COMPARATIVE ANALYSIS OF THE LEVELS OF NATURALLY OCCURING RADIONUCLIDES IN SOIL AND VEGETABLE SAMPLES FROM A SELECTED HOSPITAL WASTE DUMPSITE.

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Abstract: The activity concentration of the gamma ray emitting from naturally occurring radionuclides ^{40}K, ^{232}Th and ^{238}U in hospital waste dumpsite soil and vegetable samples at Ado-Ekiti were determined using gamma spectrometer CsI (Ti). Their mean activity concentration were 352.88 ± 42.79, 25.51 ± 3.21 and 19.33 ± 1.56 Bq/kg for soil samples and 1091.07 ± 132.10, 45.07 ± 5.67 and 24.47 ± 1.98 Bq/kg for vegetables respectively. Radiological parameters such as absorbed dose rate, radium equivalence, annual effective dose equivalent, internal and external hazard indices were calculated to know the hazardous nature of these environmental samples to the inhabitants of the study area. In most cases, the calculated radiological parameters for vegetables were relatively higher than the world average values and the control.

Keywords: Comparative analysis, Naturally occurring radionuclides, Soil and vegetables, Radiological parameters.

1.0 Introduction

The challenges that the human race are facing due to release of heavy metal and radionuclide elements into the atmosphere, land, and water which has direct outcome on their health and ways of life are enormous. Science and technology are looking for solutions, most especially in the field of environmental protection and conservation *(Velasco et al., 2012)*. Therefore, radionuclides mobilized through the spill, weapon invention, mining, dumping of wastes and radioisotopes used in the machine has become the major problem of the discharge of the elements in the environment and ecosystem at large *(Pauwels, 2005)*. The existence of radionuclides in soil (loamy and sandy) and plants have been confirmed as a negative effect (*Olufunmbi et al., 2016*). Whenever the soil is used for planting crops such as legumes and vegetables, transportation of pollutants from the earth's surface from soil to plant occurs, which may eventually have adverse effect *(Isinkaye & Agbi, 2013)*. There is a high possibility that at the dumpsite, radiation can be emitted from the waste through the presence of radioactive material in the landfill which may pose a long term risk.*(Gupta & Voronina, 2018)*. However, nuclear weapon testing and nuclear facilities have been found to be the effect of global fallout among the public. These activities have contributed to the substantial amount of natural radionuclides in the environment and caused contamination globally. *(Velasco et al., 2012)*

2.0 Materials and methods

2.1 Samples collection

Four (4) soil samples were collected at the site using a merchant (Cutlass) to dig the surface of the land and the soils were taken at the position where the plant samples were uprooted. After that it was transferred into well labelled clean polyethylene bags. Twelve (12) vegetable samples (*amaranthus cruentus*-popularly known as Africa spinach) were collected at the dumpsite where clinical substance, chemical and various materials were dropped for incineration process before and after burning. These samples were collected at different distances apart with different hand gloves to avoid contamination. Four (4) identical samples each for both soil and vegetable) were also collected at the site where no anthropogenic pollution took place as the control.

2.2 Experimental method

Gamma spectrometer of Caesium Iodide CsI (Tl)) scintillator detector (model Bircom) was used to determine the levels of the natural occurring radionuclides in the samples. Caesium Iodide (CsI(Tl)) scintillation gamma detector consists of two major parts namely; the detector and the electronic instrumentation which included high voltage power supply (HVPS), a preamplifier, an analogue-to-digital converter (ADC), a multichannel analyzer all combined in a single unit called Universal Radiation Spectrum Analyzer II (URSA II) and a Visual displayed unit (Laptop). The Universal Radiation Spectrum Analyzer (URSA II) was used in processing the spectra Gamma ray spectrometry after counting for 10 hours. The activity concentration of the radionuclides was computed directly and checked using the comparative method. The results obtained were used to assess the radiological health impact on the samples.

