RADIOLOGICAL ANALYSIS OF SOIL IN ZAKI-BIAM, UKUM LGA, BENUE – NIGERIA

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ABSTRACT

The concentration of radionuclides in Zaki-Biam were collected, measured and analyzed for indoor and outdoor exposure rate at different points. The samples were soil collected in Dump site, Farm Land and the Industrial site and measurements of the background radiation were taken using the Geiger counter. Gamma ray spectrometry was used to analyze the radionuclide concentrations of 238U, 232Th and, 40K in the samples. The radionuclide concentrations of 238U, 232Th and 40K varied in the range of 4.72±1.96 to 35.35±2.86Bq/Kg, 14.92±2.57 to 87.30±8.59Bq/Kg and 105.79±9.74 to 874.54±70.83Bq/Kg respectively, indicating the highest concentration of 40K in the farm land. The result further reveals that the concentrations of 40K in the soil samples in all the study areas were higher compared with the global average value of 400Bq/kg. The highest radionuclide concentration of 232Th on the average was obtained at the Industrial site quantified by 43.68±4.69Bq/Kg. Results also indicate that the radionuclide concentration of 238U on the average was greatest at the Farm land (18.48±3.99Bq/Kg) followed by the Dumpsite (13.93±3.64Bq/Kg) and with the least concentration at Industrial site (8.88±2.32Bq/Kg). Results indicate that the farm land (FL7) has the highest dose of 79.14nGyh^{-1} . Interpretation shows that the radioactive level index at some points in all the three sites under study indicated a concentration above the required and standard normal value of unity.

Keywords: *Absorbed-Dose, Background-Radiation, Effective-Dose, Exposure, Indoor, Outdoor, Radionuclides.*

I. INTRODUCTION

Gamma radiation from radionuclides which are characterized by half-lives comparable to the age of the earth, such as Poatasium-40 (40K) and the radionuclides from the Uranium-238 (238U) and Thorium-232 (232Th) series, and their decay products, represents the main external source of irradiation to the human body. The absorbed dose rate in air from cosmic radiation outdoors at sea level is about 30nGyhr^{-1} [1]. External exposures to gamma radiation outdoors arise from terrestrial radionuclides occurring at trace levels in all ground formations. Therefore, the natural environmental radiation mainly depends on geological and geographical conditions [2].

Man is by the very nature of his environment exposed to varying amounts of ambient radiation with or without his consent. The ambient radiation encompasses both the natural and artificial radioactivity in his environment [3]. The issue of radiation exposure has become a continuing and inescapable feature of life on earth [4]. Therefore, human societies have become concerned with environmental protection and management for the purpose of ensuring the safety of organisms against the effects of ionizing radiation.

The concentration of Naturally Occurring Radioactive Materials (NORMS) in food and water varies with factors such as local geology, climate and agricultural practices. There are local variations in the levels of human population exposure to radiation. This observation depends on a host of factors which include; the height above sea level, the amount and the type of radionuclides in soil, the composition of radionuclide in air, food, and finally, the quantity of radionuclide inhaled or ingested into the body of an organism. For example, there are specific areas on the surface of the earth where the levels of background radiations are relatively higher and even ten times higher than the world average. Some of the areas with such conditions are Kerala State in India and the Pocos del Caldas Plateau in Brazil. The main natural sources of radiation are radon gas, cosmic rays, gamma radiation from rocks and soil as well as radionuclides in food and water. Exposure to natural sources of radionuclide includes inhalation of radioactive gases, ingestion of naturally-occurring radioactive elements in food and water as well as irradiation from radioactive elements in the soil [1]&[2].

The issue of radiation exposure from natural sources has been considered as an issue of global concern. This has resulted in many developed countries taking necessary steps needed to determine the levels of background radiation in order to allay the fear of citizens of any possible radiation exposure. In order to ascertain the radiation exposure of any human population, it is very important to estimate the potential dose from both natural (primordial) and anthropogenic radionuclide sources. In Canada for instance, the average dose due to naturally occurring background radiation is about 2mSv per year. This is mainly due to inhalation of naturally occurring radon and its short-lived decay products like Lead-214 (214Pb) and Polonium-215 (215Po) [5]. Radionuclides may be present in the body and irradiate various organs with alpha and beta particles as well as gamma rays.

Naturally occurring radioactive materials have been part of the human environment since creation primarily due to their long half-lives. Anthropogenic activities have increased the environmental load of other artificial radionuclides. Even though many developed countries have taken steps to determine radioactivity distribution in their environments, not much research work has been carried out on the radiological quality of the environment in most developing countries. It is evident that human activities through mining, generation of nuclear power, agricultural practices, unguided dumping or disposal of refuse and many industrial activities have added artificial radionuclides to the environment. Undoubtedly, higher levels of radionuclide concentration in food and water have adverse effect on the health of people exposed to these radionuclides. Meanwhile, Zaki-Biam which is a major area in Benue State which is named a major food basket in the country is experiencing increasing number of such activities while most of the communities depend on borehole and surface water sources for domestic use.

Like many developing countries, the levels of natural and artificial radionuclides in groundwater, soil and tuber crops grown in the Zaki-Biam District are not known. However, knowledge of the levels and distribution of radionuclides in the environment is necessary if levels of human exposure to radiation from radionuclides are to be controlled. This study therefore aims to determine the activity concentrations of natural radionuclides (238U, 232Th and 40K) at the selected sites (Dumpsite, Industrial site and Farm land). In the Zaki-Biam District, there have not been much industrial activities except for the rice meal station from which samples were collected for analysis as such, the levels of NORMS in the area could predominantly be caused by human activities such as the other two under study (unsafe method of refuse disposal together with farming activities).Through this study, adequate data on natural and artificial radionuclide concentrations in the district will be established. This will help in assessing any possible radiological hazard that the population could be exposed.

