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Measurement of natural radioactivity concentration at E-waste dumpsite around Alaba international market Lagos, Nigeria

[1]*Bello I. A., [2]Najib M. U. [3]Umar S. A. and [4]Ibrahim G. G.

[1]Kabba College of Agriculture, Ahmadu Bello University, Zaria, Nigeria
[2]Nigerian Nuclear Regulatory Authority, North West Zonal Office, Kastina, Nigeria
[3]Department of Physics, Bauchi State University, Gadau, Nigeria
[4]Department of Physics, Federal College of Education (Technical), Potiskum, Nigeria

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ABSTRACT

Radiation exposure at e-waste dumpsite around Alaba International market, Lagos was assessed by gamma ray spectroscopy using a highly shielded Canberra NaI(Tl) detector. Twenty soil samples from the e-waste dumpsite were analyzed while a total of fifteen soil samples from control sites in Ibadan were equally analyzed. The mean value of ^{40}K, ^{226}Ra, and ^{232}Th concentrations for the soil samples were 84.26 ± 28.08 Bq/kg, 20.70 ± 0.21 Bq/kg, and 13.32 ± 12.86 Bq/kg respectively. The mean value of ^{40}K, ^{226}Ra, and ^{232}Th concentrations for soil samples from Oritaperin control dumpsite were 488.91 ± 217.24 Bq/kg, 27.93 ± 10.52 Bq/kg, and 44.93 ± 7.24 Bq/kg re spectively while that of Ring road control dumpsite were 405.89 ± 75.79 Bq/kg, 35.10 ± 10.97 Bq/kg, and 52.46 ± 7 .29 Bq/kg respectively. The mean values of ^{40}K, ^{226}Ra, and ^{232}Th obtained were below that from the control sites and also below world average values of 400 Bq/kg, 35 Bq/kg and 30 Bq/kg respectively as indicated by UNSCEAR. The mean Annual Effective Dose Rate obtained for soil samples from e-waste dumpsite, Oritaperin and Ring road control dumpsites were respectively 0.03mSv/yr, 0.07mSv/yr, and 0.01mSv/yr. These are all below the limit of unity. The mean absorbed dose rate of samples from e-waste dumpsite was 21.12nGy/hr which is lower than world average of 60nGy/hr. Values for other hazard indices were below the world average. Hence, e-waste does not pose any immediate radiological risk to the people working/living on the dumpsite, the international market and its environs. However, this work represents a baseline for future radiological evaluations in the environment due to radioactive contamination.

INTRODUCTION

The use of electronic devices has become so popular especially in this era of information technology (IT). 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 become a global village with people doing business and communicating with their loved ones, associates, partners and colleagues via telephones/mobile phones, internet, videoconferencing and the like. People relax by playing video games on PCs, watching television, satellites etc.

Two hundred and thirty million computers were sold globally in 2007 (Jakobsen, 2009). Oketola (2012) reports that the Nigerian Telecoms Industry capacity, according to Nigerian communication commission (NCC), increased from 158 million lines in January, 2011 to 173.3 million lines in December of same year – an alarming increase by 15.3 million lines in a short space of 12 months. Also, teledensity increased from 0.73% in 2001 to 64.17 % in January

2011 and up to 68.4% in December 2011. The above data gives an insight into the large number of mobile phones used in Nigeria. The rapid growth in IT has led to a continuing improvement in the capacity of computers but at the same time, a decrease in a product's lifetime, and this is not only the case for computers, but for all consumer electronic products (Osibanjo and Nnorom, 2007). Also, computer intended lifespan has dropped from 4 – 6 years in 1997 to 2 years in 2005 (Babu et al., 2009) and the life span of a mobile phone has decreased from 3 – 4 years to 18 months as at 2002 (Osibanjo et al., 2007).

These old, abandoned phones, computers and other electronic products finally end up as waste in dumpsites. They are called electronic waste (e-waste)! The United Nation Environment Program estimates that 20 – 50 million tons of e-waste is produced globally every year (Puckett et al., 2005) and the world is faced with new environmental challenges due to poor management of e-waste generated/imported by developing countries that seriously depend on second hand electronic devices. Nigeria's e-waste generation is by far the highest in all of West African countries (Andreas et al., 2011) and this is very alarming. However, what is more alarming is the volume of e-waste imported from Europe and America. It is estimated that 50 – 80% of all e-waste collected in U.S for recycling are not really recycled but exported to developing countries particularly in Asia and Africa (Electronics Takeback Coalition, 2010).

