RADIOLOGICAL IMPACT ASSESSMENT OF SOIL MATRICES FROM SAJE AND ILARO DUMPSITES IN SOUTHWESTERN NIGERIA

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S. K. Alausa[1]*, I. O. Akanmu[2], Kola Odunaike[1], Adebayo Adeyeloja[3] and A. O. Olabamiji[1]
[1]Department of Physics, Olabisi Onabanjo University, P. M. B.2002 Ago-Iwoye, Nigeria
[2]Ogun State Ministry of Environment, Okemosan Abeokuta, Ogun State Nigeria
[3]Department of Physical Sciences, Yaba College of Technology, Yaba Lagos State, Nigeria
*Corresponding author: alausakunle@yahoo.com

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Abstract: The radiological assessment of soils from two dumpsites in Southwestern Nigeria was carried out to determine the level of human exposure in the area. A total of 15 representative samples were randomly collected around the perimeter of each dumpsite and the samples were analyzed using a 2.0 by 2.0 cm NaI(Tl) gamma-ray spectrometric detector manufactured by ORTEC. The mean activity concentrations of radionuclides in the soil from Saje dumpsite were 172.84±121.16 Bq/kg for ^{40}K, 32.71±16.33 Bq/kg for ^{226}Ra and 48.72±22.26 Bq/kg for ^{232}Th while from Ilaro dumpsite, themean activity concentrations were 195.04±75.45 Bq/Kg for ^{40}K 61.33±16.86 Bq/kgfor ^{226}Ra and 75.84±33.31 Bq/kg for ^{232}Th. The respective mean gamma and effective dose rates were 53.65±19.04 nGy/h and 0.066±0.023 mSv/y for Saje dumpsite and 84.78±27.87 nGy/h and 0.104±0.034 mSv/y. The outdoor gamma dose, outdoor effective dose, and the cancer risk due to ionizing radiation exposure from Saje were lower than the values obtained for Ilaro. The difference in the radioactivity levels from the two dumpsites may be attributed to the composition of refuse in the dumpsites. The results showed that the radioactivity levels from the two dumpsites were lower than the world average values recommended by UNSCEAR. Therefore no serious radiological hazard is expected on the populace living around the dumpsites

Keywords: Radiological assessment, soil matrices, human exposure, Ilaro dumpsite

Introduction

Humans are faced with unavoidable exposure to ionizing radiation from natural and artificial radioactive elements contained in dumpsites. Reports from various studies showed that primordial radionuclides ^{238}U, ^{232}Th and ^{40}K embedded in the earth crust are the major sources of natural radiation exposure (Jibiri *et al.*, 2011; Alausa, 2012). Besides, radiation exposure also emanates artificial radionuclides generated from nuclear installations, radioactive substances and irradiating devices used for energy production, research and teaching, industrial and medical applications.

Thus, both the natura land artificial radionuclides are the potential sources of radiation exposure of the general environment and the resulting radiological health risksfrom the undesirable consequence of the exposure (UNSCEAR, 2000). It has been reported that refuse in dumpsites contained traces of radioactive material with different degree of ionizing radiation exposure (Jibiri *et al.*, 2011, Oladapo *et al.*, 2012). The composition and type of wastes produced depend on the level of industrialization and population growth of a country (Augustine *et al.*, 2015). Domestic wastes containing radioactive materials are indiscriminately dumped either in open fields or designated sites across many cities in Nigeria. Also, industrial wastes, known to contain potential artificial radionuclides are carelessly dumped in the open environment in industrial areas.

Thus, the containment of artificial radionuclides in such refuse may elevate the radioactivity level at the dumpsite. The natural radionuclides in the soil and other environmental matrices, municipal wastes with major constituents like plastics materials, electronics casings, disposals from abattoirs, domestic and office wastes, industrial and mechanical wastes dumped in refuse sites are the sources of human exposure to ionizing radiation (Avwiri and Olatubosun, 2014). If dumpsites are not properly managed, the wastes in the dumpsites decompose or decay and rain water drain the leachates into the soil. Consequently, the radioactivity levels of the soil and environment are increased thereby posing a serious health problem to the populace living around the dumpsites (Olubosede *et al.*, 2012).