2.3 Energy calibration of the Caesium Iodide detector CsI(Tl)

The term energy calibration simply means assigning a channel number to radionuclides of known energy. The energy calibration is essential in determining the relationship between peak position in the spectrum and the corresponding gamma-ray energy. This was accomplished in this study by comparing the spectrum of a known source emitting gamma-rays with energy. The detector was calibrated using three-point sources (Ba-133, Cs-137 and Co-60) with a gamma emitter sample of known energy which resulted into a linear equation relating gamma energy to channel number:

$$y = mx + c \quad (1)$$

where y corresponds to the gamma energy expressed in keV, m is the slope of the calibration line expressed in keV/channel, x is the relative channel and c is the intercept on the energy axis expressed in keV

2.4 Determination of peak areas

The peak corresponding to 1460 keV for K-40, 609.3 keV (Bi-214) for U-238 and 936.6 keV (Ac-228) for Th-232 were used for the estimation of natural radionuclides in all the samples. The integrated counts recorded under the energy peaks 1460, 609.3 and 936.6 keV were noted for each spectrum.

2.5 Calculation of radionuclide concentration

The specific activity concentration of each radionuclide in the samples was obtained by direct comparison of known activity concentration of the standard IAEA 385 with that of our samples using the total net counts under the selected photo-peak after subtracting the appropriate background counts. Mathematically,

$$C_X = C_S \frac{M_S(A_X - A_0)}{M_X(A_S - A_0)} (\text{Bqkg}^{-1}) \quad (2)$$

Where C_X = concentration of specific radioactivity in the sample,
C_S = specific activity concentration of the standard,
A_S= the area of the standard, A_X= the area of the sample, A_0= the background radiation
M_S= standard mass and M_X= sample mass

2.7 Absorbed dose rate

The dose rate from the dumpsite wastes was calculated using the given equation (Charles, 2001)

$$D\ (\text{nGy/hr}) = 0.0417C_K + 0.604C_{Th} + 0.428C_U \quad (3)$$

where D = dose rate (nGy/h) of ^{238}U, ^{232}Th and ^{40}K in the soil and vegetable samples

C_U, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K in the soil and vegetable samples respectively.

2.8 External radiation hazard index

This shows the decay of naturally occurring radionuclides in soils which produces an external radiation field to which all human beings are exposed during activity.(*Adedokun et al., 2019)*

$$H_{ex} = \frac{CK}{4810} + \frac{CTh}{259} + \frac{CU}{370} \quad (4)$$

The Internal Radiation hazard index was determined using

$$H_{in} = \frac{CK}{4810} + \frac{CTh}{259} + \frac{CU}{185} \quad (5)$$

while the Gamma level index ($I\gamma r$)

$$I\gamma r = \frac{CK}{3000} + \frac{CTh}{200} + \frac{CU}{300} \quad (6)$$

3.0 Results and discussion

The risk assessment of some naturally occurring radionuclides (^{40}K, ^{232}Th and ^{238}U) in soil and vegetable samples from the site and control were determined using gamma spectrometer. Table 1 shows the activity concentration of radionuclides in the soil samples collected from the site.

Table 1: Activity concentration of radionuclides in soil samples

Sample ID	^{40}K		^{232}Th		^{238}U	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Site A1-A4 (n = 4)	1091.07 ± 132.10	1058.97 - 1123.17	45.07 ± 5.67	39.40 - 50.74	24.47 ± 1.98	22.49 - 26.45
Control C1-C4 (n = 4)	1116.70 ± 135.42	981.28 - 1252.12	39.99 ± 5.04	34.95 - 45.03	19.38 ± 1.57	17.81 - 20.95

Table 2: Activity concentration of radionuclides in vegetable samples

Sample	^{40}K (Bq/Kg)		^{232}Th (Bq/Kg)		^{238}U (Bq/Kg)	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
VEGETABLE SAMPLES (BEFORE BURNING) (n=4)	352.88 ± 42.79	310.09 - 395.67	25.51±3.21	22.30 - 28.72	19.33±1.56	17.7 - 20.89
VEGETABLE SAMPLES (AFTER BURNING) (n=4)	371.95 ± 45.11	326.84 - 417.06	27.82±3.51	24.31 - 31.33	22.60±1.83	20.77 - 24.43

