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Evaluation of Radionuclides in Eliozu Dumpsite, Obio-Akpor L.G.A. South-South Nigeria

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ABSTRACT

This research investigated the presence of radionuclides (40K, 238U and 232Th) in the dumpsite soil and groundwater around Eliozu dumpsite. The work was aimed at assessing possible radiation from heterogeneous waste disposed at the dumpsite. Five samples of water and soil were collected and tested with NaI (TI) detector gamma spectrometric device ^{40}K, ^{238}U and ^{232}Th radionuclides. The results showed that specific activity for ^{40}K ranges from 242.36 ± 2.94 Bq/kg to 501.97 ± 2.93 Bq/kg with an average value of 368.25 ± 3.46 Bq/kg, ^{238}U ranges from 18.41 ± 2.47 Bq/kg to 34.53 ± 3.08 Bq/kg with an average activity of 24.06 ± 2.82 Bq/kg, while ^{232}Th ranges from 21.89 ± 5.53 Bq/kg to 43.14 ± 3.12 Bq/kg with an average activity of 30.45 ± 5.77 Bq/kg for soil samples. For water samples, ^{40}K ranges from 19.47 ± 9.48 Bq/L to 33.12 ± 2.73 Bq/L with an average activity of 24.77 ± 8.30 Bq/L, ^{238}U ranges from 7.32 ± 1.82 Bq/L to 9.94 ± 3.14 Bq/L with an average activity of 7.92 ± 2.7 Bq/L while ^{232}Th ranges from 3.61 ± 1.43 Bq/L to 8.92 ± 1.09 Bq/L with an average activity of 6.96 ± 2.4 Bq/L. The absorbed dose rate and equivalent dose rate for soil samples were 46.08 ± 5.18 nGy/hr and 0.40 ± 0.0.04 mSv/yr while that for the water samples were 9.76 ± 3.76 nGy/hr and 0.09 ± 0.03 mSv/yr respectively. The results were within the permissible limits of ICRP and UNSCEAR showing that the radiation poses no radiological hazard to the environment. However, conscious effort must be made to curb indiscriminate disposal of waste at the dumpsite as the amount of radiation being emitted by radionuclides has increased compared to the study carried out at same geographical location by previous research.

Keywords: Radionuclide concentration, specific activity, absorbed dose rate, equivalent dose rate, dumpsite

INTRODUCTION

Background of the Study

Olubosede *et al.* (2012) stated that wastes constitute an environmental and public health nuisance in major cities all over the world. The disposal of waste indiscriminately exposes the environment and its inhabitants to different forms of hazards. Presence of disease causing organisms and odour are not the only hazard posed by waste dumpsites, they can result in radiation emanating from these dumpsites. Contamination of land and water can also occur from deposition of waste materials without adequate treatment to meet permissible limits at which they will not constitute danger to the populace. In Nigeria, there exist waste dumpsites all over the nation which are without adequate soil protection measures. In many cases, this practice does result in the pollution of the soil and groundwater respectively. The various types of waste generated by human activities are of varying hazardous effects ranging from relatively innocuous

substances to toxic substances including high level (radioactive) waste which contains harmful substances that pose great hazardous effect to the environment and its inhabitants. It has been established that vegetation and environmental fields in Nigeria contain traces of radionuclides (Akinloye and Olomo, 2005). All these, are contained in the domestic waste which are indiscriminately dumped on open fields (Ojoawo *et.al*, 2011), farms soils (Jibiri *et al.*, 2011), Quarry sites (Odunaike *et al.*, 2008), rivers (Farai and Oni, 2002), well and boreholes (Jibiri *et al.*, 2010), industries (Iyang *et al.*, 2009) and even on road sides and mechanic workshops (Nworgu *et al.*, 2011). Farai *et al.*, (2007) stated that waste disposal by landfill has led to the pollution of the environmental resource such as water, land and air thus; landfills are liable recipient of any such failure in the containment of radioactive materials.

Nuclear radiation has become a huge public concern all over the world, even though nuclear radiation is an inevitable part of our natural environment (Rashid-Nizam *et al.*, 2014). The deleterious radiological health hazards posed by human activities, especially in the production of energy, research, medical application of nuclear facilities as well as oil and gas extraction and production have attracted great concern and tremendous interest over the years in the field of radiation protection (Arogunjo *et al.*, 2004).

