

# ASSESSMENT OF RADIONUCLIDES CONTENT OF DUMPSITES WITHIN KADUNA METROPOLIS

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## ABSTRACT

This study assessed the concentration of radionuclides (Ra-266, Th-232, U-238, and K-40) in selected dumpsites within some Local Government Areas of Kaduna State. Radiological analysis was carried out using a gamma spectrometer (HPGE) located at the Energy Research Center, University of Ibadan, Nigeria. The results of the concentration of Ra-266, Th-232, U-238 and K-40 in the study area were as follows: 196.12 – 239.14 Bq/kg, 126.79 – 171.32 Bq/kg, 84.96 – 115.96 Bq/kg, and 317.11 – 521.77 Bq/kg respectively for Chikun LGA; 213.84 – 268.98 Bq/kg, 102.17 – 122.90 Bq/kg, 110.89 – 137.80 Bq/kg, 407.64 – 486.38 Bq/kg respectively for Igabi LGA; 187.15 – 364.50 Bq/kg, 166.04 – 387.00 Bq/kg, 97.35 – 180.57 Bq/kg, and 541.72 – 801.08 Bq/kg respectively for Kaduna North LGA; and 128.98 – 293.45 Bq/kg, 139.43 – 182.96 Bq/kg, 70.57 – 132.02 Bq/kg and 526.19 – 707.42 Bq/kg respectively for dumpsites in Kaduna South. The results revealed that K-40 had the highest concentration in all the study areas and was found to be above the UNSCEAR (2000) recommended limit of 300 bq/kg. Ra-266, Th-232, and U-238 were found to be 37, 31, and 51 Bq/kg above the UNSCEAR (2000) recommended limits of 35, 30, and 50 Bq/kg, respectively. The annual effective dose was in the range of 1.23–2.30 mSv<sup>y</sup>(-1) above the UNSCEAR (2000) recommended safety limit. The radioactivity level in the study areas was high; therefore, continuous exposure to these radionuclides and their progenies may pose a severe risk to public health. All the sampled radionuclides were found to be within the recommended standard of  $\leq 1.0$  WHO reference values.

**Keywords:** Radioactivity, Radionuclide, Activity concentration, Dumpsites, Gamma Spectrometer.

## INTRODUCTION

A radionuclide is an atom that has excess nuclear energy, making it unstable. This excess energy can be used in one of three ways: emitted from the nucleus as gamma radiation; transferred to one of its electrons to release it as a conversion electron; or used to create and emit a new particle (alpha particle or beta particle) from the nucleus. During those processes, the radionuclide is said to undergo radioactive decay (Petrucci *et al.*, 2002). These emissions are considered ionizing radiation because they are powerful enough to liberate an electron from another atom. The radioactive decay can produce a stable nuclide or will sometimes produce a new unstable radionuclide, which may undergo further decay. Radioactive decay is a random process at the level of single atoms; it is impossible to predict when one particular atom will decay (Best *et al.*, 2013). However, for a collection of atoms of a single element,

the decay rate and thus the half-life ( $t_{1/2}$ ) for that collection can be calculated from their measured decay constants (Chakraborty *et al.*, 2013).

Radionuclides occur naturally or are artificially produced in nuclear reactors, cyclotrons, particle accelerators, or radionuclide generators. Radionuclides are of concern to the environment and human health because they transfer from soil to plants in any ecosystem. Human activities create waste, and the way they are handled, stored, and disposed of can result in health hazards for the environment. Dump sites in most cities in Nigeria, apart from constituting a threat to the environment, pose a serious health hazard to the populace. However, the hazards caused by dumpsites are not only in terms of odor and the presence of disease-causing microorganisms, but can also result from the radionuclides emanating from such dumpsites. Shikali, (2013) in Kenya works on the activity concentration of naturally occurring radionuclides in soil using a sodium iodide detector [NaI(Tl)]. He found out that the activity concentrations of <sup>226</sup>Ra were 0.79 mSv/yr, <sup>232</sup>Th was 0.51 mSv/yr, and <sup>40</sup>K was 0.91 mSv/yr. His results were within the acceptable limit of 1.0 mSv/yr set by the United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR, 2008).

