ASSESSMENT OF NATURAL RADIONUCLIDE LEVELS AT E-WASTE DUMPSITE IN LAGOS AND WASTE DUMPSITES IBADAN, NIGERIA

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Abstract: Considering the negligent manner, they are disposed of, the risks that this huge production and imports of e-waste pose to the environment and human health cannot be overestimated. The goal of the current study is to evaluate the radiological health hazards in e-waste dumpsite and waste disposals dumpsite. The ^{40}K, ^{226}Ra, and ^{232}Th activity concentrations were measured using gamma ray spectroscopy at Computer Village e-waste dumpsite Lagos, in comparison with waste dumpsite at Ibadan, Oyo state Nigeria. Fifty soil samples were analyzed from in all the dumpsites. The mean value of ^{40}K, ^{226}Ra, and ^{232}Th concentrations for the samples at e-waste dumpsite were 87.26 ± 25.08 Bq/kg, 19.70 ± 0.21 Bq/kg, and 17.32 ± 12.86 Bq/kg respectively. The average activity concentration of ^{40}K, ^{226}Ra, and ^{232}Th of Gbagi dumpsite were 482.91 ± 205.24 Bq/kg, 27.85 ± 10.48 Bq/kg, and 44.85 ± 7.24 Bq/kg respectively, the Bodija dumpsite were 405.89 ± 75.79 Bq/kg for ^{40}K, 32.10 ± 10.97 Bq/kg for ^{226}Ra, and 48.46 ± 7.29 Bq/kg for ^{232}Th. The average activity concentration on the location of the e-waste dump and Control dumpsite, Lagos was less to the global standard, while the activity average concentration of Bodija and Gbagi Dumpsite, Ibadan were slightly above the world standard. In soil samples obatined from an e-waste dumpsite, the mean Annual Effective Dose Rate of Gbagi and Bodija control dumpsites were below the standard limit of unity. The soil from E-waste dumpsite's soil has the least absorbed dose rate of 21.12 ± 8.51 nGy/h compared to that of the waste dumpsite and control sites, which is less than the global average of 60 nGy/h. Other estimated radiological hazard indices fell short of the benchmark. Therefore, the level of natural radionuclide from e-waste dumpsite and waste dumpsites does not immediately present any radioactive concern to the local population near the dumpsites. However, cautions should be taken against long term cumulative effect.

Keywords: Gamma Spectrometry, Activity Concentration, Dumpsites, E-waste and Waste

Introduction

The present era of information technology (IT) had made the use of electronic devices to be of high demand. The dependence, and the vital role information and communication technology (ICT) is contributing to world economy has brought about an increase in the use of electronic equipment (Odeyingbo, 2011). The world has indeed, a global village has emerged across the world with people utilizing internet, videoconferencing, phones and similar tools to conduct business and communicate with their loved ones, associates, partners, and colleagues. People enjoy by watching TV, using satellites, or playing electronic games on their computers.

In 2021, about three hundred and forty-one million computers were shipped globally in (Canalys, 2022). Nigeria is particularly affected by the e-waste problem, with over 1.1 million tons of e-waste produced annually (Propakwestafica, 2022). The above data gives an insight into the high increase of e-waste in Nigeria. The e-waste comprises of abandoned phones, computers and other electronic products end up as waste in dumpsites. Nigeria produces by far the most electronic garbage of any nation in West Africa, which is quite concerning (Andreas et al., 2011). Given the indiscriminate way in which they are abandoned, landfilled, and burned in order to recover certain essential pieces of the waste, the risks presented to human health and the environment by this vast generation and importation of e-waste cannot be overemphasized. Inhalation of toxic fumes is one the major issue with regard to health and safety e.g. (Pb, Cd, Hg etc.). Human radiation could either be external due to ^{40}K, ^{226}Ra and ^{232}Th or Internal due to radon inhalation in smoke, and dust from waste deposal site (Jibiri *et al*., 2011). The contamination of atmosphere, soil and ground water may lead to the possibility of radiation exposure from the ashes, smoke, and dust from the dumps

Nigeria lacks effective regulations on the importation of e-waste into the country, little information on the radiological status of dumpsites, and no regular monitoring system to check radiation levels. The activity concentration of soil samples from dumpsites in Nigeria, were carried out (Obed *et al*., 2005, Emelue *et al*. 2013, Jibiri *et al*., 2014, Oyebanjo *et al*., 2019), but only few studies were done with regards to e-waste. These studies indicate that the radiological health hazard in dumpsite were insignificant to the populations. The goal of the current study is to assess the radiological health hazards in e-waste dumpsite and waste disposals dumpsite. The study will assist the government in creating a baseline data for natural radioactivity in e-waste dumpsite and waste dumpsite in Nigeria.

