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ORIGINAL RESEARCH

Natural Radionuclide Concentrations and Associated Doses Around Three Dumpsites in Lagos, Nigeria.

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Introduction: Monitoring of dose from environmental radionuclides helps to ascertain healthy vicinity which is a catalyst to the economic development of the area.
Aims: The research was put in place to establish the activity concentration of naturally occurring radionuclides in three (3) dumpsites in Lagos State, Ilupeju, Gbagada, and Olusosun Landfill, Ojota, Nigeria and to obtain the level of radioactive exposure hazards experienced by people living in these vicinities.
Materials and Methods: A total of thirty soil (30) samples were randomly collected into a polythene bag. They were oven-dried at 110°C, pulverized, and sieved. Quantities of the samples (400 g) were sealed in cylindrical sample holders and kept for about 28 days to attain secular equilibrium between 226Ra and its decay products before analysis using gamma-ray spectrometry.
Results: The mean activity concentration obtained for 40K, 226Ra, and 234Th at, Ilupeju, Gbagada, and Ojota were 339.23±33.66, 11.83±19.174, 11.95±22.752 Bq/kg, 337.56 ± 36.22, 11.49±22.14, 11.54 ± 19.33 Bq/kg and 334.87±32.44, 11.42±22.39, 11.56±18.52 Bq/kg respectively. The mean absorbed dose nGy/h, annual effective dose mSv/y were calculated and their results were found to be below the global values.
Conclusion: The results indicate that the radiation level within the dumpsites poses no significant health risk to the people living close to the dumpsites.
Keywords: Concentration, Radionuclides, Radiation, Detector, Hazard

All co-authors agreed to have their names listed as authors.

1. INTRODUCTION

Human beings are exposed to radiation mainly from cosmic rays which are from the atmosphere or outer space and the gamma-ray emitters in soils, building materials, water, food, and air. Investigation concerning the level of radionuclide distribution in the environment provides essential radiological information [1]. Human beings are primarily exposed to ionizing radiations emitted from naturally occurring radioactive materials found in the earth's crust as well as from man-made sources [2]. Dose above the global average effective of 2.4 mSv/yr [3] might create a problem for the people living within the vicinity of the dumpsite. The radioactivity concentration in the soil gives information on both natural and man-made sources which is important in radiological monitoring and assessment of radiation dose for the public [4].

Wastes as man-made, are unwanted or abandoned materials that are discarded after use and are discharged into the dumpsites but the way they are disposed of and handled can have a dangerous impact on the environment especially when the wastes containing hazardous material are not properly managed. Avwiri *et al*[3] are correct when they said the disposal of wastes without adequate management particularly the radioactive contaminants can expose the populace to radiation hazards [5]. Sources of the materials at the dumpsite may be municipal wastes, healthcare waste, and so on.

The leachate produced from the decomposition of the waste can generate radioactive pollutants that enter rivers, lakes, seas, and oceans when absorbed by aqueous plants and animals both directly from the water and the preceding link in the food chain. The resultant pollution contaminates all living organisms within the body of water and ultimately the people who depend on the fish for their main source of protein and their economic livelihood. Also, the photosynthetic and fruiting ability of the trees around are impaired with a consequent decrease in production. Communities living near dumpsites, including scavengers, may suffer health problems arising from these unpleasant scenarios.

Open burning is one of the methods employed to reduce the hipping of wastes. But the method brings about air pollution which can contribute to the greenhouse effect, degrading the ozone layer [6] and release foul odourto the vicinity as in the case of the Ojota dumpsite in Lagos. Also, the smoke commonly contains carbon monoxide and other contaminants like heavy metals gases which are hazardous to human health.

Therefore, great interest has been expressed worldwide for the study of naturally occurring radiation sources as well as environmental radioactivity; this has resulted in extensive surveys in many countries [7]. In Nigeria, Lagos State to be precise has a good number of dumpsites in areas such as Gbagada, Ilupeju, and Olusosun, and so on.

