[1.]Ajetunmobi Abayomi EKUNDAYO, [1.]Alausa Shamsideen KUNLE, [1.]David Timothy WEMIMO, [1.]AdetoroTemitope TALABI, [2.]Odogboro Omolola JANET, [2.]Peter Biere EBIBULOAMI, [1.]Adeleye Tunde PATRICK

ASSESSMENT OF RADIOLOGICAL IMPACT OF WASTE –CONCEALED OJOTA ROAD–NETWORK IN LAGOS, SOUTHWESTERN NIGERIA

[1.]Physics Department, Olabisi Onabanjo University, Ago–Iwoye, NIGERIA
[2.]Niger Delta University, Wilberforce Highland, Bayelsa State, NIGERIA

Abstract: Dumpsites constitute a nuisance in addition to environmental radiation exposure when not properly managed. Road networks leading to various dumpsites are known to be littered with waste being carried by trucks to the dumpsites, and many of such roads are mini dumpsites due to indiscriminate disposal of waste. The exposure of the users of the road network of the dumpsites at Ojota, Lagos State to ionizing radiation has been investigated. Ambient dose rates were quantified, randomly using the RADS–30 survey meter. Radiation dose–risk software was used to predict the cumulative doses of users of road networks. Radiometric analysis of twenty (20) soil samples was conducted in the Radiation Laboratory of the Department of Physics, Federal University of Agriculture, Abeokuta, using a Sodium Iodide detector. Results reveal that the mean values for the ambient dose rates ranged from (320–450) μSv/h, while the mean values for the predicted cumulative dose estimated for five years ranged from (3.87–5.45) mSv. Activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K ranged from (16.6—113.8), (229.2—518.4), and (107.1–496.6) Bq/kg, and their corresponding mean values are (57.37, 371.9, and 296.3) Bq/kg, respectively. The estimated absorbed dose rates and the annual dose rates for the study ranged from (210 — 340) nGy/h with a mean of 260 nGy/h and (110–210) μSv/y with a mean of 480 μSv/y, respectively. Almost all estimated radiological parameters are greater than the world average; therefore, a continuous radiological survey of not only the road network but also the dumpsite is strongly recommended.
Keywords: Assessment: Exposure: Radiological: Road network and waste concealed

1. INTRODUCTION – BACKGROUND

Human beings have been constantly subjected to ionizing radiation from naturally occurring radioactive materials and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) like radioactive waste from mines, medical procedures, atomic weapons, and so on. [1]. It is quite important in the health management of the general public that there should be a timely, comprehensive, and categorized assessment of exposure; hence, the understanding of radiation sources within an environment is very important [2–3]. The earth's crust is the reservoir of metallic elements and natural radionuclides that easily enter the air, soil, air, water, food, buildings, and humans [4]. The source of these materials is the earth's crust, but they find their way into the soil, building materials, air, water, food, and the human body itself. Human activities generate different forms of waste, and when improperly managed, they can lead to malodour due to waste degradation. This mismanagement not only poses a health burden and creates aesthetic nuisances but also decreases the economic and social values of an area. Radioactive waste gives off radiation, especially when it mixes with natural background radiation. When waste is not managed properly, it can lead to dangerous exposure to radioactive materials. This situation can harm public health, highlighting the need for better waste management to protect communities and the environment. [5]. Dumpsites' locations and composition are not just an environmental nuisance but a public discomfort and can serve as a source of radiation due to the accumulation of radionuclides within them [6]. Point sources of contamination, such as landfills, present significant environmental hazards not only due to foul odours and the proliferation of disease–causing microorganisms but also because of radiation emissions. These emissions contribute to the continuous exposure of our natural environment to ionizing radiation from both natural and artificial sources. The most common radionuclides in soil are the radioactive isotopes from the three natural decay series