A study was conducted by Ajaiya and Ibikunle (2013) in Oyo State, south-western Nigeria, to investigate the radioactivity of surface soils in urban and rural areas. They reported that the annual effective dose for urban areas was 0.1 mSv/yr, while that of rural areas was 0.3 mSv/yr, with a standard deviation of 0.02 mSv/yr and 0.3 mSv/yr for urban and rural areas, respectively, within the recommended standard set by UNSCEAR, 2000. Similarly, Caroline *et al.*, (2013) assessed the activity concentration of radionuclides in sediment from the non-oil and oil-producing communities in Delta State, Nigeria. The result of their study showed a significant difference in the activity concentration of radionuclide in sediment between non-oil-producing and oil-producing sites. The average values of their results obtained from non-oil-producing and oil-producing sites were 0.32 and 0.87 mSv/yr, respectively, which were below the permissible limit of 1.0 mSv/yr set by UNSCEAR 2000. Abdullahi *et al.*, (2013) work on the analysis of Sodium (Na), Potassium (K), and Calcium (Ca) in soils along the bank of the Kaduna River in Nigeria using X-ray fluorescence techniques. Their result shows that the activity concentrations of Na, K, and Ca were 0.8, 0.4, and 0.6 mSv/yr respectively, which were below the permissible limit of 1.0 mSv/yr set by UNSCEAR, 2000.

Adetutu *et al.*, (2018) investigated the radionuclide concentrations, radiological hazard indices, and physiochemical properties in water, fish, and sediment samples from the river Kaduna and found

that the activity concentration and hazard indices for  $^{232}\text{Th}$  were 0.8 mSv/yr and 0.6 mSv/yr, respectively, which were within the accepted limit of 1.0 mSv/yr recommended by UNSCEAR, while in sediment, they observed that the activity concentration was 1.35 above the permissible limit set by UNSCEAR, 2000. They conclude that the concentration of these radionuclides, if not controlled, will have negative effects on the inhabitants. Due to the rapid increase in population, indiscriminate dump sites (domestic dumps), and housing development in Kaduna State, There is a need to assess the radionuclide concentration at dumpsites in Kaduna State in order to know the level of emission they have generated in Kaduna State. This study aimed at assessment of radionuclides of dump sites in Kaduna State, North Central of Nigeria. To determine the radionuclides concentration (Radium- 226 (Ra-226), Uranium-238 (U-238), Thorium 232 (Th-232) and Potassium 40 (K-40). The study is designed to cover four local government areas Kaduna State, namely: Kaduna North, Kaduna South, Igabi and Chikun Local governments. the study area using Gamma spectrophotometer (Phoenix 986),

## MATERIALS AND METHODS

### Materials

The detection and measurement of radionuclides in the samples were carried out using materials such as five samples of surface soil from each of the four sites using composite sampling techniques. While a gamma spectrometer (hpGe detector) and an AAS (Model 219/211 VGP) were used for detection, on the other hand, a plastic container of about 1–2 vol was used for sampling.

