Assessment of Activity Concentration and Health Effects of Radiation Exposure from Dumpsite Soil Samples Within Kaduna Metropolis, Nigeria

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Abstract

The concentration of naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K in soil samples from eighteen selected dumpsites within Kaduna metropolis were analyzed using NaI(Tl) γ–spectrometry in order to determine their activities and assess the potential radiological health hazards associated with the soils. In comparison with the recommended limit, activity concentrations of the radionuclide ^{40}K are higher than the worldwide average value in four of the sites while ^{238}U is higher than the world average value in six of the sites. Whereas for ^{232}Th, values were below the recommended average value in all except two sites. To assess the radiological hazards of the soil samples, twelve radiological and health hazard indices were calculated. The results indicated that in twelve out of the eighteen sites analyzed, some of the health hazard parameters were higher than the recommended levels. Hence, there is a fingering potential radiological hazard directly associated with the soils from these twelve locations. In the remaining six sites, the hazard parameters were below the recommended average level, and poses no health risk to people living around the sites. A comparison between the values obtained from dumpsites and that obtained from the control site shows that the effect of NORM on dumpsite is considerably less significant to NORM from farming locations as a result of extensive use of fertilizers and chemicals during the farming seasons.

Key Words: Activity, Detectors, Dose, Environment, Gamma Ray Spectroscopy, Ionizing Radiation, Radionuclides, Soil, Waste

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INTRODUCTION

It is evident that the quality of air, food, water and the environment of habitation is significant to human health. Indeed, Nigeria is among the committee of nations showing great concern for matters pertaining to the environment. The Government in succession, at federal and state levels, exhibited their uneasiness towards the state of the environment and human health most importantly through enactment of decrees and promulgation of laws that compel citizens to respect the environment by keeping it clean (Agba & Sadiq, 2011). Sanitary and public health inspectors promote environmental health among Nigerians by ensuring that the monthly environmental sanitation introduced in 1984 to ensure clean environment is upheld. Through this routine programme, which has become part and parcel of Nigerians, citizens are compelled to clean their surroundings at least once in a month.

Nonetheless, presently in Kaduna metropolis, there lies several illegal dumpsites, constantly posing serious threats to humans and the environment at large. As a result, there exists the obligatory need to be concerned about how the government and the citizens generally address the issue of waste disposal and management in a metropolitan city like Kaduna, North Western Nigeria. While the citizens appear to be making matters worse by defecating and dumping refuse at the road sides, obvious gaps can be noticed in the institutional waste disposal structure and strategies that seem to routinely turn the state into a dunghill. The natural state of different strata of the environment is affected as a result of human activities with the soil playing host to the direct and by-products of these human activities. Meanwhile, the soil on which a crop is grown is a huge factor in determining the concentration or quantity of nutritive elements present in a crop while also having the essential feature of retaining and accumulating for a long time, external elements and radionuclides. It is well known over years, that radionuclide contaminated soil, serves as a source by which trace elements, radionuclides, and heavy metals enter agricultural produce and eventually penetrate the food chain from the soil by plant root uptake. (Agomuo & Jibirin, 2007). Thus, arbitrary and indiscriminate waste dumps in urban areas, causing significant pollution to the environment, contaminating both air and water and leading to difficulty in aerobic respiration for living creatures and scarcity of portable water; is an alarming phenomenon requiring diverse responses

including scientific investigation of their health hazard and impact. Reckless location of waste dumps also affects the environmental aesthetic and should be provided for in accordance with projections projection taking note that waste management is considered a statutory social service for which government must plan and be responsible (Eja, Alobi, Ikpeme, Ogri & Inyang, 2010).

LITERATURE REVIEW

Assessment and monitoring of quantities and distributions of radionuclides in soil has been noted to be of importance, acting as insight to monitoring changes in environmental radioactivity related to anthropogenic activities or other events of release of radioactive elements (Al Jundi et al, 2003). These may significantly contribute to the collective radiation dose received by the population living within a particular mining, industrial or dump site environment.

It has been reported that urban solid waste disposal in many countries, including Nigeria, may be the primary source of environmental pollution and numerous public health issues (Rushbrook, 2001; Gobbard, 2002; El-Taher, 2010; Erenturk et al., 2014). Jibiri et al. (2007) also revealed that most of the foods eaten by Nigerians carry traces of radionuclide and, as a result, refuse dumpsites are viable recipients of radioactive materials. It was noted that municipal, commercial and household wastes such as food, plastic, paper, textiles, scrap metals, polythene, glass, wood, insecticide cans, lamps, paints; accumulating at street corners and gutters; have the likelihood of generating some radioactivity. Most of these waste dumps contain a combination of hazardous, general, contagious or nuclear waste and may release radiation to unsuspecting scavengers or to the environment through burning. It has been established by Iwuegbue et al, (2007) that large and excess accumulation of radioactive materials and heavy metals in soil, over time, may finally lead to the contamination of the food chain. The pollution of soils and plants at dumpsites can be reported as a recent big concern for everyone (Song & Greenway, 2006). Thus, radiations released to the environment from waste dumpsites as well as from certain anthropogenic radionuclides are now considered as major contributions to terrestrial outdoor exposure (IAEA, 1989; Isola et al, 2009; Odunaike et al., 2008).

Avwiri et al (2011) corroborated this when he stated that waste disposal without adequate management especially within residential

vicinities can lead to exposure to radioactive contaminants and radiation hazards. Hazards posed by these dumpsites are not only in terms of the presence of disease-causing microorganism and odour, but also much more from radiation emanating from such dumpsites (Ojoawo & Sangodoyin, 2011; Amuda et al., 2014; Beretka & Mathew, 1985). Radioisotopes that are contained in a soil affect terrestrial gamma radiation levels to a large extent. Various radioactivity measurements show the presence of traces of radionuclide in staple foods consumed in Nigeria and all are contained in domestic waste dumped indiscriminately on the street which seeps into boreholes, well, rivers and farmland.

Although there have been some radiological studies on some dumpsites across the country, the results cannot be generalized, since dumpsites are not homogeneous. There is therefore the need to look at some dumpsites in Kaduna metropolis, North West, Nigeria.

Of the numerous studies carried out with respect to radiation from dumpsites, one of note focused on the activity concentrations of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in 50 soil samples from Bethlehem Province, West Bank, Palestine; (Abu Samreh, Thabayneh & Khrais, 2014). Gamma-ray Spectroscopy using High Purity Germanium Detector was used for the measurement with the results obtained comparable to or less than similar reported data worldwide.

