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# BASELINE RADIOLOGICAL ASSESSMENT OF SOIL AND WATER AROUND DANGOTE REFINERY, PRIOR TO COMMERCIAL PRODUCTION IN LAGOS, NIGERIA

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## ABSTRACT
The increasing industrialization of urban landscapes necessitates comprehensive environmental safety evaluations, especially concerning radiological impacts. This study presents a pre-commercial production radiological assessment of soil and water in Dangote Refinery's neighbourhood arising from the presence of the naturally occurring radionuclides - uranium-238 ($^{238}$U), thorium-232 ($^{232}$Th), and potassium-40 ($^{40}$K). The investigation aims to establish baseline data on the activity concentrations of these radionuclides in soil and hand-dug well water samples collected from three communities within a 2.5 km radius of the refinery site. Sodium Iodide [NaI(Ti)] gamma spectrometry was employed for radionuclide analysis, with results interpreted in accordance with the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) guidelines. The results showed that the distribution of the radionuclides activity concentrations (Bq/kg) in soil samples falls between 8.00±1.91 and 12.00±4.95 for $^{238}$U, 8.00±1.38 and 10.00±5.43 for $^{232}$Th, 297.32±4.41 and 328.12±4.07 for $^{40}$K in soil samples; whereas in hand-dug well water samples, the activity concentration (Bqm$^{-3}$) ranged between 8.00±1.91 and 12.00±4.95 for $^{238}$U, 8.00±1.21 and 10.00±5.43 for $^{232}$Th and 245.61±1.10 and 308.37±0.10 for $^{40}$K. The results are within globally accepted limits for natural background radiation specified by the UNSCEAR. The calculated radiological hazard indices also fell below the standard values for human safety as specified by UNSCEAR. This baseline data is essential for future comparative studies and environmental monitoring following the commencement of refinery operations. It also provides a scientific foundation for regulatory compliance and public health protection in the area.

**Keywords:** Natural radionuclides, Radiological assessment, Dangote refinery, Environmental monitoring, Gamma spectrometry

## INTRODUCTION
Radiological assessments of industrial sites situated near populated areas are vital for ensuring environmental safety and public health. Although petroleum refineries are not directly associated with the intentional use of radioactive materials, their operations can enhance the mobility and concentration of Naturally Occurring Radioactive Materials (NORM) such as radium-226 and radon-222. These radionuclides can accumulate in processing equipment- such as pipelines and storage tanks and may be released into surrounding media during drilling, refining, and petrochemical handling activities (Ravindra *et al.*, 2020; Ali *et al*., 2022). Such releases have the potential to contaminate air, soil, and water resources, thereby posing ecological and human health risks.

In addition to NORM, certain industrial activities within refineries, such as radiographic inspection and quality control procedures, may involve the use of artificial radioactive sources. These practices, while essential for operational integrity, can further contribute to localized radiological hazards if not properly managed (El-Taher & Al-Amoudi, 2023). Chronic exposure to low-level radiation, whether occupational or environmental, is associated with long-term health effects, including increased cancer risk, genetic mutations, and developmental disorders. Of particular concern is the contamination of soil and groundwater, which can facilitate radionuclide entry into food chains and drinking water supplies, thereby expanding the radius of exposure (Al-Mashaqbeh *et al.*, 2021; Orosun *et al.*, 2021).

A pre-commercial production radiological assessment provides a necessary baseline for evaluating and monitoring changes in environmental radiation levels over time. Such assessments are essential not only for identifying potential radiological risks in advance but also for establishing control measures to prevent or mitigate future contamination. This process typically involves systematic sampling of environmental media, quantification of activity concentrations of key radionuclides, and comparison with international safety benchmarks (Wang *et al*., 2019; Bello *et al.*, 2022).

Furthermore, such evaluations are critical for compliance with national and international regulatory frameworks. Organizations such as the International Atomic Energy

Agency (IAEA) and the U.S. Environmental Protection Agency (EPA) mandate the characterization of baseline radiological conditions as part of broader environmental impact assessment protocols (IAEA, 2020; EPA, 2022). Implementing such assessments enhances preparedness, supports regulatory oversight, and promotes sustainable industrial development by protecting both human populations and ecosystems.