Radioactive Pollution

There is nowhere on Earth that you cannot find natural radioactivity (Brodsky, 1978). Alausa Shamsideen (2014) stated that radioactivity occurs when unstable nuclei spontaneously disintegrate by emitting nuclear particles and energy in order to attain stability. During radioactivity, heavy charged α-particles (He^{++}) and the light β-particles (e^{+} or e^{-}) together with neutral and much lighter particles called neutrinos are emitted. The sources of this radiation include natural or anthropogenic sources and terrestrial sources (primordial radionuclides) or extraterrestrial sources (cosmic rays) which according to UNSCEAR (1993; 2000), naturally occurring radioactive materials (NORMS) are acknowledged as the largest sources of exposure to human health. Radiation exposure received by individuals in the environment from the primordial sources is known to constitute about 85% of the natural background radiation (IAEA, 1996; Obed *et al.*, 2005; UNSCEAR, 2000).

Our natural environment is continuously bombarded with ionizing radiations from both natural and man-made sources of ionizing radiation (Ademola, 2008; Chad-Umoren, 2012). Radioactive isotopes of the three natural decay series (^{235}U, ^{238}U, and ^{232}Th) and K-40 are the most common radionuclides found in groundwater and soil. Natural sources of radiation constitute almost 80% of the collective radiation exposure of the World's population (UNSCEAR, 2000). Human beings are exposed naturally due to sources outside their bodies, mainly cosmic ray and gamma ray emitters in soil, water, food and air, etc (Agbalagba et al, 2012). The most common radionuclides and some important parameters are shown on table 1.

Table 1: Overview of most important radionuclides with some important parameters.

Radionuclides	Type of Radiation	Half life	Energy (MeV)
^{40}K	β	1.28×10^{9} yrs	1.40
The Uranium Series			
^{238}U	α	4.48×10^{9} yrs	4.20
^{226}Ra	α	1600 yrs	4.80
^{210}Pb	β	22.3 yrs	<0.10
^{210}Pb	α	138 days	5.30
The Thorium Series			
^{232}Th	α	1.41×10^{10} yrs	4.00
^{228}Ra	β	5.75 yrs	<0.10

Source: Norse, (2006)

The Study Area

The study area lies between latitude $4^{0}50^{1}N$ - $4^{0}56^{1}N$ and longitude $6^{0}58^{1}E$ -

$7^{0}02^{1}$E. The study area is within the Port Harcourt municipal area of Rivers State as shown in Fig.1.The state has one of the largest economies in Nigeria, mainly because of its crude oil potential. It has two major refineries, two major seaports, an airport, and various industrial estates spread across it. Mineral contents of the study area are petroleum, natural gas, silica sand, glass and clay. Eliozu Dumpsite is located within Obio-Akpor Local Government Area within Port Harcourt. The dumpsite contains mixed waste of different sorts, ranging from chemical toxic wastes, hazardous industrial wastes, medical wastes, metal scraps and other debris. This dumpsite that has existed for a long period of time has been a concern to the populace around which it is situated as the hazard that it constitutes to the environment cannot be overlooked. The odour, unpleasant site, host to disease causing organisms, contamination of soil and underground water are some but few of the problems it poses to the environment and its inhabitants. As already stated, the main source of gamma exposure for the observed population is naturally occurring radionuclides, especially ^{40}K, which s found in soil, water, meats and high-potassium foods like banana and Eliozu Dumpsite contains a large amount of these types of wastes. As a result of this, it is necessary to assess the amount of radioactive pollution that is posed to the soil, water and even the populace situated around the dumpsite due to the occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) present in the dumpsite.