II. MATERIALS AND METHOD

A. Description of the Study Area

Zaki-Biam is a major town in Ukum Local government area of Benue state. Its geographical coordinates are 7^{o} 31' 0'' North, 9^{o} 37' 0''East. The geo-political entity called Ukum local government was carved out of Katsina-Ala local government on October 31, 1991. With headquarters at Sankerra. The local government is situated in the North-East of Benue State. Ukum local government shares boundaries East-ward with Wukari local government in Taraba state. In the South-East and South-West, it is bounded by Katsina-Ala and Logo local government areas. It has a land mass of 429.10 square kilometers. The inhabitants of the local government are predominantly Tiv and are farmers. Those settling in the area include Hausa, Ibo, Jukun, Idoma amongst others who are mainly traders.

Although Ukum local government is part of a geological formation with lots of mineral deposits, feasibility studies to determine the viability of industrial exploitation of these deposits is yet to be done. However, there is a crude salt industry in Tsav ward which is locally exploited by the local people, producing unrefined salt for consumption as well as medicinal purposes.

Agriculture is the main stay of the economy of Ukum local government. The area is indeed endowed with abundant rich and fertile agricultural soil. The bulk of yam in the country is produced in the local government area. Furthermore, Ukum local government provides the biggest tuber market in Africa, South of the Sahara. Other food crops that are grown and produced substantially in Zaki-Biam include groundnuts, maize, citrus, and guinea corn. A trunk 'A' bitumen road runs through the local government from katsina-Ala through Zaki-Biam and Kyado towns to Wukari in Taraba State. This road is joined by several feeder roads to ensure easy evacuation of goods.

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C. Sample Collection and Preparation

Soil samples were collected at about 15-20cm in each of the selected sites (Dump site, Farm land and Industrial site). Soil samples collected from the dumpsite were labelled DS1, DS2, DS3, DS4, DS5, DS6 and DS7 and those collected from the farm land were labelled FL1, FL2, FL3, FL4, FL5, FL6, and FL7 while those from the industrial site were equally labelled IS1, IS2, IS3, IS4, IS5, IS6 and IS7. After collection of samples, they were cleaned and dried under room temperature to near perfect dryness and crushed into fine powder of less than 125µm by using an agate mortar and pestle and sieved through a 2mm pore size mesh into a previously weighed beaker. The homogenized soil samples were then dried in an oven at 40℃ and weighed constantly until a steady weight was attained for all the samples using an electronic weighing balance indicating a perfect dryness of the samples. Each of the powdered soil samples were packed into a clean and radon- impermeable polythene bags of uniform size and double sealed for a period of about 30 days to allow for secular equilibrium to be established between the long-lived and short-lived radionuclides of the 238U and 232Th decay series and their respective gaseous progenies prior to analysis. Each sealed sample was identified with a code for easy traceability.

A Geiger- Muller counter capable of detecting α- particles, β-particles, γ- rays and X-rays within the temperature range of -100 ºC to 500ºC was used to measure the indoor and outdoor exposure rates. The tube of the counter was raised to the standard height of 1.0m above the ground [3] with its window facing the site to be measured and then vertically downward. The GM tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization and each pulse is electronically detected and registered as a count. In –situ measurement of background ionizing radiation was done in each of the seven points in all the three sites of emphasis.

Readings were obtained between the hours of 1300 and 1600 hours, because the exposure rate meter has a maximum response to environmental radiation within these hours [3]. For each location, three readings spanning over three minutes were carried out and these measurements were then averaged to a single value. Data obtained for the indoor and outdoor exposure rate in (CPM) was converted into equivalent dose rate in (µSv/hr).

$$HT_c = \frac{\beta \times \mu \times 24 \times 365}{1000} \quad (1)$$

$$\beta = \frac{HT}{Q} \quad (2)$$

HT = Equivalent Dose in µSv/hr, HT_c = Equivalent Dose in $mSvyr^{-1}$, β = Absorbed Dose in $Gyhr^{-1}$, Q = Quality Factor = 1, µ= outdoor occupancy factor = 0.18 for residential areas, and 0.5 for industrial areas. The samples were counted on the High Purity Germanium (HPGE) detector for 36000s. The activity concentrations of the radionuclides earmarked for determination in the samples were determined on dry weight basis in Bq/kg.

D. Sample Analysis

The gamma spectrometric measurement was carried out using Gamma ray spectrometric system coupled with a NaI(Tl) model 802 detector at the National Institute of Radiation Protection and Research (NIRPR) University of Ibadan Campus, Ibadan. The detector is mounted vertically coupled with 8K PC based Multi- Channel Analyzer (MCA) and the detector is enclosed in a massive lead shield to reduce background from the system. The detector was calibrated with point sources ^{60}Co, ^{137}Cs, ^{241}Am and ^{22}Na for energy calibration and the efficiency calibration of the detector was done with volume source, IAEA-385. The detector which was well calibrated used Genie 2000 (template which computes energy, percentage error, count, uncertainty, Activity

concentration, uncertainty in activity, Gamma probability, uncertainty in Gamma probability, Efficiency and uncertainty in Efficiency) as its operating software in the analyses of various energies of ^{238}U, ^{232}Th and ^{40}K. Each sample was sealed in an already washed Marinelli beaker for twenty eight days in order for it to attain secular equilibrium (to allow buildup of radionuclide in the beaker) before placing it in the shielded detector. The counting time for the samples was 36,000 seconds. Each sample was counted for 36,000 seconds to reduce the statistical uncertainty. An already washed empty Marinelli beaker was also placed in the detector for the same counting time (36,000 seconds) under identical geometry to determine the background radiation level of the laboratory environment. It was later subtracted from the measured γ−ray spectra of each sample. At the end of the measurement, the various regions of interest which were deducted from the background reading were computed with a specialized template. This template (which covers energy, percentage error, count, uncertainty, Activity concentration, uncertainty in activity, Gamma probability, uncertainty in Gamma probability, Efficiency and uncertainty in Efficiency) was used to determine the radionuclide concentration in each sample

E. Calibration of the Gamma Spectrometer

Before sample analysis, energy and efficiency calibrations were performed to ensure proper identification and quantification of the radionuclides of interest. The detector system was calibrated using the multinuclide reference standard material. The standard in liter Marinelli beaker was measured using a counting time of 36,000 seconds to acquire spectral data.