This study therefore aims to determine the baseline concentrations of selected radionuclides in soil and groundwater samples collected from the neighbourhood of the Dangote Refinery in Lagos, Nigeria, prior to the commencement of full-scale operations. The findings will serve as a reference point for future monitoring and radiological risk assessment in the region.

## MATERIALS AND METHODS

The study, conducted in December 2023, was carried out within a 2.5-kilometre radius surrounding the Dangote Refinery, located in the Ibeju-Lekki region of Lagos State, Nigeria.

### Study Area

Sampling locations (Fig. 1) included three communities: Idaso (6°25′42.1″N, 3°59′0.2″E), Ilege (6°28′13″N, 4°19′30″E), and Imobido (6°25′60″N, 3°58′0″E), located at approximate distances of 500 m, 1.4 and 2.5 km from the refinery, respectively. These communities lie within the Lekki Free Trade Zone, an area undergoing rapid industrialization (Nubi & Omirin, 2016).

The region experiences a humid tropical climate with bimodal rainfall, high annual humidity (68–90 %), and a dew point around 80 °F (Adeaga & Adebayo, 2021). Vegetation comprises lowland rainforest and agricultural plantations, while the geology is dominated by sandy clay, lignite, and sedimentary deposits typical of the Dahomey Basin (Sojobi *et al*., 2016; Nton & Esan, 2010). Socio-economic activities include farming, fishing, and emerging commercial enterprises due to industrial expansion (Olowoporoku *et al*., 2020). The selected communities reflect varying land use and exposure gradients, providing a representative environmental baseline for radiological assessment.