Five hundred containers of secondhand computer-related electronic equipment of various states of condition and age enter the country each month, most of which end up in Lagos. On average, each container contains about 800 computers and monitors, which amount to about 400,000 arriving each month or 5 million units a year (Puckett et al., 2005; Osibanjo and Nnorom, 2007). Kuper and Hojsik (2008) report that 25 – 75% of these secondhand products exported to Africa cannot be reused.

The dangers posed by this massive generation and importation of e-waste to human health and environment cannot be overemphasized considering the indiscriminate manner they are dumped, land filled and burnt in order to retrieve some vital parts of the waste. Health and safety concerns include: inhalation of toxic fumes (from Pb, Cd, Hg etc.), toner dust; injuries and cuts sustained from sharp waste fractions; contamination of soil and ground water and potential exposure to radiation from ashes, smoke and dust from the dumpsites. Since Nigeria has no data on the radiological status of our dumpsites, no routine monitoring mechanism to check radiation levels in e-waste sites and has no effective regulation on the importation of e-waste into the country, it is necessary to carry out this research work to forestall the possibility of a radiation accident as experienced in Mayapuri- India (The Times of India, 2010; New York Times, 2010) and some parts of the world.

Alaba international market in Ojo local government area of Lagos state is the largest electronics market in West Africa. It is envisaged that data collected via this research will help government to update the data on e-waste in Nigeria and will form a baseline data of natural radioactivity in Alaba e-waste dumpsite. This may equally help government to enact laws and implement radiation safety policy and standards for Alaba e-waste generation, importation and management. However, the objectives of this work are as follows:

1. To measure the natural radioactivity levels of soil samples from the e-waste dumpsite;
2. To determine the following hazard indices: Radium Equivalent activities (Ra_{eq}), internal and external hazard indices (H_{in} and H_{ex}), absorbed dose rate (D), representative level index (I_{γ}) and effective dose rate of the collected samples; and
3. To compare the natural radioactivity concentration of soil from e-waste site with soil from non – e-waste sites

MATERIALS AND METHODS

2.1. Study Area

Lagos state lies within latitude 6^{o} and 35^{o}N and longitude 3^{o} and 45^{o}E, with population of about 17,553,924. It covers an area of approximately 3,475.1km^2. Lagos state is divided into five administrative divisions which are further divided into 16 local government areas one of which is Ojo local government area - a host to Alaba international market (the study area). Alaba international market is the largest electronics market in West Africa. It was founded in 1978 and occupies a land area of approximately 2 km^2 in the southwest of Lagos. The market features more than 2,500 shops doing refurbishing and offering used electrical and electronic products for sale. Most of these devices are imported second-hand products which include electronics products from communications, broadcasting, computers, televisions, videos, home appliances, refrigerators, video games to generators, satellite

systems, general goods etc. These are available to buyers from as far as Ghana, Niger, Chad, Togo, Benin Republic, etc.

A major dumpsite (about 70m^2 in size) is located outside the market where e-waste collectors, refurbishers and recyclers work and indulge in burning and other crude recycling practices at the dumpsites without care for their health or environment, in an attempt to recover some useful parts/scrap from e-waste. Make shift structures are also erected on the site for accommodation (figures 1 and 2).

Fig 1: Alaba e-waste dumpsite in Lagos

Fig 2: Make Shift structures built for accommodation on Alaba E-waste dumpsite

2.2. Geology of Ojo L.G.A

The geological setting of the study area reveals that it lies solely within the extensive Dahomey basin, the basin extending almost from Accra to Lagos. The area is a sedimentary basin whose thickness increases from north to south (down dip) and from east to west. The littoral and lagoon deposit of recent sediment underlies the area. The coastal belt varies from about 8km near the Republic of Benin border to 24 km towards the eastern end of the Lagos Lagoon (Nton, M.E, 2001). More also, the area consist of sediment of clay, unconsolidated sands and mud with a varying proportion of vegetable matter along the coastal areas while the alluvial deposit consists of coarse claying unsorted sand with clay lenses and occasional pebble beds.