The standard used for the energy and efficiency calibrations consisted of a mixed radionuclide in solid water supplied by the IAEA in 2006. The standard solution has the following radionuclides with the corresponding energies; 241Am (59.54 keV), 109Cd (88.03keV), 57Co (122.06 keV), 139Ce (165.86 keV), 203Hg (279.20 keV), 113Sn (391.69 keV), 85Sr (514.01 keV), 137Cs (661.66 keV), 60Co (1173.2 keV and 1332.5 keV) and 88Y (898.04 keV and 1836.1 keV). However, only 4 radionuclides in the standard were selected for the energy calibration namely: 241Am, 57Co, 137Cs, 60Co.

F. Energy Calibration

Energy calibration was performed by matching the energies of the principal gamma rays in the spectrum of the standard reference material to the channel number of the spectrometer. This was done both manually and by a computer. The equation relating the energy and the channel number is given by the expression (3).

$$E\gamma = A_0 + A_1 CN \quad (3)$$

Where; Eγ is the energy in keV, CN is the channel number for a given radionuclide, and A_0 and A_1 are calibration constants for a given geometry.

G. Efficiency Calibration

The efficiency calibration was performed by acquiring a spectrum of the calibration standard until the count rate at the peak of total absorption can be calculated with statistical uncertainty of less than 1% at a confidence level of 95%. The net count rate was determined at the photo peaks for all the energies to be used for the determination of the efficiency at the time of measurement. The efficiency of each energy was plotted as a function of the peak energy and extrapolated to determine the efficiencies at other peak energies for the measurement geometry used. The efficiency was then related to the count rate.

H. Estimation of Doses

Absorbed Dose Rates

Absorbed dose rate is the most important parameter used when considering the radiation risk to a biosystem [7]. The external absorbed dose rate, *D* (nGy h^{-1}) in air at 1m above the ground level for soil containing the concentrations of the radionuclides measured in the samples was calculated using the following equation [1]

$$D(nGy.h^{-1}) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \quad (4)$$

The maximum permissible dose rate is 50nGyhr^{-1} [6].

Annual Effective Dose Rates

The annual effective dose equivalent (AEDE) was calculated from the absorbed dose rate by applying the dose conversion factor of 0.7Svyr^{-1} with an outdoor occupancy of 0.2 and 0.8 for indoor [1]. To estimate the annual effective dose rates, the conversion coefficient from absorbed dose in air to effective dose (0.7 Svyr^{-1}), outdoor occupancy factor (0.2) (i.e. people on the average spend 20% of the time outdoor), and indoor occupancy factor (0.8) (i.e. people on the average spend 80% of the time indoor) proposed by [6]&[1] are used. Therefore, the annual effective dose rate (mSvyr^{-1}) was calculated using the following formula:

$$AEDR(outdoor) = 1.2D \times 10^{-3} mSv.y^{-1} \quad (5)$$

$$AEDR(indoor) = 4.91D \times 10^{-3} mSv.y^{-1} \quad (6)$$

Radioactive Level Index (I_Y)

The radioactive level index (I_Y) is defined from the following formula [3]:

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (7)$$

$I_Y \leq 1$ corresponds to an annual effective dose of less than or equal to 1mSv, while $I_Y \leq 0.5$ corresponds to annual effective dose less or equal to 0.3mSv.

Radium Equivalent

To represent the activity levels of ^{238}U, ^{232}Th and ^{40}K which take into account the radiological hazards associated with them, a common radiological index has been introduced. This index is called radium equivalent activity (Ra_{eq}) and is mathematically defined by Equation (8) [1].

$$Ra_{eq} = A_u + 1.43A_{Th} + 0.077A_K \quad (8)$$

Where A_U, A_{Th} and A_K represent the activity concentrations of Uranium, Thorium and Potassium respectively. The permissible limit of Ra_{eq} is 370Bqkg^{-1} in soil that contain ^{238}U, ^{232}Th and ^{40}K measured in Bqkg^{-1}.

Hazard Index

The radioactive level index or hazard index (I_Y) is defined from the following formula [3].

$$I_\gamma = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad (9)$$

$I_Y \leq 1$corresponds to an annual effective dose of less than or equal to 1mSv, while $I_Y \leq 0.5$ corresponds to annual effective dose less or equal to 0.3mSv [3].

III. RESULTS

Tables 1, 2 and 3 show the Background Radiation from in-situ measurement in counts per minutes (CPM), the 40K, 238U and 232Th Activity Concentrations in top Soils (Spectrometric Result) and the Absorbed Dose Rate (D), Radium Equivalent (Ra_{eq}) and Annual Effective Dose Rate (AEDR) (indoor and outdoor) for the various points in the study areas respectively.

Table 1: Background radiation (CPM)

Sample Identity	Location		Background Radiation (CPM)			Average Background Radiation per point (CPM)	Average Background Radiation per site (CPM)	Equivalent Dose (μSv/hr)
	North	East	1st	2nd	3rd			
IS1	07°30.097'	09°36.712'	24	21	17	20.67	18.38	0.280
IS2	07°30.095'	09°36.700'	16	18	25	19.67		0.267
IS3	07°30.970'	09°36.696'	17	12	23	17.33		0.237
IS4	07°30.115'	09°36.696'	18	18	18	18.00		0.245
IS5	07°30.113'	09°36.688'	15	18	20	17.67		0.241
IS6	07°30.108'	09°36.699'	17	14	21	17.33		0.237
IS7	07°30.100'	09°36.696'	18	17	19	18.00		0.245
DS1	07°30.692'	09°36.727'	20	20	20	20.00	19.19	0.098
DS2	07°30.696'	09°36.729'	16	22	21	19.67		0.096
DS3	07°30.698'	09°36.730'	23	16	20	19.67		0.096
DS4	07°30.704'	09°36.734'	16	16	18	16.67		0.082
DS5	07°30.707'	09°36.737'	21	13	11	15.00		0.072
DS6	07°30.705'	09°36.742'	19	23	21	21.00		0.103
DS7	07°30.683'	09°36.729'	28	21	18	22.33		0.109
FL1	07°30.581'	09°36.670'	25	16	18	19.66	18.62	0.096
FL2	07°30.576'	09°36.671'	18	16	17	17.00		0.084
FL3	07°30.570'	09°36.688'	20	16	18	18.00		0.088
FL4	07°30.581'	09°36.618'	16	18	20	18.00		0.088
FL5	07°30.561'	09°36.677'	25	18	20	21.00		0.103
FL6	07°30.571'	09°36.660'	23	16	17	18.67		0.092
FL7	07°30.574'	09°36.678'	18	16	20	18.00		0.088

