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Environmental Radiation Exposure and Lifetime Cancer Risk at Lumoru Dumpsite, Western Kenya

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Abstract

This study quantified the activity concentrations of natural radionuclides ^{238}U, ^{232}Th, and ^{40}K in soils from the Lumoru Dumpsite, Bungoma County, Kenya, using a NaI (Tl) gamma spectrometer. The mean concentrations were 7 ± 0.4 Bq/kg for ^{238}U, 57 ± 2.0 Bq/kg for ^{232}Th, and 25 ± 1.3 Bq/kg for ^{40}K. From these values, the absorbed dose rate was estimated at 39 ± 3.4 nGy/h, the outdoor annual effective dose equivalent at 0.09 ± 0.01 mSv/y, and the radium equivalent activity at 91 ± 3.4 Bq/kg. The hazard indices (H_{ex} = 0.25 ± 0.01; H_{in} = 0.28 ± 0.01) were all within international safety limits, while the mean excess lifetime cancer risk was 0.30 ± 0.03 × 10^{-3}. Compared with similar dumpsites in Kenya and across Africa, Lumoru exhibited lower activity concentrations and radiological risks than Machinjoni, Nigerian, and Ukrainian landfills, though its risks remain comparable to food-chain pathways in Bungoma. These findings establish Lumoru as a moderately impacted site and provide a critical baseline for monitoring cumulative exposures from environmental and household sources in Western Kenya.

Subject Areas

Nuclear Physics

Keywords

Natural Radionuclides, ^{238}U, ^{232}Th, ^{40}K, Annual Effective Dose, Hazard Indices, Excess Lifetime Cancer Risk, Lumoru Dumpsite, Bungoma, Kenya

1. Introduction

Naturally occurring radionuclides such as ^{238}U, ^{232}Th, and ^{40}K are widely distributed in soils, rocks, and anthropogenic waste materials, contributing to terrestrial gamma radiation exposure [1]. When waste accumulates in poorly managed dumpsites, radionuclides may become concentrated in soils through leachates, ash, and construction debris, thereby elevating background radiation levels and creating potential public health concerns [2] [3]. Several studies across Africa and beyond have documented enhanced activity concentrations in dumpsite soils, including those in Lagos [4], Kaduna [3], and Ogun State [1], often reporting values above global averages. Comparable findings have been reported in Namibia [5] and Ukraine [2], underscoring that radiological risks in dumpsites vary with waste type, geology, and management practices.

In Kenya, radiological assessments of dumpsites remain limited, with the Machinjoni Dumpsite in Kitale being among the few investigated [6]. However, recent evidence suggests that exposure in Bungoma County may also arise from other pathways, including agricultural produce [7] and imported consumer goods such as sanitary wares [8]. This highlights the need to evaluate dumpsites not in isolation but as part of a wider exposure landscape. The present study focuses on soils from Lumoru Dumpsite in Bungoma County, Western Kenya. By quantifying activity concentrations of ^{238}U, ^{232}Th, and ^{40}K and evaluating absorbed dose rates, hazard indices, and excess lifetime cancer risk, the research provides baseline radiological data for the site. Its relevance lies in situating Lumoru within regional and global contexts while also contributing to Kenya's limited body of information on environmental radiation exposure from unmanaged waste sites.

2. Study Area and Methodology

2.1. Study Area

Lumoro dumpsite is geographically located at latitude 0.3360 N and longitude 34.3300 E, within Muanda village, South Bukusu Ward, Bumula Sub-County, Bungoma County, Kenya. The surrounding village has a total population of 14,320, with approximately 257 households situated near the dumpsite [9], which serves as a primary solid waste disposal site for Bungoma town and nearby settlements. The area is characterized by a tropical climate with bimodal rainfall, influencing soil composition and leaching processes. Waste deposited at the site includes domestic refuse, agricultural residues, ash, and construction debris, many of which are potential sources of naturally occurring radioactive materials (NORMs). The proximity of residential areas and daily human activity within the dumpsite makes it a relevant site for assessing possible radiological risks. (See **Figure 1**)