VEGETABLE SAMPLES (CONTROL) (n=4)	192.97 ± 23.40	169.57 - 216.37	26.16±3.29	22.87 - 29.45	18.84±1.52	17.32 - 20.36

In soil samples, the activity concentration ranged from 981.28 - 1252.12 Bq/Kg, 34.95 – 45.07 Bq/Kg and 17.81-26.45 Bq/Kg for ^{40}K, ^{232}Th and ^{238}U respectively.

The result (in table 2) showed that activity concentration of the observed radionuclides in the vegetables ranged from 169.57 - 395.67 Bq/Kg, 22.30 - 31.33 Bq/Kg and 17.32 – 24.43 Bq/Kg for ^{40}K, ^{232}Th and ^{238}U respectively. This implied that the activity concentration of ^{40}K was relatively higher than ^{232}Th and ^{238}U. ^{238}U had the least and could be less toxic in the soil sample.

Table 2 indicates the activity concentration of the three radionuclides in the vegetables.

Also, the activity concentration of ^{40}K in vegetable samples was relatively higher than the other two radionuclides. Table 3 depicts the comparison of these concentrations in both soil and plant samples and control (Bq/kg).

Table 3: Comparison of activity concentration of the observed radionuclides in soil and plant samples at the site and control (Bq/kg)

Samples	^{40}K		^{232}Th		^{238}U	
	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range
Soil (site) A1-A4 (N=3)	1091.07 ± 132.10	1058.97-1123.17	45.07 ± 5.67	39.40 - 50.74	24.47 ± 1.98	22.49 - 26.45
Soil (Control) C1-C4 (N=3)	1116.70 ± 135.42	981.28 - 1252.12	39.99 ± 5.04	34.95 - 45.03	19.38 ± 1.57	17.81 - 20.95
VEGETABLE P1-P4 (BEFORE BURNING) (N=4)	352.88 ± 42.79	310.09 - 395.67	25.51 ± 3.21	22.30 - 28.72	19.33 ± 1.56	17.77 - 20.89
VEGETABLES P5-P8 (AFTER BURNING) (N=4)	371.95 ± 45.11	326.84 - 417.06	27.82 ± 3.51	24.31 - 31.33	22.60 ± 1.83	20.77 - 24.43
VEGETABLES P9-P12 (CONTROL) (N=3)	192.97 ± 23.40	169.57 - 216.37	26.16 ± 3.29	22.87 - 29.45	18.84 ± 1.52	17.32 - 20.36

Table 4: Comparison of activity concentration (Bq/kg) in the soil samples for present study with previous studies reported from different State

Sample	^{40}K	^{232}Th	^{238}U	Reference
Present study	371.95 ± 45.11	27.82 ± 3.51	22.60 ± 1.83	
Agbara	111.05 ± 7.98	26.84 ± 2.20	42.95 ± 7.87	Gbadamosi *et al.*, 2017
Ojota	318.90 ± 27.40	35.10 ± 2.10	23.10 ± 2.50	Gbadamosi *et al.*, 2017
Port Harcourt	643.10 ± 5.53	62.61 ± 18.97	41.96 ± 5.33	Gbadamosi *et al.*, 2017
Worldwide	370	30	35	Gbadamosi *et al.*, 2017

Table 5: The Dose rate (nGy/hr), Radium equivalent dose rate (Ra_{eq}) in (Bq/Kg), external radiation Hazard index (H_{ex}) and internal radiation Hazard index (H_{in}) of soil and vegetables sample was determine