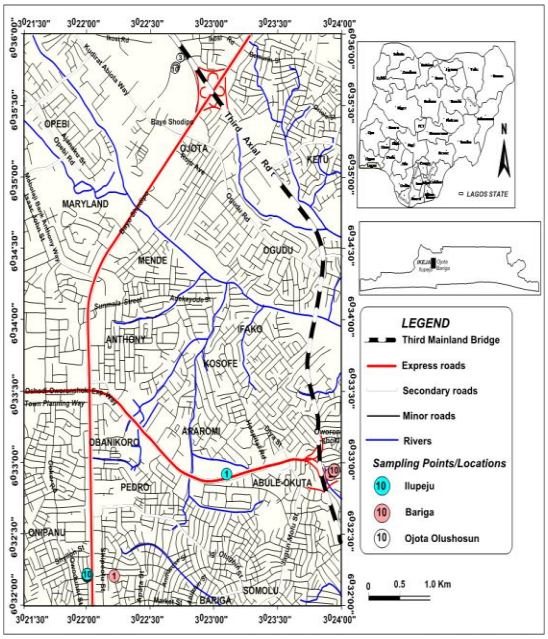
A very little data of radiological impacts on the people and environment around the abandoned dumpsite in Lagos, Nigeria is available. Therefore the concept of this research work is to conduct a thorough study on the radiological implications of the abandoned dumpsites on the public and surrounding environment and to analyze the activity concentrations of radionuclides and estimating the doses in soil samples collected from the abandoned sites. This type of measurement is of great importance as it will provide us with a clear picture of the radiation health hazards due to the possible presence of radionuclides in the abandoned dumpsites used as study areas.

2. MATERIAL AND METHODS

2.1. Study Area

Samples were collected from three (3) abandoned dumpsites in Lagos State which are Ilupeju, Gbagada, and Olusosun Landfill of Ojota area as depicted in Figure 2. Lagos is one of the largest urban areas located in southwest Nigeria with a good number of abandoned dumpsites. The geographical coordinates of study areas are (6°32' 54.0''N to 3°23' 5.97''E), (6°32'12.5''N to 3°22' 0.35" E), and (6° 35'49.44001" N to 3°22'43.50935" E), for Ilupeju, Gbagada, and Olusosun, Landfill respectively. Ilupeju is a local government area in Lagos State and shares boundaries with urbanized communities and Gbagada is located within two Local Governments (Kosofe and Shomolu), the Olusosun landfill is a 100 acres landscape generally believed to be the largest dumpsite in Africa and one of the largest in the world, it was once located on the outskirts of the populated area, however, Lagos has in recent years undergone such massive expansion that the site is now surrounded by commercial and residential areas.

Figure 1: Map of the study areas.



2.1.1.Sampling and Sample Preparations

One of the sites visited has proximity to the residential houses and the remaining two sites have been abandoned recently. Soil samples were picked randomly at varying depths of about 0cm to 10cm below the earth's surface from the dumpsites. Ten samples were collected and labelled from each site, making a total of thirty soil samples collected in a nylon bag and brought to the laboratory and dried in the oven at 110^{o}C for about 24 hours. The samples were then crushed into a fine powder mixed homogenously and passed through the sieve of 400 mm mesh size. The samples were then transferred into sealable cylindrical plastic containers. The sample-filled containers were marked individually with an identification number. The containers were sealed tightly with insulating tape and left for 28 days to maintain radioactive secular equilibrium between ^{226}Ra and its daughter products[8]. The sealed containers were later analysed using a Sodium iodide detector.

2.3.Detection Technique

2.3.1 Measurement of Radionuclide with Gamma-Ray Spectroscopy

All samples were analysed using a well-calibrated NaI (TI) and well-shielded detector coupled to a computer resident quantum MCA2100R Multichannel analyzer for 36,000 s. The background sample measurement by the detector was achieved by filling an empty thoroughly clean plastic container withdistilled water and counted at the same reasonable period as the sample and the peaks were resolved for the natural radionuclide.