2.2. Sample Collection and Preparation

Soil sampling was conducted at 15 administrative locations within the study area. A random sampling technique was employed to enhance the statistical represent-

ativeness of the samples [10]. At each location, three soil samples were collected using a trowel at depths ranging from 10 to 50 cm. The sampling depth of 10 - 50 cm was adopted following IAEA [11] and UNSCEAR (2000) guidelines, and similar approaches by Xinwei *et al.* [12] and Taskin *et al.* [13], to minimize surface contamination and capture stable radionuclide concentrations representative of undisturbed soil layers. The 0 - 10 cm surface soil, though contributing more to external exposure, was excluded to avoid variability arising from anthropogenic and environmental disturbances near the Lumoru dumpsite. The samples from each site were combined to form a single composite sample weighing approximately 700 g. In the laboratory, the soil samples were initially air-dried on plastic sheets at room temperature for one week, followed by oven drying at 110˚C for 8 hours. Stones and organic matter were removed, and the dried soil was pulverized to a particle size appropriate for gamma spectroscopic analysis. The soil was then sieved through a 2 μm mesh to ensure homogeneity [10]. Finally, the homogenized soil was treated with concentrated hydrochloric acid and allowed to sit for at least one month to achieve secular equilibrium between radon and its progeny prior to gamma spectroscopic measurement [14].

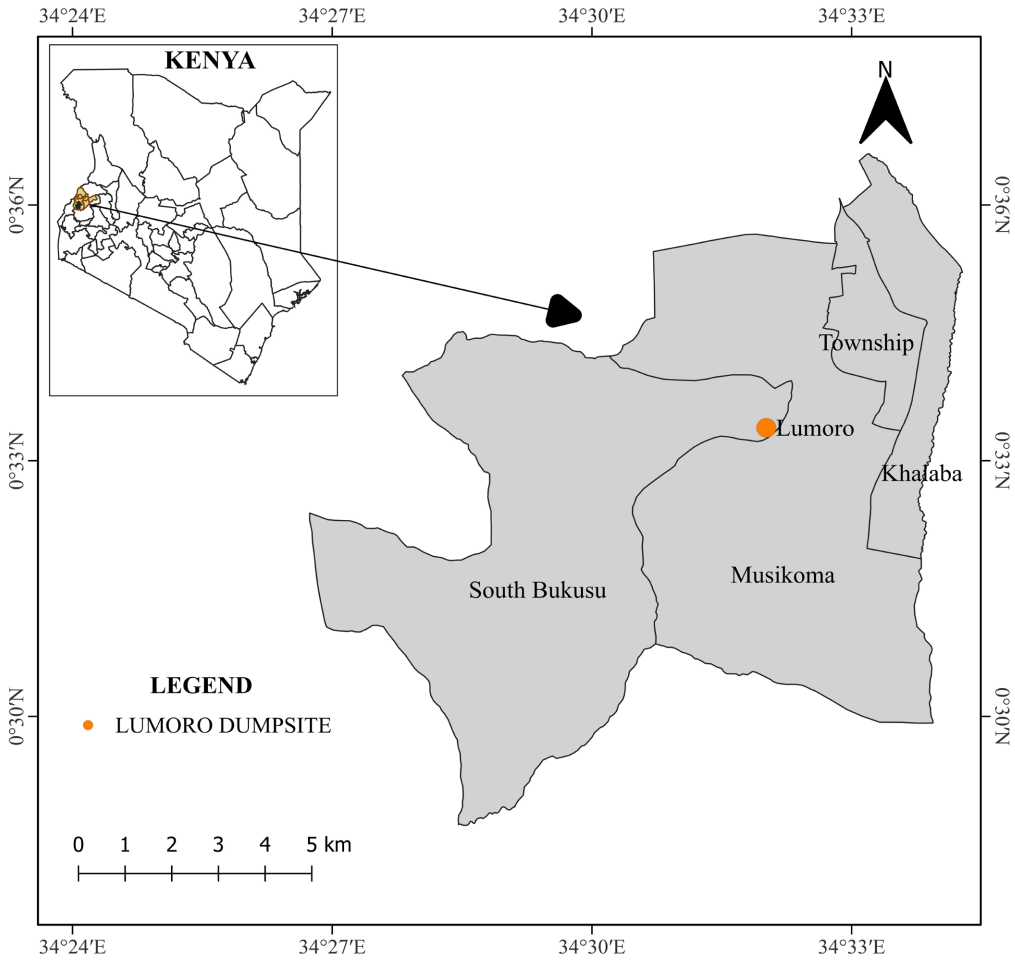

Figure 1. Study area. (Source: the authors)