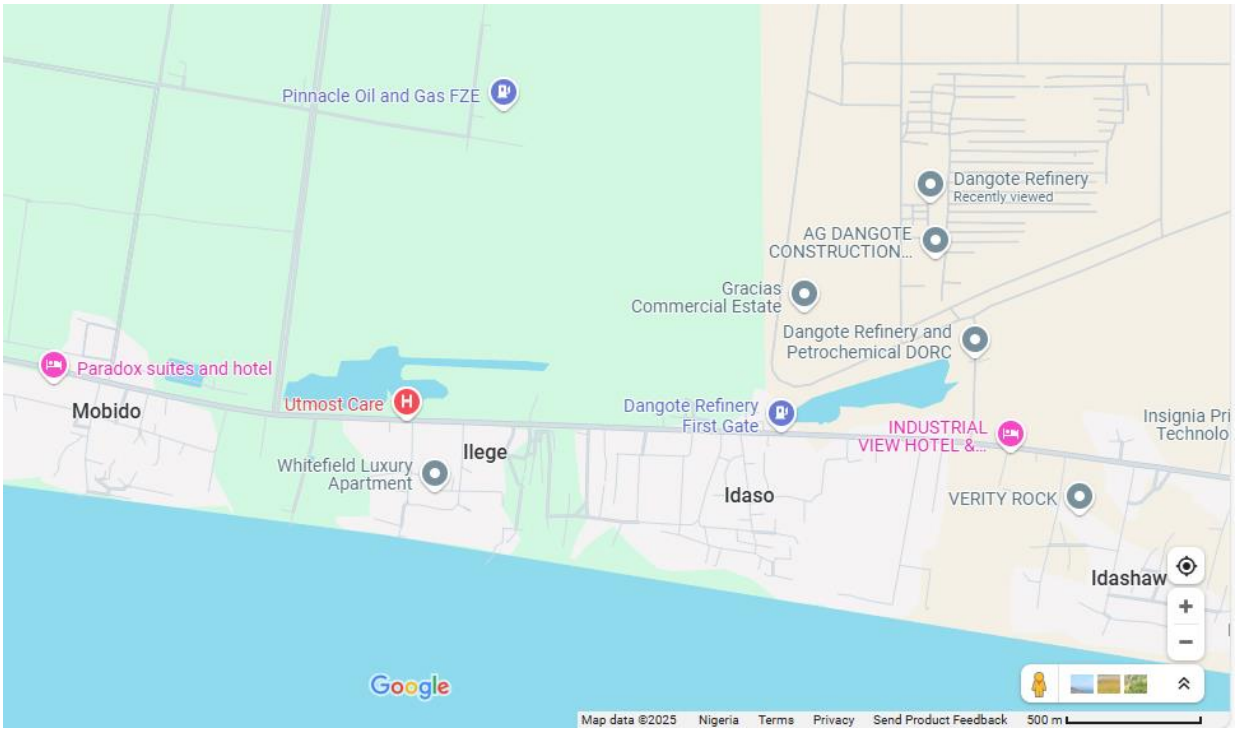


**Figure 1: Map of study area (Google Maps, 2025)**

### Sample Collection and Preparation

A total of 20 environmental samples were randomly collected across the three selected communities, comprising 9 soil samples and 11 water samples obtained from hand-dug wells. The soil samples were stored in clean polythene bags and later air-dried at ambient temperature for 72 h in the laboratory. They were then homogenized and passed through a 2 mm mesh sieve to ensure uniform particle size distribution. A 500 g portion of each soil sample was weighed into a 500 ml plastic container and hermetically sealed.

Water samples were initially collected in clean plastic bottles. Subsequently, 250 ml aliquots were transferred into uncontaminated, uniform cylindrical plastic

containers (60 mm height × 65 mm diameter) and securely sealed to prevent leakage and atmospheric exchange.
Both soil and water samples were stored for 30 days to allow for secular equilibrium between radon-222 and its parent radionuclide - Ra 226, as recommended in standard radiological protocols (Ononugbo *et al*., 2016; Usikalu *et al*., 2019). This equilibration period is critical to ensure accurate gamma spectrometric analysis (Thabayneh *et al*., 2012).

**Gamma Spectrometric Analysis**
The sample analyses were carried out at the Radiation and Health Physics Laboratory, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.
Gamma spectrometric analysis was performed using a properly shielded sodium iodide (NaI(Tl)) detector system connected to a Quantum MCA2100R multichannel analyzer. The system was calibrated for efficiency using a certified reference mixed-radionuclide source obtained from the Analytical Quality Control Services (AQCS, USA), with known activities and a geometric configuration identical to the sample containers.
Energy calibration was achieved by matching the characteristic photopeaks of the calibration sources to corresponding channels, thereby establishing a channel-to-energy conversion. Each sample was counted for 36,000 seconds to ensure statistical reliability, and a background count using an empty container of identical geometry was also acquired for the same duration.
The specific radionuclides were identified based on characteristic gamma energies: potassium-40 at 1460 keV, bismuth-214 - a daughter product of uranium-238 - at 1764.5 keV, and thallium-208 - a decay product of thorium-232 - at 2614 keV. These energies were used to calculate the specific activity concentrations of the radionuclides in both soil and water samples.

**Calculations**
The activity concentrations of radionuclides in the samples were estimated using Equation (1), following standard gamma spectrometric analysis protocols (Maduar & Miranda, 2007; IAEA, 2003):

$$A(Bq/kg) = \frac{C_S - C_{BG}}{\epsilon_\gamma * I_\gamma * M * T} \quad (1)$$

where $A$ is the specific activity, $C_s$ is the area under a specific photopeak, $C_{BG}$ is the activity from the surrounding background, $\varepsilon_\gamma$ is the efficiency of the detector for a specific gamma (γ) ray, $I_\gamma$ is the probability of γ ray emission, $T$ is the gamma spectrum counting time (s), and $M$ is the mass (kg) of the prepared sample.

**Radiological Hazards Indices**
**i. Ingestion dose:** The annual ingestion dose, E in the water samples was computed using equation 2 (Ogundare and Adekoya, 2015)

$$E = \sum A_i * DCF_i * 0.73 \quad (2)$$

where $A_i$ is the activity concentration of individual radionuclides present in the water samples and $DCF_i$ is the dose conversion factor for ingestion of the individual natural radionuclides for an adult. The conversion factor or dose per unit intake by ingestion of naturally occurring radionuclides for adult members of the public used were: $4.5 \times 10^{-5}$ mSvBq$^{-1}$ for $^{238}$U and $2.3 \times 10^{-4}$ mSvBq$^{-1}$ for $^{232}$Th (WHO, 2006). A daily water intake of 2 litres/day is assumed (US-EPA, 2000), thus resulting in an annual consumption rate of 730 litres/year, which is equal to 0.73 m$^3$ y$^{-1}$.