Table 2: 40K, U238 and 232Th Activity Concentrations in Top Soils (Spectrometric Result)

S/NO.	SAMPLE	K-40 (Bq/Kg)	U-238 (Bq/Kg)	Th-232(Bq/Kg)
1	DS1	437.49±38.44	4.72±1.96	52.49±5.54
2	DS2	181.24±16.56	19.17±4.73	87.30±8.59
3	DS3	95.39±9.09	15.51±3.85	14.92±2.57
4	DS4	250.61±21.92	12.52±3.38	21.93±2.58
5	DS5	163.0 3±14.95	20.47±5.02	19.38±2.26
6	DS6	128.34±12.12	12.76±3.39	27.45±2.86
7	DS7	264.49±23.68	12.38±3.16	21.65±2.42
8	FL1	388.92±33.92	21.19±4.95	40.32±4.34
9	FL2	874.54±70.83	11.94±3.36	15.56±1.72
10	FL3	631.735±51.65	22.97±5.28	47.40±5.07
11	FL4	849.39±68.88	11.65±3.18	36.50±3.94
12	FL5	448.33±39.12	10.21±2.71	41.74±4.45
13	FL6	559.32±47.18	16.08±4.13	35.09±3.73
14	FL7	695.03±58.05	35.35±7.54	54.47±5.55
15	IS1	558.02±47.07	9.29±2.86	64.52±6.43
16	IS2	320.42±29.51	15.12±3.76	37.78±4.16
17	IS3	256.68±23.14	17.87±4.23	67.03±6.70
18	IS4	312.87±30.23	BDL	41.64±5.27
19	IS5	362.91±32.47	BDL	32.26±3.48
20	IS6	206.82±18.30	12.14±3.22	28.72±3.18
21	IS7	105.79±9.74	7.75±2.19	33.82±3.59

Table 3: The Absorbed Dose Rate (D), Radium Equivalent (Ra_{eq}), Annual Effective Dose Rate (AEDR) (indoor and outdoor) and the Radioactive Level Index (I_Y) for the various points in the study areas.

Sample	Absorbed Dose ($nGyh^{-1}$)	Radium Equivalent (B/Kg)	Annual Effective Dose Rate (AEDR) (outdoor) ($mSvy^{-1}$)	Annual Effective Dose Rate (AEDR) (indoor) ($mSvy^{-1}$)	Radioactive Level Index(I_Y)
DS1	53.02	113.47	0.064	0.260	0.848
DS2	70.63	157.97	0.085	0.347	1.122
DS3	20.42	44.20	0.025	0.025	0.316
DS4	29.85	63.18	0.036	0.147	0.470
DS5	28.30	60.73	0.034	0.139	0.520
DS6	28.30	61.90	0.034	0.139	0.445
DS7	30.20	72.38	0.036	0.148	0.475
FL1	51.05	108.80	0.061	0.251	0.495
FL2	51.65	101.53	0.062	0.324	0.818
FL3	66.39	139.39	0.080	0.326	1.048
FL4	63.47	129.25	0.076	0.312	1.009
FL5	49.34	104.42	0.059	0.242	0.784
FL6	52.54	109.33	0.063	0.258	0.831
FL7	79.14	166.76	0.095	0.389	1.244
IS1	67.63	144.52	0.081	0.332	1.079
IS2	43.81	93.82	0.053	0.215	0.692
IS3	60.59	133.48	0.073	0.297	0.961
IS4	38.91	83.64	0.047	0.191	0.625
IS5	35.16	74.07	0.042	0.173	0.565
IS6	32.06	69.14	0.039	0.157	0.433
IS7	28.99	64.27	0.035	0.142	0.460

IV. ANALYSIS AND DISCUSSION

Figures 1, 2, 3, 4, 5, 6, 7 show the Dose Equivalent of Samples from Background Radiation ($mSvyr^{-1}$), the Radionuclide Concentration of Potassium (40-K) (Bq/Kg), the Radionuclide Concentration of U-238 (Bq/Kg), the b Radionuclide Concentration of TH-232 (Bq/Kg), the Absorbed Dose ($nGyh^{-1}$), Radium Equivalent (B/Kg), and Raximum Permissible Radium Equivalent, the Annual Effective Dose Rate (AEDR) (outdoor) ($mSvy^{-1}$), Annual Effective Dose Rate (AEDR) (indoor) ($mSvy^{-1}$) and the Radioactive Level Index (I_γ) of the respective points at every site under study respectively.