Sample	Dose rate (nG/hr)	Radium equivalent dose Ra_{in}	H_{ex}	H_{in}
Soil (unburnt)	39.05	82.98	0.22	0.28
Soil (burnt)	32.31	91.02	0.25	0.31
Soil (Control)	32.55	71.12	0.19	0.24
African spinach (Site)	84.03	172.93	0.47	0.53
African Spinach (Control)	78.59	162.55	0.44	0.49

Table 6: Comparison of radiation risk quantities with threshold limits

Samples	Absorbed dose Rate (nGy/hr)	Effective dose rate	External Radiation hazards H_{ex}	Reference
Present study (soil)	39.05	0.047	0.22	
Present study (African spinach)	84.03	0.10	0.47	
UNSCEARS(2000)	60	Nil	< 1	(Journal, 2011)
ICRP(2000)	Nil	1	Nil	(Journal, 2011)

3.0 Discussion

3.1 Activity concentration in soil and plant samples

The activity concentration for ^{40}K was relatively higher than ^{232}Th and ^{238}U in both soil and plant samples. Table1 shows the activity concentration of ^{40}K which ranged from (192.97 to 371.95 Bq/Kg), for ^{232}Th, it ranged from (25.51 to 27.82 Bq/Kg) and ^{238}U ranged from (18.84 to 22.60 Bq/kg) in the site and control. This shows that samples contained more of ^{40}K in the soil samples than others. Table 2 depict that the activity concentration of ^{40}K was higher than the ^{232}Th and ^{238}U in the dumpsite and control. The mean value of the vegetable sample in ^{40}K ranged from (981.28 to 1252.12 Bq/kg) in ^{232}Th it ranged from (34.95 to 50.74) and ^{238}U ranged from (17.81 to 26.45 Bq/kg) in the vegetable sample in the site and control.

The mean activity concentrations recorded from the present study were also compared with the world health organization (WHO) guideline value of activities concentration for radionuclides in soil.

3.2 Absorbed dose rate and annual effective dose rate of the samples

The results of the calculated absorbed dose rate in the soil samples ranged from (32.31 to 39.05 nGy/h) with a mean value of 34.64nGy/h and the absorbed dose rate in vegetable samples ranged from (78.59 to 84.03 nGy/h) with a mean value of 81.31nGy/h. These values were comparatively higher than that of the soil. The mean absorbed dose rate was also higher than the recommended limit (59nGy/h). The values were within the internal value (1 mSv/yr) recommended by international commission on radiation protection (ICRP, 2007). The radium equivalent dose rate (Ra_{eq}) Bq/kg, for the external and internal radiation hazard index, the values of Ra_{eq} activity in the soil sample ranged from 71.12 to 91.02 Bq/kg with the mean value of 81.71 Bq/kg in the vegetable samples ranged from 162.55 to 172.93 Bq/kg, with a mean value of 167.74 Bq/kg. The result showed that the H_{in} and H_{ex} value for all the soil and vegetable samples were below unity, indicating that the radiation dose was below the permissible limit of 1mSv/yr recommended by ICRP.

In other to check the health effect from human exposure to the ionizing radiation of the earth surface material containing ^{40}K, ^{232}Th, and ^{238}U radiation hazard from the internal and external sources are important. The main objective of the hazard indices is to limit dose equivalent limit of 1μSv/yr. the index value must be less than unity in other to keep the radiation hazard to be insignificant. The calculated values of internal hazard ranged from 0.24 to 0.31 in the soil sample and external hazard ranged from 0.19 to 0.25.

Hence, there is no radiological risk emanating from the external exposure of the people, working or living around the dumpsite to these natural radionuclides

4.0 Conclusion

Comparative analyses of the levels of NORM in soil and plant samples were determined and compare with world wide range. The study also discussed how radionuclides contents are transferred to human from soil to plant. The Research showed that activity Concentration of ^{40}K was relatively higher than ^{232}Th and ^{238}U in soil and plant samples. Generally, the radioactivity concentrations of vegetable samples were also higher than soil and moderate when compared with the worldwide range value. The Comparative analysis of the levels of NORM in soil and vegetable were rightly determined and compared with world wide range. In the soil Samples activity concentration of ^{40}K were higher than ^{232}Th and ^{238}U but in the control ^{40}K was lower which make it fit for cultivation of crops and less toxic.