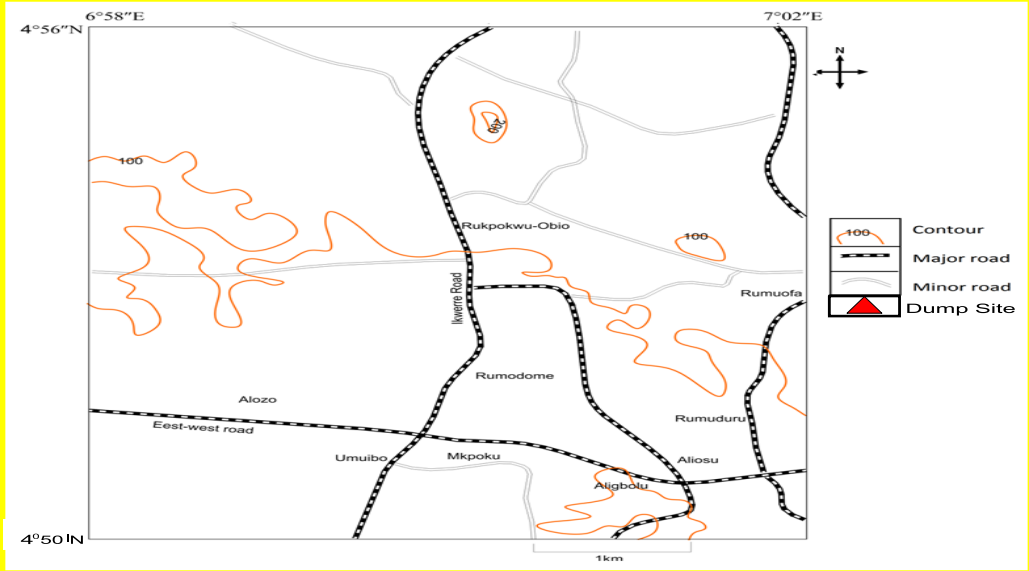

Fig.1: Accessibility Map of the Study Area Showing the Dump Site, Soil and Water Sample Collection Site

Aim of the Study

The aim of this research is to determine the specific activity and radionuclide doses of the occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) in soils and water from the dumpsite and the absorbed dose rates and equivalent human dose rates in the dumpsite.

LITERATURE REVIEW

Umar *et al.*, (2012) carried out a study that involved measuring natural radioactivity in environmental samples (soil, vegetation and water) from the (Idu) industrial district of Federal Capital Territory (FCT) Abuja, Nigeria using gamma-ray spectrometer with NaI (Tl) detector to establish a baseline data for activity concentration of ^{40}K, ^{226}Ra and ^{232}Th. Results from the twelve field samples analysed indicated that the activity concentration due to ^{40}K in the soil samples ranked highest against the lowest value obtained for sediments in the water samples. The work of Jibiri *et al.*, (2007) showed that staple food stuffs consumed in some parts of

Nigeria contain traces of radionuclides due to anthropogenic activities in the study area. Chad-Umoren and Umoh, (2012) carried out a research on baseline radionuclide distribution patterns in soil and radiation hazard indices for Abak, Nigeria. The results showed that naturally occurring radionuclides ^{226}Ra, ^{232}Th and ^{40}K were found present in the samples with 40K being in highest concentration. The hazard posed was much lower than the ICRP permissible limits for soil showing that the soil of the study area poses no radiological threats to the public.

Agbalaba *et al.*, (2012) analysed the natural radioactivity levels and estimated the hazard indices, radium equivalent activities, representative level index, external and internal hazard index, absorbed dose rate and the effective dose rate in soil and sediment of ten oil and gas field in Delta state using gamma-ray spectroscopy. Results shows that the activity levels of the radionuclides showed enhanced activity concentrations across the area under study. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were found to be 41.0 ± 5.0, 29.0 ± 4.0 and 412.5 ± 20.0 Bq/kg respectively. The values obtained for ^{226}Ra and ^{40}K was slightly higher than the world average. A study was undertaken to measure the ionizing radiation distribution in Rivers state (Chad-Umoren and Briggs Kamara, 2010). In the study, Rivers State was divided into three sub environments - an upland college campus environment, a rural riverine environment and an industrial zone environment. The values obtained for the industrial zone were all higher than the CERN recommended value of 1.0mSv/yr for the general population who are not engaged in nuclear radiation related occupations, while the values for the other two environments were within CERN standard. This conclusion was attributed to several factors including the higher concentration of oil operations and establishment in the industrial zone.

A study by Avwiri (2012) was carried out to determine some radiological parameters and radiation health hazard for Ogulogu-Olo, in Ezeagu Local Government Area and Amagu-Umuene, in Udi Local Government Area of Enugu State, south-east Nigeria. The three natural radionuclides (^{40}K, ^{226}Ra and ^{232}Th) were found in the two boreholes that were studied. However their concentrations were below the respective world average values (UNSCEAR, 2000) and the hazard indices was less than the permissible value of one (Oregun *et al.*, 2007). Also, Alausa Shamsideen (2014) assessed radiological study of soils on the waysides of the road under construction in Ijebu-Ode, Ogun State, South western Nigeria. Results revealed that the activity concentrations in the entire area of study were 396.1 ± 70.9 Bqkg^{-1}, 17.7 ± 4.6 Bqkg^{-1}, and 33.9 ± 6.7 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively. The absorbed dose rate and the outdoor effective dose rate were 27.6 ± 5.5 nGyh^{-1} and 33.9 ± 6.7μSvy^{-1} respectively. The collective health detriment was 1.1 x 10^{-4}. The radiological health effect on the populace in the area were insignificant as the results showed very low radioactivity levels and collective health detriment indicated that 11 out of 100,000 people were vulnerable to any type of cancer.