As such the soil samples from the zones were considered to have merely revealed natural background radiation levels. Also, Avwiri & Olatubosun (2014) estimated the radionuclide concentration of

Also, Avwiri & Olatubosun (2014) estimated the radionuclide concentration of soil samples from selected dumpsites within Port Harcourt metropolis, Rivers State, Nigeria. To achieve this, In-situ measurements were first carried out using Geographical Positioning System (GPS) and the Radalert Nuclear Radiation Monitor. In the measurement of the specific activity, a gamma ray spectrometry analysis was carried out on the samples using a NaI(Tl) scintillation detector. Generally, the burden of radiation and accompanied risk posed by the municipal wastes on the scavengers and studied environment was minimal. Furthermore, in evaluating the potential radiation hazards associated with the process of incinerating municipal solid waste, Fernando, (2017) identified that through burning, radionuclides of

anthropogenic origins may be released as radioactive particles or gases into the atmosphere building up in the environment. The results from the study highlighted that radionuclide released into the atmosphere may lead to slight enhancement of the natural background radiation. The study also showed that burning of municipal solid waste which may contain radioactive isotopes such as ^{131}I, ^{137}Cs, ^{75}Se, ^{60}Co, and ^{241}Am located in cardboard, textile, plastic, glass, aluminium, or other metals eventually lead to the production of slag, fly ash, and atmospheric aerosols. For the study, gamma ray spectroscopy using a heavily shielded Canberra NaI(Tl) detector was used to analyse radiation exposures at three municipal waste dumps situated in Ibadan in Oyo State, Ado Ekiti in Ekiti State and the electronic waste dumpsite around Alaba International Market in Lagos State, all in South Western Nigeria. To serve as control, a sample was collected at a location with no traces of waste. From the results obtained, the activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th at the e-waste dumpsite at Alaba was found to be less than those obtained at the municipal waste dumpsites and control site and also below the UNSCEAR prescribed world average values. Values derived for other indexes of hazard were below the global average and below their respective allowable limits. Therefore, it was concluded from the study that there is no direct radiological exposure to people working or living next to the dumpsites of either the e-waste or the industrial waste facilities. Furthermore, in a study aimed at revealing the need for a "GIS-based model for siting a municipal solid waste incinerator in Kaduna metropolis" conducted by Dogara & Auwal (2016), it was emphasized that a key issue that threatens environmental quality in Kaduna metropolis is solid waste. This assertion was made considering the fact that distance to major dump sites is a huge factor in the formation of illegal dumpsites within the metropolis. The researchers further ascertained that there is no incinerator within the metropolis despite the significance of incineration to waste management systems.

In all, the need for continuous environmental monitoring of radioactivity from waste dumpsite in therefore established with gamma spectroscopy highlighted as a major technique for such studies.

METHODS

Location for Sampling

Kaduna, is located in the North-West geo political zone of Nigeria. The capital city of the state is Kaduna city which is mostly the

metropolis and some fast-growing suburbs. Kaduna city, Zaria and Kafanchan are the main metropolitan areas of the state. Kaduna State, with coordinates 10°31'23'N'7°26'25''E, has a total area of 1,190 square miles (3,080 km^2) with River Kaduna spanning through it and serving as a major regional economic hub and transportation node.

Three of the four Local Government that makes up Kaduna Metropolis were considered in this study, namely, Kaduna South, Kaduna North and Chikun Local Government Areas. The fourth, Igabi Local Government Area was excluded due to the high level of insecurity in the area. Figure 1 below locates the LGAs studied withing the Map of Kaduna State.

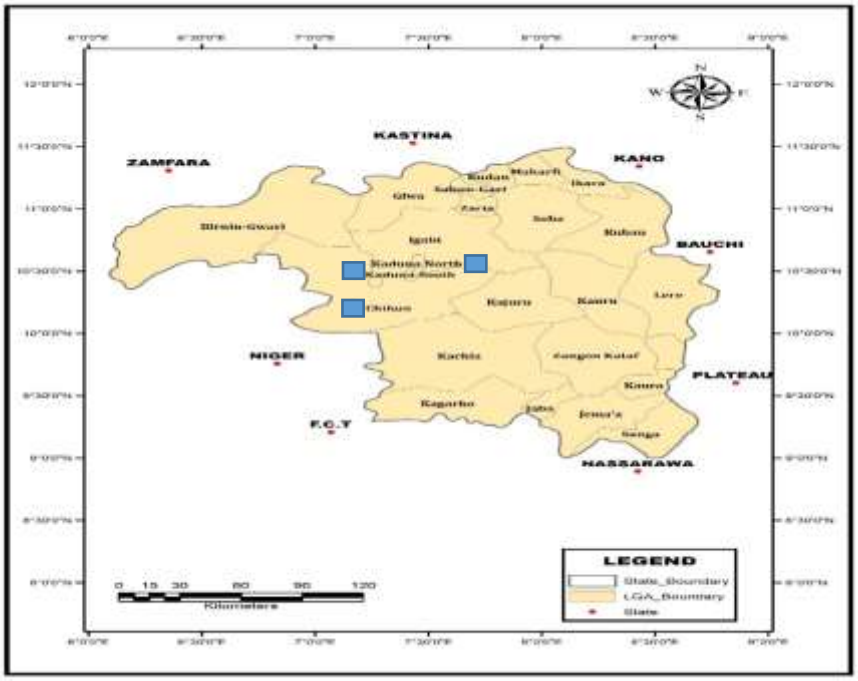

Figure 1: Map of Kaduna State Indicating Study Area with ■

In Situ Measurement with 4EC Radiation Alert Meter

The in-situ survey for this research; which was based on preliminary reconnaissance assessment considering accessibility and security; served as a basis to identify areas of elevated ionizing radiation in the different dumpsites scattered across Kaduna Metropolis. These in-situ measurements are however not reliable for quantifying amount of radiation, since they do not take into account the extent at which ionizing radiation is emitted from the soil but rather determine the level of background radiation in a

location. They only provided a guide to the most suitable location to collect sample for further study.

The measure of ionizing radiation present at each dumpsite was determined using the handheld radiation alert monitor 4EC in air for a minute at gonad level of 1m above the ground for all sites. To determine the location with the peak radiation at each dumpsite, data was obtained at five different locations at each site at a distance of 0 m (right on top of the dumpsite), 1m, 5m and 10m away from the dumpsite respectively. The mean Counts Per Minute (CPM) of the five measurements represents the measure of the detection rate of ionization events per minute for each site. The distances provide an insight into how the radiation exposures diminished with distance on scavengers (0m), pedestrians (1m), passengers on vehicles (5m) and residents (10 m) found around the various waste dumpsites. All round view of the 4EC Radiation Alert Monitor used for the field survey is presented in Figure 2. Also, Table 2 contain the locations where soil samples were collected for further studies.