(^{238}U,^{232}Th, and ^{40}K). The road network at the dump sites has lots of people using it daily. Radioactive and non–radioactive wastes from the dumpsites find their way into these road networks, where commercial activities also take place. Some residents live close to the road network, and their stay time in the vicinity of the road network predisposes them to radioactive radiation from the radionuclides in the soil samples from the road. It is important, therefore, to ascertain the exposure level of all the users of the road network and check if their level of exposure is beyond the permissible limit. The study is important because it attempts to ascertain the level of exposure of the public and workers in the dumpsite to radioactive radiation from the soil samples from the road network accessed by many users of the dumpsite daily. Based on the researcher's current state of knowledge, there has not been such a study conducted in the study location, and there is no known literature on road networks of dumpsites, hence, it will serve as a baseline for future radiological studies for similar studies. It will also enhance the existing knowledge base for similar studies. This study aims to ascertain the level of exposure of the users of the road network around the Ojota dumpsite to radionuclides in the soil samples from the study location.

2. MATERIALS AND METHODS

Description of the study area

The study area is situated in Ojota, Lagos State, Nigeria, which has a population exceeding 9,013,534 and an annual growth rate of 3.2% (NPC, 2006). The region encompasses Ikosi–Ketu, Oregun industrial estates, the commercial zone along Kudirat Abiola Way, the Ojota residential area, and the LAWMA dumpsite (Figure 1), also called Olusosun landfill [7]. The dumpsite lies between 6°23′N; 2°42′E and 6°41′N; 3°42′E. It is the biggest dumpsite in Lagos State and has harbored more than 50% of the total refuse generated in Lagos since 1989 [8]. The landfill site is located approximately 10 km southeast of Ikeja, the capital city of Lagos, within the Ikeja Local Government Area (LGA). This area is a prominent commercial district in Lagos State.

Figure 1: Location Map of Ojota Dumpsite (Source: Coker [9])

Measurement of ambient dose Rates at the road network of Ojota dumpsite, Lagos

For data collection and the reporting of the study, the road network was divided into five sections for data collection, and the dose rates were taken using a RADS30 survey meter placed at one meter above the ground level. The survey meter was allowed to run for 300 seconds before taking the readings per sectional division of the road network. Dose rates measurement for the survey meter range of RADS30 is from 0.01 μSv/h–100 mSv/h or from 1 μrem/h –10 rem/h, while the dose rate proportionality is ± 10 % ±1 digit within the range of 0.1 μSv/h–100 mSv/h or 10 μrem/h to 10 rem/h. Standardization accuracy is ± 5 % of the measurement in ^{137}Cs exposure, at 3 mSv/h, +20°C (68°F). The energy sensitivity is ± 30 % over the range of 48 keV–3 MeV. The angular sensitivity of the survey meter is ± 25 % within ± 45 % from the standardization direction at 48 keV. Dose assessment range: from 0.01 μSv –1 Sv or from 1 μrem–100 rem.

Figure 2: RADS 30 Survey meter

Radiation dose to risk Software (Uranium Wise Project): A dose to risk predictive tool

The software was used to estimate the safety risk due to the exposure of users of the road network to possible ionizing radiation from the radionuclides in the road network linking the dump site. The interface of the software is user–friendly, and the measured dose rates were entered as input

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

parameters for the estimation of the radiological parameters associated with the exposure of the scavengers and other users visiting the dumpsites. The predictive number of years adopted for the study is five years and was used in the estimation of the cumulative doses that may be accrued by users of the road network for the next five years. In the estimation of risks related with inputted parameters, the software adopted a risk factor of ICRP [10] with values of 0.04 for workers and 0.05 for the public, respectively. A conversion factor from absorbed gamma energy in the air to the effective dose recommended by UNSCEAR [2] with values of 0.7 Sv/Gy, 0.8 Sv/Gy, and 0,9 Sv/Gy for adults, children, and infants, respectively, was adopted for the study.

Soil sampling, preparations, and spectrometric analysis.

20 soil samples from the road network were randomly collected by digging some centimeters into the soil. About 400 g of soil samples were collected at each sampling point, carefully packed in polythene bags, and labeled before being taken to the laboratory for spectrometry analysis. In the laboratory, the samples were air–dried at ambient temperature for three weeks before being crushed, pulverized to a fine powder, and sieved with a 2mm mesh size. The samples were thereafter oven dried to remove moisture at a temperature of 110°C until a constant mass was obtained. 200g mass of each of the samples was measured and packed into a plastic container of dimensions 12 cm by 4.2 cm, sealed, and kept for 30 days to allow the parent and daughter nuclides to reach a state of secular equilibrium, so that their radioactivity becomes balanced [11].