The 1460 KeV gamma-radiation of ^{40}K was used to determine the concentration of ^{40}K in the sample. The gamma transition energy of 1764.5 KeV ^{214}Bi was used to determine the concentration of ^{238}U while the gamma transition energy of 2614 KeV,^{208}Ti was used to determine the concentration of ^{232}Th while ^{137}Cs was detected by its 661.6 KeV gamma energy. The efficiency calibration of the detector was done using a reference standard mixed source traceable to Analytical Quality Control Service (AQCS, USA), which has certified activities of the selected radionuclides and has a geometrical configuration identical to the sample container.

The activity concentrations of the samples were determined using the total net counts under the selected photopeaks, the measured photopeak efficiency, gamma intensity, and mass of the samples. After correcting for background and Compton contribution, the activity concentrations of ^{232}Th, ^{226}Ra, and ^{40}K weredetermined. Equation 1 gives the relationship between the activity concentration A_C and other parameters [9].

$$Ac = \frac{C_{net}}{I_\gamma x E_{ff}(E_\gamma) x\, m} \ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where C_{net} is the net peak counts. Iγ is the absolute gamma decay intensity for the specific energy photopeak (including the decay branching ratio information). E_{ff} (Eγ) is the absolute efficiency of the detector at this energy and m is the mass of the sample in kg.

RESULTS AND DISCUSSION

The photopeaks in each sample belonging to the natural radioactive decay series headed by ^{238}U and ^{232}Th and as well as the singly occurring natural radionuclide ^{40}K were identified. Although, other radionuclides if present appeared rather infrequently at low levels or occurred at levels below the minimum detectable limits (MDL). From the result, the average values for the activity concentration(Bq/kg) at Ilupeju,Gbagada,and Olusosun are 334.88±32.44, 337.56 ± 27.81, 339.24±33.67;11.42±22.93,11.50±23.38, 13±83±19.17;11.56±20.34,11.54±19.23, 11.95±22.75 for^{40}K ,^{226}Ra and ^{232}Th respectively. The mean values of the activity concentrations are lower than the mean values given by UNSCEAR 2000 (12)

Table 1**:** The activity concentration levels of natural radionuclides in soil samples collected fromthe three dumpsites.

Sample	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)
Spot 1 A	321.43 ± 32.00	12.23 ± 3.19	11.03 ± 2.10
Spot 1 B	331.18 ± 15.72	11.15 ± 3.11	10.01 ± 1.25
Spot 1 C	312.16 ± 10.01	13.19 ± 3.01	11.12 ± 2.08
Spot 2 A	320.09 ± 20.16	11.61 ±0 6.40	10.93 ±1 2.13
Spot 2 B	312.38 ± 45.07	13.03 ±14.95	10.75 ± 2.03
Spot 2 C	308.37 ± 30.10	11.35 ± 01.21	11.03 ± 3.24
Spot 3 A	361.22 ± 47.03	15.10 ± 13.57	12.02 ±01.38
Spot 3 B	321.14 ± 25.86	14.13 ± 40.20	10.39 ±1 2.40
Spot 3 C	381.43 ± 38.00	13.43 ±1 3.19	11.03 ± 22.10
Spot 4 A	298.18 ± 15.75	10.25 ± 13.09	12.08 ± 12.13
Spot 4 B	382.16 ± 30.01	11.19 ± 3.01	12.13 ± 2.08
Spot 4 C	330.09 ± 60.16	11.01 ± 6.40	10.93 ± 5.43
Spot 5 A	322.38 ± 45.07	12.03 ± 2.15	10.42 ± 02.10
Spot 5 B	308.37 ± 30.10	12.31 ± 1.21	12.03 ±10.24
Spot 5 C	405.22 ± 47.03	10.27 ± 3.57	16.22 ± 10.31
Spot 6 A	398.37 ± 30.10	10.37 ± 30.10	12.37 ± 30.10
Spot 6 B	375.22 ± 47.03	11.22 ± 47.03	14.22 ± 47.03
Spot 6 C	318.17 ± 30.10	11.10 ± 30.10	11.31 ± 30.10
Spot 7 A	345.22 ± 47.03	10.12 ± 47.03	12.12 ± 47.03
Spot 7 B	398.30 ± 30.10	10.37 ± 30.10	12.37 ± 30.10
Spot 7 C	341.22 ± 47.03	11.22 ± 47.03	13.12 ± 47.03
Spot 8 A	352.27 ± 30.10	11.07 ± 30.10	11.17 ± 30.10
Spot 8 B	321.22 ± 17.03	10.02 ± 47.03	10.22 ± 47.03
Spot 8 C	312.13 ± 30.10	12.30 ± 30.10	12.27 ± 30.10
Spot 9 A	301.22 ± 27.03	10.22 ± 47.03	11.12 ± 47.03
Spot 9 B	310.37 ± 10.10	11.37 ± 30.10	13.10 ± 30.10
Spot 9 C	315.22 ± 14.03	12.22 ± 47.03	10.12 ± 47.03
Spot 10 A	328.37 ± 30.10	11.19 ± 20.10	12.37 ± 11.10
Spot 10 B	315.22 ± 27.03	10.20 ± 17.03	10.22 ± 10.03
Spot 10 C	368.37 ± 30.10	12.17 ± 10.10	12.37 ± 30.10
Mean	337.22	11.58	11.68
World Average	400	35	30