### Study Area

The area to study is Kaduna State, which is located in the northern part of Nigeria and was created in 1967 as a north-central state, with its capital being its namesake. Kaduna State has a total area of 431 km<sup>2</sup> at latitude 10.60931 and longitude 7.429504, with an elevation of 250 m (166 sq mi). It has a population of 6,113,503 (2006 census) and 23 local government areas. Four out of which the study is based are: Kaduna North, Kaduna South, Igabi, and Chikun Local Government Areas of Kaduna State. The vegetation cover is Sudan Savannah type, characterized by scattered short trees, shrubs, and grasses. The soil type is mostly loamy to sandy, with a substantial amount of clay found in a few locations. Kaduna State is an industrial center of Northern Nigeria and the Middle Belt, manufacturing products like textiles, machinery, steel, aluminum, petroleum products, and bearings. Other light manufacturers include: plastics, pharmaceuticals, leather goods, furniture, and televisions. (KCEE, 2016). Agriculture is also a major industry in Kaduna, and as such, the Bank of Agriculture has its headquarters in the town of Kaduna (SunFia, 2020). Automobile manufacturing is one of the important parts of the Kaduna economy (Peugeot Nigeria, 2016); Kaduna Refinery and Petrochemical Company (KRPC) is also one of the Nigerian four main oil refineries located in Kaduna (NNPC, 2019).

### Imagery Map of the Study Area

The map of Kaduna State where the research is being carried out is as shown in Figure 1, with the selected sites clearly indicated.



Figure 1: Imagery map of Kaduna showing the dump sites (Google Map)

### Sample Collection

The soil samples were collected under five different land uses, namely Kaduna North labeled (KN), Kaduna South labeled (KS), Igabi labeled (IG), and Chikun labeled (CKN), and the control

samples were labeled as (Cont. KN, KS, IG, and CKN, respectively). The samples were collected in May 2018 from the surface layer (0–15 m) of the soil with a stainless steel auger from five (5) different locations in each local government area of study.

The difference from one sample point to another was 50 m apart for the analyzed samples and 100 m away from the dump sites for the control samples. Each of the collected samples was weighed at 1.0 kg, packaged in a clean polyethylene bag (container), and labeled KN, KS, IG, CKN, and Control for each selected site. There were a total of twenty-five (25) soil samples per site, summing up to 100 samples, 80 analyzed samples, and 20 control samples. In each of the study sites, 25 samples were collected and 5 samples emerged to obtain 1 composite sample, therefore 20 composite samples were obtained.

### Soil Digestion for Radionuclide

About 500 g of soil was measured and poured into a 500-ml Marinell beaker. The beaker was covered with the beaker lid and sealed properly to ensure that there was no room for the escape of any radioactive gas. It was left for 28 days to attain secular equilibrium before counting. It was moved to the gamma counting room for counting. Each sample was counted for 18000 seconds, peak analysis was done with Genie 2000 software, and concentrations of radionuclides were taken. The specific activity concentration was determined by the earlier efficiency calibration.

### Activity concentration

The activity concentration of a certain radionuclide (C) in the soil samples is the ratio of the net gamma counting rate for peak energy to the product of the detected efficiency of a specific  $\gamma$ -ray and the intensity of the  $\gamma$ -line. The activity concentration of radionuclides is computed using equation 1 (Abdel-Ghany, 2010).

$$C(Bqkg^{-1}) = \frac{Ca}{\epsilon \times I_{eff} \times M_S} \quad (1)$$

where;

Ca is the net gamma counting rate (counts per second) for a peak at energy E,  $\epsilon$  is the detected efficiency of a specific  $\gamma$ -ray,  $I_{eff}$  is the intensity of the  $\gamma$ -line in radionuclides, and  $M_S$  is the mass of the soil sample under consideration measured in kilograms.

### Radium equivalent activity

The radium equivalent activity ( $Ra_{eq}$ ), measured in  $Bqkg^{-1}$ , is a quantity used to identify the uniformity of radiation exposure. The  $Ra_{eq}$  calculated values are used to compare the specific activity of materials containing different amounts of  $^{238}U$ ,  $^{232}Th$ , and  $^{40}K$ . Besides,  $Ra_{eq}$  data can be used to assess the health hazard effects produced by the activity concentrations of  $^{238}U$ ,  $^{232}Th$ , and  $^{40}K$  radionuclides in soil. The measured values of  $Ra_{eq}$  are obtained using equation 2 (Alharbi et al., 2011).

$$R_a(Bqkg^{-1}) = AU + 1.43 \times A_{Th} + 0.077 \times AK \quad (2)$$

Where;