The prepared soil samples were analyzed to determine the activity concentrations of radionuclides using a thallium–activated 2″×2″ Canberra vertical high–purity Sodium Iodide [NaI(Tl)] detector at the Radiation Laboratory, Department of Physics, Federal University of Agriculture, Abeokuta. The detector was linked to an ORTEC 456 amplifier and connected to a computer running the MAESTRO software, which identified gamma–ray energies by comparing them to a library of known isotopes. The samples were placed in cylindrical plastic containers measuring 7.6 cm × 7.6 cm and positioned directly on the NaI(Tl) detector. To minimize background radiation, the detector was shielded with 15 cm–thick lead on all sides and 10 cm on the top and bottom.

The system had an energy resolution of 2.0 keV and a relative efficiency of 33% at 1.33 MeV. Each sample was measured for 10,800 seconds to reduce statistical uncertainties. Throughout the analysis, the detector's configuration and geometry were maintained consistently, in line with the laboratory's standard procedures. The International Atomic Energy Agency (IAEA) sources were used for calibration, IAEA [12]. From the counting spectra lines, the activity concentrations of the radionuclides, 226Ra, 232Th, and 40K were calculated using a computer program. The peak corresponding to 1460 keV for 40K, 1764.5 keV (214Bi) for ^{238}U, and 2614.5 keV (^{208}Ti) for ^{232}Th were factored in when assessing the activity levels (Bq kg^{-1}). The background counts were obtained by measuring an empty container matching the dimensions of the sample containers and then subtracting this from the total count. The activity concentrations of the samples were calculated using the net area under the photo peaks by the equation (1);

$$A_C = \frac{Cn}{P\gamma\, M\, \varepsilon} \tag{1}$$

Where Ac is the activity concentrations of the radionuclides (^{238}U, ^{232}Th, and ^{40}K) in the sample and unit is Bqkg–1, Cn is the net count rate under the corresponding peak, Pγ is the absolute transition probability of the specific γ–ray, M is the mass of the sample (kg) and ε is the detector efficiency at the specific γ–ray energy. The containers were sealed and made airtight to prevent the release of gaseous ^{220}Rn and ^{222}Rn, they were then incubated for approximately a month to allow the daughter radionuclides to reach secular radioactive equilibrium with their corresponding long–lived parent isotopes [13–14].

3. ESTIMATION OF RADIOLOGICAL PARAMETERS DUE TO RADIONUCLIDES IN SOIL

Absorbed Dose Rate

The absorbed dose rates D (nGy/h) were calculated using the equation (2) (UNSCEAR [2]:

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

$$D_R = 0.0417A_k + 0.462A_u + 0.604A_{th} \quad (2)$$

where $A_k A_u$, and A_{th} are the activity concentrations of ^{40}K, ^{238}U, and ^{232}Th, respectively in Bq.kg^{-1}.

Annual Effective Dose Rates

The annual effective dose (H_e) was calculated using equation (3) where H_e is the annual effective dose rate in mSv y^{-1} and D is the value of the absorbed dose rate calculated, T is the occupancy time (T= f × 24 × 365.25h y^{-1}) f is the occupancy factor and F_o (0.8) is the conversion factor (0.7 SvGy^{-1}) UNSCEAR [15]. Dose conversion factors are utilized to change the radioactivity absorbed by the body into an equivalent radiation dose.

$$H_e = DTF_o \quad (3)$$

Radium Equivalent Activity

The importance of activity concentration of ^{40}K, ^{226}Ra, and ^{232}Th in relation to radiation exposure is quantified through the concept of radium equivalent activity (Ra_{eq}), which was calculated using Equation 5, Beretka and Matthew [16]. As per the OECD guidelines [17] for the radiological impact to be deemed negligible, this maximum value should be below 370 Bq.kg^{-1}.