MATERIALS AND METHODS

Sampling

Five soil samples of soil and water were collected from different locations for the radiometric study. The bulk soil samples were collected at varying distances from the dumpsite location in waste covered level areas and in remote locations from man-made structures such as roads and buildings to prevent any external influence on the results. Each soil sample with weight of 0.5kg was collected sporadically from an area of approximately 80m^2 and up to 0.25m to 0.50m. The samples were collected in polythene bags, labelled with paper tapes to avoid wrong sampling and then transported

to the laboratory for analysis. The water samples taken from the dumpsite at varying distances from its location included water, leachates and well water were collected from landfill and houses in the surrounding area of the dumpsite. The loss of radon is avoided by precautionary measures in the laboratory and equilibrium was established before gamma-ray spectrometric analysis was done. Also, water samples were acidified with 9M HCL at the rate of 0.8ml per litre of sample to avoid adsorption of radionuclide on the walls of the container.

Gamma-ray Spectrometry

The gamma-ray detector was set vertically and connected to the Multi-Channel Analyzer (MCA). The detector was enclosed in a large lead shield to protect the environment from exposure and reduce background radiation of the system. The reference materials used for calibration of the system were Uranium ore (RG U-1) and Thorium ore (RG Th-1) which are of IAEA standards and KCl powder of known radioactivity. The gamma-ray spectrometer was initially calibrated to a certain range of energy and efficiency which is from 59.5KeV to 2.8MeV. Each sample was counted in isolation for about 1600 seconds (1.1 hours) with the aim of reducing or avoiding statistical uncertainty. The lowest level of measurable was determined from the background radiation spectrum.

The spectrum activity concentrations Ac_k, Ac_u and Ac_{Th} for ^{40}K, ^{238}U and ^{232}Th respectively were computed using the relation (Beck *et al.*, 1972);

$$Ac = \frac{SAc(s) \times m(s)}{Asm}$$

Where Ac = radioactivity level of sample; A = full peak area of samples; SAc(s) = radioactivity concentration level of standard sample; m(s) = mass of standard sample.

The Absorbed Dose Rate, D (nGy/hr), above the ground surface as a result of concentrations of 40K, 238U and 232Th in the soil in all sampling locations was calculated using the Beck *et al.*, (1972) relation as follows;

$$D = 0.042Ac_k + 0.429Ac_u + 0.666Ac_{Th}$$

Where Ac_k = activity concentration of ^{40}K; Ac_u = activity concentration of ^{238}U; Ac_{Th} = activity concentration of ^{232}Th.

The Equivalent Dose Rate (mSv/yr) was determined using the correlation; 1 nGy/hr = 0.00876581277 mSv/yr.

RESULTS AND DISCUSSIONS

The results of the analysis are shown table 2 and table 3;

Table 2: Activity Concentration of Radionuclides in Soil samples and Permissible limits

Soil samples (Bq/kg)						
Sample Name	**^{40}K**	**^{238}U**	**^{232}Th**	**Absorbed Dose Rate (nGy/hr)**	**Equivalent Dose Rate (mSv/yr)**	**Permissible Dose Rate (mSv/yr)**
S1	501.97 ± 2.94	34.53 ± 3.08	43.41 ± 3.12	64.87 ± 3.52	0.57 ± 0.03	1.0 ± 0.21
S2	411.23 ± 3.21	22.35 ± 2.79	21.89 ± 5.53	41.44 ± 5.01	0.36 ± 0.04	1.0 ± 0.21
S3	361.74 ± 4.48	25.13 ± 3.25	41.10 ± 9.23	53.35 ± 7.73	0.47 ± 0.07	1.0 ± 0.21
S4	323.94 ± 3.75	19.86 ± 2.49	22.54 ± 3.87	37.14 ± 3.80	0.33 ± 0.03	1.0 ± 0.21
S5	242.36 ± 2.94	18.41 ± 2.47	23.29 ± 7.08	33.59 ± 5.86	0.29 ± 0.05	1.0 ± 0.21
Average Value	368.25 ± 3.46	24.06 ± 2.82	30.45 ± 5.77	46.08 ± 5.18	0.40 ± 0.04	1.0 ± 0.21

Table 3: Activity Concentration of Radionuclides in Water samples and Permissible limits