**ii. Radium equivalent $Ra_{eq}$ (Bq kg$^{-1}$):** It is a single quantity that takes into account the activity levels of radionuclides with the associated radiation hazard index; the calculation is achieved using equation (3) (UNSCEAR, 2000; OECD-NEA, 1979):

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (3)$$

where $A_{Ra}$, $A_{Th}$ and $A_K$ are the specific activity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K, respectively; the maximum limit value of $Ra_{eq}$ activity is 370 BqKg$^{-1}$ (UNSCEAR, 2000).

**iii. External hazard index ($H_{ex}$):** These indices assess the risk from gamma radiation to human health by ensuring exposure remains below the permissible limit of unity (≤1) (Ramasamy *et al*., 2009; El-Taher & Alashrah, 2014).
External Hazard Index ($H_{ex}$)

$$H_{ex} = \frac{A_{Ra}}{370\ Bq\ Kg^{-1}} + \frac{A_{Th}}{259\ Bq\ Kg^{-1}} + \frac{A_K}{4810\ Bq\ Kg^{-1}} \leq 1 \quad (4)$$

**iv. Absorbed dose rate ($D_R$):** The absorbed gamma dose rate in air at 1 m above ground level was computed from equation (5), using conversion coefficients from UNSCEAR (2000):

$$D_R\ (nGy\ h^{-1}) = 0.462A_U + 0.604A_{Th} + 0.042A_K \quad (5)$$

**v. Annual effective dose equivalent (AEDE):** The annual effective dose equivalent is the gamma radiation energy emitted by a radioactive source in relation to the varying radio-sensitivity of different human organs. This was derived using a conversion factor of 0.7 Sv/Gy and an outdoor occupancy factor of 0.2 (UNSCEAR, 2000):

$$\text{AEDE}\ (mSv\ y^{-1}) = D_R\ (nGy\ h^{-1}) \times 0.00123 \quad (6)$$

**vi. Annual gonadal dose equivalent (AGDE):** The annual gonadal dose equivalent (AGDE) is a fertility factor that yields the yearly radiation dose absorbed by the gonads (reproductive organs). AGDE estimation with respect to exposure to natural radioactive sources is estimated with equation (7) (Krieger, 1981)

$$AGDE\ (\mu Svy^{-1}) = 3.09A_U + 4.18A_{Th} + 0.314A_K \quad (7)$$

**vii. Excess lifetime cancer risk (ELCR):** The potential cancer risk accompanying gamma radiation exposure through ingestion or external contact with radioactive sources and the possibility of developing cancer over a lifetime is assessed with equation 9 (Thabayneh & Jazzar, 2012; IRSN, 2009)

$$ELCR = AEDE \times DL \times RF \quad (8)$$

The *DL* in the expression is the life expectancy (70 years) and *RF* is the risk factor for cancer considering the stochastic effects whose value is $0.05Sv^{-1}$ for the public [IRSN, 2009]

## RESULTS AND DISCUSSION

### Activity Concentrations of Natural Radionuclides

The activity concentrations of naturally occurring radionuclides - $^{238}$U, $^{232}$Th and $^{40}$K in soil and water samples collected from the three communities around Dangote Refinery are presented in Tables 1 and 2, respectively.

**Table 1: Activity concentration (Bq/kg) of $^{238}$U, $^{232}$Th, $^{40}$K in soil samples**

| Location | Samples ID | $^{238}$U | $^{232}$Th | $^{40}$K |
|---|---|---|---|---|
| DASO | 1 | 9.00 ± 3.01 | 9.00 ± 2.08 | 302.14 ± 3.01 |
| | 2 | 10.00 ± 6.40 | 10.00 ± 5.43 | 320.05 ± 2.16 |
| | 3 | 10.00 ± 3.75 | 8.00 ± 4.09 | 297.32 ± 4.41 |
| | **Mean±SDM** | **9.67 ± 0.33** | **9.00 ±0.58** | **306.50 ± 6.91** |
| ILEGE | 1 | 10.00 ± 1.01 | 9.00 ± 1.12 | 303.13 ± 2.01 |
| | 2 | 11.00 ± 5.28 | 8.00 ± 3.34 | 300.48 ± 3.28 |
| | 3 | 12.00 ± 4.95 | 8.00 ± 3.16 | 328.12 ± 4.07 |
| | 4 | 8.00 ± 1.91 | 8.00 ± 3.24 | 308.13 ± 3.10 |
| | **Mean±SDM** | **10.28 ± 0.86** | **8.25 ± 0.25** | **309.97 ± 6.26** |
| IMOBIDO | 1 | 10.00 ± 1.51 | 9.00 ± 1.28 | 305.12 ± 2.03 |
| | 2 | 8.00± 1.21 | 8.00± 3.24 | 308.37 ± 0.10 |
| | **Mean±SDM** | **9.00 ± 1.00** | **8.50 ±0.50** | **306.75 ± 1.63** |