$$Ra_{eq} = A_{Ra} + 1.43A_{th} + 0.077A_K \quad (4)$$

External Exposure Index

The external exposure index (H_{ex}) is a commonly used index that indicates the level of external exposure to gamma radiation. This index is derived from the relationship described in Equation 5. by UNSCEAR [2]:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{th}}{259} + \frac{A_k}{4810} \quad (5)$$

Internal Exposure Index

Alongside internal exposure to radiation, it is measured using the internal exposure index as defined by UNSCEAR. [2] and expressed in equation 6

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (6)$$

4. RESULTS AND DISCUSSION

The section presents the results, statistical analysis, and pictorial representation of the results of the study. The results of the study were compared with similar studies in the nation, similar studies abroad, and permissible limits recommended by various regulatory bodies. Tables 1, 2, and 3 present the measured dose rates, and the estimated radiological parameters associated with four sectional division of the road network at dumpsites (tables 1) and the activity concentrations of the radionuclides in soil samples from the road network at Ojota dumpsite (Table 2) and estimated radiological parameters associated with exposure to the ionizing radiation from the soil samples in the road networks for the present study respectively (Table 3). Figure 3 presents the plots of activity concentrations of the soil samples Vs soil identification (ID),

The mean measurement of the ambient dose rates for the first sectional division of the road network is 410 $\mu Sv/h$ which is greater than the world average (42 nSv/h). The cumulative dose that may be accrued for a period of five years for continuous users of the road network is 4.96 mSv and is quite greater than the permissible limit of 0.48 mSv/y. The mean and mean measurement of the ambient dose rates for the remaining sectional division of the road

Table 1: Measured ambient dose rates and cumulative dose rates for the study

Road Network	Ambient dose rates (μSv/h)	Cumulative dose rates (mSv/y)
Section 1	360	4.36
	450	5.45
	460	5.57
	390	4.72
	390	4.72
Mean±σ	410±43.1	4.96±0.5
Section 2	320	3.87
	680	8.23
	390	4.72
	430	5.21
	430	5.21
Mean±σ	450±136.2	5.45±1.7
Section 3	460	5.57
	360	4.36
	430	5.21
	430	5.21
	390	4.72
Mean±σ	414.0±39.0	5.01±0.5
Section 4	390	4.72
	180	2.18
	280	3.39
	360	4.36
	390	4.72
Mean±σ	320±90.3	3.87±1.1

networks ranged from (320−450)$\mu Sv/h$, which is also greater than the world average. The estimated cumulative dose for the pathways ranged from (3.87−5.45) mSv. The implication of this is that users of the road network for the consecutive five years are to be in the continuous field of the ionizing radiation from the radionuclides in the soil samples from the road network. This is a stochastic exposure for the users of the network with a possible stochastic effect of radiation.

There have been various research works based on radiological and heavy metals impacts of soil samples from dumpsites on the immediate environment [18–20] but none on the exposure of users of the road network of the dumpsites, hence, in comparing the results of the present study, the closest that can be adopted for the comparison are based on soil samples from the dumpsites, knowing fully well that the road network are many times littered with waste as they convey them to the dumpsite.[21] reported a dose rate of 142.4$\mu Sv/h$ for the dump site at Owerri, and lower than the value for the present study. This may be due to the volume of dump waste at the Lagos dumpsite from various industries around Lagos. Okon [22] reported the dose rate of 180 $\mu Sv/h$ for the dump site at Eket local government, Akwa Ibom, and its environment, and is again lower that the value for the present study. Jibiri [23] reported the dose rate of 93 $\mu Sv/h$ for the e–waste dumpsite at Alaba market in Lagos and which is also lower than the values obtained for the present study.