Figure 2: All Round View of 4EC Radiation Alert Monitor

Table 1: Table of Dumpsites Withing the LGAs of the Study

S/N	Kaduna North LGA	Kaduna South LGA	Chikun LGA
1	GSS Kawo	Television market	Sabo under bridge
2	Mando High Tension	LEA Zango, Tudun Wada	Narayi market
3	Abakpa Rail	Ungwan Sunday	Bayan Dutse
4	Ungwan Shanu	Ungwan Sule, Romi	Ungwan Boro
5	SMC		Ungwan Gimbiya
6	LEA Badarawa		Federal Housing Estate Gonin-Gora
7			Dominion street, New Yakowa Road
8			Control site

In all, samples were collected from 17 dumpsites and one Control Location where there is no dumpsite. The control site, located in Chikun LGA was selected due to its significant distance from any dumpsites.

GAMMA-RAY SPECTROSCOPY

Most radioactive sources produce gamma rays, which are of various intensities and energies. When these emissions are detected and analyzed with a spectroscopy system, a gamma-ray energy spectrum can be produced. The quantitative study of this energy spectra of gamma-ray sources is referred to as Gamma-Ray Spectroscopy. A detailed analysis of this spectrum is generally used to determine the quantity and identity of gamma emitters present in a sample. The equipment used in this analysis includes an energy-sensitive radiation detector, electronics to process detector signals produced by the detector, such as a pulse sorter (i.e., multichannel analyzer), and associated amplifiers and data readout devices to generate, display, and store the spectrum.

In this technique, γ-rays entering the NaI crystal, interacts primarily with the bound K or L electrons from the iodine atoms in the crystal. The binding energy of an electron in the iodine K shell is only 33keV and so the recoiling electron takes most of the energy of the incident γ-ray. This recoil electron passes through the NaI crystal and loses energy by ionization including electronic and thermal excitations. A fixed fraction of the electron energy is then converted to visible photons, which then impinges on the photocathode of the photomultiplier tube. These photons produce photoelectrons from the photocathode surface of the photomultiplier which is then attracted to the first element of the dynode by a positive voltage. A cascade of electrons is thus produced down the elements of the dynode to give an electrical pulse at the anode which is proportional to the energy of the incident γ-ray. Pulses from the anode are thereby fed through the preamplifier, amplifier and into the multichannel analyser for analysis.

Measurement Facility

Activity concentrations of ^{238}U, ^{232}Th and ^{40}K were measured by Canberra manufactured, high resolution, low background γ-ray spectrometer with 8cm co-axial NaI(Tl) scintillation detector located at NIRPR having relative efficiency of 20.2%. The detector has 10cm thick lead shield to isolate background radiation from natural sources of atmospheric radon, cosmic radiation,

instrument background and other radiation sources used in nearby surrounding (ICRP, 1960). The lead shield is graded with copper of thickness 0.1cm aimed at reducing the contribution of lead X-ray fluorescence. The energy resolution of the detector is about 0.662Mev and its operating voltage is 600V. This resolution is capable of distinguishing the gamma ray energies of interest in the study. The spectrometer was tested for its linearity and; as noted earlier; it was calibrated for energy and efficiency using the well calibrated standard gamma source obtained from the International Atomic Energy Agency (IAEA).

To ensure wide statistical spread and minimize uncertainty, all the samples were counted for 18,000s (5h) for ^{238}U, ^{232}Th and their daughter products and ^{40}K. Also, measurements were repeated at intervals for quality assurance purposes as well as to ascertain the stability of the measuring system. The background radiation due to the naturally occurring radionuclides in the environment around the detector was measured using an empty plastic container; the empty plastic container was measured in the same manner as the soil samples for the same counting time of 18,000s (5h). The background spectrum was subtracted from the measure spectra to obtain the net radionuclides activities. The 1,764 MeV line of ^{214}Bi for ^{226}Ra was used in the assessment of the activity concentration of ^{238}U; the 2,615 MeV line of ^{208}Tl was used for investigating the activity concentration of ^{232}Th while the single 1,460 MeV line of ^{40}K was used for its content evaluation.

Sample Collection and Preparations for Gamma Ray Spectroscopy

The samples from each dumpsite were coded using the names of the dumpsite's location in order to prevent identification error. Seventeen soil samples from dumpsites and One from a control site were collected using a flat stainless-steel auger. Collected samples were transferred into a polythene bag and labelled accordingly using masking tape. The samples were collected at spots where elevated radiation levels were observed using radiation level meter. To ensure a good representation of the dumpsites, each dumpsite was segmented into five sections, one at each of the four ends and one at the centre. A total of five soil samples were collected in each site and further mixed and dried until a fairly constant dry weight was achieved. The dried samples were pulverized using grinders and filtered through 2 mm mesh sieve. About 500 g of the pulverized,

grinded and sieved samples were measured using an analytical weighing balance with a precision of ± 0.01g. These were then poured into temporary air tight containers, labelled accordingly and transported to the gamma spectrometry Laboratory at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan, Oyo State, South-West Nigeria. At the laboratory, the samples were poured from the temporary containers into plastics analysis containers of suitable dimension, hermetically sealed with adhesive tape and kept for 30 days to ensure that the parent and daughter nuclide (radium and its progenies) in the samples attain secular equilibrium after which gamma spectroscopic counting was carried out. During the preparation process, all materials were cleaned subsequent to each sample preparation to avoid cross contamination. Picture Plates of the Sample Preparation Stage are presented in Figure 3.

Figure 3: Sample Preparation Process (a) Drying (b) Pulverization using Grinder (c) Sieving (d) Weighing (e) Cleaned Container (f) Samples in Temporary Container

Energy and Efficiency Calibration

Standard point sources of ^{241}Am (59.54 keV), ^{60}Co (1173.24 and 1332.49 keV) and ^{137}Cs (661.66 keV) IAEA were used for energy calibration of the gamma spectroscopy system. The gamma emitting sources were exposed to the NaI(Tl) detector and gamma spectrum was acquired for 1000 seconds. The channel numbers versus the gamma energies were plotted to give a linear curve. This calibration is stored in the memory of the multichannel analyzer throughout the experiment

Furthermore, the efficiency calibration of the detector was determined by using a 650g mixed CANBERRA soil standard containing ^{125}Sb, ^{155}Eu, ^{54}Mn, ^{65}Zn and ^{40}K in Marinelli beaker in the energy range of 35.5keV to 1460.8 keV. The standard reference sample and the experimental samples' containers were geometrically identical. The detection's absolute efficiency was determined for each of the gamma energies under consideration by using the equation 1.0.

$$\varepsilon = \frac{NC_i}{A_i \times y_i \times M \times T} \quad (1.0)$$

Here, ε =efficiency of the NaI(Tl) at the energy of the i^{th} radionuclide

NC_i= net counts of the i^{th} radionuclide (background subtracted) in the corresponding photopeak

A_i is the activity concentration of the i^{th} radionuclide in Bq/kg

y_i= the emission probability of the i^{th} radionuclide

M=Mass of the soil sample in kg

T= counting time (18000 seconds).

