/y

with an average of 0.04mSv/y . However, comparing the results with world wide data, the obtained value was lower than 6nGyh^{-1} reported by UNSCEAR in 2000.

Table 3. The radium equivalent (R_{eq}), the external hazard (H_{ex}) and excess lifetime cancer risk (ELCR) of the soil samples.

Locations	Radium Equivalent Activity R_{eq} (Bq/kg)	External Hazard index (H_{ex})	Excess Lifetime Cancer risk (Sv^{-1})
		0.195	1.08×10^{-4}
A1	74.12	0.159	1.08×10^{-4}
A2	64.50	0.197	1.34×10^{-4}
A3	74.80	0.197	1.34×10^{-4}
A3	74.80	0.172	1.15×10^{-4}
A4	63.54	0.201	1.15×10^{-4}
A5	74.46	0.187	1.18×10^{-4}
A6	65.02	0.195	1.34×10^{-4}
A7	72.32	0.184	1.24×10^{-4}
A8	68.33	0.180	1.21×10^{-4}
A9	66.81	0.194	1.30×10^{-4}
A10	71.86	0.196	1.27×10^{-4}
A11	70.31	0.221	1.37×10^{-4}
A12	76.60	0.221	1.43×10^{-4}
A13	79.85		

Relative contribution to dose due to ^{40}K was 88.7% followed by the contribution of dose to ^{238}U and ^{232}Th as 6.6% and 4.6% respectively. The estimated values of Ra_{eq} in the present study ranged from 63.54 to 80.90 Bqkg^{-1} are lower than the recommended maximum value of 370 Bqkg^{-1} by UNSCEAR. The external radiation hazard index (H_{ex}) calculated ranged from 0.159 to 0.221 which are lower than upper limit of unity. However, the value of this index must be less than unity in order to keep the radiation hazard insignificant. The estimated values of excess lifetime cancer risk (ELCR) for all the samples from Table 3 ranged from 1.08×10^{-4} to 1.46×10^{-4} which is lower than world average of 2.9×10^{-4} [19].

4. Conclusion

In the present study, the results indicate that the natural radioactivity concentrations of ^{40}K , ^{232}Th and ^{238}U are relatively lower than the allowable limits recommended by UNSCEAR publication. The obtained results of absorbed dose rate, annual effective dose were found lower than recommended safety limits. Although the result in this study pose not treat to workers and people in the surrounding, it indicated the existence of radioactive materials in the environments where such activities are taking place. Also the ranged value of Ra_{eq} activity and external health hazard index values were found to be lower than recommended safe limit values, this study still made available data helpful for future evaluations, in case gross contamination of the area.

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