Materials and Methods

Study Area

West Africa's largest electronics market is Alaba International Market Lagos. It was founded in 1978 and is situated in the southwestern part of Nigeria, on a piece of land that is about 2 km^2. There are more than 2,500 stores in the market that sell used electronic equipment as well as refurbishing them. Most of these devices are imported second-hand products which include electronics products. In an effort to salvage some usable pieces or scrap from e-waste, e-waste collectors, refurbishers, and recyclers work at a large dumpsite (about 70 m^2 in area), where they engage in crude recycling procedures like burning without regard for their health or the environment. Make shift structures are also erected on the site for accommodation (figure 1). The refuse dumps in Ibadan, which are found in geological basement complex of Ibadan are part of the sampling sites. In comparison to sedimentary rocks found in the majority of Lagos, igneous rocks, which are more prevalent in Ibadan, exhibit higher levels of radioactivity (Oyawole, 1972).

Sample Collection and Preparation

At a distance of 10 cm from the e-waste dumpsite, twenty (20) soil samples were collected. At the Gbagi and Bodija landfills in Ibadan, fifteen samples were taken. At a reference point near the Lagos e-waste dumpsite, five samples were taken for control samples. The soil samples were collected with a clean steel hoe, put in black polythene bags with labels, and delivered safely to the Physics laboratory at the University of Ibadan, Nigeria. The samples were sun dried in the laboratory until dry weight was achieved. Each sample, which weighed 200 grams and was packaged in 6.6 cm-diameter plastic containers to match the NaI (Tl) detector used for the test. (Bello, 2012). It took 30 days for the samples to reach secular equilibrium between radium and the products of its gaseous disintegration. The samples were securely covered, taped shut, and kept in place for that time frame.

Measurement

To locate and measure the radionuclide present in a sample, it is crucial to calibrate the detection system. The Multi-Channel Analyzer (MCA) energy's calibration (ECAL) analysis tool was used to fit the data, producing a linear graph, and the International Atomic Energy Agency (IAEA) reference source material was used as the basis for the energy calibration. The linear relationship obtained between the channel number (N) and the γ-energy (E) in MeV is represented by the equation below (UNSCEAR, 2008):

$$E(Mev) = 1.83 \times 10^{-2}N + 0.36$$
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(1)

The net area A under the photo-peak above background level was computed and related to the activity concentration C of the reference source using the relation (Farai and Ejeh 2006)

$$E_p = \frac{C}{A\gamma mt} E_p = \frac{C}{A\gamma mt}$$

(2)

Where: E_p = detection efficiency, C = net count above background after counting a reference sample of known activity A ($Bq.kg^{-1}$), m = mass (kg) for a time, t (s) and γ = gamma yield. Each sample was counted for 10 hours and the background count was subtracted from them to obtain the gross count for each sample. The Uranium content of the samples was determined from the intensity of the 1.760 MeV photo-peak of ^{214}Bi, the Thorium content from the 2.614 MeV photopeak of ^{199}Th and Potassium content from the 1.460 MeV photopeak of ^{40}K decay.

After taking account for background and Compton contribution, the activity concentrations of the samples were calculated using the net counts. The activity concentrations of ^{232}Th, ^{226}Ra and ^{40}K were obtained using (Ademola, 2005):

$$A_c = \frac{C_{net}}{I_\lambda \times E_{ff}(E_\lambda) \times m}$$
$$A_c = \frac{C_{net}}{I_\lambda \times E_{ff}(E_\lambda) \times m}$$

(3)

Where: C_{net} = net peak counts, I_λ = absolute gamma intensity, E_{ff} (E_λ) = absolute detector efficiency and m = sample mass (kg).