Water samples (Bq/L)						
Sample Name	**^{40}K**	**^{238}U**	**^{232}Th**	**Absorbed Dose Rate (nGy/hr)**	**Equivalent Dose Rate (mSv/yr)**	**Permissible Limit (mSv/yr)**
W1	33.12 ± 2.73	9.24 ± 2.10	8.54 ± 5.24	11.04 ± 4.50	0.10 ± 0.04	1.0 ± 0.21
W2	31.97 ± 7.11	12.41 ± 3.11	8.92 ± 1.09	12.61 ± 2.36	0.11 ± 0.02	1.0 ± 0.21
W3	28.35 ± 3.25	9.94 ± 3.14	6.14 ± 6.38	9.54 ± 5.73	0.08 ± 0.05	1.0 ± 0.21
W4	19.47 ± 9.48	7.32 ± 1.82	3.61 ± 1.43	6.36 ± 2.13	0.06 ± 0.02	1.0 ± 0.21
W5	24.58 ± 7.12	9.02 ± 2.54	6.51 ± 4.08	9.23 ± 4.11	0.08 ± 0.04	1.0 ± 0.21
Average Value	24.77 ± 8.3	7.92 ± 2.7	6.96 ± 2.4	9.76 ± 3.76	0.09 ± 0.03	1.0 ± 0.21

Analysis of Results

The ^{40}K radionuclide activity in the soil samples is significantly higher than that of ^{238}U and ^{232}Th as shown in Fig. 1, ranging from 242.23 ± 2.94 Bq/kg to 501.97 ± 2.82 Bq/kg having an average activity of 368.25 ± 3.46 Bq/kg. This is due to the fact that ^{40}K radionuclide can be found in many waste materials that are disposed at the Eliozu Dumpsite as percentage radiation constituted by each of the radionuclides in the soil samples is highest with ^{40}K as shown in Fig. 3. Fig. 2 shows that ^{232}Th concentration in the soil samples is higher than ^{238}U concentration ranging from 21.89 ± 5.53 Bq/kg to 43.41 ± 3.12 Bq/kg with an average activity of 30.45 ± 5.77 Bq/kg. The absorbed dose rate for soil samples ranges from 33.59 ± 5.87 nGy/hr to 64.87 ± 3.52 nGy/hr with an average activity of 46.08 ± 5.18 nGy/hr while equivalent dose rate ranges from 0.29 ± 0.05 mSv/yr to 0.57 ± 0.03 mSv/yr with an average activity of 0.40 ± 0.04 mSv/yr.