Table 2: Activity concentrations of radionuclides in soil samples from road–network at Ojota Dumpsite

Sample Id	^{226}Ra (Ba/kg)	^{232}Th (Bq/kg)	^{40}K (Ba/kg)
SI	51.3 $\pm$ 2.3	353.7$\pm$12.9	271.3$\pm$ 23.8
S2	50.0 $\pm$ 2.6	380.5$\pm$ 11.0	336.9$\pm$ 20.5
S3	52.5 $\pm$ 3.4	369.5$\pm$ 11.0	266.8$\pm$22.4
S4	40.3 $\pm$ 2.5	359.8$\pm$ 10.1	126.5$\pm$ 26.2
S5	47.8 $\pm$ 2.4	287.8$\pm$ 13.2	254.8$\pm$ 22.3
S6	90.1 $\pm$ 1.6	357.3$\pm$ 11.3	496.6$\pm$16.7
S7	78.5 $\pm$ 1.6	326.8$\pm$ 11.2	147.4$\pm$ 25.1
S8	113.8$\pm$ 1.9	378.1$\pm$ 9.9	168.3$\pm$ 24.3
S9	68.7 $\pm$ 2.7	448.9$\pm$ 9.8	345.9$\pm$ 15.5
S10	52.5 $\pm$ 1.8	288.9$\pm$ 13.1	230.9$\pm$ 23.1
S11	73.9 $\pm$ 1.6	456.2$\pm$ 10.3	651.7$\pm$ 15.5
S12	14.8 $\pm$ 3.1	393.9$\pm$ 11.2	477.2$\pm$ 17.5
S13	34.5 $\pm$ 4.1	518.4$\pm$ 10.9	369.7$\pm$ 24.2
S14	21.8 $\pm$ 1.8	436.4$\pm$ 11.0	266.8$\pm$ 21.4
S15	72.1 $\pm$ 1.5	229.2$\pm$ 16.5	108.6$\pm$ 28.2
S16	60.6 $\pm$ 2.1	390.3$\pm$ 12.3	436.9$\pm$ 20.0
S17	109.2$\pm$ 1.4	384.2$\pm$ 13.3	305.6$\pm$ 25.0
S18	39.7 $\pm$ 3.2	315.8$\pm$ 11.2	241.4$\pm$ 21.9
S19	58.8 $\pm$ 1.9	330.5$\pm$ 11.6	107.1$\pm$ 28.6
S20	16.6 $\pm$ 2.3	430.9$\pm$11.7	314.5$\pm$ 23.9
Mean	57.4 $\pm$ 2.3	371.9$\pm$ 11.7	296.3$\pm$ 22.5

In Table 2, the range of the activity concentrations of 226Ra, 232Th and40K ranged from (16.6 −113.8) Bq/kg with a mean of 57.4 Bq/kg, (229.2–518.4) Bq/kg with a mean of 371.9 Bq/kg and (107.1–651.7) Bq/kg with the mean of 296.3 Bq/kg respectively.[8] worked on the same dumpsite for this study, but with a focus on the active and dormant dumpsite. Their study seems to focus on the exposure of workers and some scavengers at the dumpsite, while the present study focuses on the wider population of human influx using the road network for commercial purposes, and houses are sited close to the road network. In their study the activity concentrations of the radionuclides in the active dumpsite for ^{238}U,^{232}Th, and ^{40}K were (69.69 $\pm$ 19.10, 14.49 $\pm$ 3.22 and 409.44 $\pm$ $\mathbf{86.08}$) Bq/kg respectively while that of the dormant dumpsite, the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K were(61.25 $\pm$ $\mathbf{21.82,}$ 12.08 $\pm$ 1.74, 345.98$\pm$ $\mathbf{56.92}$ **).** The concentrations of work of thorium (232Th) for the present study is higher than those of [8] , with the mean value of 371.86 Bq/kg, but the soil from the active dumpsite in their study has an enrichment of ^{40}K with the concentration value of 409.44 Bq/kg. The activity concentrations for ^{226}Ra, a progeny of Uranium (^{238}U) for [8] are slightly higher than those of the present study with a mean value of 69.69 Bq/kg. The reason for their higher values may be due to the continuous usage of the active dumpsite by various users dumping different materials that may be radioactive and non–radioactive. Also, Gbadamosi [24] worked on the soils of a dumpsite at Agbara in Lagos and reported that the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K were (11.50 $\pm$ $\mathbf{1.0, 166.0}$ $\pm$ $\mathbf{40}$ $\boldsymbol{and}$ $\mathbf{15.6}$ $\pm$ $\mathbf{1.8}$) kg. The result of the present study shows that the activity concentrations of all the radionuclides in the present study are higher than the value obtained by Gbadamosi [25]. The reason for higher activity concentrations for all the radionuclides may be because the Lagos dumpsite is located in a more cosmopolitan area with more industrially generated waste products that may be radioactive. Again Ulakpa [26], reported that the mean activity concentrations of ^{238}U, ^{232}Th, and ^{40}K are $(24.06 \pm 2.82,\ 30.45 \pm 5.77\ and\ 368.25 \pm 3.4)$ Bq/kg respectively, and the values are lower than the values of the activity concentrations of radionuclides in the soil samples of the road network for the present study except for the activity concentration of ^{40}K.