Results and Discussion

Activity concentration

From table 1, the activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the soil collected from E-waste site (E-waste dumpsite) ranged between 27.36 ± 4.32 $Bqkg^{-1}$ and 179.71 ±5.18$Bqkg^{-1}$, 6.43 ±1.10 $Bqkg^{-1}$ and 42.94±1.87 $Bqkg^{-1}$, and between 2.18 ±1.05 $Bqkg^{-1}$ and 34.48 ±1.42 $Bqkg^{-1}$ respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 87.26 ±25.08 $Bqkg^{-1}$, 19.70 ±0.21 $Bqkg^{-1}$, and 17.32 ±12.86 $Bqkg^{-1}$ respectively as shown in table 1. The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the soil collected from Gbagi Dumpsite ranged between 297.91±6.18 $Bqkg^{-1}$ and 1026.17±9.42 $Bqkg^{-1}$, 6.91±1.12 $Bqkg^{-1}$ and 39.61 ±1.79; and 25.60±1.36 $Bqkg^{-1}$ and 54.02 ±1.60 $Bqkg^{-1}$ respectively as shown in table 1. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 482.91±205.24 $Bqkg^{-1}$, 27.85±10.48 $Bqkg^{-1}$, 44.85 ±7.24 $Bqkg^{-1}$ respectively. The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil collected from Bodija Dumpsite ranged between 297.91 ±6.18 $Bqkg^{-1}$ and 494.49 ±7.18 $Bqkg^{-1}$, 25.61±1.54$Bqkg^{-1}$and 53.25 ± 2.0$Bqkg^{-1}$; and 45.58±1.48 $Bqkg^{-1}$and 64.02 ±1.68 $Bqkg^{-1}$respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 405.89 ±75.79 $Bqkg^{-1}$, 32.10±10.97 $Bqkg^{-1}$, and 48.46±7.29 $Bqkg^{-1}$. The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil from control reference point, outside e-waste dumpsite ranged between 187.64± 5.30 $Bqkg^{-1}$ and 177.81 ±5.43$Bqkg^{-1}$; 19.77±1.42 $Bqkg^{-1}$ and 27.64 ±1.58 $Bqkg^{-1}$; and 27.46 ± 1.32 $Bqkg^{-1}$ and 25.85±1.36 $Bqkg^{-1}$ respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 162.73 ±14.26 $Bqkg^{-1}$, 23.70±5.60 $Bqkg^{-1}$, and 25.18±0.99 $Bqkg^{-1}$ respectively (table 1 and figure 2). The average activity concentration at the E-waste Dumpsite and Control dumpsite, Lagos was below the world standard, while the activity average concentration of Bodija and Gbagi Dumpsite, Ibadan were slightly above the world standard. The activity concentration from the study area might be due to rock composition function of the sampling environment. Lagos is predominant of sedimentary rock while granitic rocks, know to consist higher concentration of radionuclide's, dominant most part of Ibadan. Table 2, compared the activity concentration of the e-waste dumpsite and municipal dump-site with values obtained from related studies of municipal dumpsites in Nigeria. The activities concentration obtained from the present study compared favorably with other published studies.

Determination of Radiation Hazard Indices

The radiation hazard level assessment to the inhabitant due to natural radionuclide from the e-waste and waste dumpsite, the following radiation hazard indices were used. The outdoor absorbed dose rate (D) resulting from gamma radiations in the air at 1 meters above the ground for the uniform distribution of the naturally occurring radionuclide (^{40}K, ^{226}Ra, and ^{232}Th) were calculated using equation (4) (UNSCEAR 2000).

$$D(nGy^{-1}) = 0.462C_{Ra} + 0.621C_{Th} + 0.0417C_k$$

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(4)

Where: C_{Ra}, C_{Th} and C_k are activity concentration for ^{40}K, ^{226}Ra, and ^{232}Th respectively. The mean absorbed dose rate for E-waste, Bodija, Gbagi and Control site is 21.12±8.51 nGy/h, 64.83 ±11.02, 60.43±7.41 nGy/h and 34.95±2.57 respectively. The soil from E-waste dumpsite has the least absorbed dose rate compared to that of the waste dumpsite and control sites. This is less than the world mean of 60 nGy/h as shown in Table 3. However, Bodija control site has the highest absorbed dose rate, higher than the world average.

The Radium Equivalent Index represents the activity levels of ^{40}k, ^{226}Ra, and ^{232}Th by a single quantity. It was calculated using equation (5) (UNSCEAR 2000).