Materials and Methods

Study locations

Saje and Ilaro dumpsites depicted in Fig. 1 are the two locations where samples were collected for the study. Saje inAbeokuta is located on Lat: 7°9'39"N, Long 3°20'54"E and situated on crystalline pre-Cambrian basement complex of igneous and metamorphic origin noted for high contents of natural radioactive elements (Jibiri *et al.*, 2009). Abeokuta and its environs have a population of 593,140 (NPC 2006). Saje dumpsite in Abeokuta contains mostly domestic waste products like plastics materials, electronics casings, effluents from abattoirs, domestic and office wastes, industrial and mechanical wastes.

Ilaro a town in Yewa South Local Government, Ogun State, Nigeria is about 50 km from Abeokuta. The town is located on lat: 6°53'00"N, long: 3°01'00"E is located on Ilaro formation which is predominantly coarse sandy estuarine, deltaic and continental beds (Akaegbobi and Ogungbesan, 2016). Ilaro has a landmass area of 629 km^2 with a population of 168,850 (NPC 2006). The dumpsite in Ilaro contains both domestic and industrial wastes, particularly from the plastic factory and cement industry.

It is therefore, necessary to measure the radioactivity levels in the soils from the two dumpsites to achieve the following objectives:

(i) measure the activity concentrations of ^{40}K,^{226}Ra and ^{232}Th in soils from the dumpsites

(iii) determine the gamma and effective doses due to the soil samples from the dumpsites

(iii) determine lifetime cancer risks due to the soil samples from the dumpsites.