Figure 4, presents the Picture of the Gamma Spectroscopic Facility at NIRPR, UI, Ibadan and the screenshot of the Energy Calibration curve from the Canberra NaI(Tl) detector used for the study.

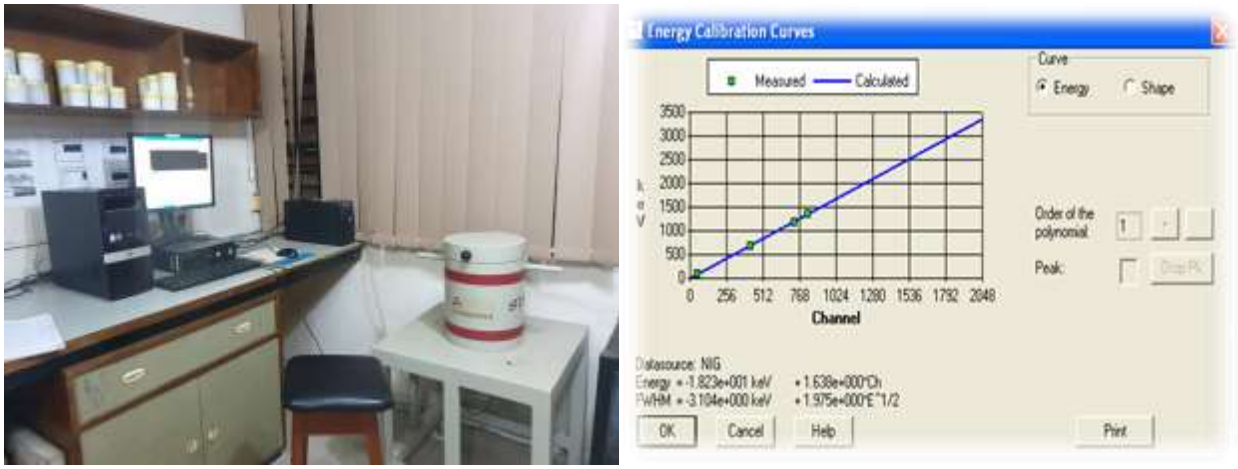

Figure 4: (a) Picture of the NIPRP NaI(Tl) Gamma Spectrometry Unit (b) Energy Calibration curve obtained for this Study

RESULTS AND DISCUSSION

In-Situ Measurement

Results obtained during the in-situ measurements are presented in Table 2. Here I_1, I_2, I_3, I_4, and I_5 in Counts Per Minute (CPM) are the results from the five different points on the dumpsite as obtained using the

4EC Radiation Alert Monitor while I_{mean} is the average value of I_1 to I_5.

Table 2: Results of In Situ Measurements in CPM

S/N	DUMPSITES	Ionizing Radiation Level in Counts per Minute (CPM)					
		I_1	**I_2**	**I_3**	**I_4**	**I_5**	**I_{mean}**
1	**GSS KAWO**	60	80	80	80	40	68
2	**MANDO HIGH TENSION**	40	40	20	60	60	44
3	**ABAKPA RAIL**	40	40	40	40	20	36
4	**UNGWAN SHANU**	80	40	20	80	60	56
5	**SMC**	40	60	40	80	20	48
6	**LEA BADARAWA**	20	40	100	80	80	64
7	**SABO UNDER BRIDGE**	60	80	40	60	80	64
8	**NARAYI MARKET**	20	10	10	20	40	20
9	**BAYAN DUTSE**	60	20	20	40	80	44
10	**UNGWAN BORO**	40	40	60	40	60	48
11	**UNGWANGIMBIYA**	40	60	60	60	20	48
12	**FEDERAL HOUSING GONIN-GORA**	120	200	80	80	100	116
13	**DOMINION STREET, NEW YAKOWA ROAD**	80	40	20	80	40	52
14	**TELEVISION MARKET**	60	80	20	40	40	32
15	**LEA ZANGO, TUDUN WADA**	40	40	20	20	40	32
16	**UNGWAN SUNDAY**	40	60	80	100	60	68
17	**UNGWAN SULE, ROMI**	60	100	60	40	100	72
18	**CONTROL SITE**	80	80	60	40	80	68
	WORLD MEAN						120

While the length of time of expsoure is an important factor, the CPM reading of up to 100 is considered a warning level by the Radiation Network. It would take 432 days at a CPM of 100 for there to be a 1% chance of cancer from radaition in a location (Ulakpa & Eyankware, 2016). From the preliminary results above, all the sample sites except that of Federal Housing, Gonin-Gora, have a mean CPM below 100. Hence, the investigated zones can be considered to have normal levels of natural background radiation. According to the Radiation Network recommendations, the radiation level of 116 CPM, which is slightly higher than the alert level, of 100 CPM, implies that after a total of 501days and 12hours (≈ 1year and three months), the probability of getting cancer by 1 person (e.g a scavenger) out of a 100 who spends at least an hour on this dumpsite is ≤ 1.

Gamma Spectroscopic Measurement

The results obtained from gamma spectroscopic measurement showed different activity concentrations of the radionuclides in counts per seconds. The Activity

Concentration *(A)* of ^{238}U, ^{232}Th and ^{40}K in $Bqkg^{-1}$ was obtained using the relation:

Sample Activity *(A)* in $Bqkg^{-1}$ =

$$\frac{NC_i}{\varepsilon \, X \, y_i \, X \, T \, X \, M} \qquad (2.0)$$

Here, NC_i = The net peak area after subtraction of background of the gamma ray line at energy, E.

$\boldsymbol{\varepsilon}$ = Detector efficiency of gamma ray line at photopeak energy, E.

$\mathbf{y_i}$ = The emission probability of the gamma ray photons of energy, E under consideration.

T = Time of measurement in seconds.

M = Mass of sample in g.