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_k$$

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(5)

The following mean radium equivalent values were obtained: 46.23±19.55 Bq/kg for E-waste dumpsite, 129.83 ± 18.60 Bq/kg for Gbagi dumpsite, and 141.38±23.87 Bq/kg for Bodija dumpsite and 76.88 ±5.25 Bq/kg for control dumpsite. The soils from all dumpsites were below the world standard limit of 370 Bq/kg as shown in Table 3. Indicating that the soil from all the dumpsite as safe for use.

The Annual Effective Dose rate to the population due to activity concentration of natural radionuclide from the dumpsites, assist to assess the effectiveness of the gamma dose in causing damage to human tissue. It was calculated using equation (6) (UNSCEAR 2000).

$$\text{Eff. dose rate } (mSvyr^{-1})(mSvyr^{-1}) = D(nGyh^{-1}) \times 8760hyr^{-1} \times 0.7 \times \left(10^3\, mSv/10^9\, nGy\right) \times 0.2$$

$$E_{ff}Dose = D \times 1.2264 \times 10^{-3}$$

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(6)

The soil from E-waste dumpsite has the least Annual Effective Dose rate compared to other dumpsite. This is lower than the value of 1 mSv/yr as shown in Table 3. The Mean Annual Effective Dose rate from all the dumpsites were below the recommended limits.

The Representative level index (I_γ) was used to estimate gamma radiation associated with the natural radionuclide from the dumpsites. Representative level index (I_γ) was calculated using equation (7) (ICRP, 2000).

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{150} \leq 1$$

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{150} \leq 1$$

(7)

The Mean Representative level index (I_γ) for samples from E-waste dumpsites, Gbagi dumpsite, Bodija dumpsite and control were 0.33 ± 0.14, 0.96 ± 0.12, 1.03 ± 0.17 and 0.55 ± 0.04 respectively. The soil from E-waste dumpsite has the least Mean Representative level index (I_γ) compared to that of the other dump sites. The Mean Representative level index in all the dumpsites were lower than the standard limit of unity as shown in Table 2.

The External Hazard Index (H_{ex}) represents the external exposure and was calculated using equation (8) (UNSCEAR, 2000).

$$H_{ex} = \frac{C_{Ra}}{370} + C_{Th} = 259 + \frac{C_k}{4810}$$

$$H_{ex} = \frac{C_{Ra}}{370} + C_{Th} = 259 + \frac{C_k}{4810}$$

(8)

The Mean External Hazard Index was: 0.12± 0.06, 0.32 ± 0.04, 0.38 ± 0.06 and 0.21 ±0.01 for E-waste dumpsites, Gbagi dumpsite, Bodija dumpsite and control respectively.

The internal hazard index (H_{in}) measures the amount of internal exposure to radon and its offspring products. It was calculated using equation (9) (UNSCEAR, 2000).

$$H_{in} = \frac{C_{Ra}}{185} + C_{Th} = 259 + \frac{C_k}{4810}$$

$$H_{in} = \frac{C_{Ra}}{185} + C_{Th} = 259 + \frac{C_k}{4810}$$

(9)

The Mean External Hazard Index was 0.18 ± 0.06, 0.43 ± 0.06, 0.48 ± 0.09 and 0.27 ± 0.03 for E-waste dumpsites, Gbagi dumpsite, Bodija dumpsite and control respectively. The mean value of H_{ex} and H_{in} were less than world standard of unity. It is of no cause for concern but subsequence monitoring should be done at regular interval.

Conclusion

In soil samples obtained from e-waste and other municipal trash dumpsites in two major cities in Nigeria, the natural activity levels of ^{40}K, ^{226}Ra, and ^{232}Th were detected, using gamma ray spectrometer. The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th across E-waste dumpsite are: 87.26±25.08 $Bqkg^{-1}$, 19.70 ±0.21 $Bqkg^{-1}$, and 17.32 ± 12.86$Bqkg^{-1}$ respectively. The average activity concentration at the E-waste Dumps and Control dumpsite, Lagos were less than the global standard, while the activity average concentration of Bodija and Gbagi Dumpsite, Ibadan were slightly above the world standard. No artificial sources were detected in the soil samples. The soil taken from E-waste dumpsite has the least absorbed dose rate when compared to the waste dumpsite and control sites. This is less than the global mean of 60 nGy/h. The soil from E-waste dumpsite has the least Mean Representative level index (I_γ) compared to that of the other dump sites. The mean value of H_{ex} and H_{in} in the dumpsites samples were below the world standard of unity. Therefore, there is no immediate radiological hazard to the inhabitants from the level of natural radionuclide at e-waste disposal sites or other trash dump sites, but cautions should be taken against long term cumulative effect.