2.3. Sample Collection and Preparation

At the Alaba dumpsite, five samples each were collected from the four cardinal points at about 1m distance and at a depth of about 10 cm. The total soil samples collected at the e-waste dumpsite was twenty (Figure 2). Also, a total of fifteen samples were collected at Oritaperin and Ring Road control dumpsites in Ibadan. A Digital gamma Survey meter (RAD EYE PRD) was first used to take the environmental radiation exposure of the sampling locations while a Global Positioning System (Etrex Vista) was used to determine the longitude and latitude of each sampling location.

The soil samples were separately collected with a clean steel hoe and packed in black polythene bags, labeled, and safely conveyed to Radiation and Health Physics laboratory of Physics Department of the University of Ibadan. At the laboratory, they were sun dried to attain dry weight, pulverized, and sieved using a 2mm mesh sieve. Two hundred grams (200g) of each sample was subsequently measured using an electronic balance and packed in plastic containers of diameter 6.6cm of similar dimension to the NaI (Tl) detector used for the measurements. The samples were tightly covered and sealed with masking tape and allowed to stay for 30 days in order to attain secular equilibrium between Radium and its gaseous decay progenies.

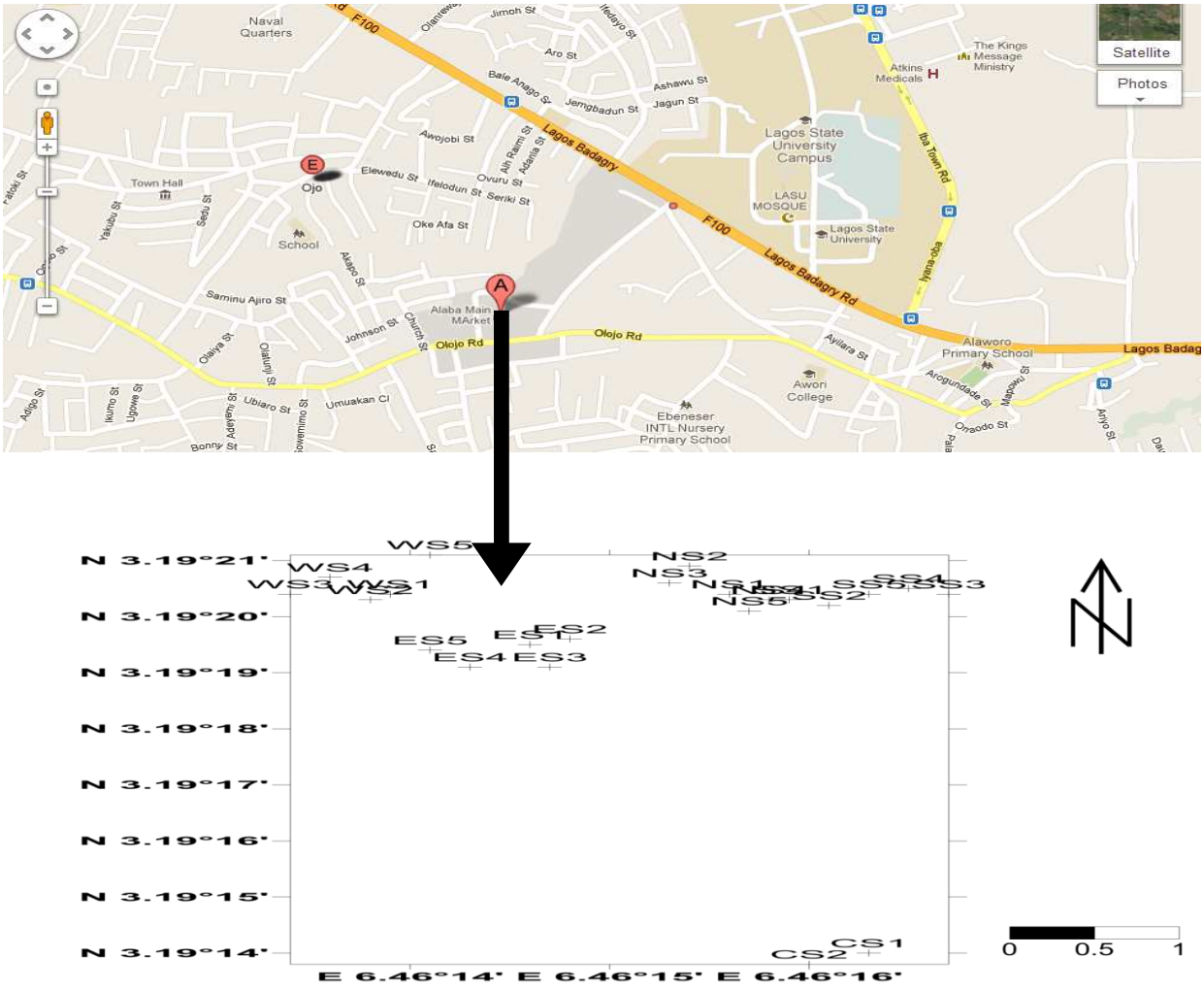

Fig 3: Aerial view of Ojo L.G.A Showing Alaba international market and Sample Collection points

2.4. Measurement

Calibrating the detector system is important so as to identify and quantify the radionuclide present in a sample. The energy calibration was carried out using International Atomic Energy Agency (IAEA) reference source material and using the energy calibration (ECAL) analysis function of the Multi-Channel Analyzer (MCA) to fit the data which

gave a linear graph. The linear relationship obtained between the channel number (N) and the γ-energy (E) in MeV is represented by the equation below:

$$E(Mev) = 1.83 \times 10^{-2}N + 0.36 \quad (2.0)$$

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

$$E_p = \frac{C}{A\gamma mt} \quad (2.1)$$