AU, ATh, AK,  $Ra_{eq}$  are the average activity concentrations of  $^{238}U$ ,  $^{232}Th$ ,  $^{40}K$ , and  $Ra_{eq}$  respectively. In calculating  $Ra_{eq}$  values, the average activity concentrations of  $370 Bqkg^{-1}$ ,  $259 Bqkg^{-1}$ , and  $4810 Bqkg^{-1}$  used for  $^{238}U$ ,  $^{232}Th$ , and  $^{40}K$  respectively, are assumed to produce the same gamma dose rate (Mahur et al., 2010).

### Absorbed dose rate in air ( $D_r$ )

The effects of gamma radiation originating from radioactive sources in the environment are expressed in terms of the total gamma radiation absorbed dose rate in the air,  $D_r$ . The values of  $D_r$  in air and 1 m above the ground level are calculated from the measured activity concentrations of  $^{238}U$ ,  $^{232}Th$ , and  $^{40}K$  using equation 3 (Fatima et al., 2008).

$$D_r(nGyh^{-1}) = 0.427 \times A_U + 0.662 \times A_{Th} + 0.043 \times A_K + 0.462A_{Ra} \quad (3)$$

Where;

0.427, 0.662, 0.043 and 0.462 are the dose rate conversion factors to convert the activity concentrations of  $^{238}U$ ,  $^{232}Th$ , and  $^{40}K$  and  $A_{Ra}$  radionuclides into absorbed dose rates as proposed by UNSCEAR (UNSCEAR, 1993). Basically, these factors are representative of the absorbed dose rates in air per unit activity per unit of soil mass, in units of  $nGyh^{-1}$  per  $Bqkg^{-1}$ .

### Annual effective dose equivalent

The annual effective dose equivalent (AEDE) received by individuals is calculated from the calculated values of  $D_r$  by applying the dose rate conversion factor of  $0.7 SvGy^{-1}$  and the occupancy factors of 0.2 (5/24) and 0.8 (19/24) for outdoors and indoors, respectively (UNSCEAR, 1993). The annual effective outdoor doses,  $D_{out}$ ; the annual effective indoor doses,  $D_{in}$ ; and total annual effective doses,  $D_{tot}$ , are calculated using equations 4, 5, and 6 respectively (Veiga et al. 2006).

$$D_{out}(nGyh^{-1}) = D_r(mGyh^{-1}) \times 24h \times 365.25d \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \quad (4)$$

$$D_{in}(nGyh^{-1}) = D_r(nGyh^{-1}) \times 24h \times 365.25d \times 1.4 \times 0.8 \times 0.7SvGy^{-1} \times 10^{-6} \quad (5)$$

$$D_{tot}(mSvy^{-1}) = D_{out} + D_{in} \quad (6)$$

### External and internal radiation hazard indices

The external radiation hazard index, corresponding to  $^{238}U$ ,  $^{232}Th$ ,  $^{40}K$ , and  $^{226}Ra$  natural radionuclides, is calculated using equations 7 and 8, respectively (Shams et al. 2013). The results should be less than or equal to unity, that is,  $\leq 1$ . Normally, the maximum value of ( $= 1$ ) corresponds to the upper limit of  $Ra_{eq}$  ( $370 Bq kg^{-1}$ ). In order to keep the radiation hazard insignificant, the values of should be lower than 1 (Mahur et al. 2010).

$$H_{ex} = \frac{AU}{370Bqkg^{-1}} + \frac{A_{Th}}{259Bqkg^{-1}} + \frac{AK}{4810Bqkg^{-1}} \quad (7)$$

where

AU, ATh and AK are the average values of Uranium, Thorium and Potassium.