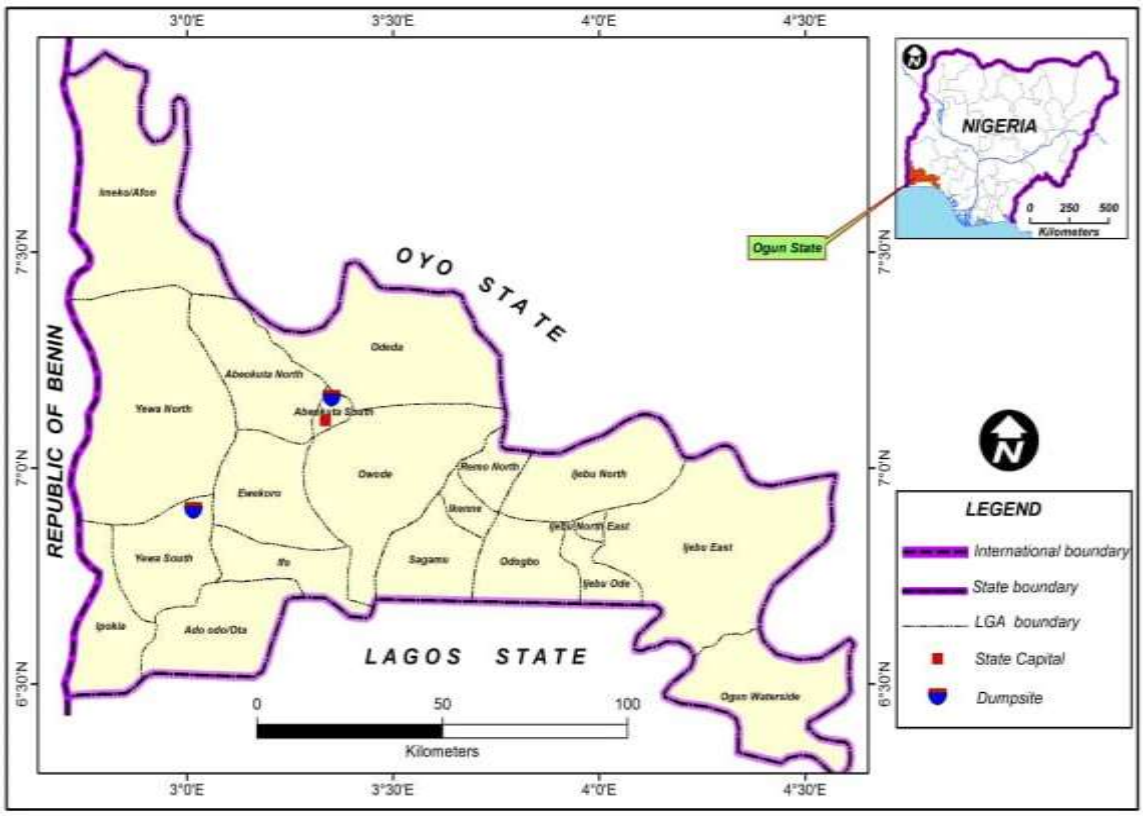

Fig. 1: Map of Ogun State showing the study locations (Alausa & Odusote, 2013)

Sample collection

A total of fifteen (15) sampling grids of 3 by 4 m^2 each were randomly marked round the perimeter of each dumpsite. At each sampling point, soil sample was collected to a depth between 2 and 3 cm with a hand auger and about 4 or 5 soil samples were then collected from each grid and mixed thoroughly to represent a sample. Each sample was then packed into a polythene bag and labeled to form a representative sample. The polythene bags containing the samples were then labeled properly and taken to Physics Laboratory Olabisi Onabanjo University Ago-Iwoye for preparation.

Sample preparation

All the soil samples along with debris were oven-dried at a steady temperature of 110^0C between 4 and 5 h to remove all the moisture and to obtain constant mass for each representative sample. The oven-dried samples were pulverized, sieved with a 2 mm and 200 g each of the samples were weighed, packed into a clean and radon-impermeablecylindrical plastic container of uniform size. The container wassealed for about 30 days to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective gaseous progenies before gamma spectroscopy.

Radioactivity measurements

The soil samples were analyzed using a well-calibrated and well shielded 2 × 2 cm Canberra Vertical High Purity NaI(Tl) gamma-ray spectrometric detector manufactured by ORTEC. The detector system uses a high voltage of 550 volts with Amplifier Coarse gain of 3.6 and shaping time of 0.75 µs. The system has an energy resolution of 8% (^{137}Cs) and 20% counting efficiency. The detector was kept in a vertical position in a lead cylindrical shield of 10 cm thickness, 55 cm height and a removable shielded cover. The internal dimensions of the free surface inside the shielding enclosure are 13 cm in diameter and 15 cm in depth. The detector was coupled to a 256 multi-channel pulse height analyzer (MCA) and the system was calibrated for the gamma-energy range from 80 KeV-3.2 MeV. The gamma-ray energy at 1.46 MeV, 1.76 MeV and 2.61 MeV were considered for ^{40}K, ^{226}Ra, ^{232}Th, respectively. The ranges for the gamma rays chosen in the measurement were 1.30-1.60, 1.62-2.00 and 2.45-2.90 MeV for ^{40}K, ^{226}Ra, ^{232}Th, respectively. Before the counting of the soil samples, the background gamma-ray was measured using empty sample containers of the same size with the ones that contained the samples. The efficiency of the detector was determined using a reference standard mixed jelly source traceable to Analytical Quality Service (AQSC, USA), which has certified the activities of the selected radionuclides. The containers used for the determination of the efficiency have geometrical configurations identical to the sample container. The energy-channel calibration was performed using the peaks of the radionuclide present in the standard sources and the channel number was found to be proportional to the energy. The channel scale was then converted to an energy scale. The counting time was 36,000s and the data acquisition, display and on-line spectrum analysis were carried out using the Genie 2000 spectroscopy software from Canberra.

Equation (3.1) shows the usual relationship between activity concentration and the count rate under the photopeak of a given gamma-ray spectrometry detector (Aközcan, 2014);

$$A = \frac{C}{\varepsilon \times I_\gamma \times m_s} \qquad (1)$$

Where: A is the activity concentration of the radionuclides in the sample (Bqkg^{-1}); C is the count rate under the photopeak;ε is the detector efficiency at a specific gamma-ray energy(cps/Bq); $I_\gamma$is the gamma yield (absolute transition probability) of the specific gamma-ray and m_s(in kg) is the mass of the sample.