Where E_p is the detection efficiency, C is the net count above the background after counting a reference sample of known activity A ($Bq.kg^{-1}$), m is the mass (kg) for a time, t (s) and γ is the gamma yield.

Each sample was counted for 36,000 seconds 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 photo peak of ^{209}Th and Potassium content from the 1.460 MeV photo peak of ^{40}K decay.

The activity concentrations of the samples were determined using the net counts after correcting for background and Compton contribution. The activity concentrations of ^{232}Th, ^{226}Ra and ^{40}K were obtained using:

$$A_C = \frac{C_{net}}{I_\lambda \times E_{ff}(E_\lambda) \times m} \quad (2.2)$$

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

RESULTS AND DISCUSSION

3.1.1 Activity concentration in soil samples from E-waste site

The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil collected from E-waste site (Alaba E-waste dumpsite) ranged between 27.36 ± 4.35 $Bqkg^{-1}$ and 139.71 ± 5.18 $Bqkg^{-1}$, 6.43 ± 1.10 $Bqkg^{-1}$ and 42.94 ± 1.84 $Bqkg^{-1}$, and between 2.15 ± 1.05 $Bqkg^{-1}$ and 34.52 ± 1.42 $Bqkg^{-1}$ respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 84.26 ± 28.08 $Bqkg^{-1}$, 20.70 ± 0.21 $Bqkg^{-1}$, and 13.32 ± 12.86 $Bqkg^{-1}$ respectively. See table 1 and figure 4.

3.1.2. Activity concentration in soil samples outside E-waste site

The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil outside e-waste dumpsite ranged between 157.64 ± 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 ± 1.35 $Bqkg^{-1}$ and 28.85 ± 1.36 $Bqkg^{-1}$ respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 167.73 ± 14.26 $Bqkg^{-1}$, 23.70 ± 5.60 $Bqkg^{-1}$, and 28.15 ± 0.99 $Bqkg^{-1}$ respectively. See table 1 and figure 4.

3.1.3 Activity concentration in soil samples from Oritaperin dumpsite

The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil collected from Control site I (Oritaperin Dumpsite) ranged between 297.91 ± 6.15 $Bqkg^{-1}$ and 1026.17 ± 9.42 $Bqkg^{-1}$, 6.91 ± 1.12 $Bqkg^{-1}$ and 39.61 ± 1.79; and 28.60 ± 1.36 $Bqkg^{-1}$ and 54.02 ± 1.60 $Bqkg^{-1}$ respectively. However, the average values for ^{40}k, ^{226}Ra, and ^{232}Th from this site are: 488.91 ± 217.24 $Bqkg^{-1}$, 27.93 ± 10.52 $Bqkg^{-1}$, 44.93 ± 7.24 $Bqkg^{-1}$ respectively. See table 1 and figure 4.