3.1. CALCULATION OF DOSES

3.1.1. Absorbed Dose Rates: The absorbed gamma dose rates due to terrestrial (γ) - rays from the nuclides ^{226}Ra, ^{232}Th, and ^{40}K at 1m above the ground level was calculated using:

$D\ (nGyh^{-1}) = 0.0414\ P_k + 0.623\ P_{Th} + 0.416\ P_{Ra}$……. (2).

Where, P_k, P_{Th}, and P_{Ra} are the average activity concentration of the radionuclides in the samples[10].

3.1.2. Annual Effective Dose Rates

The absorbed dose rates were converted into annual effective dose rate equivalent by using a conversion factor of 0.7 $SvGy^{-1}$ recommended by the UNSCEAR (United Nations Scientific Committee of the effect of Atomic Radiation) and 0.4 for the outdoor occupancy factor by considering that the people on the average, spent 20% of their time outdoors. The effective dose due to natural radionuclide in the soil sample was calculated using equation 4 by [11],

$E = D\ (nGyh\text{-}1) \times 8760\ (hy\text{-}1) \times 0.4 \times 0.7\ Gy\text{-}1 \times 10^3$……. (3).

3.1.3. External Hazard Index (Hex)

The external hazard index (Hex) is the indoor radiation dose rate due to the external exposure to gamma radiation in construction material of dwelling which was calculated [5]

$$\mathbf{H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810}$$

…….(4).

Where, C_U, C_{Th}, and C_k are specific activities of ^{238}U, ^{232}Th, and ^{40}K in Bq/kg^{-1} respectively. This index value must be less than unity to the radiation hazards isinsignificant i.e., the area is safe to the human for living.

3.1.4. Gamma Index ($I\gamma$): Gamma index ($I\gamma$) proposed by the European Commission has been calculated from the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in soil samples using the following formula[12]:

$$I\gamma = \mathbf{A_{Ra}/150 + A_{Th}/100 + A_K/1500} \leq 1 \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where, A_U, A_{Th}, and A_K are the activity concentrations (Bq kg−1) of Uranium (^{238}U), thorium (^{232}Th), and potassium (^{40}K), respectively. Values of index $I\gamma \leq 2$ correspond to an absorbedgamma dose rate of 0.3 mSv/year, whereas $2 < \gamma \leq 6$ corresponds to an absorbed gamma dose rate of 1mSv/year and materials with $I\gamma > 6$ correspond to dose rates higher than 1 mSv/year, which is the highest dose rate value recommended for the population.