The hazard levels from the inhalation of alpha particles emitted from the radon short-lived radionuclides such as  $^{222}Rn$ , the daughter product of  $^{226}Ra$ , and  $^{220}Rn$ , the daughter product of  $^{224}Ra$ , can be quantified by the internal hazard index,  $H_{in}$ . This index can be calculated using equation 22(Shams et al. 2013).

$$H_{in} = \frac{AU}{185Bqkg^{-1}} + \frac{A_{Th}}{259Bqkg^{-1}} + \frac{AK}{4810Bqkg^{-1}} \quad (8)$$

The measured values of  $H_{in}$  should also be less than or equal to unity, that is,  $H_{in} \leq 1$ . This of great importance to keep the concentration levels of radon and its short-lived daughters low enough for the respiratory organs of humans living in the dwellings, comparable to or even lower than the assigned international levels of  $40 Bq m^{-3}$  (UNSCEAR, 2000).

## RESULTS

### Activity Concentration of Radionuclide

The results of the activity concentration of some radionuclides (Radium-226, Uranium-238, Thorium-232, and Potassium-40) in the soil samples of the selected local governments in Kaduna State are presented in Tables 1–4.

**Table 1:** Concentration of Ra-226, U-236, Th-232 and K-40 of Soil Samples in Chikun (CKN) Local Government Area.

SAMPLE CODE	Ra-226 (Bq/Kg)	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
CKNCONT.C	230.46±11.95	111.43±5.74	136.07±7.61	390.58±20.66
CKN P1	196.12±10.23	100.42±5.18	126.79±8.24	496.50±26.26
CKN P2	221.01±11.49	115.96±5.97	144.88±7.86	317.11±16.78
CKN P3	239.14±12.41	108.32±5.59	171.32±9.34	379.04±20.05
CKN P4	181.86±9.46	84.96±4.38	123.67±6.90	521.77±27.60
Mean				
UNSCEAR	213.72	104.22	140.55	421.00
	35	50	30	400

**Table 2:** Concentration of Ra-226, U-236, Th-232 and K-40 Soil Samples in Igabi (IG) Local Government Area.

SAMPLE CODE	Ra-226 (Bq/Kg)	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
IG CONT.C	227.59±11.79	110.89±5.71	122.90±6.48	407.64±21.56
IG P1	243.33±12.61	114.69±5.90	102.17±5.39	486.38±25.73
IG P2	231.97±12.01	116.58±6.00	110.98±6.20	460.50±24.36
IG P3	213.84±11.10	112.96±5.82	108.96±5.73	484.61±25.63
IG P4	268.98±13.94	137.80±7.09	111.69±6.05	467.50±24.73
Mean conc.				
UNSCEAR	237.14	118.58	111.34	461.33
	35	50	30	400

**Table 3:** Concentration of Ra-226, U-236, Th-232 and K-40 Soil Samples in Kaduna North (KN) Local Government Area.

SAMPLE CODE	Ra-226 (Bq/Kg)	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
CONT.C	364.50±18.84	180.57±9.30	387.00±21.73	724.56±38.32
KN P1	333.77±17.26	159.33±8.20	281.84±15.42	801.08±42.48
KN P2	187.15±9.78	97.35±5.01	166.04±9.11	541.72±28.65
KN P3	268.96±13.95	133.45±6.87	202.25±11.41	656.27±34.71
KN P4	303.18±15.70	129.98±6.70	220.26±11.99	771.79±40.82
Mean conc.	291.51	140.14	251.48	699.08
UNSCEAR	35	50	30	400

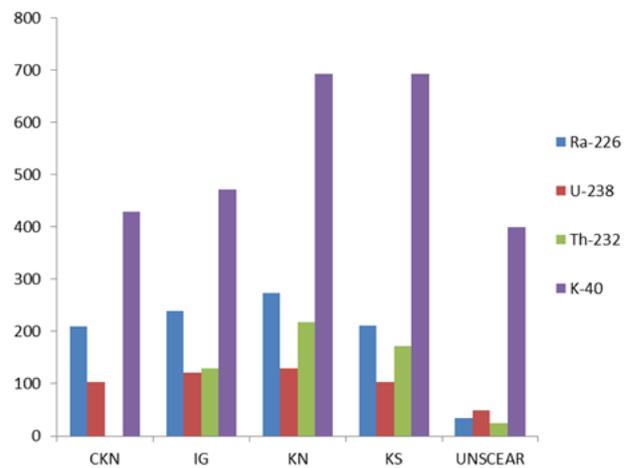
**Table 4:** Concentration of Ra-226, U-236, Th-232 and K-40 Soil Samples in Kaduna South (KS) Local Government Area.