3.1.4 Activity concentration in soil samples from Ring road dumpsite

The activity concentration of ^{40}k, ^{226}Ra and ^{232}Th, in the Soil collected from Control site II (Ring road Dumpsite) ranged between 297.91 ± 6.15 $Bqkg^{-1}$ and 494.49 ± 7.18 $Bqkg^{-1}$, 25.61 ± 1.54 $Bqkg^{-1}$ and 53.25 ± 2.0 $Bqkg^{-1}$; and 45.58 ± 1.52 $Bqkg^{-1}$ 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}, 35.10 ± 10.97 Bqkg^{-1}, and 52.46 ± 7.29 Bqkg^{-1} respectively. See table 1 and figure 4.

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

Location	Activity Concentration (k) (Bq/kg)	Activity Concentration (Ra) (Bq/kg)	Activity Concentration (Th) (Bq/kg)
E-waste Dumpsite	84.26	20.70	13.32
Around E-waste Site	167.73	23.70	28.15
Oritaperin Dumpsite (Control)	488.91	27.93	44.93
Ring Road dumpsite (Control)	405.89	35.10	52.46

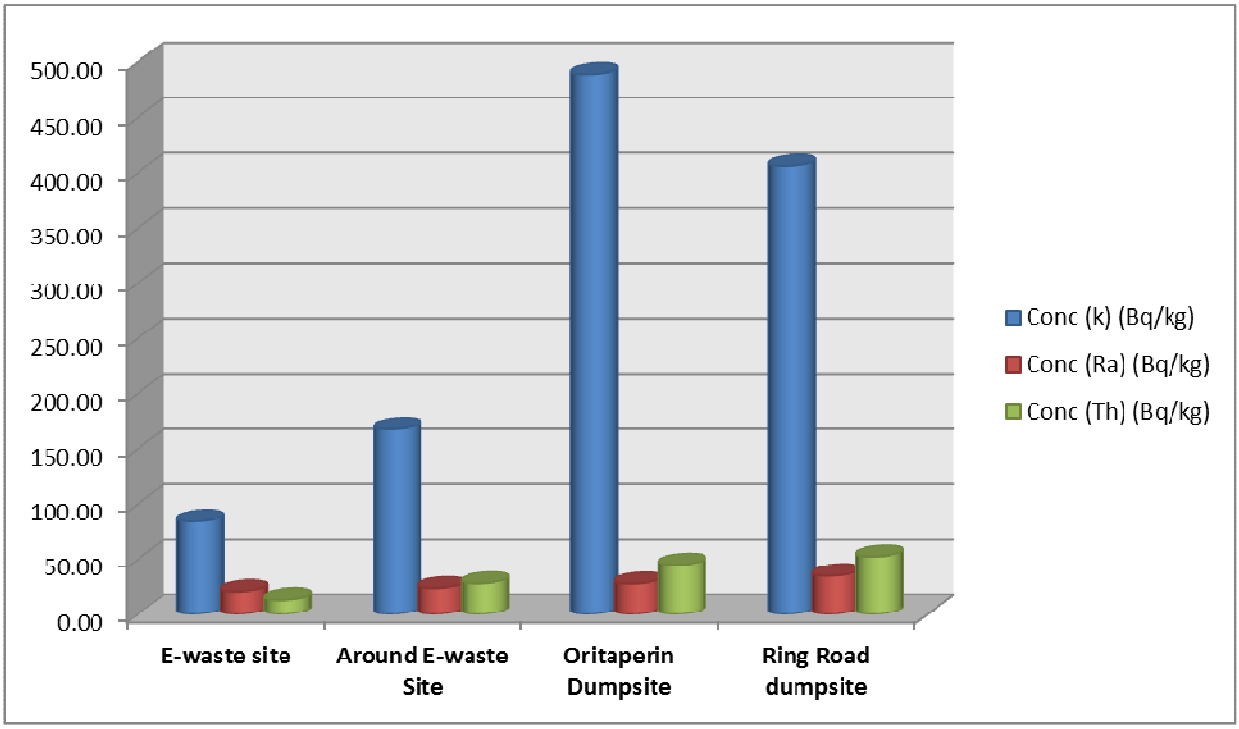

Fig 4: Graph of Mean Activity Concentration of ^{40}K, ^{226}Ra and ^{232}Th across the four locations