SDM – Standard Deviation of Mean

**Table 2: Activity concentration (Bq$m^{-3}$) of $^{238}$U, $^{232}$Th, $^{40}$K in hand-dug well samples**

| Location | Samples ID | $^{238}$U | $^{232}$Th | $^{40}$K |
|---|---|---|---|---|
| IDASO | 1 | 8.00 ± 3.57 | 8.00 ± 1.38 | 275.11 ± 1.03 |
| | 2 | 10.00± 6.40 | 10.00 ± 5.43 | 303.09 ± 0.16 |
| | 3 | 10.00 ± 1.01 | 9.00 ± 1.12 | 252.13 ± 2.01 |
| | 4 | 10.00 ± 3.75 | 8.00 ± 4.09 | 260.12 ± 1.01 |
| | **Mean ± SDM** | **9.50 ± 0.50** | **8.75 ± 0.49** | **272.61 ± 11.26** |
| ILEGE | 1 | 12.00 ± 2.37 | 10.00 ± 2.33 | 245.61 ± 1.10 |
| | 2 | 11.00 ± 5.19 | 10.00 ± 1.09 | 270.60 ± 1.22 |
| | 3 | 12.00 ± 4.95 | 8.00 ± 3.16 | 301±38 ± 5.07 |
| | **Mean ± SDM** | **11.67 ± 0.33** | **9.33 ± 0.66** | **272.53 ± 16.13** |
| IMOBIDO | 1 | 10.00 ± 1.51 | 9.00 ± 1.28 | 305.12 ± 2.03 |
| | 2 | 8.00± 1.21 | 8.00± 3.24 | 308.37 ± 0.10 |
| | 3 | 10.00 ± 4.20 | 9.00 ± 2.40 | 261.14 ± 1.10 |
| | **Mean ± SDM** | **9.33 ± 0.61** | **8.67 ± 0.33** | **291.54 ± 15.27** |

SDM – Standard Deviation of Mean

In the soil samples, the activity concentrations ranged from 8.00 ± 1.21 to 12.00 ± 4.95 Bq/kg for $^{238}$U, 8.00 ± 3.16 to 10.00 ± 5.43 Bq/kg for $^{232}$Th, and 297.32 ± 4.41 to 328.12 ± 4.07 Bq/kg for $^{40}$K. In the hand-dug well water samples, which serve as the primary source of drinking water in the area, the activity concentration levels (Bqm$^{-3}$) ranged from 8.00 ± 1.21 to 12.00 ± 4.95 for $^{238}$U, 8.00 ± 1.38 to 10.00 ± 5.43 for $^{232}$Th, and 245.61 ± 1.10 - 308.37 ± 0.10 for $^{40}$K Notably, $^{40}$K exhibited the highest concentration in both environmental media. This observation aligns with its known abundance in the Earth's crust, where it constitutes a major natural source of terrestrial gamma radiation (UNSCEAR, 2000; IAEA, 2010).

The comparable levels of radionuclides in soil and water samples suggest a direct geochemical influence, likely due to the underlying lithology of the region, where porous sedimentary formations facilitate leaching and percolation from soil into shallow groundwater (Nwankwo *et al*., 2020). This finding is consistent with previous reports by Avwiri and Agbalagba (2007) in Delta State and Usikalu *et al*. (2019) in Ogun State, which documented similar patterns of radionuclide mobility in sedimentary terrains.

Comparatively, the values obtained in this study fall within the global average activity concentrations for naturally occurring radionuclides in soil and water, as established by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000; 2020). The reported global averages are approximately 33 Bq/kg for $^{238}$U, 45 Bq/kg for $^{232}$Th, and 400 Bq/kg for $^{40}$K, in soil. Thus, the lower activity levels recorded in this study indicate that the radiological risk associated with the refinery environment is minimal, supporting its suitability for human habitation and agricultural activity.