SAMPLE CODE	Ra-226 (Bq/Kg)	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
CONT.C	126.98±6.64	73.90±3.80	139.43±7.60	526.19±27.83
KS P1	161.11±8.50	112.17±5.77	182.62±10.15	577.16±30.53
KS P2	293.45±15.17	132.02±6.79	182.96±10.02	707.42±37.42
KS P3	167.75±8.82	70.57±3.65	146.34±8.16	656.79±34.74
KS P4	220.26±11.45	95.22±4.92	175.59±10.12	699.78±37.01
Mean conc.	193.91	96.78	199.76	633.47
UNSCEAR	35	50	30	400

**Table 5:** The Absorbed dose  $D_r$  ( $nGy\cdot h^{-1}$ ) and Annual Effective Dose Rate ( $mSv\cdot y^{-1}$ ) of Radionuclide in Soil Samples within the Study Area

LGA	Absorbed dose ( $nGy\cdot h^{-1}$ )	Annual Effective Dose rate ( $mSv\cdot y^{-1}$ )		
		AEDEout	AEDEin	Total
CKN	245.70	0.03	1.20	1.23
IG	246.88	0.30	1.20	1.50
KN	375.56	0.46	1.80	2.30
KS	277.99	0.34	1.40	1.43

The results of the mean concentrations of radionuclides in the selected local governments were compared with UNSCEAR Standard as in Figures 2



**Figure 2** Comparison of the mean concentrations of radionuclide with UNSCEAR standard in Kaduna State

### External and Internal Index of Radionuclide

External and internal index of radionuclide in soil samples within the study area obtained using equations 7 and 8 respectively and the results presented on Table 6.

**Table 6:** External and Internal Index of Radionuclide

	Radionuclide (Bq/kg)			
	Ra	U	Th	K
External index	0.80	0.20	0.30	1.00
Internal index	0.55	0.98	0.20	0.89

Hazard index of  $\leq 1.0$  means all the sampled radionuclide were within the recommended standard of  $\leq 1.0$  WHO.

### DISCUSSION

#### Concentration of Radionuclide

The results in Table 1 show the concentration of radionuclide in Chikun local government. The result indicates that there is a high concentration of potassium (496.50 and 521.77 Bq/kg) at sampling points 2 and 5, respectively, which was above the recommended standard of 400 Bq/kg set by UNSCEAR, while the concentrations at sampling points 1, 3, and 4 were below the recommended standard. The results for radium, thorium, and uranium concentrations were in the range of 181.86–239.14, 126.79–

171.32, and 84.96–115.96 Bq/kg, which is above the recommended standard 30 (Bq/kg) set by UNSCEAR, (2000) in all the study sites. This result is in line with the findings of Shikali *et al.*, (2013), who observed the activity concentration of naturally occurring radionuclides in soil ranging from  $^{226}\text{Ra}$  (36.79–185.21 Bq/kg),  $^{232}\text{Th}$  (51.12–158.92 Bq/kg), and  $^{40}\text{K}$  (322.38–960.53 Bq/kg), which is in agreement with the values recorded in this research and could be attributed to natural occurrence, age of the waste dumpsite, and topography of the soil.