Authors Biography

Bello I. A.: Bello is an academician at Ahmadu Bello University, Zaria, Nigeria. His research focus is in nuclear radiation safety advisory, environmental radioactivity measurements, radiation protection and optimization of procedures in medicine and industry. He had published and reviewed several Journals related to environmental soil radioactivity. **Vatsa M. A**: is an academician at Ahmadu Bello University, Zaria, Nigeria. His research focus is in Radiation

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Authorship contribution statement

Bello I. A.: Conceptualization, Formal analysis, Resources, Writing , Editing. **Vatsa M. A.:** Data collection, formal analysis, supervision **Olowu E.:** Resources, Supervision, writing, and editing. **Ismail, W. O.:** Data collection and formal analysis. **Mohammed T. N.:** Supervision, writing, and editing.

Declaration of Interest

There is no conflict of interest related to this work.

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Fig 1.0: E-waste dumpsite in Lagos

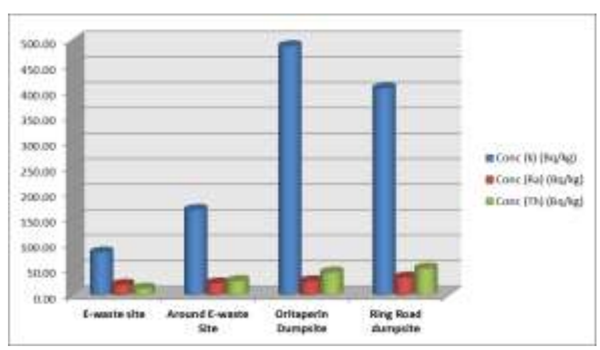

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Fig 2.0: Graph of Mean Activity Concentration of ^{40}K, ^{226}Ra and ^{232}Th across the four locations

Table 1: Mean Activity Concentrations of ^{40}K, ^{226}Ra and ^{232}Th across the four locations

Location	No. of Samples	Statistics	Activity Concentration (Bq/kg)		
			^{40}K	**^{226}Ra**	**^{232}Th**
E-waste Dumpsite (Lagos)	**25**	**Mean ± r**	**87.26 ± 25.08**	**19.70 ±0.21**	**17.32 ±12.86**
Gbagi Dumpsite (Ibadan)	**10**	**Mean ± r**	**482.91± 205.24**	**27.85±10.48**	**44.85 ±7.24**
Bodija dumpsite (Ibadan)	**10**	**Mean ± r**	**405.89 ±75.79**	**32.10±10.97**	**48.46±7.29**
Control (Lagos)	**5**	**Mean ± r**	**162.73 ±14.26**	**23.70±5.60**	**25.18±0.99**
World Standard (UNSCEAR 2000)			**400**	**32**	**30**

Table 2: Comparison of the activity concentration of ^{40}k, ^{226}Ra and ^{232}Th with related studies

Location	**Activity Concentration (Bq/kg)**			**Reference**
	^{40}K	**^{226}Ra**	**^{232}Th**	
E-waste (Lagos)	**87.26 ± 25.08**	**19.70 ±0.21**	**17.32 ±12.86**	**Present study**
Gbagi (Ibadan)	**482.91± 205.24**	**27.85±10.48**	**44.85 ±7.24**	**Present study**
Bodija (Ibadan)	**405.89 ±75.79**	**32.10±10.97**	**48.46±7.29**	**Present study**
Control (Lagos)	**162.73 ±14.26**	**23.70±5.60**	**25.18±0.99**	**Present study**
E-waste (Lagos)	**84.26 ± 28.08**	**20.70 ± 9.40**	**13.32 ± 12.86**	**Jibiri *et al*., 2014**
Owerri	**BDL-686.17**	**BDL-103.51**	**BDL-65.28**	**Emelue et al., 2013**
Akure	**180 ± 6**	**51 ± 6**	**34 ± 4**	**Faweya & Babalola, 2010**
Port Harcourt	**643.10 ± 5.94**	**41.96 ± 5.53**	**62.61 ± 18.97**	**Avwiri & Olatubosun, 2014**
World Standard	**400**	**32**	**30**	**UNSCEAR, 2000**