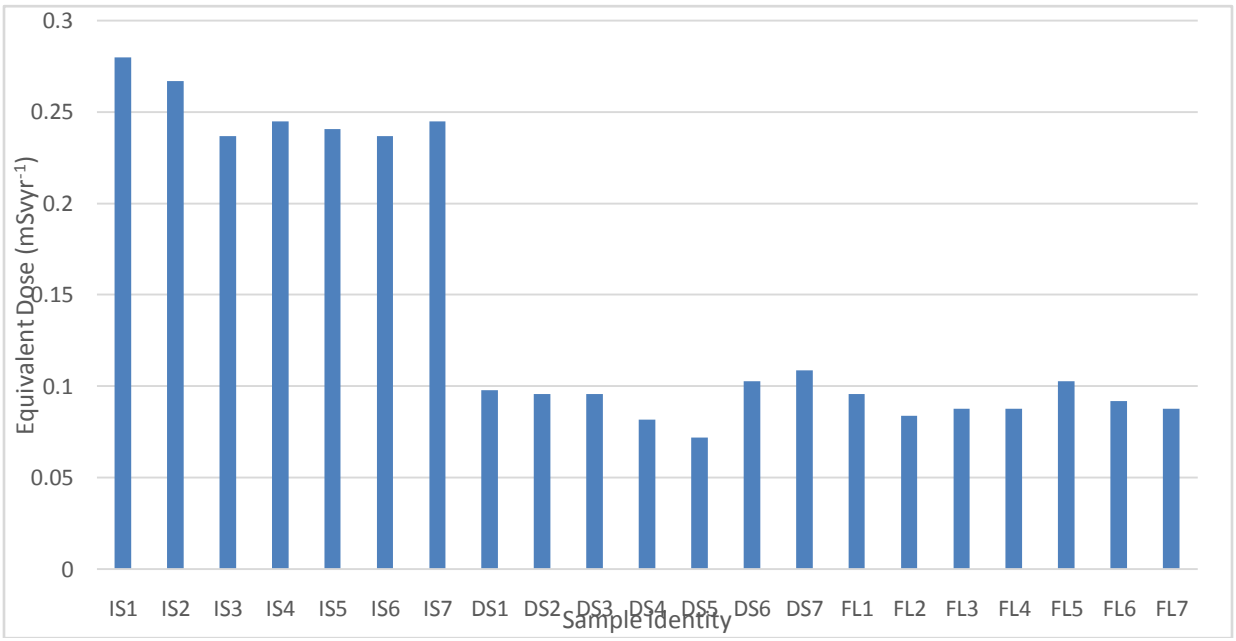

Figure 1: Dose Equivalent of Samples from Background Radiation ($mSvyr^{-1}$).

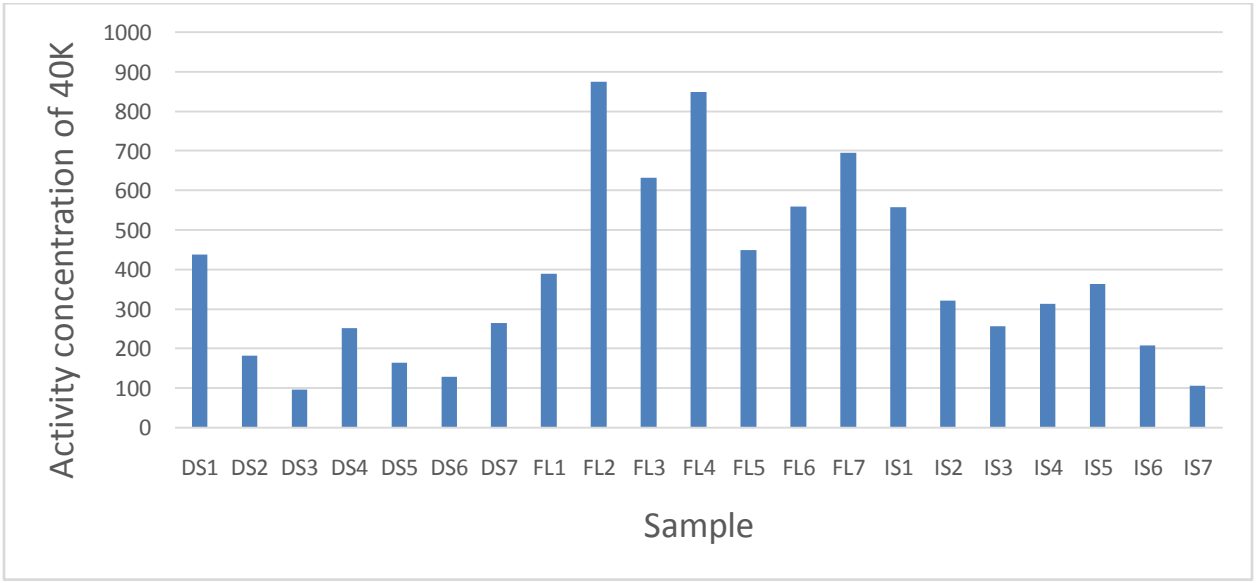

Figure 2: Activity Concentration of Potassium (40-K) ($Bqkg^{-1}$).