The result of table 2 shows that the concentrations of radionuclide in all the study sites in Igabi Local Government Area are in the range of Ra (213.84–268.98 Bq/kg) with a mean value of 241.41 Bq/kg; U (110.89–137.80 Bq/kg) with a mean value of 124.35 Bq/kg; Th (102.17–122.90 Bq/kg) with a mean value of 112.54 Bq/kg; and K (407.64–486.38 Bq/kg) with a mean value of 447.01 Bq/kg, respectively. These values are above the recommended standard of 35, 50, 30, and 400 (Bq/kg) set by UNSCEAR 2000. Bello *et al.*, (2015) investigated the concentration of radionuclides in an e-waste dumpsite around Alaba International Market, Lagos, and reported the mean values of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  concentrations for the soil samples to be  $84.26 \pm 28.08$  Bq/kg,  $20.70 \pm 0.21$  Bq/kg, and  $13.32 \pm 12.86$  Bq/kg, respectively. While those of the Ring road control dumpsite were  $405.89 \pm 75.79$  Bq/kg,  $35.10 \pm 10.97$  Bq/kg, and  $52.46 \pm 7.29$  Bq/kg, which are lower than the values recorded in this analysis, and it could be due to the nature of the anthropogenic activities in the area, or it could be that the e-waste contributes less radionuclide substance. Sunday *et al.*, (2020) also reported the activity concentration of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  from soil samples collected in soil within Igabi LGA, with a mean activity of  $^{40}\text{K}$  ( $237.4\text{Bqkg}^{-1}$ ),  $^{232}\text{Th}$  ( $86.2\text{Bqkg}^{-1}$ ) and  $^{226}\text{Ra}$  ( $128.4\text{Bqkg}^{-1}$ ).

From Table 3, the result shows that, for all the radionuclides in Kaduna North except K-40, the control samples were found to have a higher activity concentration compared to the analyzed samples in all the sample sites. This could be a result of the leaching and deposition of industrial effluents. Ulakpa *et al.*, (2016) investigated the presence of radionuclides ( $^{40}\text{K}$ ,  $^{238}\text{U}$ , and  $^{232}\text{Th}$ ) in the dumpsite soil around Elioazu dumpsite. The results showed that specific activity for  $^{40}\text{K}$  ranges from 242.36 to 501.97 Bq/kg;  $^{238}\text{U}$  ranges from 18.41 to 34.53 Bq/kg; and  $^{232}\text{Th}$  ranges from 21.89 to  $43.14 \pm 3.12$  Bq/kg, which is lower than the value reported in this work, probably due to the amount of rainfall that leaches the substance and the nature of the soil.

Table 4 shows that the concentrations of radionuclide in all the study sites in Kaduna South Local Government Area are in the range Ra (126.98–293.45 Bq/kg) with a mean value of 193.91 Bq/kg; U (70.57–132.02 Bq/kg) with a mean value of 96.78 Bq/kg; Th (139.43–175.76 Bq/kg) with a mean value of 199.76 Bq/kg; and K (526.19–707.40 Bq/kg) with a mean value of 633.47 Bq/kg, respectively. These values are above the recommended standard of 35, 50, 30, and 400 Bq/kg set by UNSCEAR, (2000). Abdulkarim *et al.*, (2018) studied the activity concentrations of natural radionuclides  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  in soil samples taken from the tin mining area in Gura Top, Jos. The average specific activity concentrations of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  determined in the soil sample ranged from  $11.26 \pm 3.16\text{Bq/Kg}$  to  $543.35 \pm 0.64\text{Bq/Kg}$  with a mean activity concentration of  $161.96 \pm 7.56\text{Bq/Kg}$  for  $^{40}\text{K}$ , that of  $^{226}\text{Ra}$  ranged from  $7.19 \pm 1.23\text{Bq/Kg}$  to  $144.20 \pm 10.18\text{Bq/Kg}$  with a mean activity of  $46.47 \pm 5.19\text{Bq/Kg}$ , while  $^{232}\text{Th}$  ranged from