2.3. Gamma Spectrometric Analysis

The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in the soil samples were determined using a 7.6 cm × 7.6 cm NaI (TI) detector crystal optically coupled to a Photomultiplier Tube (PMT). The detector was enclosed in a 6 cm lead shield with cadmium and copper sheets. This arrangement is to minimize the effects of background and scattered radiation. It has an Oxford Multichannel Analyzer (MCA) card that is coupled with software for spectral data acquisition and analysis. It also consisted of a charge sensitive pre-amplifier, a shaping amplifier, high voltage, 80,000 kHz Wilkinson Analogue to Digital Converter (ADC) with MCA. Data acquisition and analysis are carried out by MCA, which consists of a software package and a Multichannel Buffer (MCB). The samples were placed in the detector cavity and measured for a period of 29,000 seconds for each radionuclide. [15]. The 295.22 keV, 351.93 keV for ^{214}Pb and 609.32 keV, 1120.29 keV and 1764.49 keV for 214Bi gamma lines were used in the assessment of activity concentration of ^{238}U, while 911.21 keV for ^{228}Ac and 968.97 keV and 238.63 keV for ^{212}Pb were used for ^{232}Th. The isotope of ^{40}K was obtained from the single 1460 keV Gamma-line of ^{40}K [5] [10]. The peak area of each energy in the spectrum was used to compute the specific activity concentration in the sample as well as other radiological hazards. The net count rates were converted into activity concentrations (Bq/kg) using detector efficiency and sample mass.

3. Radiological Parameters

3.1. Specific Activity Concentration

The calculation for specific activity concentration was done by procedure given in Equation (1) [16] [17].

$$A_C\left(\mathrm{Bq/kg}\right)=\frac{C_a}{nP_r m_s} \tag{1}$$

C_a —Net gamma counting rate (counts per second), n —Detector efficiency of the specific gamma ray, P_r —The absolute transition probability of gamma decay and m_s —The mass of the sample (kg).

3.2. Radium Equivalent (Ra_{eq})

This radiological parameter will be estimated using empirical Equation (2) [18].

$$\mathrm{Ra}_{\mathrm{eq}}=C_{\mathrm{U}}+1.423C_{\mathrm{Th}}+0.077C_{\mathrm{K}} \tag{2}$$

where C_{U} is the mean activity of ^{238}U, C_{Th} is the mean activity ^{232}Th and C_{K} is the mean activity concentrations of ^{40}K in soil samples expressed in Bq·kg^{-1}.

3.3. Absorbed Dose Rate (ADR)

It is a measure of radiation dose intensity or it can be defined as a measure of the chemical or physical effect created by given radiation exposure or physical effect created by given radiation exposure to a living matter. The absorbed gamma dose

rates were calculated from activity concentration of ^{232}Th, ^{238}U and ^{40}K using the activity concentration-dose (nGy^{-1} per Bq/kg) conversion coefficients of 0.622, 0.462 and 0.0432 as provided by UNSCEAR reports. Equation (3) shows the model used to estimate the dose rate from the activity concentrations [11].

$$ADR\left(nGy/h\right) = 0.462C_{\mathrm{U}} + 0.622C_{\mathrm{Th}} + 0.043C_{\mathrm{K}} \tag{3}$$

where C_{U}, C_{Th}, and C_{K} are the average activities concentration of ^{238}U, ^{232}Th and ^{40}K respectively.

3.4. Annual Effective Dose Rate (AED)

To evaluate the effective dose to the population attributable to radioactivity in the soil a conversion factor of 0.7 Sv/Gy was used [19]. The evaluation of the indoor and outdoor doses used the occupancy factors of 0.6 and 0.4 respectively [6]. The corresponding AED was evaluated using Equations (4) and (5).

$$AED_{IN}\left(mSvy^{-1}\right) = ADR\left(nGyh^{-1}\right)\times 8760\times 0.6\times 0.7\left(SvGy^{-1}\right)\times 10^{-6} \tag{4}$$

$$AED_{OUT}\left(mSvy^{-1}\right) = ADR\left(nGyh^{-1}\right)\times 8760\times 0.4\times 0.7\left(SvGy^{-1}\right)\times 10^{-6} \tag{5}$$

where; AED_{IN} and AED_{OUT} are Annual effective dose rate for indoor and outdoor environments respectively, $ADR\left(nGyh^{-1}\right)$ is the absorbed dose rate in air, 8760 is the time in hours for one year, 0.7 (SvGy^{-1}) is the conversion factor which converts the absorbed dose rate in the air to an effective dose, 0.6 is the indoor occupancy factor and 0.4 is the outdoor occupancy factor [5] [10]. These occupancy factors (indoor and outdoor) were selected to reflect the semi-rural lifestyle of communities around Lumoru dumpsite, where residents divide their time between indoor domestic life and outdoor livelihood activities such as farming, trading, and waste handling. These values align with UNSCEAR [11] standards while realistically representing local exposure conditions.