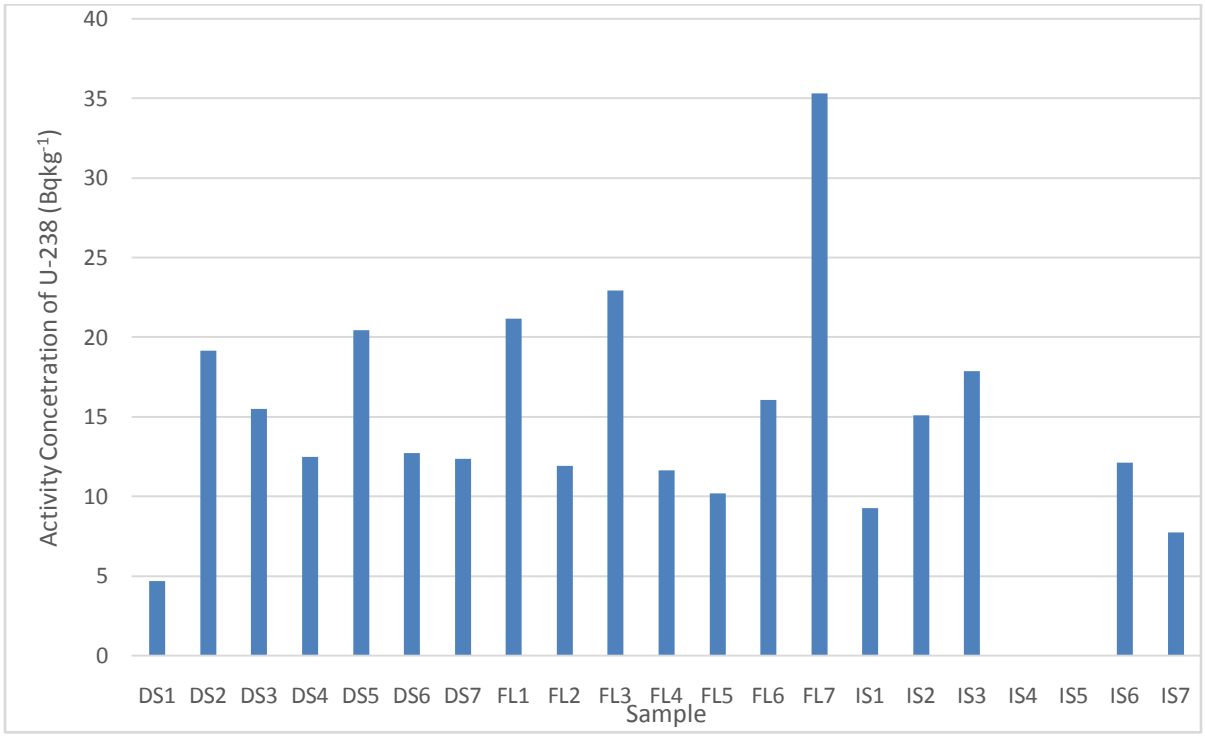

Figure 3: Activity Concentration of U-238 ($Bqkg^{-1}$).

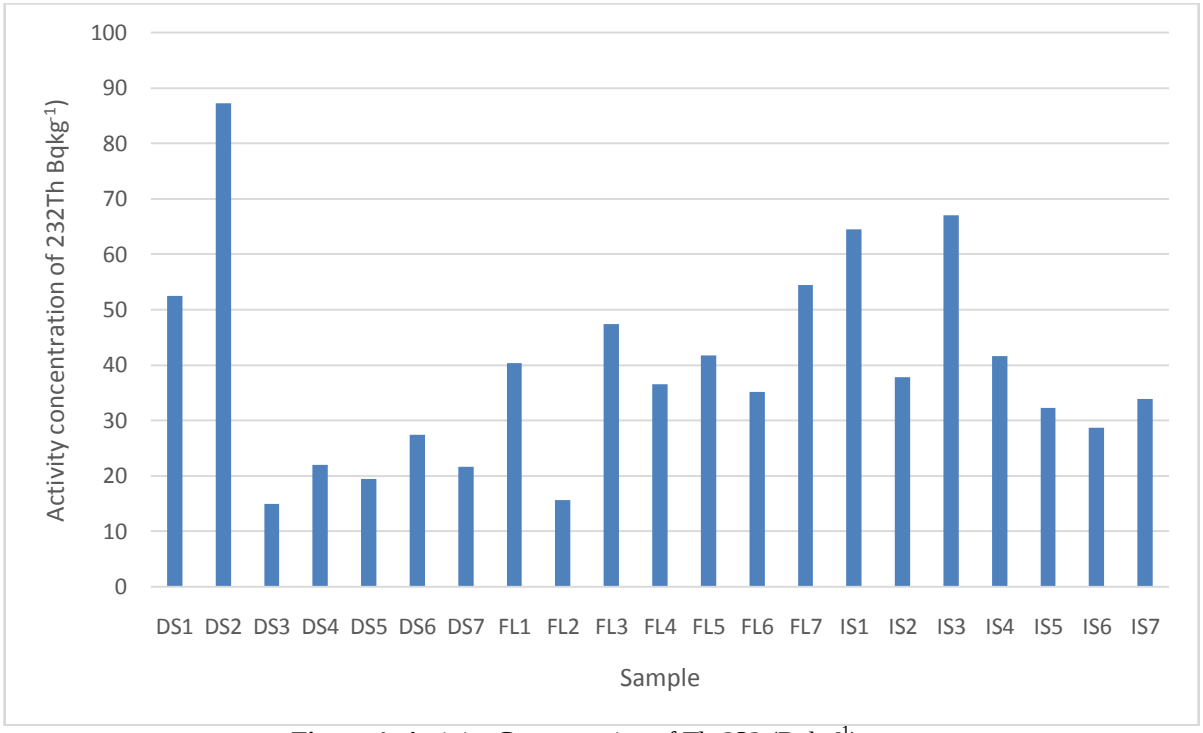

Figure 4: Activity Concentration of Th-232 ($Bqkg^{-1}$).