Results of Activity concentration obtained are shown in Table 3

Table 3: Activity Concentrations of Radionuclides for each Dumpsite

S/N	SAMPLE	U-238 (Bq/Kg)	Th-232 (Bq/Kg)	K-40 (Bq/Kg)
1	**GSS KAWO**	129.62±21.06	27.13±2.08	546.43±35.84
2	**MANDO HIGH TENSION**	51.58±10.18	22.33±1.71	241.81±18.32
3	**ABAKPA RAIL**	62.12±8.07	13.87±0.90	348.75±19.22
4	**UNGWAN SHANU**	36.24±9.40	11.11±1.20	225.54±17.38
5	**SMC**	149.41±22.72	24.81±1.91	194.70±15.39
6	**LEA BADARAWA**	127.62±18.28	10.01±1.12	274.07±21.56
7	**SABO UNDER BRIDGE**	72.04±14.77	12.27±1.19	372.56±25.73
8	**NARAYI MARKET**	116.95±19.83	6.58±0.70	360.00±24.52
9	**BAYAN DUTSE**	13.30±2.78	21.58±1.36	507.94±27.34
10	**UNGWAN BORO**	60.48±12.05	12.15±1.11	52.82±4.58
11	**UNGWAN GIMBIYA**	40.47±11.97	17.79±1.50	52.53±4.51
12	**FEDERAL HOUSING**	49.36±10.54	18.77±1.56	395.12±28.60
13	**DOMINION STREET**	123.84±22.64	81.36±5.23	832.77±53.36
14	**TELEVISION MARKET**	135.18±20.47	24.29±1.91	211.83±16.10
15	**LEA ZANGO, TUDUN WADA**	60.70±12.64	13.80±1.27	206.12±15.45
16	**UNGWAN SUNDAY**	66.04±13.07	7.37±0.74	107.91±8.94
17	**UNGWAN SULE, ROMI**	23.57±7.65	14.69±1.37	238.67±18.08
18	**CONTROL SITE**	99.83±12.27	54.03±3.26	778.13±41.83
	MEAN	78.80 ± 13.91	21.89±1.67	330.43±22.04
	WORLD MEAN	35.00	30.00	400.00

Table 3 presents the *A* of Naturally Occurring Radioactive Elements (NORMs) ^{238}U, ^{232}Th and ^{40}K in the soil samples which ranged from $13.30 \pm 2.78 \geq A_{[238U]} \leq 149.41 \pm 22.72$ $Bqkg^{-1}$; $6.58 \pm 0.70 \geq A_{[232Th]} \leq 81.36 \pm 5.23$ $Bqkg^{-1}$; and $52.53 \pm 4.51 \geq A_{[40K]} \leq 832.77 \pm 53.36$ $Bqkg^{-1}$ respectively. The average values are 78.80 ± 13.91 $Bqkg^{-1}$, 21.89 ± 1.67 $Bqkg^{-1}$, and 330.43 ± 22.04 $Bqkg^{-1}$ for ^{238}U, ^{232}Th and ^{40}K respectively. In comparison

with worldwide average, average *A* of ^{238}U is higher than the global average of 35 $Bqkg^{-1}$, while that of ^{232}Th and ^{40}K are less than the worldwide average value of 30 and 400 $Bqkg^{-1}$ respectively (UNSCEAR,2000). However, it should be noted that the *A* for ^{238}U is higher than the world average value in sixteen of the samples including the control site; it is higher than the world average in only 2 of the sites including the control site for ^{232}Th and in only 3 of the sites including the control site for ^{40}K.

For this study, the results obtained for the *A* of the different primordial radionuclides showed that $^{232}Th<^{238}U<^{40}K$ in all the sampling sites including the control site. The wide variation in the activity concentrations is a measure of the spatial distribution of the radionuclides within the sites and indicates the influence of physical and geo-chemical processes on the accumulation of radionuclides in the soil within the dumpsites (Isinkaye & Emelue, 2015).

The high *A* of ^{238}U in most of the samples in the present study may be traceable to the solubility and mobility of Uranyl (U(VI)O2+2) (UNSCEAR, 2000); and that of ^{40}K due to the high content of monazite (Orgun et al, 2007) since the presence of mineral monazite which contains radioactive elements results in higher natural radioactivity (Singh, Shanker, Neelakandan & Singh 2007). Also, the high *A* in the control sample may be as result of use of fertilizer in the location over time.

Determination of Radiation Hazard Parameters

To estimate the radiation hazards due to the activity levels of the measured samples in the selected dumpsites within Kaduna metropolis, some radiation hazard indices have been calculated. These hazards include Excess Lifetime Cancer Risk (ELCR), γ-Ray Absorbed Dose Rate (DR), Outdoor, Indoor and Total Annual Effective Dose Equivalent ($AEDE_{out}$, $AEDE_{in}$ and $AEDE_T$), Annual Gonadal Dose Equivalent (AGDE), Radium Equivalent (Ra_{eq}), Activity Utilization index (AUI), Exposure Rate (ER), Internal and External Hazard Indices (H_{int} and H_{ext}) and External (γ-radioactivity) Level Index ($I_{\gamma r}$).

It should be noted that, even though the total AC of radionuclides is calculated, it does not provide exact indication of the total radiation hazards because of the unevenness of the distribution of the NORMs (^{238}U, ^{232}Th and ^{40}K,) in the soil sample from the dumpsites. For all the calculated radiological parameters, mean values within the limit of

Standard Deviation uncertainties have been presented in Table 4a and 4b respectively with world averages by UNSCEAR (2000) given.

Absorbed dose rate (D_R):

From Equation 3.0, the calculated DR is presented in Table 4a.

$$D_R = 0.462AC_U + 0.604AC_{Th} + 0.0417AC_K \quad (3.0)$$

Calculated values vary from 29.71 ± 5.12 - 141.08 ± 15.84 nGyhr^{-1}. From the present study, five out of the eighteen sites have the calculated D_R higher than the recommended limits of 84 nGyhr^{-1} (UNSCEAR, 2000). The seven sites include GSS Kawo with 99.10 ± 12.48 nGyhr^{-1}; SMC with 92.13 ± 12.29 nGyhr^{-1}; Dominion street, New Yakowa Road with 141.08 ± 15.84 nGyhr^{-1}; Television market with 85.96 ± 11.28 nGyhr^{-1} and the Control site with 111.20 ± 9.38 nGyhr^{-1}

The contribution of natural radionuclides to the absorbed dose rates depends on the concentrations of various radionuclides in the sediment (Erenturk et al, 2014)

Radium Equivalent (Ra_{eq})

Using the Equation 4.0, the Radium Equivalent was obtained as presented in Table 4a:

$$Ra_{eq} = A_U + 1.43A_{Th} + 0.077A_K \quad (4.0)$$

The calculated values of Ra_{eq} ranged from 62.95 ± 11.00 - 237.01 ± 20.15Bqkg^{-1}. Hence, all the sites have Ra_{eq} values lower than the safety limit of 370 Bqkg^{-1} set for this index. Therefore, from the point of view of radiological protection, the soils from these sites are safe for use as building materials.