3.5. Representative Level Index (I_{Υ})

The soil samples were then assessed to determine the safety of human beings around the Lumoru dumpsite. For this reason, the representative level index (I_{Υ}) was calculated using Equation (6) [20].

$$I_{\Upsilon} = \frac{C_{\mathrm{U}}}{150} + \frac{C_{\mathrm{Th}}}{100} + \frac{C_{\mathrm{K}}}{1500} \tag{6}$$

3.6. Annual Gonadal Dose Equivalent

According to UNSCEAR, bone marrow and bone surface cells are considered organs of interest for dose measurements. They are the most sensitive body organs to radiation. [21], it affects the most sensitive parts of the body like the bone marrow, destroying red bone marrow that produces red blood cells [3]. Excess white blood cells attack and destroy red blood cells, causing fatal leukemia, a blood cancer. [21] AGDE was calculated by the equation.

$$\boldsymbol{AGDE}\left(\boldsymbol{Sv}/\boldsymbol{yr}\right) = 3.09\boldsymbol{C}_{\mathrm{U}} + 4.18\boldsymbol{C}_{\mathrm{Th}} + 0.314\boldsymbol{C}_{\mathrm{K}} \tag{7}$$

3.7. Internal and External Hazard Indices

The internal hazard index (H_{in}) and external hazard index were determined using Equation (7) and Equation (8 [3]).

$$H_{in} = \frac{C_U}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (8)$$

$$H_{ex} = \frac{C_U}{370} + \frac{C_{Th}}{259} + \frac{C_K}{1500} \quad (9)$$

3.8. Excessive Lifetime Cancer Risk

This shows the probability for an individual to develop cancer over a lifetime at a given exposure. It was determined using Equation (9) [5].

$$ELCR = AEDR \times DL \times RF \quad (10)$$

where AEDR is Annual Effective Dose Rate, DL is duration of life or life expectancy (70 yrs) and RF is the total risk factor per Sievert given as 0.05 as per ICRP-60.

4. Results and Discussions

4.1. Activity Concentrations of Radionuclides

The mean activity concentrations at Lumoru were 7 ± 0.4 Bq/kg for ^{238}U, 57 ± 2.0 Bq/kg for ^{232}Th, and 25 ± 1.3 Bq/kg for ^{40}K, as seen in Table 1. Compared with UNSCEAR global averages of 33 Bq/kg for ^{226}Ra, 45 Bq/kg for ^{232}Th, and 420 Bq/kg for ^{40}K [11].

Table 1. Activity concentration and radium equivalent in Bq/kg.

Sample	^{238}U	^{232}Th	^{40}K	Ra_{eq}
D1	4 ± 0.2	43 ± 2.1	15 ± 0.8	67 ± 3.0
D2	7 ± 0.3	58 ± 2.5	30 ± 1.5	93 ± 3.5
D3	6 ± 0.3	81 ± 2.9	18 ± 1.0	123 ± 4.0
D4	7 ± 0.3	52 ± 2.0	17 ± 0.9	83 ± 3.0
D5	6 ± 0.3	52 ± 2.0	15 ± 0.8	82 ± 3.0
D6	6 ± 0.3	70 ± 2.7	28 ± 1.4	108 ± 3.8
D7	3 ± 0.2	40 ± 1.8	41 ± 2.0	64 ± 2.7
D8	4 ± 0.2	40 ± 1.8	14 ± 0.7	63 ± 2.6
D9	12 ± 0.5	35 ± 1.6	68 ± 3.2	67 ± 3.5
D10	11 ± 0.5	35 ± 1.6	23 ± 1.1	62 ± 3.3
D11	6 ± 0.3	37 ± 1.7	16 ± 0.8	61 ± 2.8
D12	2 ± 0.1	81 ± 2.9	16 ± 0.8	120 ± 3.9
D13	11 ± 0.5	87 ± 3.0	22 ± 1.1	137 ± 4.2
D14	8 ± 0.4	52 ± 2.0	25 ± 1.2	85 ± 3.1
D15	17 ± 0.6	90 ± 3.1	22 ± 1.1	148 ± 4.4
Mean ± SD	7 ± 0.4	57 ± 2.0	25 ± 1.3	91 ± 3.4