The absorbed dose rates for the study ranged from 180 –340 Gy/h with a mean of 260 nGy/h. The mean value is greater than the world average of 51nGy/h by UNSCEAR [2]. Similarly, the annual effective dose rates ranged from (110–210) μSv/y with a mean of 154 μSv/y. The mean values of the estimated radium equivalent, and external and internal indices are all greater than the world average, as indicated in Table 3. Further, an increase in the activity concentrations of the radionuclides in the soil samples in the road network at the dumpsites due to increased indiscriminate dumping of possibly radioactive materials may lead to further radiological exposures of the influx of users of the road network. Comparing the result of the present study with similar studies like [5] shows that the mean values for annual effective dose rates, the absorbed dose rates, external exposure index ranged from (30 – 53) μSv/y with a mean of 49 μSv/y, (0.8 – 116) nGy/h with a mean of 82.55 nGy/h, (0.05 –0.78) with a mean of 0.49 respectively. These values are all lower than those of the present study, as seen in Table 3. The annual dose rates reported by [8] (255 μSv/y) for the dormant dumpsite are higher than the value for the present study (155 μSv/y). This may be due to the differences in the activity concentrations of the dormant dumpsites and road networks. However, the annual dose rate values (1310 –2280) μSv/y for the study reported by Usikalu [27] are greater than the present study value (110–210) μSv/y. This may be due to the variation in activity concentrations of the radionuclides in the different locations, coupled with differences in the geological composition of the two locations selected. The value for the mean absorbed dose rates for the present study is greater than the work of Jibiri [21], (21.12 nGy/h). This may be due to the volume of possible dump waste at the Lagos dumpsite from various industries around Lagos

Table 3: Estimated radiological parameters for the present study

	concentration	H_E (μSv/y)	Ra_{eq}	E_{ex}	E_{in}
1	250	150	578	1.6	1.7
2	270	160	620	1.7	1.8
3	260	160	601	1.6	1.8
4	240	150	564	1.5	1.6
5	210	130	479	1.3	1.4
6	280	170	640	1.7	1.9
7	240	150	557	1.5	1.7
8	290	180	667	1.8	2.1
9	320	190	737	1.9	2.2
10	210	130	484	1.31	1.5
11	340	210	776	2.1	2.3
12	260	160	615	1.7	1.7
13	340	210	804	2.2	2.3
14	280	170	666	1.8	1.9
15	180	110	408	1.1	1.3
16	280	170	652	1.8	1.9
17	300	180	682	1.8	2.1
18	220	130	510	1.4	1.5
19	230	140	540	15	1.6
20	280	170	657	1.8	1.8
Mean	260	154	612	1.7	1.8
W/Aver.	51 nGy/h	480 μSv/y	370	1.0	1.0

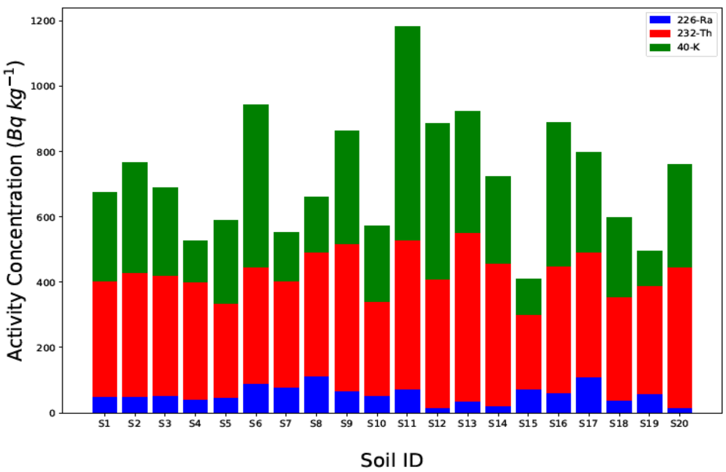

Figure 3: Plot of Activity concentrations (Bq/kg) Vs Soil ID

Figure 3 shows the pictorial representation of the activity concentrations of the radionuclides in the soil samples from the road network at the dump site.