3.2. Determination of Radiation Hazard Indices

3.2.1 Absorbed Dose Rate

The absorbed dose rate of the samples were calculated using equation (1) below as provided by UNSCEAR 2000. The following were the average values obtained for the samples: 21.12 ± 8.51nGy/h for Soil from E-waste dumpsite, 34.95 ± 2.57nGy/h for soil outside e-waste dumpsite, 60.43 ± 7.41nGy/h for Oritaperin control site, and 64.83 ± 11.02nGy/h for Ring road control site

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

The soil from E-waste dumpsite has the least absorbed dose rate compared to that of the control sites. This is lower than the world average of 60nGy/h given by UNSCEAR 2000. However, Ring road control site has the highest absorbed dose rate, higher than the world average.

3.2.2 Radium Equivalent Index

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 (2) below as provided by UNSCEAR 2000. The following were the average values obtained for the samples: 46.23 ± 19.55Bq/kg for Soil from E-waste dumpsite, 76.88 ± 5.25Bq/kg for soil outside e-

waste dumpsite, 129.83 ± 15.60 Bq/kg for Oritaperin control site, and 141.38 ± 23.84Bq/kg for Ring road control site.

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_k \quad (2)$$

The soil from E-waste dumpsite has the least Radium Equivalent Index compared to that of the control sites. This is within the limits of world background soil standard (i.e. ≤370 Bq/kg) given

3.2.3 Annual Effective Dose rate

The Annual Effective Dose rate in air helps in assessing the effectiveness of the gamma dose in causing damage to human tissue. It was calculated using equation (3) below as provided by UNSCEAR 2000. The following were the average values obtained for the samples: 0.026 ± 0.01mSv/yr for Soil from E-waste dumpsite, 0.04mSv/yr for soil outside e-waste dumpsite, 0.07 ± 0.01mSv/yr for Oritaperin control site, and 0.08 ± 0.01mSv/yr for Ring road control site.

Effective dose rate $(mSvyr^{-1})$

$$= D(nGyh^{-1}) \times 8760hyr^{-1} \times 0.7 \times \left(103\,{}^{mSv}/_{10^9}\right) nGy \times o.2$$

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

The soil from E-waste dumpsite has the least Annual Effective Dose rate compared to that of the control sites. This is lower than the value of 2.5mSv/yr recommended by UNSCEAR 2000. However, Ring road control site has the highest Annual Effective Dose rate but within recommended limits.

3.2.4 Representative level index (I_γ)

The Representative level index (I_γ) of the samples were calculated using equation (4) and the following were the average values obtained for the samples: 0.33 ± 0.14 for Soil from E-waste dumpsite, 0.55 ± 0.04 for soil outside e-waste dumpsite, 0.96 ± 0.12 for Oritaperin control site, and 1.03 ± 0.17 for Ring road control site.

$$I_\gamma = \frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_k}{150} \leq 1 \quad (4)$$

The soil from E-waste dumpsite has the least Representative level index (I_γ) compared to that of the control sites. This is lower than the standard limit of unity. However, Ring road control site has the highest Representative level index (I_γ) which is above the limit of 1.

3.2.5 External Hazard Index

The External Hazard Index (H_{ex}) represents the external exposure and was calculated using equation (5) as provided by (UNSCEAR, 2000). The following were the average values obtained for the samples: 0.12 ± 0.06 for Soil from E-waste dumpsite, 0.21 ± 0.01 for soil outside e-waste dumpsite, 0.35 ± 0.04 for Oritaperin control site, and 0.38 ± 0.06 for Ring road control site.

$$H_{ex} = \frac{C_{Ra}}{370} + C_{Th} = 259 + \frac{C_k}{4810} \quad (5)$$

The soil from E-waste dumpsite has the least External Hazard Index compared to that of the control sites. This is lower than the standard limit of unity. However, Ring road control site has the highest External Hazard Index which is equally below the limit of 1.