External and Internal Hazard Index (H_{ext} and H_{int})

Equation 5.0 and 6.0 were used in calculating the values of H_{ext} and H_{int} presented in Table 4a.

$$H_{ext} = \left(\frac{A_U}{370Bq/Kg} + \frac{A_{Th}}{259Bq/Kg} + \frac{A_K}{4810Bq/Kg}\right) \leq 1 \quad (5.0)$$

$$H_{int} = \left(\frac{A_U}{\frac{185Bq}{Kg}} + \frac{A_{Th}}{\frac{259Bq}{Kg}} + \frac{A_K}{4810Bq/Kg}\right) \leq 1 \quad (6.0)$$

Values obtained were between 0.17 ± 0.02 - 0.82 ± 0.06 for H_{ex} and 0.26 ± 0.03 - 1.16 ± 0.15 for H_{int}. The H_{ext} shows that all the sites had values lower than the recommended value of 1. As such, there is no radiological risk whatsoever from external exposure of the inhabitant or people working/living in buildings constructed with soil samples from these sites. However, the value of H_{int} exceeded the recommended permissible value in one of the sampling points i.e., Dominion Street, New Yakowa Road. Therefore, it can be concluded that while

soils from this location poses potential internal radiological risk when used as building materials with the risk of stochastic effect increasing marginally, it is not generally the case for soil samples from dumpsites (Michnev, 2000; Michalis et al., 2001; Kplangat, 2006; Mandic & Dragovic, 2010; Ramsamy et al., 2013; Raviankar et al., 2014, Mohammed et al., 2014; Jabar et al., 2010; Jegede et al., 2019;).

Table 4a: Means Results for DR, R_{aeq}, H_{ext}, H_{int}, $AEDE_{out}$ and $AEDE_{in}$

S/N	DUMPSITE	D_R	Ra_{eq}	H_{ext}	H_{int}	$AEDE_{out}$	$AEDE_{in}$
1	**GSS KAWO**	99.10 ±12.48	210.49 ±26.79	0.57 ±0.07	0.92 ±0.13	121.62 ±15.32	486.48 ±61.26
2	**MANDO HIGH TENSION**	47.40 ±6.50	102.13 ±14.04	0.28 ±0.04	0.42 ±0.07	58.17 ±7.98	232.68 ±31.91
3	**ABAKPA RAIL**	51.62 ±5.07	108.81 ±10.84	0.29 ±0.03	0.46 ±0.05	63.35 ±6.22	253.40 ±24.89
4	**UNGWAN SHANU**	32.86 ±5.79	69.49 ±12.45	0.19 ±0.03	0.29 ±0.06	40.33 ±7.11	161.31 ±28.42
5	**SMC**	92.13 ±12.29	199.88 ±26.64	0.54 ±0.03	0.94 ±0.13	113.07 ±15.08	452.26 ±60.33
6	**LEA BADARAWA**	76.44 ±10.02	163.04 ±21.54	0.44 ±0.06	0.79 ±0.11	93.81 ±12.30	375.24 ±49.19
7	**SABO UNDER BRIDGE**	56.23 ±8.62	118.27 ±18.45	0.32 ±0.05	0.51 ±0.09	69.00 ±10.58	276.03 ±42.32
8	**NARAYI MARKET**	73.02 ±10.61	154.08 ±22.72	0.42 ±0.04	0.73 ±0.11	89.61 ±13.02	358.45 ±52.08
9	**BAYAN DUTSE**	40.36 ±3.25	83.27 ±6.83	0.22 ±0.02	0.26 ±0.03	49.53 ±3.99	198.13 ±15.95
10	**UNGWAN BORO**	37.48 ±6.43	81.92 ±13.99	0.22 ±0.04	0.38 ±0.07	45.99 ±7.89	183.99 ±31.56
11	**UNGWAN GIMBIYA**	31.63 ±6.62	69.95 ±14.46	0.19 ±0.04	0.30 ±0.07	38.82 ±8.12	155.27 ±32.49
12	**FEDERAL HOUSING**	50.62 ±7.00	106.63 ±14.97	0.29 ±0.04	0.42 ±0.07	62.12 ±8.59	248.49 ±34.36
13	**DOMINION STREET**	141.08 ±15.84	304.31 ±34.23	0.82 ±0.06	1.16 ±0.15	173.14 ±19.44	692.56 ±77.76
14	**TELEVISION MARKET**	85.96 ±11.28	186.23 ±24.44	0.50 ±0.07	0.87 ±0.12	105.49 ±13.84	421.97 ±55.37
15	**LEA ZANGO**	44.97 ±7.25	96.31 ±15.65	0.26 ±0.04	0.42 ±0.08	55.19 ±8.90	220.76 ±35.59
16	**UNGWAN SUNDAY**	39.46 ±6.86	84.89 ±14.82	0.23 ±0.04	0.41 ±0.08	48.43 ±8.42	193.71 ±33.68
17	**UNGWAN SULE, ROMI**	29.71 ±5.12	62.95 ±11.00	0.17 ±0.09	0.23 ±0.05	36.46 ±6.28	145.85 ±25.13
18	**CONTROL SITE**	111.20 ±9.38	237.01 ±20.15	0.64 ±0.05	0.91 ±0.09	136.47 ±11.51	545.88 ±46.05
	MEAN	63.40 ± 8.36	135.54 ±18.00	0.37 ±0.05	0.58 ±0.09	77.81 ±10.26	311.25 ±41.02
	WORLD MEAN	84	370	≤ 1	≤ 1	70	420

Outdoor, Indoor and Total Annual Effective Dose Equivalent ($AEDE_{out}$, $AEDE_{in}$ and $AEDE_T$,)

From Equations 7.0, 8.0 and 9.0, the Outdoor, Indoor and Total Annual Effective Dose Equivalence were determined and presented in Tables 4a and 4b.

$$AEDE_{out} = D_R \times 24h \times 365.25d \times 0.2 \times 0.7Sv/Gy \times 10^{-3} \quad (7.0)$$

$$AEDE_{inr} = D_R \times 24h \times 365.25d \times 0.8 \times 0.7Sv/Gy \times 10^{-3} \quad (8.0)$$

$$AEDE_T = AEDE_{out} + AEDE_{in} \quad (9.0)$$

The calculated values for $AEDE_{out}$, $AEDE_{in}$ and $AEDE_T$ ranged from 36.46 ± 6.28 - 173.14 ± 19.44 μSv yr^{-1}; 145.85 ± 25.13 - 692.56 ± 77.76 μSvyr^{-1}; and 182.31 ± 31.42 - 865.70 ± 97.20 μSv yr^{-1} respectively; comparable with world average value of 70 μSvyr^{-1}; 420 μSvyr^{-1}; and 500 μSvyr^{-1} respectively (UNSCEAR, 2000).