5. CONCLUSIONS

The activity concentrations of the soil samples of the road network at the dumpsite and the associated radiological parameters for the exposure of the general public have been investigated. All the estimated radiological parameters are above the world average. It implies that shortly the possibility of higher exposure of the users of the road network cannot be jettisoned. There should be an effort to further enlarge the drainage system at the dumpsite to curb heavy erosion during heavy downpours, as this is the link between the waste materials and the road networks at the dumpsite.

References

[1] Sadiq A.A., Agba E.H. Background Radiation in Akwanga, Nigeria. Facta University Series working and living environmental protection.2011; 8: 7–11
[2] UNSCEAR 2000. The United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). PubMed, 79(3), 314. https://pubmed.ncbi.nlm.nih.gov/10949259
[3] Christie, D. H., Chu, M. C., & Carr, Z. (2010). Global networking for biodosimetry laboratory capacity surge in radiation emergencies. Health Physics, 98(2), 168–171.
[4] Alausa, S.K, Omotuyi, R.A., Jimoh, S. T. and Olabamiji A. O. Indoor and outdoor in–situ gamma–ray and radiological assessment of soils of Olabisi Onabanjo University Main campus, Southwestern Nigeria, FUW Trends in Science & Technology Journal. 2020; 5(1): 74–78 https://www.ftstjournal.com/uploads/docs/51%20Article%2014.pdf
[5] Egunjobi, K., Adesina, K., Chime, I., 2020. Radiological Assessment of Soil Samples from Selected Dumpsites in Mowe, Ogun State, Nigeria. CCU Journal of Science. 2020;1(1):72–80https://www.researchgate.net/profile/Kolawole–Egunjobi/publication/344446527
[6] Olubosede O., Akinagbe O. B, Adekoya O., 2012.Assessment of Radiation Emission from Waste Dumpsites in Lagos State of Nigeria. International Journal of Computational Engineering Research. 2012; 2(3): 806 –811.
[7] Bello, M. H. Geoelectric and Geochemical Evaluation of Groundwater Quality at Olusosun Refuse Dumpsite, Ojota, Lagos. Master's thesis, African Regional Center for Space Science and Technology Education in English, Ile–Ife, Nigeria, 2002.
[8] Oladapo O.O., Oni E.A., Olawoyin A.A, Akerele O.O and Tijani S.A. Assessment of Natural Radionuclide levels in Wasteland Soils around Olusosun Dumpsite, Lagos, Nigeria. IOSR Journal of Applied Physics 2012;2(3):38–43.
[9] Coker, A. O., Sangodoyin, A. Y., & Sridhar, M. K. C. (2019). The impact assessment of solid waste on groundwater quality in Olusosun dumpsite, Lagos, Nigeria. Environmental Research, Engineering and Management, 75(1), 50–59
[10] [10] International Commission on Radiological Protection. (1991). 1990 Recommendations of the International Commission on Radiological Protection (ICRP Publication 60). Pergamon Press
[11] Alausa, S. K. Akanmu, I. O. Odunaike Kola, Adeyeloja Adebayo and Olabamiji, A. O., Radiological impact assessment of soil matrices from Saje and Ilaro dumpsites in Southwestern Nigeria. FUW Trends in Science & Technology Journal; 2019:4(3) https://www.ftstjournal.com/uploads/docs/43%20Article%2035.pdf
[12] IAEA. Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM). International Atomic Energy Agency, Technical Report Series No. 419, Vienna–Austria. 2003.
[13] Ravisankar, R., , A., Sivakuma, S., Chandrasekaran, and Pream.D.A. Measurements of natural gamma radiation in beach sediments of North–East Coast of Tamil Nadu, India by gamma ray spectrometry with a multivariate statistical approach. Journal of Radiation Research and Applied Sciences. 2013; 7(1):7–1.
[14] Shittu, A. M., Okuneye, P. A., & Olarewaju, T. O. (2015). Patterns and determinants of adoption of crop production technologies among food crop farmers in Nigeria. Nigerian Journal of Agricultural Economics, 5(1), 100–108
[15] Sources and Effects of ionizing radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1993 report. (1993). In Report of the United Nations Scientific Committee on the Effects of Atomic Radiation
[16] Beretka, J. and Matthew, P.J. (1985) Natural Radioactivity of Australian Building Materials, Industrial Wastes and By–Products. Health Physics, 48, 87–95.
[17] OECD, 1979. Exposure to Radiation from Natural Radioactivity in Building Materials. Report by group of experts of the Organization for Economic Cooperation, Nuclear Energy Agency, Paris, France. Last available from (https://www.oecd–nea.org/rp/reports/1979/exposure–oradiation 1979.pdf (4)
[18] Emmanuel , I., Anthony, C. E., Ogedi , H. I., Jude, U , Okechukwu. Assessment of Heavy metals concentration in a waste dumpsite at Onitsha, Nigeria. Discovery Science. 2018; 14: 41–49 https://api.semanticscholar.org/CorpusID:222459222
[19] Awokunmi, E. E., Asaolu, S. S., & Ipinmoroti, K. O. (2010). Effect of leaching on heavy metals concentration of soil in some dumpsites. African Journal of Environmental Science and Technology, 4(8), 495–499
[20] Etim, E. E., Odoh, R., Itodo, A. U., Umoh, S. D., & Lawal, U. (2013). Water quality index for the assessment of water quality from different sources in the Niger Delta Region of Nigeria. Frontiers in Science, 3(3), 89–95
[21] Ugochukwu, K. O., Ijeoma, D., Chidiezie, C., Christiana, G., Chiamaka, C. Characterization of Radiation Exposure Dose Rate from Waste Dumpsites within Owerri, Nigeria: An Atmospheric Concern. British Journal of Applied Science and Technology.2015;11(3):1–9
[22] Okon P. A., Idopise G. E., Imeh E. E. Assessment of ionizing radiation emissionfrom select waste dumpsites in Eket, Nigeria. International Journal of Environmental Studies and Safety. 2018;3(3):95–104.
[23] Jibiri, N.N., Isinkaye, M.O. and Momoh, H.A. Assessment of radiation exposure levels at Alaba e–waste dumpsite in comparison with municipal waste dumpsites in southwest Nigeria.Journal of Radiation Research and Applied Sciences, Journal of Radiation Research and Applied Sciences. 2018; 7(4): 536–541.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