Results and Discussion

Activity concentrations in soils from Saje and Ilaro dumpsites

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in the soil from Saje dumpsite in Abeokuta are presented in Table 1. As illustrated in the table the activity concentrations in the soils range from 50.67 to 394.51 $Bqkg^{-1}$with a mean value of 172.84±121.16 $Bqkg^{-1}$ for^{40}K; 11.69 to 85. $Bqkg^{-1}$ with a mean value of 32.71±16.33 $Bqkg^{-1}$for ^{226}Ra and 15.79 to 80.15 $Bqkg^{-1}$with a mean value of 48.72±22.26 $Bqkg^{-1}$for ^{232}Th.

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th radionuclides in the soil from Ilaro dumpsite are presented in Table 2. As observed in Table 2, the range and mean activity concentrations of radionuclides in the Ilaro dumpsite was 85.81- 356.538 $Bqkg^{-1}$ with a mean value of 195.04±75.45 Bq/kg for ^{40}K; 43.56-94.09 $Bqkg^{-1}$ with a mean value of 61.33±16.86 $Bqkg^{-1}$ for ^{226}Ra and 47.72-166.31 $Bqkg^{-1}$ with a mean value of 75.84±33.31 $Bqkg^{-1}$ for ^{232}Th.

The results from the two sites indicated that the radioactivity levels in Ilaro dumpsite where industrial wastes are dumped were higher than the levels in Saje dumpsite where municipal and domestic wastes are dumped. Hence, the variance in the radioactivity levels may not only be attributed to geological settings but on the types of wastes dumped in each of the sites.

The mean activity concentrations of ^{226}Ra and ^{232}Th in dumpsites from Lagos and its environs which were 23.0±6.6 and 33.6±8.5 $Bqkg^{-1}$, respectively (Augustine *et al.*, 2015) are lower than the values obtained in the present study. The UNSCEAR (2000) recommended activity concentration values are 420, 35 and 30 $Bqkg^{-1}$ for ^{40}K, ^{226}Ra and ^{232}Th, respectively. While the value obtained for ^{40}K in the study is lower than the value reported by United Nation Scientific Committee on Effect of Atomic Radiation, the ^{226}Ra and ^{232}Th obtained in the study are higher.

Table 1: Activity concentrations of radionuclides, gamma dose and effective dose of the soil from Saje dumpsite

Grids	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Gamma dose (nGy/h)	Effective dose ($mSvy^{-1}$)
1	172.95±1.3	31.32±2.1	18.2±1.0	32.86	0.040
2	149.70±1.1	33.79±1.8	15.79±1.1	31.32	0.038
3	368.73±1.8	29.63±2.2	41.63±1.6	56.07	0.069
4	381.62±2.3	23.32±1.7	34.54±1.5	49.23	0.060
5	105.02±1.4	31.42±0.4	66.24±1.3	61.78	0.076
6	394.51±0.9	25.97±0.6	47.82±1.9	59.71	0.073
7	116.70±1.7	43.22±1.8	90.65±1.9	83.48	0.102
8	274.86±1.0	30.20±1.6	49.72±1.1	57.63	0.071
9	103.62±2.0	28.53±1.3	61.32±2.1	57.23	0.070
10	50.67±0.7	24.40±0.9	39.28±1.3	38.60	0.047
11	141.36±1.8	37.42±1.3	51.75±1.8	56.32	0.069
12	93.37±1.0	20.99±1.1	44.27±1.7	42.28	0.052
13	60.48±1.1	11.69±1.2	19.16±2.0	20.28	0.025
14	122.49±1.3	33.35±1.2	70.30±1.8	66.05	0.081
15	56.50±1.4	85.46±1.8	80.15±1.4	91.98	0.113
Mean±σ	172.84±121.16	32.71±16.33	48.72±22.26	53.65±19.04	0.066±0.023

Table 2: Activity concentrations of radionuclides, gamma dose and effective dose of the soil from Ilaro dumpsite