3.2.6 Internal Hazard Index

Internal exposure to radon and its daughter products is quantified by the internal hazard index (H_{in}). It was calculated using equation (6) and the following were the average values obtained for the samples: 0.18 ± 0.06 for Soil from E-waste dumpsite, 0.27 ± 0.03 for soil outside e-waste dumpsite, 0.43 ± 0.06 for Oritaperin control site, and 0.48 ± 0.09 for Ring road control site.

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

The soil from E-waste dumpsite has the least Internal Hazard Index compared to that of the control sites. This is lower than the standard limit of unity. However, Ring road control site has the highest Internal Hazard Index which is equally below the limit of 1.

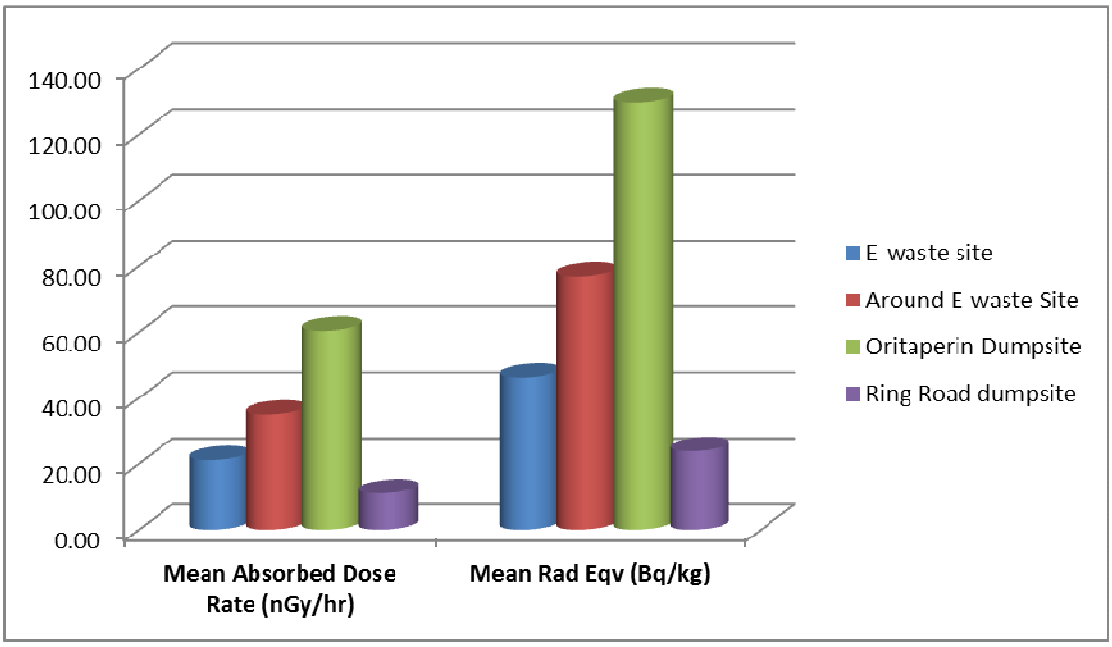

Fig 5: Graph of Mean Absorbed Dose Rate and Radium Equivalent activity

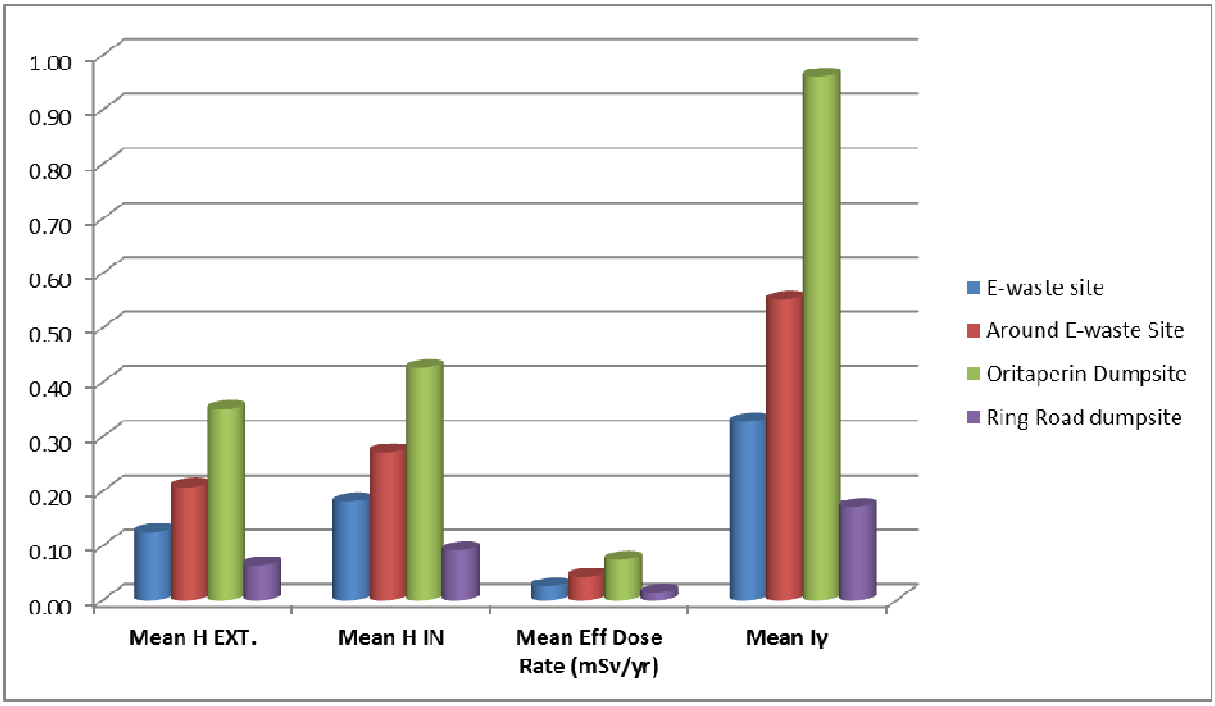

Fig 6: Mean of External Hazard index (H_{ex}), Internal Hazard index (H_{in}), Effective Dose rate and Representative level index (I_γ)

Table 2: Mean of Radiation hazard indices for the four locations

Location	Mean Absorbed Dose Rate (nGy/hr)	Mean Rad Eqv (Bq/kg)	Mean H_{ex}	Mean H_{in}	Mean Eff Dose Rate (mSv/yr)	Mean I_{γ}
E-waste Dumpsite	21.12 ± 8.51	46.23 ± 19.55	0.12 ± 0.05	0.18 ± 0.06	0.03 ± 0.01	0.33 ± 0.01
Around E-waste Site	34.95 ± 2.57	76.88 ± 5.25	0.21 ± 0.01	0.27 ± 0.03	0.05 ± 0.02	0.55 ± 0.04