[24] Gbadamosi, M.R, Ugbomeh, I.L., Banjoko, O. O., Ogunneye, A.L, Jegede, D.O and Ayofe N.A. Measurement of radiological and lifetime excessive cancer risk due to naturally occurring radioisotopes in wastes dumpsites soils in Sagamu, Southwest, Nigeria. Nigerian Research Journal of Chemical Sciences. 2012; 8(2): 66–82.

[25] Gbadamosi, M. R.,Oluwakemi O.B., Abudu A., Ogunbanjo O., Adeyemi, O.Radiometric evaluation of excessive lifetime cancer probability due to naturally occurring radionuclides in wastes dumpsites soils in Agbara, Southwest, and Nigeria. Journal of the Association of Arab Universities for Basic and Applied Sciences. 2017;24(1): 315–324

[26] Ulakpa, W., Eyankware, E. O., Eyankware, M., Eyankware, R. O. Evaluation of Radionuclides in Eliozu Dumpsite, Obio–Akpor L.G.A. South–South Nigeria. International Journal of Sciences and Healthcare Research. 2016;1(2):15–22.

[27] Usikalu, M.R., Ola, O.O., Achuka, J.A., Babarimisa, I.O., Ayara, W.A. Background Radiation dose of dumpsites in Ota and Environs. International Conference on Space Science and Communication Series 852, 2017, Kuala Lampur, Malasia.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665