Outdoor values above recommended levels were obtained for 7 sites including Dominion Street, New Yakowa Road with 696.56.14 ± 19.44 μSvyr^{-1}; GSS Kawo with 121.62 ± 15.32 μSvyr^{-1}; Narayi Market with 89.61 ± 13.02 μSvyr^{-1}; LEA Badarawa with 93.81 ± 12.30 μSvyr^{-1}; SMC with 113.07 ± 15.08 μSvyr^{-1}; Television Market with 105.49 ± 13.84 μSvyr^{-1}; and the Control site with 136.47 ± 11.51 μSvyr^{-1}. For the $AEDE_{in}$ (Table 4a) and $AEDE_T$ (Table 4b), values above world average were noted for four sites namely; Dominion Street, New Yakowa Road with 692.56 ± 77.67 μSvyr^{-1} for $AEDE_{in}$ and 865.70 ± 97.20 μSvyr^{-1} for $AEDE_T$; GSS Kawo with 486.48 ± 61.26 μSvyr^{-1} for $AEDE_{in}$ and 608.09 ± 76.58 μSvyr^{-1} for $AEDE_T$; SMC with 452.26 ± 60.33 μSvyr^{-1} for $AEDE_{in}$ and 565.33 ± 75.41 μSvyr^{-1} for $AEDE_T$; Television Market with 421.97 ± 55.37 μSvyr^{-1} for $AEDE_{in}$ and 527.47 ± 69.22 μSvyr^{-1} for $AEDE_T$; and Control site with 545.88 ± 46.05 μSvyr^{-1} for $AEDE_{in}$ and 682.35 ± 57.60 μSvyr^{-1} for $AEDE_T$. The high values from these sites can be linked to the elevated level of measured *A* of radionuclide distribution in the locations which may be based on nature of waste or the geophysical features of the location (Gbadamosi et al, 2017, Otabi et al., 2006)).

Furthermore, Equation (10.0) was used to evaluate the AGDE as reported in Table 5.

$$AGDE = 3.09A_U + 4.18A_{Th} + 0.314A_K \quad (10.0)$$

Annual Gonadal Dose Equivalent (AGDE)

The AGDE evaluates the degree of genetic implication of the annual gamma ray doses absorbed by the rapidly dividing cells existing in some sensitive organs in the body, such as the active bone marrow, lungs, female breast, gonads, and the bone surface.

Table 4b: Mean Result for $AEDE_T$, AGDE, I_{Yr}, AUI, ER and ELCR

S/N	DUMPSITE	$AEDE_T$	AGDE	GLI	AUI	ER	ELCR x 10^{-3}
1	GSS KAWO	608.09 ±76.58	685.51 ±85.02	0.75 ±0.09	1.57 ±0.22	420.59 ±52.29	0.43 ±0.05
2	MANDO HIGH TENSION	290.86 ±39.89	328.65 ±44.36	0.36 ±0.05	0.77 ±0.12	204.26 ±27.44	0.20 ±0.03
3	ABAKPA RAIL	316.75 ±31.11	359.43 ±34.73	0.39 ±0.04	0.77 ±0.09	219.57 ±21.31	0.22 ±0.02
4	UNGWAN SHANU	201.64 ±35.53	229.24 ±39.52	0.25 ±0.04	0.49 ±0.10	140.56 ±24.36	0.14 ±0.03
5	SMC	565.33 ±75.41	626.52 ±83.02	0.69 ±0.09	1.70 ±0.23	388.69 ±51.31	0.40 ±0.05
6	LEA BADARAWA	469.05 ±61.48	522.25 ±67.94	0.57 ±0.07	1.32 ±0.18	319.76 ±41.75	0.33 ±0.04
7	SABO UNDER BRIDGE	345.04 ±52.89	390.88 ±58.69	0.43 ±0.06	0.84 ±0.15	238.17 ±36.02	0.24 ±0.04
8	NARAYI MARKET	448.07 ±65.11	501.92 ±71.90	0.54 ±0.08	1.19 ±0.19	305.20 ±44.04	0.31 ±0.05
9	BAYAN DUTSE	247.66 ±19.94	290.79 ±22.86	0.32 ±0.03	0.43 ±0.04	177.05 ±14.01	0.17 ±0.01
10	UNGWAN BORO	229.98 ±39.46	254.26 ±43.31	0.28 ±0.05	0.71 ±0.13	158.63 ±26.85	0.16 ±0.03
11	UNGWAN GIMBIYA	194.10 ±40.62	215.91 ±44.67	0.24 ±0.05	0.59 ±0.13	136.46 ±27.78	0.14 ±0.03
12	FEDERAL HOUSING	310.61 ±42.95	355.05 ±48.07	0.39 ±0.05	0.72 ±0.12	217.44 ±29.54	0.22 ±0.03
13	DOMINION STREET	865.70 ±97.20	984.24 ±108.57	1.09 ±0.12	2.20 ±0.28	613.80 ±67.32	0.61 ±0.07
14	TELEVISION MARKET	527.47 ±69.22	585.75 ±76.29	0.64 ±0.08	1.56 ±0.21	363.26 ±47.16	0.37 ±0.05
15	LEA ZANGO	275.94 ±44.49	309.97 ±49.22	0.34 ±0.05	0.74 ±0.13	191.14 ±30.36	0.19 ±0.03
16	UNGWAN SUNDAY	242.13 ±42.09	268.75 ±46.29	0.29 ±0.05	0.71 ±0.13	165.58 ±28.52	0.17 ±0.03
17	UNGWAN SULE, ROMI	182.31 ±31.42	209.18 ±35.04	0.23 ±0.04	0.42 ±0.09	128.93 ±21.63	0.13 ±0.02
18	CONTROL SITE	682.35 ±57.60	778.65 ±64.68	0.86 ±0.07	1.64 ±0.16	481.33 ±39.99	0.48 ±0.04
	MEAN		438.72 ±56.90	0.48 ±0.06	1.02 ±0.15	270.58 ±35.09	0.27 ±0.04
	WORLD MEAN	500	300	≤ 1	≤ 2	600	0.29