$76.08 \pm 3.38\text{Bq/Kg}$  to  $1267.91 \pm 15.37\text{Bq/Kg}$ , which are lower than the values recorded in this work. The low values could be due to the absence of activities that release radioactive substances into the environment. Also, the result of the work suggests the existence of traces of radionuclides in all the dumpsites analyzed in the four local government areas in Kaduna State, which could be from domestic, agricultural, industrial, e-waste, type of soil, geological and mineralogical, geochemical composition, and industrial waste. Inhabitants that reside close to the dumpsites are at risk of being exposed to radiation doses. Also, the result of the work suggests the existence of traces of radionuclides in the dumpsites in the four local governments of Kaduna State, which could be domestic, agricultural, or industrial waste, e-waste, geological, geochemical, and mineralogical compositions of the dumpsites. Inhabitants that reside close to the dumpsite are at risk of exposure to radiation doses (Sombo *et al.*, 2018).

#### The Absorbed dose $D_r$ ( $\text{nGyh}^{-1}$ ) and Annual Effective Dose Rate ( $\text{mSvy}^{-1}$ )

Absorbed Dose Rate, Indoor and Outdoor Annual Effective Dose Rate, has been calculated from the activity concentrations of  $^{226}\text{Ra}$ ,  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{40}\text{K}$ , respectively, and the values are presented in Table 5, which shows that the absorbed dose rates due to gamma rays at 1m above the ground in the study area are within the range of  $245.70\text{ nGyh}^{-1}$  to  $375.56\text{ nGyh}^{-1}$  with an average of  $310.63\text{ nGyh}^{-1}$ , which is higher than the world average value of  $59\text{ nGyh}^{-1}$  UNSCEAR, 2000. The indoor annual effective doses are within the range of 1.20 to  $1.80\text{ mSvy}^{-1}$  with an average value of  $1.50\text{ mSvy}^{-1}$ , while the outdoor annual effective doses are within the range of 0.03 to  $0.46\text{ mSvy}^{-1}$  with an average value of  $0.25\text{ mSvy}^{-1}$ . The indoor values are above and the outdoor values are lower compared with the world average values of  $0.5\text{ mSvy}^{-1}$  and  $0.07\text{ mSvy}^{-1}$  UNSCEAR, 2000. This implies that the people living close to the dumpsites are at risk. Oyebanjo *et al.*, (2019) reported the absorbed dose rate, outdoor dose rate, and annual effective dose rate. The absorbed dose rates due to gamma rays at 1m above the ground in the study area were within the range of  $1.99\text{ nGyh}^{-1}$  to  $7.06\text{ nGyh}^{-1}$ , with an average of  $4.08\text{ nGyh}^{-1}$ , which is lower than the UNSCEAR average value of  $59\text{ nGyh}^{-1}$ . The annual effective doses were within the range of 0.00 to  $0.01\text{ mSvy}^{-1}$ , with an average value of  $0.01\text{ mSvy}^{-1}$ , which was lower when compared with the values obtained in this study and the UNSCEAR values of  $0.5\text{ mSvy}^{-1}$  and  $0.07\text{ mSvy}^{-1}$ , respectively. Hesham *et al.*, (2019) investigated the radiological hazards indices in Abu Rusheid Area, South Western Desert, Egypt, and reported the average values of the total annual effective dose varying from 3.30 to  $7.51\text{ mSvy}^{-1}$ , which is higher than the values recorded in this work.

#### Conclusion

The result of radionuclide concentrations in all the study sites shows that the activity concentrations of the radionuclides in the soil samples within the dumpsite are high, with potassium occurring at a very high concentration above the recommended value of 400 Bq/kg set by UNSCEAR, (2000). The high concentration of radionuclides in general and potassium in particular in all the study sites could be attributed to the high level of industrial activities within the study area that might lead to the release of potassium and potassium-related elements. The study revealed that the absorbed dose rates gave an average of  $310.63\text{ nGyh}^{-1}$ , above the world average value of  $59\text{ nGyh}^{-1}$  (UNSCEAR, 2000).

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