The distribution of radionuclides across the sampled soils showed distinct spatial variability. Uranium activity ranged from 2 ± 0.1 Bq/kg in sample D12 to 17 ± 0.6 Bq/kg in D15, reflecting localized increases possibly linked to buried construction debris or compacted waste zones. The relatively narrow range of uranium concentrations suggests limited input from industrial or phosphate waste materials, which are typical uranium carriers in other urban dumpsites [22]. Thorium, however, exhibited the widest variation, with activity spanning from 35 ± 1.6 Bq/kg in D9 and D10 to 90 ± 3.1 Bq/kg in D15, **Table 1**. This pronounced difference points to irregular deposition of ceramics, tiles, and sanitary ware, which often contain thorium-bearing minerals. Potassium activity also varied moderately, from 14 ± 0.70 Bq/kg in D8 to 68 ± 3.2 Bq/kg in D9, likely reflecting the uneven distribution of organic waste and ash residues across the site. Such variability is consistent with open, un-engineered dumpsites where waste layers are neither uniform nor segregated [4].

The comparative findings in **Table 2** show clear differences in the levels of natural radionuclides reported across dumpsites in Kenya and Nigeria. In this study, uranium and potassium levels were generally low, while thorium showed moderate enrichment. A contrasting trend was noted at the Machinjoni dumpsite in Kitale, where higher thorium activity is linked to the accumulation of building and construction debris [6]. Urban dumpsites such as Ijebu-Ode and those in Lagos-Ogun recorded higher uranium and potassium activities, likely due to the mix of industrial, organic, and metallic waste typical of larger cities [22] [23]. In comparison, the Ikorodu market dumpsites exhibited much lower activity levels, consistent with their smaller waste volumes and less complex waste profiles [4]. Overall, these observations suggest that variations in radioactivity across dumpsites are shaped more by the type and management of waste than by underlying geology [2] [24]. The results from this study therefore indicate a moderately impacted site, where the radiological characteristics reflect mainly domestic and construction waste inputs rather than industrial or natural geological sources.

Table 2. Comparison with other studies.

Location/Site	^{238}U	^{232}Th	^{40}K	Reference
Lumoru Dumpsite, Bungoma (Kenya)	**7 ± 0.38**	**57 ± 2.87**	**25 ± 1.25**	**Present study**
Machinjoni Dumpsite, Kitale (Kenya)	16 ± 0.83	68 ± 3.4	60 ± 3.0	Barasa *et al.* (2023)
Ijebu-Ode Dumpsite, Ogun State (Nigeria)	142.20 ± 25.9	16.11 ± 3.00	362.30 ± 27.6	Gbadamosi *et al.* (2021)
Lagos & Ogun States Dumpsites (Nigeria)	23.0 ± 6.6	33.6 ± 8.5	481.8 ± 14.7	Ademola *et al.* (2015)
Ikorodu Market Dumpsites, Lagos (Nigeria)	2.85 ± 6.50	2.50 ± 0.38	—	Oyebanjo *et al.* (2019)

4.2. Radium Equivalent

In this study, the radium equivalent activity (Ra_{eq}) varied across the samples, ranging from 61 ± 2.8 Bq/kg in D11 to 148 ± 4.4 Bq/kg in D15, with an average of 91 ± 3.4 Bq/kg. These values are well below the safety limit of 370 Bq/kg recom-

mended by UNSCEAR [11], confirming that the soils from this dumpsite are radiologically safe for human exposure. The observed variability likely reflects the heterogeneous composition of waste materials deposited at different sections of the site. When compared with similar investigations, the mean Ra_{eq} obtained in this study is slightly lower than that reported for the Machinjoni dumpsite in Kitale (118 ± 5.93 Bq/kg) [6] and Kaduna dumpsites in Nigeria (135.54 ± 18.00 Bq/kg) [3]. However, it is somewhat higher than values recorded in Okakarara, Namibia (57.80 ± 0.98 Bq/kg) [5]. The differences observed among sites may be attributed to variations in local geology, waste type, and disposal practices, all of which influence the concentration of natural radionuclides in soil. The relatively low Ra_{eq} values in this study therefore indicate a moderate presence of uranium- and thorium-bearing materials, consistent with general domestic and municipal waste rather than industrial residues. Overall, the results affirm that the site poses no significant radiological hazard, and that background radiation remains the main contributor to overall exposure in the surrounding area.