Table 2: Absorbed, Annual Effective Doses, External hazard index (H_{ex}), and the Gamma index (1γ) due to ^{40}K, ^{226} Ra, and^{232}Thin Ilupeju Landfill

Sample ID (A)	$D(nGyh^{-1})$	A.E.D. ($mSv\ yr^{-1}$)	H_{ex}	Iγ
Spot 1	25.82	0.32	0.13	0.19
Spot 2	93.72	0.12	0.13	0.18
Spot 3	29.4	0.36	0.15	0.23
Spot 4	24.61	0.31	0.12	1.08
Spot 5	25.39	0.31	0.13	1.16
Spot 6	29.75	0.36	0.15	0.22
Spot 7	26.51	0.33	0.13	0.2
Spot 8	26.64	0.33	0.13	0.19
Spot 9	24.11	0.29	0.12	0.18
Spot 10	26.46	0.32	0.13	0.19
Mean	33.24	0.3	0.12	0.38
World Average	55.5	0.7	≤ 1	≤ 1

Table 3: Absorbed, Annual Effective Doses, External hazard index (H_{ex}), and the Gamma index (1γ) due to ^{40}K, ^{226} Ra and ^{232}Th in Gbagada Dumpsite

Sample ID (B)	D(nGyh^{-1})	A.E.D. (mSv yr^{-1})	$\mathbf{H_{ex}}$ ($Bqkg^{-1}$)	$\mathbf{I_\gamma}$ ($Bqkg^{-1}$)
Spot 1	25.08	0.31	0.14	0.19
Spot 2	25.6	0.31	0.14	0.19
Spot 3	26.28	0.32	0.15	0.21
Spot 4	28.52	0.35	0.16	0.23
Spot 5	26.14	0.32	0.14	0.2
Spot 6	27.74	0.34	0.17	0.24
Spot 7	24.16	0.34	0.16	0.23
Spot 8	24.16	0.29	0.14	0.19
Spot 9	25.12	0.4	0.15	0.2
Spot 10	24.15	0.29	0.14	0.19
Mean	25.7	0.3	0.2	0.2

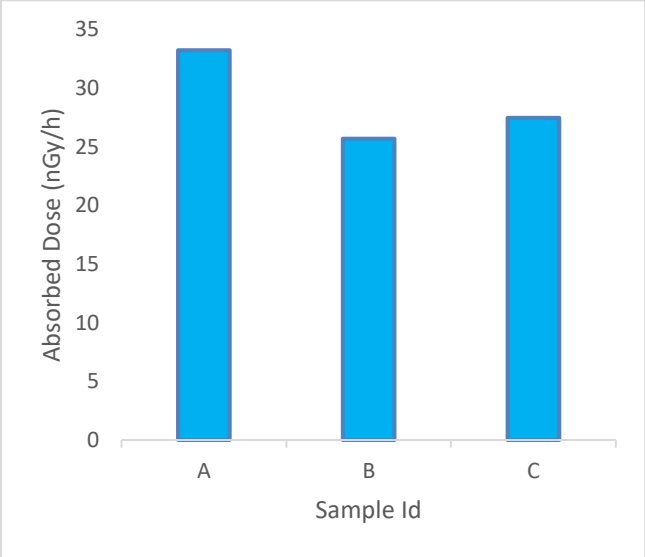


Figure 3: Gamma Absorbed dose rate (D) in the various study sites.