The study vividly showed that samples from dumpsite have higher radionuclide contents which may pose a risk to human health. The results from this works established the baseline levels of the observed naturally occurring radionuclide (^{40}K, ^{232}Th and ^{238}U) and showed some levels of pollution and contamination by this burnt and unburnt hospital waste at the site.

Based on the findings from this study, it is suggested that:

(i) Internal exposure during ingestion of vegetable sources in the study area and the air, dust that consists of K-40, Th-232 and U-238 should be properly monitored by the government.
(ii) Medical wastes should either be disposed by incinerating or bury it
(iii) The scientist and technologist should produce a radioactive meter that can read the level of natural occurring radionuclide and artificial radionuclide in the body.
(iv) Government should educate the citizen on the effect and causes of radionuclide contents in the environment.

References

1. Adedokun, M. B., Aweda, M. A., Maleka, P. P., Obed, R. I., Ogungbemi, K. I., Ibitoye, Z. A., Adedokun, M. B., Aweda, M. A., Maleka, P. P., Rachel, I., Ogungbemi, K. I., & Ibitoye, Z. A. (2019). Natural radioactivity contents in commonly consumed leafy vegetables cultivated through surface water irrigation in Lagos state , Nigeria. *Journal of Radiation Research and Applied Sciences*, *12*(1), 147–156. https://doi.org/10.1080/16878507.2019.1618084
2. Charles, M. (2001). UNSCEAR Report 2000: Sources and Effects of Ionizing Radiation. In *Journal of Radiological Protection* (Vol. 21, Issue 1). https://doi.org/10.1088/0952-4746/21/1/609
3. Gbadamosi, M. R., Banjoko, O. O., Abudu, K. A., Ogunbanjo, O. O., & Ogunneye, A. L. (2017). Radiometric evaluation of excessive lifetime cancer probability due to naturally occurring radionuclides in wastes dumpsites soils in Agbara , Southwest , Nigeria. *Journal of the Association of Arab Universities for Basic and Applied Sciences*, *24*, 315–324. https://doi.org/10.1016/j.jaubas.2017.06.003
4. Gupta, D. K., & Voronina, A. (2018). Remediation measures for radioactively contaminated areas. In *Remediation Measures for Radioactively Contaminated Areas*. https://doi.org/10.1007/978-3-319-73398-2
5. Isinkaye, M. O., & Agbi, J. I. (2013). Natural radioactivity and associated radiation hazards of some commonly used building materials in southwest Nigeria. *Radioprotection*, *48*(3), 355–365. https://doi.org/10.1051/radiopro/2013061
6. Journal, I. (2011). *Ife Journal of Science*. *13*(1), 199–209.
7. Olufunmbi, A., Akinjide, O., Moromoke, O., & Oluwafunmito, O. (2016). The Concentration Of Natural Radionuclides In Soil Samples From The Practical Year Agricultural Farmland, University Of Ibadan. *IOSR Journal of Applied Physics*, *08*(04), 60–68. https://doi.org/10.9790/4861-0804036068
8. Pauwels, E. K. J. (2005). Radioactivity Radionuclides Radiation. In *European Journal of Nuclear Medicine and Molecular Imaging* (Vol. 32, Issue 5). https://doi.org/10.1007/s00259-005-1805-0
9. Velasco, H., Cid, A. S., Anjos, R. M., Zamboni, C. B., Rizzotto, M., Valladares, D. L., & Juri Ayub, J. (2012). Variability of 137Cs and 40K soil-to-fruit transfer factor in tropical lemon trees during the fruit development period. In *Journal of Environmental Radioactivity* (Vol. 104, Issue 1). https://doi.org/10.1016/j.jenvrad.2011.09.016