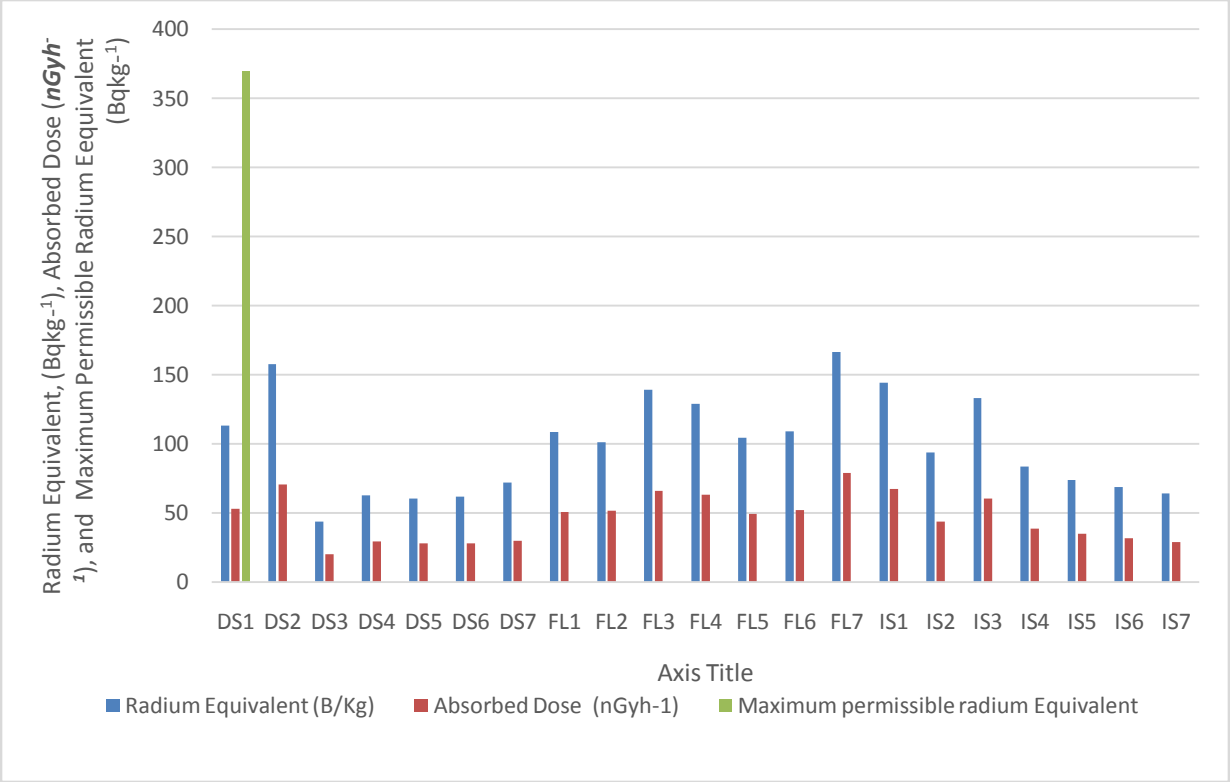

Figure 5: Absorbed Dose ($nGyh^{-1}$), Radium Equivalent ($Bqkg^{-1}$), and maximum permissible Radium equivalent ($Bqkg^{-1}$).

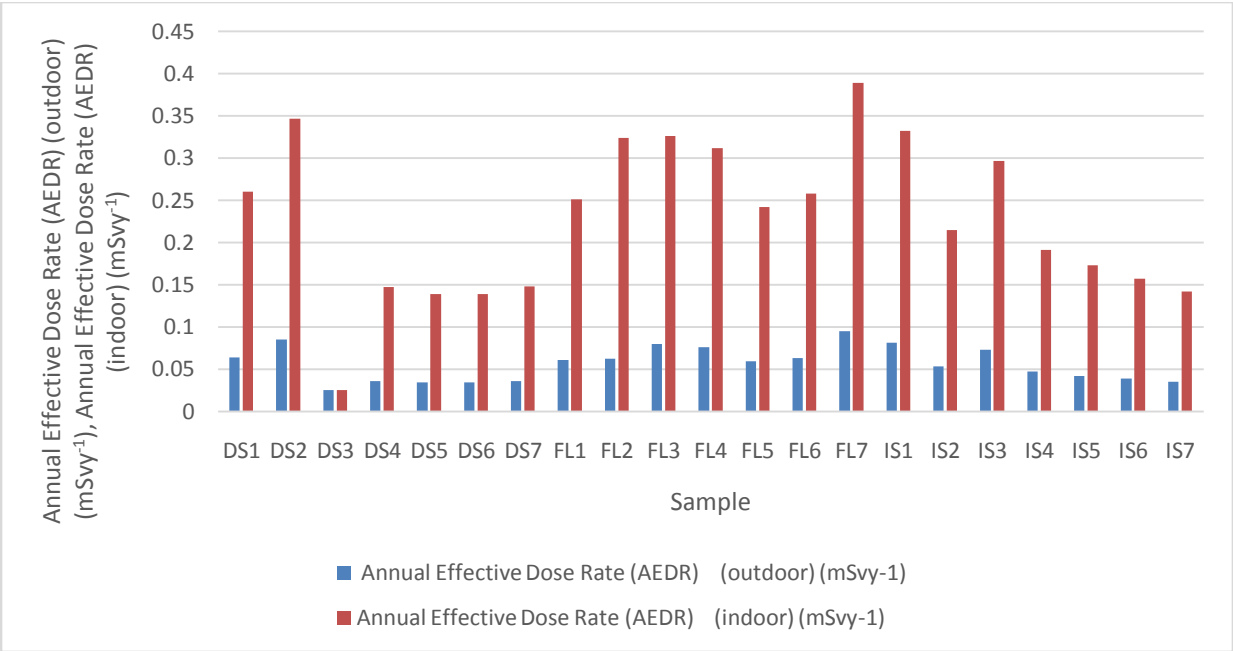

Figure 6: Annual Effective Dose Rate (AEDR) (outdoor) ($mSvy^{-1}$), Annual Effective Dose Rate (AEDR) (indoor) ($mSvy^{-1}$).