Table 4: Absorbed, Annual Effective Doses, External hazard index (H_{ex}), and the Gamma index (1γ) due to ^{40}K, ^{226} Ra,and^{232}Th in Ojota dumpsite

Sample ID (C)	D(nGyh^{-1})	A.E.D. (mSv yr^{-1})	H_{ex}	Iγ
Spot 1	26.42	0.32	0.14	0.2
Spot 2	25.36	0.31	0.13	0.19
Spot 3	29.4	0.36	0.16	0.23
Spot 4	26.09	0.31	0.15	0.2
Spot 5	32.52	0.32	0.17	0.25
Spot 6	25.88	0.39	0.13	0.21
Spot 7	27.57	0.31	0.15	0.22
Spot 8	26.82	0.33	0.14	0.2
Spot 9	25.45	0.31	0.14	0.2
Spot 10	29.23	0.35	0.16	0.22
Mean	33.24	0.3	0.15	0.2

The charts for the radiation parameter are presented in Figure 3 – 6

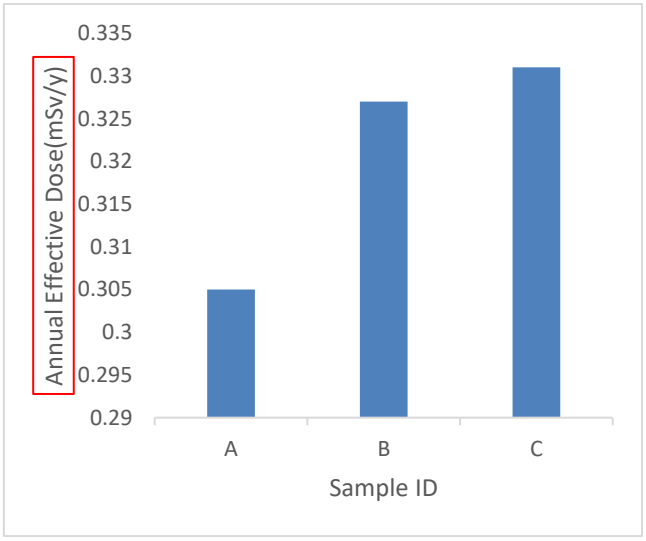


Figure 4: Annual Effective Dose rate (A.E.D.) of the study sites.

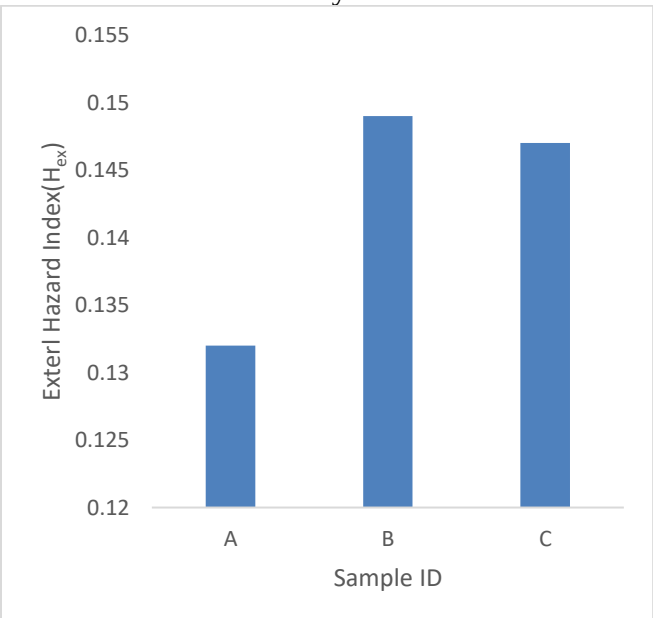


Figure 5: External hazard index of the study areas.