Grids	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Gamma dose (nGy/h)	Effective dose ($mSvy^{-1}$)
1	120.42±2.1	43.56±8.1	47.72±1.8	55.37	0.068
2	198.22±1.1	69.81±1.1	50.67±1.5	71.88	0.088
3	110.63±2.5	46.44±3.7	61.33±0.9	65.19	0.080
4	189.45±5.1	54.19±1.1	114.24±1.3	106.91	0.131
5	229.8±1.6	74.32±1.8	82.19±3.9	96.03	0.118
6	137.42±1.7	94.09±5.1	50.78±1.2	79.70	0.098
7	144.31±3.1	62.47±1.5	93.04±1.6	94.47	0.116
8	171.05±1.9	53.27±1.3	60.27±1.0	70.00	0.086
9	267.10±1.4	35.11±1.4	48.33±2.1	58.47	0.072
10	85.81±2.1	48.55±1.9	51.49±1.5	58.51	0.072
11	144.81±1.2	53.24±1.1	66.84±1.7	73.21	0.090
12	240.27±1.3	84.26±3.5	104.37±1.7	115.40	0.142
13	294.84±1.5	49.46±1.5	51.01±1.0	67.57	0.083
14	356.38±9.1	78.90±1.3	166.31±7.1	159.11	0.195
15	235.06±3.1	72.23±0.9	89.02±1.1	99.88	0.123
Mean ±σ	195.04±75.45	61.33±16.86	75.84±33.31	84.78±27.87	0.104±0.034

Gamma dose due to the soil samples from the dumpsites

The important quantity to assess when considering radiation risk to a bio-system is the absorbed dose rate. The absorbed gamma dose rate, D (nGyh^{-1}) in the air at 1 m above the ground level due to the concentration of ^{40}K, ^{226}Ra and ^{232}Th in the soil matrices used was;

$$D = a.C_{Ra} + b.C_{Th} + c.C_K + d.C_{Cs}$$ (UNSCEAR, 2000) (2)

Where: a is the dose rate per unit ^{226}Ra activity concentration (4.61 x 10^{-10}Gy h^{-1}/Bq kg^{-1}), C_{Ra} is the concentration of ^{226}Ra in the sample (Bq kg^{-1}), b is the dose rate per unit^{232}Th activity concentration (6.62 x 10^{-10}Gy h^{-1}/Bq kg^{-1}), C_{Th} is the concentration of ^{238}U in the sample (Bqkg^{-1}), c is the dose rate per unit ^{40}K activity concentration (0.43 x 10^{-10}Gy h^{-1}/Bqkg^{-1}), C_K is the concentration of ^{40}K in the sample (Bqkg^{-1}), d is the dose rate per unit ^{137}Cs activity concentration (0.30 x 10^{-10}Gy h^{-1}/Bq kg^{-1}) and C_{Cs} is the concentration of ^{137}Cs in the sample (Bq kg^{-1}). The activity concentration of ^{137}Cs was taken as zero since it was not detected in any of the samples. Using Equation 2, the gamma absorbed dose due to the soil samples from Saje and Ilaro dumpsites were determined and the results are presented in Tables 1 and 2, respectively.

The gamma dose rate due to terrestrial ^{40}K, ^{226}Ra, and ^{332}Th radionuclides in the study sites ranged from 20.28-91.98.60 nGyh^{-1} with an average of 53.7±19.0 nGyh^{-1} for Saje while in Ilaro, the gamma dose rate ranged from 55.4-159.1 nGyh^{-1} with an average value of 84.78±27.87 nGyh^{-1}. While the mean value of gamma dose rate in Saje is lower than the value from Ilaro and the world average value of 59 nGyh^{-1} (UNSCEAR, 2000), the mean value in Ilaro is higher than the recommended world average value.

Effective dose rates due to radionuclides in the soils from the dumpsites

Two additional factors must be considered to determine the outdoor effective dose rate to the populace from the calculated absorbed gamma dose rate. The first factor converts Gy to Sv and accounts for the biological effectiveness of the dose in causing damage in human tissue. The second is the occupancy factor that specifies the proportion of the total time spent outdoors.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommended 0.7 Sv Gy^{-1} as the first factor and 0.2 as outdoor occupancy factor. The effective dose rate due to soil samples from the dumpsites was calculated using the equation:

$$H_R = D \times 0.2 \times 0.7 \times 8760$$(UNSCEAR, 2000) (3)

Where: D is the absorbed gamma dose rate in (nGy h^{-1}); 0.2 is the occupancy factor; 0.7 SvGy^{-1} is the conversion factor recommended by UNSCEAR and 8760 is in hy^{-1}.