### Ingestion Dose

The mean annual ingestion dose from the well water samples is presented in Table 3. Potassium-40, though a source of radiation, does not accumulate in the body but is maintained at a constant level independent of intake (WHO, 2011); as such, its activity concentration was not included in the computation.

The observed ingestion doses for all samples are significantly lower than the maximum permissible limit of 0.1 mSv/year recommended by the World Health Organization (WHO, 2017) for drinking water. This indicates that the water sources in the study area are radiologically safe for consumption, with no immediate public health concern from internal exposure due to uranium and thorium ingestion.

Across all three communities, the ingestion dose from $^{232}$Th was consistently higher than that of $^{238}$U with dose ratios ranging from approximately 4:1 to 5:1. This observation is primarily attributable to the higher ingestion dose conversion coefficient of Th-232, which results in a greater committed effective dose per unit activity ingested. Such elevated thorium activity relative to uranium has also been reported in similar hydrogeological settings across Nigeria (Jibiri *et al*., 2016; Usikalu *et al*., 2019; Ajayi & Ibikunle, 2013), supporting the inference that this may be a regional geogenic pattern.

Among the three communities, Ilege recorded the highest ingestion doses for both radionuclides, followed by Idaso, while Imobido had the lowest values. Although all are within permissible limits, the relatively elevated levels in Ilege could be linked to variations in local rock mineralogy, groundwater flow paths, or possible anthropogenic influence. This suggests that location-specific factors may influence radionuclide mobility and concentration, warranting site-specific baseline monitoring and continue environmental assessment, particularly in areas closer to or downstream of industrial developments.

The standard deviations recorded for $^{238}U$ were generally low across all locations, indicating a uniform uranium distribution in the sampled wells. However, thorium values showed slightly more variability, especially in Ilege, which may reflect local heterogeneity in thorium-bearing minerals or fluctuations in geochemical conditions such as pH and redox potential.

**Table 3: Mean Annual ingestion dose (μSv) from well water samples**

| Community | Radionuclide | Ingestion Dose | Standard Deviation |
|---|---|---|---|
| Idaso | $^{238}U$ | $3.13\times10^{-4}$ | $1.11\times10^{-5}$ |
| | $^{232}Th$ | $1.47\times10^{-3}$ | $1.63\times10^{-4}$ |
| Ilege | $^{238}U$ | $3.80\times10^{-4}$ | $1.73\times10^{-5}$ |
| | $^{232}Th$ | $1.57\times10^{-3}$ | $1.96\times10^{-4}$ |
| Imobido | $^{238}U$ | $3.07\times10^{-4}$ | $4.04\times10^{-5}$ |
| | $^{232}Th$ | $1.45\times10^{-3}$ | $9.82\times10^{-5}$ |

**Radiological Hazard Indices in Soil Samples**

The computed radiological hazard indices in the soil samples are presented in Table 4.

Radium equivalent activity ($Ra_{eq}$) values for the study locations ranged from 44.78 Bq/kg in Imobido to 46.14 Bq/kg in Idaso. These values are well below the internationally accepted safety limit of 370 Bq/kg recommended by UNSCEAR (2000), indicating that the combined activities of $^{238}U$, $^{232}Th$ and $^{40}K$ in the soils of these communities are not radiologically hazardous under natural conditions.

The absorbed dose rates in air ($D_R$) were also low, ranging from 22.08 to 22.69 nGy/h, significantly below the global average outdoor dose rate of 55 nGy/h (UNSCEAR, 2000). This suggests that current external exposure due to terrestrial gamma radiation is minimal and comparable to background levels expected in uncontaminated environments.

The annual effective dose equivalent (AEDE) values ranged from 0.027 to 0.028 mSv/year, which are far below the public exposure limit of 1.0 mSv/year as set by ICRP (1991). This supports the conclusion that, under existing environmental conditions, the radiological impact of soil on the local population is negligible.

In terms of hazard indices, the external hazard index ($H_e$) ranged from 0.121 to 0.124. The values fall well below the permissible threshold of 1.0, indicating that the risks from external gamma radiation are well within safe limits.