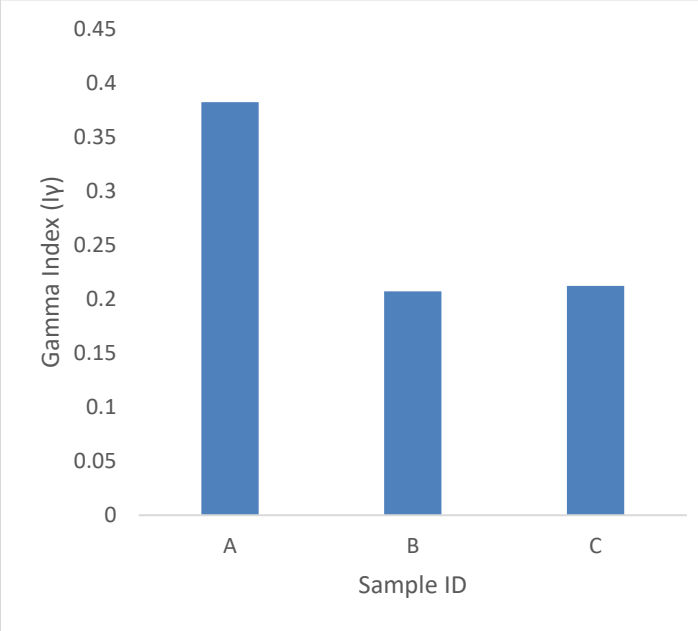


Figure 6: Showing Internal hazard index in the various study are

3.2. DISCUSSION

The level of radiation within the study area was determined from the results of the activity concentration of natural radionuclides in the soil samples collected. The results were within the world average values of 400, 35 and 30 (Bq/kg) for ^{40}K,^{226}Ra and ^{234}Th respectively[12], meaning that the radiation level within the dumpsites poses no significant health risk to the inhabitants.

The mean activity concentration of ^{40}K from the dumpsite's samples ranged from 405.22 ± 298.18 with a mean of337.22 Bq/kg, ^{226}Ra ranged from 15.10 ± 13.57 to 10.02 ± 47.03 Bq/kg with a mean of 11.58 Bq/kg and ^{232}Th values ranged from 16.22 ± 10.31 to 10.01 ± 1.25 Bq/kg with a meanof 11.68 Bq/kg. As shown in Table 1, ^{40}K has the highest activity concentration in the soil samples investigated at Spot 5C with 405.22 ± 47.03, the highest value for ^{226}Ra occurred at Spot 3A with 15.10 ±13.57 Bq/kg, while the highest value for ^{232}Th occurred at Spot 6B with a value of14.22 ±47.03 Bq/kg. The highest value of the natural radionuclides varies from place to place and this may be due to the chemical changes from the decomposition of the constituent elements of soil particles [13].

To assess the health effects, the radiation hazards such as absorbed dose rate (D), effective dose rates (E), external hazard index (Hex), and gamma Index ($I\gamma$) have been calculated from the activity concentration of nuclides ^{238}U, ^{232}Th, ^{40}K using the equations (2), (3), (4) and (5), respectively and the values are presented in Tables 2, 3, and 4 for Ilupeju Gbagada, and Ojota respectively.

The annual effective dose was calculated using a conversion factor of 0.7 $SvGy^{-1}$ to convert the absorbed dose rate to the effective dose equivalent and 0.2 for the outdoor occupancy factor and the results obtained for the three study sites are 0.7,0.3 and 0.7 respectively for Ilupeju, Gbagada, and Ojota. These values are within the world average of 0.7 μSvy^{-1}. The mean values of external radiation hazard and gamma indices are 0.15, 0.2; 0.14, 0.19,and 0.12, 0.38 for Ilupeju, Gbagada, and Ojota sites respectively. The radiation hazard values are below the world limit, this confirms thatthe site is radiologically safe for the people in that area.

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4.0. CONCLUSION

The measurements of the natural radionuclides of soil samples for the three dumpsites were carried out using gamma-ray spectrometry.

The results indicate that the natural radionuclides obtained at Ilupeju dumpsite appear higher than the remaining sites. The values of mean absorbed dose rate and annual effective dose rate are lower than the global average values also the external hazard and gamma indices are less than the average world value which indicates that the area is radiologically safe for the inhabitants. Previously, no research works on Ilupeju and Gbagada dumpsites for natural radionuclide measurement of the soil samples in Lagos State have been carried out. Therefore, this work serves as baseline data for possible future reference.

COMPETING INTEREST

There is no competing of interest

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