4.3. Absorbed Dose Rate and Annual Effective Dose

The Absorbed Dose Rate (ADR) across the Lumoru dumpsite soils showed measurable variation, ranging from 26 ± 1.32 nGy/h in sample D11 to 63 ± 3.18 nGy/h in D15, with an overall mean of 39 ± 1.96 nGy/h as seen in **Table 3**. These values are comfortably below the worldwide outdoor average of 59 nGy/h recommended by UNSCEAR [11], indicating that external gamma radiation from the site remains within safe exposure levels. The variation among samples reflects spatial differences in radionuclide distribution, likely influenced by the uneven deposition of waste materials. Slightly elevated dose rates in samples such as D13 and D15 correspond to higher concentrations of thorium and uranium, while lower values, as seen in D7 and D11, are associated with soil zones containing predominantly organic or decomposed material.

Table 3. Derived radiological parameters from activity concentrations.

Sample	AGDE (μSv/y)	ADR nGy/h	RLI	Hex	Hin	$AEDE_{out}$ (mSv/y)	ELCR ($\times 10^{-3}$)
D1	197 ± 8	29 ± 1.45	0.47 ± 0.02	0.18 ± 0.01	0.19 ± 0.01	0.07 ± 0.01	0.25 ± 0.02
D2	273 ± 10	40 ± 2	0.65 ± 0.03	0.25 ± 0.01	0.27 ± 0.01	0.09 ± 0.01	0.32 ± 0.03
D3	363 ± 12	53 ± 2.65	0.86 ± 0.04	0.33 ± 0.02	0.35 ± 0.02	0.13 ± 0.01	0.46 ± 0.03
D4	244 ± 9	36 ± 1.8	0.58 ± 0.03	0.22 ± 0.01	0.24 ± 0.01	0.08 ± 0.01	0.28 ± 0.02
D5	241 ± 9	35 ± 1.77	0.57 ± 0.03	0.22 ± 0.01	0.24 ± 0.01	0.08 ± 0.01	0.28 ± 0.02
D6	320 ± 11	46 ± 2.33	0.76 ± 0.04	0.29 ± 0.02	0.31 ± 0.02	0.11 ± 0.01	0.39 ± 0.03
D7	189 ± 8	27 ± 1.39	0.45 ± 0.02	0.17 ± 0.01	0.18 ± 0.01	0.06 ± 0.01	0.21 ± 0.02
D8	184 ± 7	27 ± 1.36	0.44 ± 0.02	0.17 ± 0.01	0.18 ± 0.01	0.06 ± 0.01	0.21 ± 0.02
D9	205 ± 8	29 ± 1.49	0.48 ± 0.02	0.18 ± 0.01	0.21 ± 0.01	0.07 ± 0.01	0.25 ± 0.02
D10	188 ± 8	27 ± 1.36	0.44 ± 0.02	0.17 ± 0.01	0.20 ± 0.01	0.06 ± 0.01	0.21 ± 0.02

Continued

D11	178 ± 7	26 ± 1.32	0.42 ± 0.02	0.17 ± 0.01	0.18 ± 0.01	0.06 ± 0.01	0.21 ± 0.02
D12	350 ± 12	51 ± 2.55	0.83 ± 0.04	0.32 ± 0.02	0.33 ± 0.02	0.12 ± 0.01	0.42 ± 0.03
D13	405 ± 13	59 ± 2.95	0.96 ± 0.05	0.37 ± 0.02	0.40 ± 0.02	0.14 ± 0.01	0.49 ± 0.04
D14	250 ± 9	36 ± 1.84	0.59 ± 0.03	0.23 ± 0.01	0.25 ± 0.01	0.09 ± 0.01	0.32 ± 0.03
D15	436 ± 14	63 ± 3.18	1.03 ± 0.05	0.40 ± 0.02	0.44 ± 0.02	0.15 ± 0.01	0.53 ± 0.04
Mean ± SD	290 ± 10	39 ± 1.96	0.64 ± 0.03	0.25 ± 0.01	0.28 ± 0.01	0.09 ± 0.01	0.30 ± 0.03