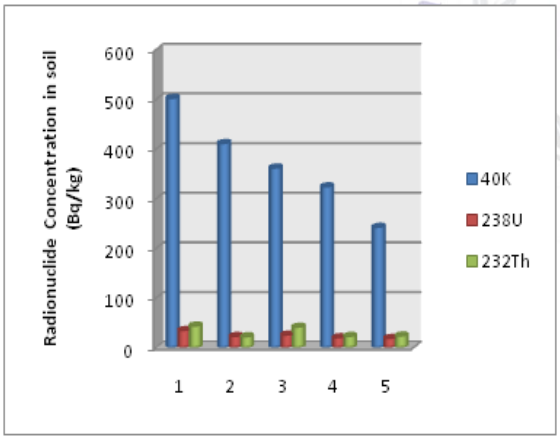

Fig. 2. Radionuclide Concentrations in Soil samples

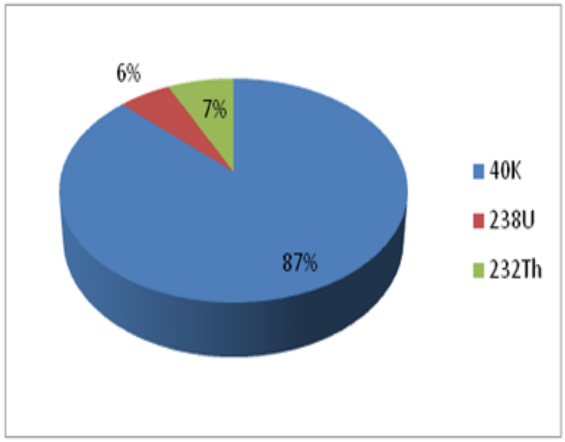

Fig. 3. Percentage Impact of Radionuclides on Soil samples

The concentration of ^{40}K radionuclide in the water samples is higher than both of ^{238}U and ^{232}Th radionuclides as shown in Fig. 4, ranging from 19.47 ± 9.48 Bq/L to 33.12 ± 2.73 Bq/L with an average activity of 24.77 ± 8.30 Bq/L. Unlike the results from soil sample analysis, ^{238}U activity is higher than ^{232}Th activity, due to the fact that the ^{238}U is moderately soluble in water (Ashraf *et al.*, 2001). Its values ranges from 7.32 ± 1.82 Bq/L to 12.41 ± 3.11Bq/L with an average activity of 7.92 ± 2.70 Bq/L while ^{232}Th activity ranges from 3.61 ± 1.43 Bq/L to 8.92 ±1.09 Bq/L with an average activity 6.96 ± 2.40 Bq/L. The percentage contribution of ^{40}K to the activity of radionuclides in the water still remains the highest as exhibited in the soil samples.

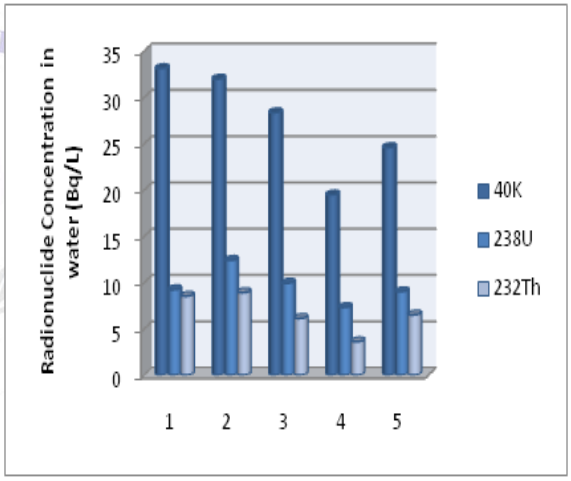

Fig. 4. Radionuclide Concentrations in Water samples

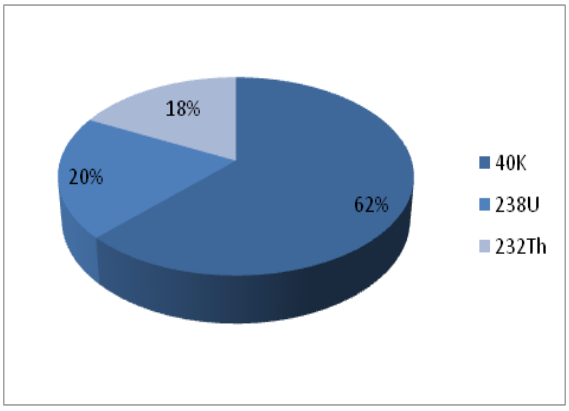

Fig. 5. Percentage Impact of Radionuclides on Water samples

The absorbed dose rate due to ingestion of these sources of water ranges from 6.36 ± 2.13 nGy/hr to 12.61 ± 2.36 nGy/hr with an average activity of 9.76 ±

3.76 nGy/hr in landfill areas. The equivalent dose rate ranges from 0.06 ± 0.02 to 0.11 ± 0.02mSv/yr with an average of 0.09 ± 0.03 mSv/yr. As with the soil samples, 40K radionuclide contributes the highest of radiation to the absorbed dose rate as shown in Fig. 5. Also from the study, it is observed that specific activity of radionuclides and absorbed dose rate is higher in soil samples than in water samples. The results also show that there has an increase in the radionuclide activity and absorbed dose rate as compared to the work of Avwiri *et al.,* (2011) though the absorbed and equivalent dose rates calculated for concentration activity ^{40}K, ^{238}U and ^{232}Th are in the range of other cities in Nigeria (Odunaike *et al.,* 2008).

CONCLUSION

From the analysis, it is observed that ^{40}K average activity exceeds permissible limits while the activity of ^{238}U and ^{232}Th are within the range of the permissible limits of UNSCEAR (2000) as the world average value for ^{40}K, ^{238}U and ^{232}Th stands at 400 Bq/kg, 35 Bq/kg and 30 Bq/kg respectively. Furthermore the results were lower than the standard maximum exposure to gamma ray of 0.7 mSv/yr (ICRP, 1991) and the UNSCEAR report for which have the average absorbed dose rate in air outdoor from terrestrial gamma radiation as 55 nGy/hr (UNSCEAR, 2000). Therefore, inhabitants around the dumpsite are constantly exposed to radiation from radionuclide activity from dumpsite but the exposure poses no radiological hazard as the amount of radiation falls within the permissible limits. However there is a possibility of amount of radiation exceeding permissible limits in the nearest future if waste materials are continuously disposed at the dumpsite.

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