The outdoor effective dose rate in Saje dumpsite ranged from 0.025-0.102 mSvy^{-1} while the outdoor effective dose rate in Ilaro ranged from 0.068-0.195 mSvy^{-1}. The mean outdoor effective dose in Saje and Ilaro dumpsites were 0.066±0.023 and 0.104±0.034 mSv/y, respectively. These values were lower than the world average effective dose of 0.30 mSvy^{-1} to individuals from soil matrices as reported by Ademola (2008).

Life time cancer risks due to the radionuclides in soils from the dumpsites

A lifetime cancer risk is defined as an estimate of the risk to a member of a population that is dying from cancer as a result of exposure to ionizing radiation (EPA, 1999).

The cancer risks due to the external radiation exposure of soils from the dumpsites are determined using a model proposed by the United States Environmental Protection Agency (UNSCEAR, 2000):

$$R = \sum r_i AT$$ (4)

Where: A is the activity concentration in Bq/kg, r_i is the cancer mortality risk coefficient for ith radionuclide and T(45.5 years) is the average life expectancy (WHO, 2008). The value of r for ^{226}Ra, ^{232}Th and ^{40}K are 1.33 x 10^{-17}kg/Bq-s, 1.97x10^{-19}kg/Bq-s and 4.66 x 10^{-16}kg/Bq-s, respectively. Using equation 4, the cancer risks due to external radiation exposure due to the soil from the dumpsites were evaluated. Figs. 2 and 3 show the bar chats illustrating the results from Saje and Ilaro dumpsites, respectively. As depicted in the figures, the UNSCEAR recommended value for cancer risk is much higher than the values obtained for Saje and Ilaro.

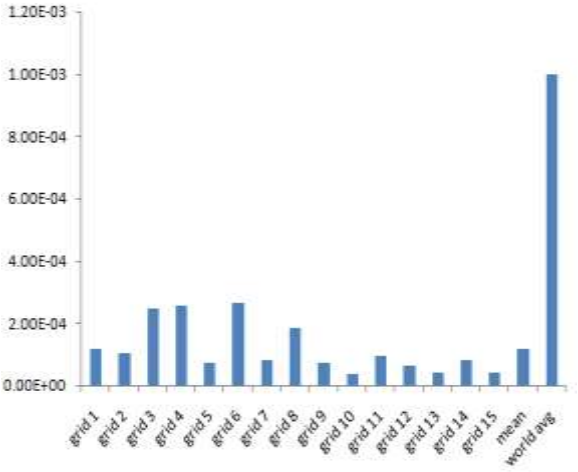

Fig. 2: Life time cancer risk due to soil from Saje dumpsite

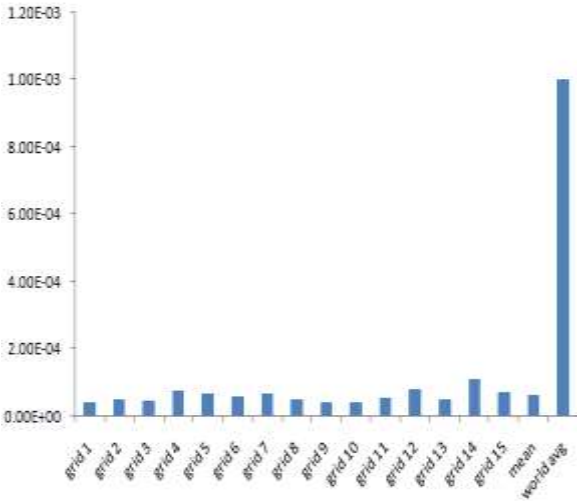

Fig. 3: Life time cancer risk due to soil from Ilaro dumpsite

Conclusion

The study has established radiometric data on activity concentration of ^{40}K, ^{226}Ra, ^{232}Th in soil samples collected from two dumpsites Saje and Ilaro in Ogun State using gamma spectrometry. The study showed that the values of ^{40}K, ^{226}Ra, ^{232}Th measured from the two dumpsites differ considerably, Ilaro dumpsite has higher radioactivity levels than Saje. The high radioactivity levels in Ilaro dumpsite may be attributed to the dumping of industrial waste in addition to the domestic waste in the site.