**Table 4: Radiological hazard indices in soil samples from the three communities**

| Location | $Ra_{eq}$ (Bq/kg) | $D_R$ (nGy/h) | $AEDE$ (mSv/yr) | $H_{ex}$ |
|---|---|---|---|---|
| **Idaso** | 46.14 | 22.69 | 0.028 | 0.124 |
| **Ilege** | 45.95 | 22.65 | 0.028 | 0.124 |
| **Imobido** | 44.78 | 22.08 | 0.027 | 0.121 |

**Table 5: Excess lifetime cancer risk for soil and water samples**

| Community | ELCR (Soil) | ELCR (Water Ingestion) | | Total ELCR |
|---|---|---|---|---|
| | | $^{238}U$ | $^{232}Th$ | |
| Idaso | $9.80\times10^{-5}$ | $1.10\times10^{-6}$ | $5.15\times10^{-6}$ | $1.04\times10^{-4}$ |
| Ilege | $9.80\times10^{-5}$ | $1.33\times10^{-6}$ | $5.50\times10^{-6}$ | $1.06\times10^{-4}$ |
| Imobido | $9.45\times10^{-5}$ | $1.07\times10^{-6}$ | $5.08\times10^{-6}$ | $1.01\times10^{-4}$ |

**Excess Lifetime Cancer Risk (ELCR)**

The computed excess lifetime cancer risk (ELCR) due to ingestion and external exposure is shown in Table 5

The ELCR values derived from external exposure to soil radioactivity ranged from $9.45\times10^{-5}$ in Imobido to $9.8\times10^{-5}$ in both Idaso and Ilege. These values fall well below the threshold of $1.0\times10^{-3}$, considered acceptable for lifetime cancer risk from environmental exposure, as recommended by the International Commission on Radiological Protection (ICRP, 1991). Ingestion-related ELCR from uranium-238 ranged between $1.07\times10^{-6}$ and $1.33\times10^{-6}$, while thorium-232 contributed slightly higher ingestion risks, ranging from $5.08\times10^{-6}$ to $5.50\times10^{-6}$. Although ingestion risks are significantly lower than external soil exposure, their contribution is non-negligible, particularly given the reliance on groundwater sources for daily consumption in these communities.

The cumulative ELCR values, combining both exposure pathways, were calculated to be $1.01\times10^{-4}$ for Imobido, $1.04\times10^{-4}$ for Idaso, and $1.06\times10^{-4}$ for Ilege. These total risk values remain significantly below the recommended global risk ceiling, suggesting that the current radiological conditions pose no significant lifetime cancer risk to the inhabitants of these communities. Nonetheless, the presence of trace radionuclide concentrations in drinking water underscores the importance of ongoing surveillance, especially as the Dangote Refinery transitions from pre-operational to fully operational status.

**CONCLUSION**

This radiological assessment of soil and groundwater in communities surrounding the Dangote Refinery in Ibeju-Lekki, Lagos State, provides a vital environmental baseline prior to the commencement of full-scale industrial operations. Activity concentrations of $^{238}U$, $^{232}Th$, and $^{40}K$

in both environmental media were found to be within global average values, with $^{40}K$ consistently exhibiting the highest activity levels, consistent with its natural geochemical abundance.

The derived radiological hazard indices were all below internationally accepted safety limits, indicating that current exposure conditions pose minimal health risk to the local population. Furthermore, the estimated excess lifetime cancer risk (ELCR), from both external soil exposure and internal ingestion pathways, remained below the ICRP-recommended threshold of $1.0 \times 10^{-3}$, with total values ranging from $1.01 \times 10^{-4}$ to $1.06 \times 10^{-4}$ across the study locations.

Collectively, these findings suggest that the immediate radiological burden in the vicinity of the refinery is negligible and does not warrant concern under existing environmental conditions. Nevertheless, this assessment establishes a scientifically valid benchmark for future comparison, which is essential for evaluating the potential impact of industrial activities over time.

To ensure long-term environmental safety, it is recommended that periodic radiological monitoring be instituted across the study area following the commencement of refinery operations. This will allow for timely detection of any deviation from baseline conditions, especially in relation to groundwater quality and soil contamination. Radiological indicators should be incorporated into routine environmental impact assessments and regulatory compliance checks. Given the local reliance on groundwater, sustained surveillance of drinking water sources is critical. Furthermore, findings from ongoing assessments should be communicated transparently to local stakeholders to enhance public awareness and inform policy decisions.

**Conflict of interest:** The authors declare no conflict of interest.

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