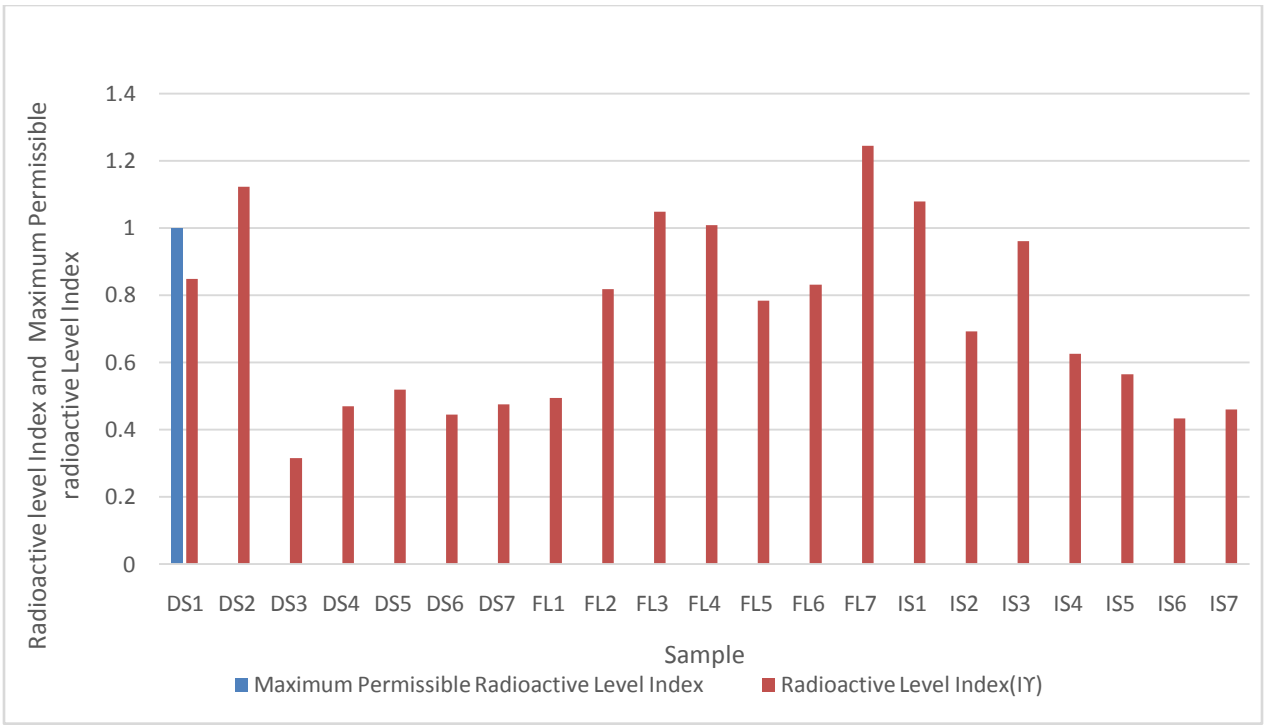

Figure 7: Radioactive Level Index (I_Υ) and Maximum Radioactive Level Index.

Background radiation as presented in Table 1 indicates that on the average the Dump site has a greater count per minute (19.19) followed by the farmland (18.62) and lastly the Industrial Site (18.38). The count rate ranged from 15 .00 to 22.33 with all of these leading values obtained at the Dump Site. The radionuclide concentration of 238U, 232Th and 40K for soil samples from the three sites are shown in Table 2. The radionuclide concentrations of 238U, 232Th and 40K varied in the range 4.72±1.96 to 35.35±2.86Bq/Kg, 14.92±2.57 to 87.30±8.59Bq/Kg and 105.79±9.74 to 874.54±70.83Bq/Kg respectively. The maximum radionuclide concentration for 238U was obtained at the farm land while that of 232Th was measured from the Dump site with the highest radionuclide concentration of 40K coming from the farmland as well. The result further reveals that the concentrations of 40K in the soil samples in all the study areas were higher compared with the global average value of 400Bq/kg. Results further revealed that 40K has the highest average concentration at the farmland (635.32±52.80Bq/kg) followed by the Industrial Site with a concentration of 303.36±27.21Bq/kg and finally the Dump site.

The radionuclide concentration of 238U on the average was greatest at the Farm land (18.48±3.99Bq/kg) followed by the Dumpsite (13.93±3.64Bq/kg) and with the least concentration at Industrial site (8.88±2.32Bq/kg). The highest radionuclide concentration of 232Th on the average was obtained at the Industrial site quantified by 43.68±4.69Bq/kg followed by the Farm land with a concentration of 38.73±4.11Bq/kg and finally the dump site with a concentration of 35.02±3.83Bq/kg.

Absorbed Dose as indicated in Table 3 and Fig. 5 indicates that the farm land (FL7) has the highest dose of 79.14 $nGyh^{-1}$ followed by the Dump Site (DS2) with an absorbed dose of 70.63 $nGyh^{-1}$ and finally the Industrial Site (IS1) with a value of 67.63 $nGyh^{-1}$. The lowest value of the absorbed dose is obtained at the Dump Site (DS3). The Radioactive Level Index as indicated in Table 3 ranges from 0.316 to 1.244. For a sample of soil to be free of harmful radiation, its radioactive level indices at any point should be at most equal to unity quantitatively. From Fig. 7 above it could be seen that both DS2, FL3, FL4, FL7 and IS1 have hazard indices that are above the recommended safety limit (1.122, 1.048,1.009,1.244,1.079 respectively) of unity.

V. CONCLUSION

The activity concentration of soil in soil samples at selected areas in Zaki- Biam Ukum local government, Benue state has been determined and the activity concentration of 40K in soil samples collected around the Dump Site, Industrial Site and Farm land were enhanced relative to what was found in samples from the area. The highest concentration of 40K obtained at the farmland is enhanced due to application of fertilizer

which has a high concentration of the mentioned element.

The radionuclide concentration of soil samples from the three areas Industrial Site, Dump Site and Farm land were measured using gamma-ray spectrometry with NaI (Tl) detector. The average outdoor gamma radiation dose values obtained due to the activity concentrations of the radionuclides in some of the spots at the respective sites are higher and at some points in all the sites lower when compared with the maximum permissible limits. However, no matter how small radiation exposure could be, it has effect on human beings and broadly on biological systems and exposure to this radiation must be reduced. The results of radionuclide concentrations in the soil showed the presence of radionuclides with 40K, 238U and 232Th having concentrations above their natural range in the soil. At lower concentrations, these radionuclides may be beneficial to the ecosystem but they are regarded to be toxic at higher concentrations. However, radionuclides are potentially toxic with prolonged exposure even at lower levels. Therefore, it is imperative to monitor their accumulation in soil samples before inhabitants can cultivate the land around the dumpsites for agricultural purposes to prevent the transfer of these radionuclide into the human system.

VI. RECOMMENDATIONS

i. The government should discourage the use of the soil/fields around these dumpsites for agricultural purposes because of the presence of these radionuclides in the sites at present.
ii. Moreover, in as much as the result for this work serve as a reference material for any future work on the presence of radionuclides in the environment of the study area and also complement data needed for formulating of guidelines, regulations and policies in the country by research scientist, there is the need to carry out similar studies on yam and groundnut grown as the district is noted for their dependence and sustenance on such practices.
iii. Tuber crops such as yam sweet potatoes, cassava and groundnut should be discouraged from being cultivated on those areas as they will have direct contact with the high radionuclide concentrations.
iv. Vegetables such as pumpkin and its kind which are consumed alongside with the stem should also be discouraged from being cultivated around such areas as this increases the transfer index of these radionuclides to human systems.
v. Crops such as maize, guinea corn which do not have their cobs buried underneath the ground should be planted in such areas as this will reduce their direct contact with the radionuclides.

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