The results ranged from 209.18 ± 35.04 - 984.24 ± 108.57 μSvyr^{-1} (Table 4b). A total of 12 out of the 18 investigated dumpsites had values higher than the world average of 300 μSvyr^{-1}(UNSCEAR, 2000). These sites include GSS Kawo with 685.51 ± 85.02 μSvyr^{-1}; Mando High Tension 328.65 ± 44.36 μSvyr^{-1}; Abakpa Rail with 359.43 ± 34.73 μSvyr^{-1}; SMC with 626.52 ± 83.02 μSvyr^{-1}; LEA Badarawa with 522.25 ± 67.94 μSvyr^{-1}; Sabo under bridge with 390.88 ± 58.69 μSvyr^{-1}; Narayi market with 501.92 ± 71.90 μSvyr^{-1}; Federal housing Gonin-Gora with 355.05 ± 48.07 μSvyr^{-1}; Dominion Street, New Yakowa Road with 984.24 ± 108.57 μSvyr^{-1}; Television Market with 585.75 ± 76.29 μSvyr^{-1}; LEA Zango, Tudun Wada with 309.97 ± 49.22 μSvyr^{-1}; and the Control

site with 778.65 ± 64.68 μSvyr^{-1}. From this, it can be deduced that the genetic implication of radiation hazards for dumpsite is not negligible.

Gamma Level Index (Iγr)

Also, Equation 11.0 was used in calculating the Iγr reported in Table 5.

$$I\gamma r = \left(\frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000}\right) \leq 1 \qquad (11.0)$$

The values obtained for the gamma level index ranged from 0.23 ± 0.04 - 1.09 ± 0.12. Only one of the sites, namely Dominion Street, New Yakowa Road with 1.09 ± 0.12 Iγr, had value greater than unity, indicating that, apart from this single site, soil from dumpsite may not generally be considered hazardous for occupants with respect to emission of excess gamma radiation when used as material for buildings.

Activity Utilization Index (AUI)

Equation 12.0 was further used to calculate the AUI for the 18 samples as reported in Table 4b.

$$AUI = \left(\frac{A_U}{50Bq/Kg}\right) f_U + \left(\frac{A_{Th}}{50Bq/Kg}\right) f_{Th} + \left(\frac{A_K}{500Bq/Kg}\right) f_K \leq 2 \qquad (12.0)$$

The calculated values for AUI, which finds application in determining the usability for building construction ranged from 0.42 ± 0.09 - 2.20 ± 0.28 and are lower than the benchmark maximum of 2 (UNSCEAR, 2000) in all sites except for the Dominion Street, New Yakowa, Road sample, with the value of 2.20 ± 0.28. The average relative contribution of the γ-index is due to higher ^{40}K followed by the contributions due to ^{238}U and ^{232}Th.

Exposure rate (ER)

The ER, a hazard parameter measured in μRhr^{-1}, quantifying the amount of ionizing radiation a person is exposed to in a vicinity per hour, was calculated using equation 13.0 and reported in Table 4b.

$$ER = 1.90A_U + 2.82A_{Th} + 0.179A_K \qquad (13.0)$$

The calculated value for the rate of exposure (ER) of individuals and scavengers to these radionuclides in the selected soil samples ranged from 128.93 ± 21.63 - 613.80 ± 67.32 μRhr^{-1} and is generally below the standard limit of 600 μRhr^{-1} (UNSCEAR, 2000) except for the sample from Dominion Street, New Yakowa Road where an ER value of 613.80 ± 67.32 μRhr^{-1}. It thus implies that, apart from this single site, human exposure to ionizing radiation from dumpsites is generally insignificant to about 97%. It should be noted that for this single site with value above recommended limit, exposure to radiation may be harmful over a period of time.

Excess lifetime cancer risk (ELCR)

Equation 14.0 has been used to calculate the ELCR, which is the risk of death of cancer in excess of the natural background risk, resulting from a lifetime exposure to carcinogens. For the 18 sites, results are reported in Table 4b

ELCR = $AEDE_{outdoor} \times DL \times RF$ (14.0)

The calculated values ranged from 0.13 ± 0.02 - 0.61 ± 0.07 (Table 4b) and is noted to be above recommended limit of 0.29 (UNSCEAR, 2000) for seven (7) of the sites making up 39% of the sampled sites. The sites with ELCR values higher than the recommended limits include Dominion Street, New Yakowa Road with 0.61 ± 0.07; Narayi market with 0.31 ± 0.05; LEA Badarawa with 0.33 ± 0.04; SMC with 0.40 ± 0.05; GSS Kawo with 0.43 ± 0.05; Television market with 0.37 ± 0.05 and the Control site with 0.48 ± 0.04. The results show that the lifetime cancer risk due to exposure for a maximum duration of 70 years is significant in 39% of the locations within Kaduna metropolis. Hence, use of dumpsite soil samples for prolonged application should be discouraged.

CONCLUSION

The study was carried out to investigate the impact of radioactivity from primordial radionuclide on the environment and health of persons within the vicinity of dumpsites located within Kaduna metropolis. In-situ measurement was carried out using 4EC handheld Radiation Alert Meter to identify locations on the identified dumpsites with elevated ionizing radiation levels. Gamma Spectrometry study was further carried out on soil samples collected from eighteen (18) dumpsites located within the metropolis and including three of the metropolitan Local Government Areas. From the study, the Average Activity Concentration *(A)* showed that $^{232}Th < ^{238}U < ^{40}K$ in all the sampling sites including the control site; was found to be higher than the world average for ^{238}U; and revealed significant variation across the sites as a result of the spatial distribution of the radionuclides within the sites which is due to the influence of physical and geo-chemical processes on radionuclide accumulation in soil. The control site, used for comparative analysis, was found to have high Activity Concentration *(A)* for all radionuclides, probably due to extensive use of fertilizers and chemicals during the farming seasons. Furthermore, the obtained values were used to estimate health and environmental hazard parameters using standard formalisms as proposed by the most recent UNSCEAR report. The values, obtained for these parameters in comparisons with recommended limits revealed that, apart from

specific sites of heightened levels of radioactivity and hazard indices, there is no generally significant hazard to health and environment from radioactivity from dumpsites in Kaduna metropolis.

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