This study is meant to create public awareness of the inherent hazard in the indiscriminate disposal and poor management of refuse. The results from the study would also inform the general public on the danger of living in such an area where refuse dumpsite is situated. Although radiation exposure may

be low from the dumpsites but prolonged low ionizing radiation exposure may lead to a radiological health effect. Therefore, the Government would need at all times to take proactive measures to ensure good sanitation and management of the investigated dumpsites to save the populace from radiological hazard.

Conflict of Interest

Authors declare that there is no conflict of interest.

References

Ademola JA 2008. Exposure to high background radiation level in the tin mining area of Jos Plateau Nigeria. *J. Radiological Protec.*, 28: 93-99.

Akaegbobi IM & Ogungbesan GO 2016. Geochemistry of the paleocene limestone of Ewekoro Formation, Eastern Dahomey Basin, Southwestern Nigeria: Implication on provenance and depositional conditions. *Ife Journal of Science*, 18(3): 669-684.

Aközcan S, Yilmaz M & Kulahci F 2014. Dose rates and seasonal variations of ^{238}U, ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs radionuclides in soils along Thrace, Turkey. *J. Radioanal Nucl. Chem.*, 299: 95-101.

Alausa SK 2012. Radioactivity in farm soils and food crops are grown in Jos and Abeokuta Nigeria and its associated cancer risks. A Doctorate Dissertation, University of Ibadan, Nigeria.

Augustine KA, Morounfolu AO & Peter OA 2015. Radiological safety assessment and determination of heavy metals in soil samples from some waste dumpsites in Lagos and Ogun State, Southwestern, Nigeria. *J. Radiation Res. and Appl. Sci.*, 8: 148-153.

Awwiri GO & Olatubosun SA 2014. Assessment of environmental radioactivity in selected dumpsites in Port Harcourt, River State, Nigeria. *Int. J. Scientific & Techn.*, 3(4): 263-269.

Environmental Protection Agency (EPA) 1999. Cancer risk coefficients for Environmental exposure to Radionuclides. United States Environmental Protection Agency. Federal Guidance Report No -13 (EPA. 402 R-99-001).

Jibiri NN, Alausa SK & Farai IP 2009 Radiological hazard indices due to activity concentrations of natural radionuclides in farm soils from two high background radiation areas in Nigeria. *Int. J. Low Radiation*, 6(2): 79-95.

Jibiri NN, Alausa SK, Owofolaju AE & Adeniran AA 2011. Terrestrial gamma dose rates and Physical-chemical properties of farm soils from ex- tin mining locations in Jos-Plateau, Nigeria. *Afr. J. Envtal. Sci. and Techn.*, 5(12): 1039-1049.

National Population Commission (NPC) 2006. Population Distribution by Sex, State, LGAs and Senatorial Districts: Census Priority Tables Vol. 3 http://www.population.gov.ng/index php/censuses (cited in May 2019).

Oladapo OO, Oni EA, Olawoyin AA, Akande OO & Tijani SA 2012. Assessment of natural radionuclide level in wasteland soil around Olusosun dumpsite Lagos, Nigeria. *Journal of Applied Physics*, 2(3): 38-43.

Olubosede O, Akinnagbe OB & Adekoya O 2012. Assessment of radiation emission from waste dumpsites in Lagos State of Nigeria. *Int. J. Computational Engr. Res.*, 2(3): 806-811.

United Nations Scientific Committee on the effects of Atomic Radiation (UNSCEAR). 2000. United Nations Scientific Committee on the effects of Atomic Radiation, UNSCEAR 2000 Report to the General Assembly, New York: United Nations.

World Health Organization (WHO) 2008. Meeting the MDG Drinking Water and Sanitation Target: The Urban and Rural Challenges of the Decade. WHO Library Catalogue-in-Publication Data.