Oritaperin Dumpsite (Control)	60.43 ± 7.41	129.83 ± 15.60	0.35 ± 0.04	0.43 ± 0.06	0.07 ± 0.01	0.96 ± 0.12
Ring Road dumpsite (Control)	64.83 ± 11.02	141.38 ± 23.84	0.38 ± 0.06	0.48 ± 0.09	0.08 ± 0.01	1.03 ± 0.17

CONCLUSION

In view of the environmental threats posed by e-waste around the globe and in Nigeria in particular, the activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in soil samples from Alaba E-waste dumpsite was carried out using gamma ray spectrometer NaI(Tl) detector. The mean activity concentration of ^{40}K, ^{226}Ra and ^{232}Th across Alaba E-waste dumpsite are: 84.26 ± 28.08 $Bqkg^{-1}$, 20.70 ± 0.21 $Bqkg^{-1}$, and 13.32 ± 12.86 $Bqkg^{-1}$ respectively. These are below the values obtained from the control sites and equally below the world average. The radiation hazard indices were below world average. Also, no artificial sources were found in any of the samples. So, e-waste and recycling activities on Alaba e-waste dumpsite does not pose any immediate radiological risk to the people working/living on the dumpsite, the international market and its environs.

Radiation emissions from e-waste dumpsites are still due to natural radionuclides. This suffices to say that this work represents a baseline for future radiological evaluations in the environment due to radioactive contamination.

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