The corresponding annual effective dose equivalent for outdoor exposure (AEDEout) ranged from 0.06 ± 0.01 mSv/y in D11 to 0.15 ± 0.01 mSv/y in D15, with an average of 0.09 ± 0.01 mSv/y. These results fall below the global average of 0.48 mSv/y for outdoor terrestrial radiation, implying that radiation doses received by individuals living or working near the dumpsite are well within permissible limits. The relatively small spread in AEDE values across the samples indicates minimal movement or buildup of radionuclides in the surrounding soil environment, suggesting stable waste-radiation interaction over time. In summary, the observed ADR and AEDE values confirm that radiation exposure at the Lumoru dumpsite is primarily due to natural background sources. The measured doses are too low to pose any significant health risk, underscoring the radiological safety of the surrounding environment.

4.4. Annual Gonadal Dose Equivalent (AGDE)

The AGDE values for Lumoru soils averaged 290 ± 10 μSv/year, ranging from 178 ± 7 to 436 ± 14 μSv/year. This parameter is particularly important because gonadal tissues are among the most radiosensitive organs, and prolonged exposure could have hereditary implications. While no strict international limit exists for AGDE, values reported in Lumoru are within the same order of magnitude as those observed in other Kenyan studies. These values, though modest, underscore the need to monitor long-term exposure, particularly for waste handlers and scavengers who spend extended hours at the dumpsite.

4.5. Hazard Indices and Radiological Safety

The radiological hazard indices derived from soils at the Lumoru dumpsite indicate that radiation exposure levels are within safe limits. The Representative Level Index (RLI) ranged from 0.42 ± 0.02 to 1.03 ± 0.05, with a mean of 0.64 ± 0.03, suggesting that the overall gamma radiation level remains below the permissible threshold of unity. The external hazard index (H_{ex}) and internal hazard index (H_{in}) recorded means of 0.25 ± 0.01 and 0.28 ± 0.01, respectively, both comfortably below the international limit of one [11]. Slightly higher values observed in samples such as D13 and D15 reflect area-based variations in radionuclide concentration, while the majority of samples show uniformly low radiation levels, confirming overall radiological stability across the site.

The Excess Lifetime Cancer Risk (ELCR) values ranged from 0.21×10^{-3} to 0.53×10^{-3}, averaging 0.30×10^{-3}, which lies within the globally acceptable range of 0.29×10^{-3} to 1.0×10^{-3} for outdoor exposure. These low risk levels indicate that prolonged contact with or residence near the dumpsite is unlikely to result in significant health effects. Taken together, the radiological hazard indices demonstrate that the Lumoru dumpsite presents no measurable carcinogenic or radiological threat. The findings underscore that natural background radiation remains the principal source of exposure, confirming that the site is radiologically safe for ongoing human and environmental activities.

5. Conclusions

This study assessed the activity concentrations of naturally occurring radionuclides ^{238}U, ^{232}Th, and ^{40}K in soils from the Lumoru dumpsite and evaluated the associated radiological hazards. The mean activity concentrations were 7 ± 0.38 Bq/kg for ^{238}U, 57 ± 2.87 Bq/kg for ^{232}Th, and 25 ± 1.25 Bq/kg for ^{40}K. The corresponding absorbed dose rate averaged 39 ± 1.96 nGy/h, while the annual effective dose equivalent (AEDEout) was 0.09 ± 0.01 mSv/y, both of which are below the recommended global averages of 59 nGy/h and 0.48 mSv/y respectively (UNSCEAR, 2000). These results indicate that the ambient gamma radiation levels at the site are consistent with normal background exposure and do not present any immediate radiological threat to the nearby population.

The calculated radiological hazard indices further support this finding. The Representative Level Index (RLI) averaged 0.64 ± 0.03, while the external (H_{ex}) and internal (H_{in}) hazard indices recorded mean values of 0.25 ± 0.01 and 0.28 ± 0.01 respectively, all below the safety threshold of unity. The excess lifetime cancer risk (ELCR) averaged 0.30×10^{-3}, which lies within the globally acceptable range of 0.29×10^{-3} to 1.0×10^{-3} for outdoor exposure. These results confirm that radiation exposure at the Lumoru dumpsite is within safe limits, with no significant health implications under current conditions. Overall, the findings demonstrate that the site is radiologically safe, and continued monitoring is recommended to ensure that future waste accumulation does not alter the existing radiological balance.

Conflicts of Interest

The authors declare no conflicts of interest.

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